//FIGHTING THE GOOD FIGHT

Factors affecting fungicide performance
Part 3 of 3: Depletion factors

By Jim Kerns Ph.D.

***Editor's note:** This is third of three articles by Dr. Kerns on disease management and control.*

In the two previous articles we discussed the importance of fungicide selection, application rate, application timing, disease pressure and fungicide resistance. All of these factors help turfgrass managers develop solid disease management programs, but what happens to the product once it is applied?

Six processes affect the persistence of fungicides in an environment: volatilization, plant uptake, biotic degradation (microbial metabolism), abiotic degradation (photodegradation or pH activity), solubility-based movement in water and sorption and desorption to plant and soil surfaces.

After application of a fungicide, there are many different fates for the product.

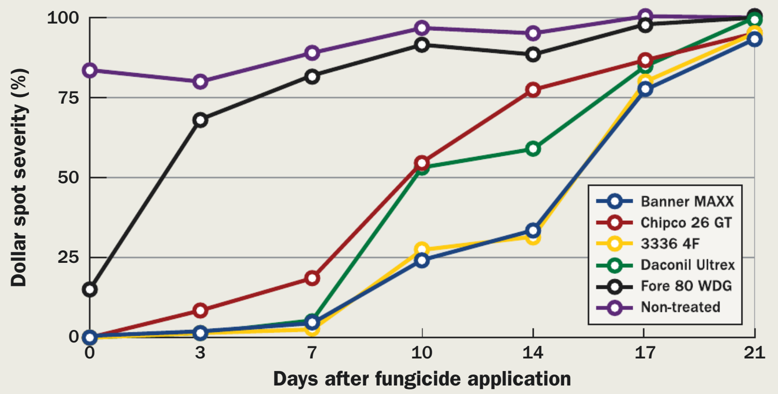
FUNGICIDES ARE FUNGISTATIC

Dr. Rick Latin conducted an interesting experiment investigating the depletion of commonly used dollar spot fungicides. Fungicides were applied in the field, cores were collected and inoculated at zero, three, seven, 10, 14, 17 and 21 days after the initial fungicide application. The fungicides he used were Banner MAXX (propiconazole), Chipco 26 GT (iprodione), 3336 4F (thiophanate methyl), Daconil Ultrex (chlorothalonil) and Fore (mancozeb).

Figure 1 shows his results nicely, yet notice that in almost every case, protection of the foliage started to break down around seven to 10 days after the initial fungicide application. Although many of these products may provide 14 days of dollar spot suppression, this work clearly shows that these products were depleted fairly rapidly from the leaf surface (Latin, 2011). Please do not view this as justification to apply fungicides every seven days.

FIGURE 1

Depletion of five fungicides commonly used for dollar spot control in creeping bentgrass turf.



The study was a bioassay in which fungicides were applied to field plots and cores were removed and inoculated with the dollar spot fungus at zero, three, seven, 10, 14, 17 and 21 days after fungicide application. Figure was adapted from Latin, 2011.

We know that fungicides are really fungistatic. Fungistatic means that fungal cells are killed, but the entire fungal body is not destroyed in response to a fungicide application. Therefore, once the fungus overcomes the shock of cell death, growth can resume if conditions are favorable. The current suite of fungicides is effective, but they only kill small portions of the fungal body. Keep in mind that once we see disease develop, the amount of fungal tissue required to induce that reaction is large.

Fungi are extremely prolific organisms and even the absolute best fungicides cannot kill all the fungal cells present in the tissue. So depending on the current environment, it may take the fungus a few days or weeks to recover from the fungicide applications. For example, our research with dollar spot clearly shows that the fungus needs four or five days of colonization before inducing plant symptoms. If we apply one of the fungicides above and assume eight to 10 days of protection of the foliage, another four or five days of conducive conditions for fungal re-growth, then 12 to 15 days of dollar spot suppression should be expected. In some cases, the disease may "break through" the common re-application interval for a fungicide, but that does not necessarily mean fungicide resistance has developed in the population. Under certain circumstances we may be fighting an active pathogen population and active depletion of the fungicides as well.

TEMPERATURE TREATMENTS

Of the six processes that affect fungicide persistence in the environment, the first four mentioned above [volatilization, plant uptake, biotic degradation (microbial metabolism), abiotic degradation (photodegradation)] are governed by temperature.

We wanted to examine the influence of temperature on the persistence of iprodione and chlorothalonil to see if fungicide indeed breaks down faster as temperatures increase. We followed a similar protocol as Dr. Latin's experiment, where we applied both fungicides to field plots and collected cores for sampling. We used commercially available ELISA (enzyme linked immunosorbant assay) kits for each fungicide to determine fungicide concentration on the leaf surface in response to the following temperatures: 50, 68 and 86 degrees F. We collected tissue at zero, seven, 14, 21 and 35 days after the initial fungicide application and this data allowed us to calculate half-life values for each fungicide within each temperature treatment.

For iprodione we found average half-life values of 39, 8.6 and 4.4 days at 50, 68 and 86 degrees F respectively. For chlorothalonil we determined that half-life values were 9.48, 8.5, 4.0 days at 50, 68 and 86 degrees F respectively. These values are averaged across two or three experiments we conducted in 2010 and 2011 (Koch, 2012). Clearly temperature has a profound influence on the persistence of these two fungicides and most of the fungicides we use in turf.

With these experiments, cores were removed from the field and placed in growth chambers without mowing. When we collected cores from the field at each of the sampling dates above, without incubation at a specific temperature, half-life values for iprodione and chlorothalonil were 1.76 and 2.1 days, respectively. Not only does temperature influence depletion of fungicide, but so does physical removal due to mowing (Koch, 2012).

PHOTO BY: JIM KERNS

SCIENCE OF RE-APPLICATION

Most fungicide failures occur during the summer months when most turf pathogens are highly active and fungicides are readily depleted. With certain diseases, it may be necessary to use high rates and short intervals in order to maintain adequate protection, regardless of the status of fungicide resistance within the population. On the other hand, when pathogens are not as active and fungicide depletion is minor, extended residual control can be expected.

Fairy ring is shown on an ultradwarf bermudagrass putting green.

The two extremes are Pythium blight or Pythium root rot and snow mold. When Pythium blight or Pythium root rot develop, many times shortened application intervals and potentially high rates are recommended in order to maintain disease suppression. However with snow molds, one or two properly timed fungicide applications protect turf plants for many months. Turf managers should not expect protection well after snow melts in the spring. Our research shows that fungicides deplete readily as snow melts in the spring. Re-application of fungicide will be required to protect turf against Microdochium patch.

The science behind re-application intervals is not exact. Most of the recommendations come from fungicide efficacy testing at universities. I think these are solid, but they can fail too. We do not have a handle on how many fungal cells are killed with an application and then how long it takes for the fungus to recover in every situation. For example, Dr. Latin conducted another experiment investigating the residual efficacy of fungicides for brown patch control. Again he found that fungicide residues were not sufficient on the leaf surface to protect against brown patch beyond seven to 10 days after the initial application (Latin, 2011).

This study was conducted in a similar fashion to his dollar spot study mentioned above. Yet, we routinely see 21 to 28 days of control with some of the products he used in his study: azoxystrobin and flutolanil. So why do we see extended control of brown patch in many cases, but not with dollar spot or Pythium blight?

It could be that fungicides that are superior for brown patch may be ultra toxic to *Rhizoctonia solani* and many more fungal cells are killed when applying fungicides for preventative control of brown patch. Another possible explanation could be that these fungicides persist longer in thatch and soil where the brown patch fungus resides.

Dr. Gail Schumann investigated the fate of fungicides in a Kentucky bluegrass sward in 2000. She found that propiconazole was not detectable seven days after application on the leaves, similar to the findings of Dr. Latin and our results mentioned above. However, her work examined more components of the turf systems such as roots, soil and thatch. She found almost no propiconazole in the soil or roots; rather most of the residue persisted for 28 days in the

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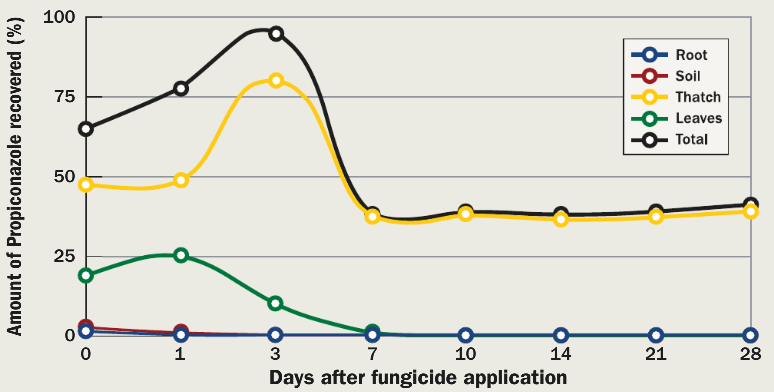
FIGURE 2

Fate of propiconazole after application using a boom-sprayer in a Kentucky bluegrass sward.



Roots, soil, thatch and leaves were sampled zero, one, three, seven, 10, 14, 21 and 28 days after the initial fungicide application to determine percent recovery of propiconazole. Figure was adapted from Schumann et al., 2000.

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thatch (Figure 2) (Schumann, 2000).

Most turf pathologists acknowledge that the thatch is where *R. solani* survives when not causing disease; therefore it is plausible that fungicide residues in the thatch may prevent the fungus from starting new infections for about one month or so. Of course the major assumption here is that products, such as azoxystrobin and flutolanil, follow the same fate as propiconazole. At least with azoxystrobin, Syngenta materials claim the product readily binds to organic matter. It is likely a safe assumption that most azoxystrobin residue would reside in the thatch (Syngenta, 2005).

KNOW YOUR ENEMY

Many different factors affect fungicide persistence in the environment. Turfgrass systems are extremely dynamic with respect to plant growth and microbial metabolism and consequently, fungicides applied to the foliage do not persist for more than seven to 10 days. Although most fungicides are re-applied every 14 to 28 days when conditions favor disease development, in some cases it may be necessary to tighten that re-application interval to account for increased pathogen activity and fungicide depletion.

Alternatively, fungicides may persist for long periods of time (> 28 days) when pathogen activity and/or fungicide depletion is low. Fungicide depletion is important to consider when breakthrough occurs because not all fungicide failures should or can be attributed to fungicide resistance. During hot, humid summers when pathogen activity is high, shorter intervals may be needed to overcome fungicide depletion and intense disease pressure, regardless of the status of fungicide resistance in the fungal population.

My goal with these articles are not to frighten superintendents, but to educate on all the factors that encompass fungicide program development. Developing a fungicide program is more complex than simply picking a product or products and applying them on a pre-designated application strategy. Improvisation is likely needed depending on what Mother Nature deals us during the season.

Most superintendents develop sound fungicide programs that hold up season after season, but if problems have occurred I encourage you to investigate some of the topics I've discussed. In some instances we can extend residual control of fungicides and in others we cannot. Fungicides are essential, valuable tools for superintendents, but they do have limitations. When used in conjunction with sound agronomic practices they will work. However there are times when they fail and it is not necessarily the fault of the chemistry.

The best way to combat diseases and thereby maximize fungicide efficacy is to understand the diseases and the fungicides that are used to control them.

Remember that when fighting diseases and good luck this season!

Jim Kerns, Ph.D. is an assistant professor and extension specialist in turfgrass pathology in the Department of Plant Pathology at North Carolina State University. Dr. Kerns can be reached at jpkerns@ncsu.edu.

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