Disease Prediction for Golf Courses

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How do you decide when to apply a fungicide? Experienced turf managers use their historical knowledge of diseases in the area, current symptoms and signs of disease problems, recent weather conditions, expected weather conditions in the next few days, along with the many other factors that can affect disease severity: compaction, mowing heights, fertilizer and pesticide applications, and other management practices.

Turf managers are under considerable pressure to justify and, preferably, reduce their pesticide applications. Calendar schedules for fungicide applications are not only difficult to justify environmentally, but they are also costly. In addition, as fungicides become more specific in their modes-of-action, a scheduled fungicide might not be effective for the particular disease that is developing. There are many reports of disease enhancement (increased disease severity) when a fungicide is applied that does not control the pathogen that is currently active. Thus, the wrong fungicide can not only be a waste of money, it can also exacerbate the existing problem. Finally, calendar-based sprays may actually give less than optimal control because disease pressure might be greatest right at the end of an application interval when little fungicide remains to fight the pathogen.

There are, of course, some possible advantages to calendar-based fungicide applications. Many of the available fungicides are broad-spectrum and are likely to control a number of important and common diseases. Calendar applications can be scheduled for days on which a golf course is closed to members or times that are otherwise convenient for the turf manager. Scheduled applications generally provide disease prevention and potentially reduce turf injury compared to curative applications.

Despite these potential advantages, most turf managers would agree that environmental conditions and disease problems vary quite a bit from year to year. They would probably also agree that for environmental and economic reasons, they would prefer to apply fungicides only when they are really needed— if they could also avoid some of the potential risk of waiting for disease-conducive conditions.

At this time, most fungicide applications involve educated guessing. Unlike weed and insect pests which can be counted, turf managers must use past experience and weather predictions to determine when diseases are likely to occur. Disease prediction systems offer a way to make more precise and timely applications that may improve disease control and, perhaps, even reduce the number of applications.

Fungicide applications may be reduced by using prediction systems in two ways. First, conducive weather conditions may approach, but not quite reach, the levels necessary for a disease outbreak. If these conditions are monitored more precisely, a turf manager could confidently skip an unnecessary application and still sleep at night. Fungicide applications might also be reduced by substituting biocontrol agents applied according to predictions. Many biocontrol agents are currently being studied. They are living organisms, and it is difficult to maintain high populations for long time periods. If they could be applied when disease pressure is greatest, their short-term activity might be very effective and reduce the need for fungicide applications.

There are two main approaches to disease predictions. Disease prediction may be made by monitoring environmental conditions that lead to disease outbreaks. Predictions may also be made by directly monitoring the activity of the pathogen that causes the disease through the use of immunoassays, or antibody tests, such as the commercial Alert® field diagnostic kits (Neogen Corporation). It may also be possible to combine these approaches.

Disease Prediction Using Environmental Factors

The initial step in the study of any turf disease is to determine what environmental factors lead to disease development. It is well known that fungi that cause turf diseases are active over a wide range of temperatures. Different temperatures appear to be important for the various prediction systems. Systems may use minimum, maximum and mean air temperatures. Some prediction systems also include soil temperatures. Even though some fungi are more active at high temperatures and others at lower temperatures, there is still considerable overlap in the temperature range of activity. Clearly, temperature alone is not enough to predict most turf diseases.

The most important additional factor is water. This may be soil moisture, high relative humidity, actual water droplets on leaf blades, or some combination of these factors. Leaf wetness is technically difficult to measure accurately, yet it is critical in disease prediction because most fungal spores and mycelium require free water for germination and growth. Measures of high relative humidity are often used to estimate periods of leaf wetness.

In general, there are particular combinations of moisture and temperature that allow a fungus, the most common type of turfgrass pathogen, to invade a turfgrass plant. The combinations of factors which provide a pathogen with the opportunity to successfully infect a plant are called "infection periods." Infection periods can be used to predict disease outbreaks. Of course, other factors, such as nitrogen fertility, affect disease severity, but most existing prediction systems use only environmental factors at this time.

Two commercial computerized environmental monitoring stations are currently available to turf managers, the Envirocaster@ and the Metos@ Golf. Both of these instruments monitor environmental factors several times each hour, than average and store all of the hourly environmental data. Computer models then calculate turf disease predictions from these data. The use of computerized weather stations allows the models to reflect the biological complexities of the real world without overburdening a busy turf manager with time-consuming calculations.

Infection period models. For severe diseases such as Pythium blight and brown patch (Rhizoctonia blight), turf managers should be informed each time an infection period occurs. When environmental conditions are not favorable for disease, the message from the computer may simply state that an infection period has not occurred. Infection

Pythium Foliar Blight Model

Environmental Factors Monitored:
(over 24 hour period)

Hall Model
Air Temperature:
>18 hrs at >70 degrees F with a minimum of 68 degrees F for high risk conditions.

Nutter Model
Air Temperature:
Max: >86 degrees F, Min: >68 degrees F
Relative Humidity >90% for 14 hours

Field validation
The Hall Model does not include a measure of moisture which may make it inaccurate in drier regions. The Nutter Model has been most widely field tested because it is available in commercial computerized weather stations.

Comments
Shane reports that the Nutter Model could miss outbreaks under Ohio conditions. He suggests reduction of the high relative humidity requirement from 18 hr to 9 hr and some slight changes in temperature requirements. He cautions that both models should be field tested where they are to be used.

The author's observations in western Massachusetts for the past 7 years suggest that the Nutter Model, as programmed in the Envirocaster®, predicts the rare Pythium outbreaks in that region. It is likely that many superintendents often apply fungicides unnecessarily in New England. On the other hand, golf courses with low lying turf areas and poor air movement might find that the model underpredicts in those disease-conducive conditions.

period models may also determine if a disease outbreak if likely to be severe, moderate, or light which may be helpful in making a fungicide application decision. Disease prediction systems may also include recommended cultural practices such as avoiding mowing or irrigation during a time when the risk of spreading active fungal mycelium is high.

The computer message may list the current limiting factors as conditions approach those needed for an infection period. For instance, if daily maximum temperature is the limiting factor for an infection period and the day is definitely going to become hotter, then an infection period will probably occur. Thus, environmental monitoring can be combined with weather predictions to determine the likelihood of disease outbreaks.

Severity models. Infection period models are most useful for diseases that develop quickly and can be very damaging. For less threatening diseases, fungicide applications are usually made only after disease potential reaches a certain level. Severity prediction models are more useful for such diseases as anthracnose, leaf spot, and red thread. Such a model has been created for anthracnose at Michigan State University. It accumulates "anthracnose severity units" based on leaf wetness and average air temperature. While the severity units themselves are actually based on infection periods (the potential for the fungus to successfully infect the turf), it predicts disease only after a series of infection periods, each of which accumulates points according to the Anthracnose Severity Index. A fungicide application is made only when a certain threshold number is reached. Severity prediction models have the added advantage allowing a turf manager to modify the threshold number to meet the local conditions of a particular turf site.

Degree day models. A third type of prediction model has been applied to other pest problems, but has few applications for turf diseases at this time. It is based on the concept of "degree days" which reflect an accumulation of "heat units" during a growing season. Degree days are a way to

Rhizoctonia Brown Patch

Environmental Factors Monitored

Fidanza Model (perennial ryegrass)
Soil Temperature: $\geq$61 degrees F
Air Temperature: $\geq$61 degrees F
Relative Humidity: $\geq$95% for >8 hr, mean $\geq$75%
Precipitation: $\geq$0.47 inches (12 mm) or
Leaf Wetness: $\geq$6 hr
Equally effective: $E = -21.5 + 0.15RH + 1.4T - 0.033T2$ (RH= mean relative humidity and T = minimum daily air temperature. A warning is produced when $E \geq 6$)

Schumann Model (creeping bentgrass at putting green height)
Soil Temperature: Mean >70 degrees F; Minimum >64 degrees F
Air Temperature: Mean >68 degrees F Minimum >59 degrees F
Relative Humidity: >95% for at least 10 hr
Precipitation: 0.1 inches (0.254 cm)
Cancel prediction if Air Temperature <59 degrees F in the 24-48 hr post-warning.

Field Validation
Fidanza et al tested their model under Maryland conditions. Schumann et al tested their model in Massachusetts, New Jersey and Georgia. The model was not helpful under Georgia conditions which may reflect the long periods of conducive environmental conditions and/or different strains and species of the pathogen.

Comments
The similarity between the models developed independently in Massachusetts and Maryland is interesting. Disease predictions appear to be based on the effects of environmental conditions on fungal activity rather than the specific plant environment. Nearly all false predictions can be eliminated in the Schumann Model, if a cancellation policy is used based on minimum air temperature following a warning. Turf managers can consult weather predictions to determine if a fungicide is needed following a disease prediction. This is an important feature in regions that often cool off following the hot, humid weather that favor brown patch.

The author has observed severe brown patch outbreaks following very heavy rainfalls, but relatively cool weather, which could not be accommodated in the Massachusetts Model. Turf managers should be aware of this disease potential in very wet weather.

Sclerotinia Dollar Spot

Environmental Factors Monitored

Hall Model
Air Temperature and Rain: mean >72 degrees F over two days with rain or >64 degrees F over three days with rain.

Mills and Rothwell Model
Air Temperature: maximum >77 degrees F
Relative Humidity: >90% any 3 days in 7

Field validation
Burpee and Goulty evaluated both models in the field over two seasons. They suggest that the Hall model underpredicts and the Mills and Rothwell model overpredicts.

Comments
The author has been making daily dollar spot observations for several seasons in Massachusetts in an attempt to correlate environmental factors with disease outbreaks without major progress. It may be that environmental factors are too variable for a simple environmental model to recommend fungicide timing for dollar spot.

measure what we intuitively sense when we notice that a year has an "early spring" or a "late spring." This concept has been applied to certain pest control measures that are timed according to the blooming of forsythia or other plant development stages. The development of all organisms is tied to the accumulation of degree day units. By doing experimental work on a specific pest, it is possible to accurately determine the degree day thresholds for that pest. As with the disease prediction models already described, however, degree day models are monitoring only the environmental conditions, not whether there is actually enough of a pest or pathogen to warrant control.

Degree day prediction models exist for Poa annua seed head formation, crabgrass germination, and several turfgrass insect pests. Degree day models have important potential applications for disease prediction as well. For example, it is known that brown patch is a summer disease. Even though hot, humid weather may occur briefly in spring, it does not seem to trigger brown patch until soil temperatures reach a critical threshold. Because soil temperatures can vary considerably from week to week, a degree day threshold might be the most appropriate way to determine when in early summer to start using a daily brown patch infection period prediction system.

Predictions for root diseases. Summer patch and necrotic ring spot are difficult diseases to manage because fungicide applications must be applied before symptoms occur. A degree day model combined with soil moisture might be an accurate means of determining when fungicide applications should be applied to be most effective.

In general, root diseases such as summer patch, necrotic ring spot, take-all patch, Pythium root rot and even nematode problems are difficult to predict using the environmental factors used for brown patch, Pythium blight, and other foliar diseases. Moisture on the leaves is a limiting factor for diseases that begin with infection of leaves. The pathogens that cause root diseases are certainly affected by moisture and temperature, but they are also associated with conditions such as soil compaction, low mowing heights, heat stress, and root zone pH. Turf managers should act to reduce the stress factors associated with these diseases rather than relying on fungicide applications. It may be possible, however, to use factors such as soil moisture and temperature for root disease warnings.

Disease Prediction Immunoassays

All of the prediction methods just described are based solely on environmental monitoring. They determine when conditions are right for disease development. They are unable to determine if a previous fungicide application is still actively suppressing disease or if the fungus population is sufficient to cause significant disease. New developing technology may provide this missing information. Tests are available for rapid and quantitative detection of pathogens in turfgrass. Called immunoassays, or antibody tests, they use antibodies formed by the immune systems of animals.

Anthracnose Foliar Blight Model
(on annual bluegrass)

Environmental Factors Monitored
Leaf Wetness - hours
Air Temperature - degrees Celsius, average for a 3-day period

An Anthracnose Severity Index (ASI) table has been generated which allows severity factors to be accumulated each day until a "threshold" is reached, triggering a fungicide application.

Field validation
This model was validated by its creators under summer conditions in Michigan.

Comments
One limitation to the practical use of this model is that leaf wetness is difficult to monitor accurately. There are no published reports on how well this model predicts anthracnose outside of the Michigan area. Anthracnose is often a stress disease enhanced by low fertility, low mowing heights, and compaction.These factors would also affect what ASI threshold should trigger a fungicide application. In some area, a cool-weather form of this disease commonly occurs which would not be predicted by this model.

This is currently the only published turfgrass disease prediction system which uses severity values rather than individual infection periods to recommend a management action. A major advantage to this system is that the thresholds could be modified for different climates and different stress factors. The concept behind this type of model could be applied to a number of other turf diseases which vary in severity from year to year.

Highly purified samples of turf disease fungi can be injected into animals. The animals do not become diseased, but their immune systems still recognize these fungal proteins as "foreign." Antibodies specific to each fungus are formed. The antibody-producing cells can be grown in culture for inexpensive mass production of antibodies. The antibodies can be attached to enzymes which can cause a color change. Such tests are called ELISA, enzyme-linked immunosorbent assays, to describe the method. The color change occurs only when the correct fungus is detected. The attached enzyme results in a very sensitive test that detects even tiny amounts of a fungus.

ELISA field kits require no specialized equipment or training and indicate the presence of the fungus by a color change in about 10 minutes. The same technology is used for home pregnancy tests and a number of other medical tests. At this time, kits are available for detection of the fungi that cause brown patch, dollar spot, and Pythium blight. Each test is developed with antibodies specific to only one pathogen. Thus, a separate test must be run for each disease.

It is important to sample turf in areas where disease is expected to develop first, sometimes called "hot spots." It is also important to avoid including thatch and soil in the sample because the fungal pathogens are almost always present in thatch and soil, even when they are not actively causing disease.

The next question is whether a threshold fungus population requiring treatment is present. A meter is available that measures the intensity of the color development in the test. Results can also be compared to a color chart that accompanies the kits. A darker color reflects a greater amount of fungus detected in the sample.

In field evaluations of immunoassays thresholds, most researchers have found that the meter readings were highly variable. Most agree that the greatest benefit of the antibody field kits is their ability to confirm a diagnosis quickly without a microscope at the early stages of a disease. ELISA kits can also be used in conjunction with environmentally-based predictions to determine if a fungicide is still suppressing fungal activity.

The Future

One of the limitations to the use of disease prediction systems on golf courses is that fungicide applications must be made quite soon after a prediction occurs. This may not seem practical for some turf managers at this time. However, future pesticide regulations may require greater justification for fungicide applications, and prediction systems offer a scientific basis for your decisions.

Fungicides applied according to disease predictions may offer improved efficacy if the chemical can be applied when disease control is needed most. If turf managers gain confidence in the accuracy of a model, they may actually reduce fungicide applications even when weather conditions are making them nervous about disease.

Further research is necessary to make the current prediction models more accurate and for the development of models for additional diseases. Disease severity is affected by many factors in addition to environmental ones. These include differences in cultivar susceptibility and pathogen races in various geographical areas. Other important factors that affect disease severity are nutrient levels, use of plant growth regulators, mowing height, and various soil factors.

Predictive models will become fine-tuned over time to become more accurate, but they must always be carefully evaluated before use in new areas to make sure that the predictions are appropriate for the local conditions.

Disease prediction by environmental monitoring and immunoassays will probably be a part of every fungicide application decision in the future. As these technologies improve, turf managers should be able to get better control through more precise timing of applications and also have the confidence to extend spray intervals when conditions are not conducive for disease.

Immunoassays that can measure fungicide residues may be developed in the future and would be an invaluable tool in applications decisions. Now that biological agents are becoming available for turf disease management, these could be applied according to prediction systems to determine if this improves their efficacy. Environmental and immunoassays prediction systems are an easy and accurate way to document and justify when fungicide and biocontrol applications are necessary.

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