Fungicides: What You Should Know

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Part I: Formulations and Topical Modes of Action

Following my presentation on fungicides at the Wisconsin Turfgrass and Greenscape EXPO, I have received numerous e-mail requests for the outline of the material I presented. With most of you developing your management plans for this year, this might be a good time to share some "back to the basics" information with you. The more that you know about a fungicide, the better off you will be as a consumer and the more efficient your fungicide program will be.

Over the next three issues of *The Grass Roots* I will be detailing everything that you should know about fungicides. In this article I have taken an in-depth look at formulations and topical modes of action. In the May/June issue I will be concentrating on fungicide families and host/pathogen interactions. The final installment will be an article on fungicide resistance and management programs to prevent resistance. Enjoy the series, and if you ever have questions on fungicides, I am only an e-mail or a phone call away.

Fungicide vs. Fugistat

Even though we commonly refer to our disease control chemicals as fungicides, this is actually incorrect. Most of the fungicides used today are actually fungistats. If you break down the root word of fungicide ("fungi", fungus, and "cide", to kill), this would mean that we would only have to spray the fungicide once. But we all know this isn't the case. What a fungistat actually does is inhibit the growth of the fungus either by preventing germination of spore or inhibiting hyphal growth. In simpler terms you could consider fungicides as growth regulators of fungi. This inhibition usually occurs for a determinant amount of time, due to the expected life of the chemical.

Formulations

There are four major formulations that fungicides are manufactured as; granulars, wettable powders, wettable granulars, and liquids. Granulars (G) are usually applied to a fertilizer, clay, or corncob carrier. The amount of active ingredient in these products is reported as a percentage. An example of this is Turfcide 10G, where the amount of active ingredient is 10%. Knowing how active ingredients are labeled for percentage can aid in product and price comparison. This is the only formulation that is applied to the turf in the dry form.

Wettable powders now come in two forms, WP (Wettable Powders) and WSP (Water Soluble Packet). Both of these forms are the same, with the only difference being the packaging. The WSP have become more popular recently due to limited exposure to the handler. The water-soluble packet can be added directly to the tank, and the packaging material will dissolve in water. Care should be used in storing and handling to prevent the packaging from getting wet. It is also a good idea to dissolve the packets in a bucket and then pour the bucket into the spray tank. Like the granulars and the wettable granulars, wettable powders active ingredient is labeled as a percent. Prostar 70WP is an example of a 70% wettable powder.

The next group probably has the largest collection of formulations and very little differences among them. A majority of the difference is based on what the different manufactures decided to call them. This group includes Wettable Dry Granulars (WDG), Wettable Granulars (WG), Dry Granulars (DG), and Extruded Granulars (EG). You may also find some of these formulations as WSP's. In general, the size of the particle in these products makes them more convenient to handle because less dust is given off when weighing or mixing. As mentioned above, these products are measured in percent A. I. An example of this is Bayleton 50 DF. The wettable powders and wettable granulars go into suspension when mixed with water, therefore it is important that proper agitation is provided when using these products.

The final group of formulations is the liquid forms, which include Flowables (F), Soluble Concentrates

(SC), Aqueous Suspensions (AS), Emulsifiable Concentrates (EC), and Microencapsulated Concentrates (MC). The flowable, soluble concentrate, and aqueous suspension are all suspension formulations. They require proper agitation prior to putting them in the tank. This is probably not as crucial with the EC and MC formulations as these are in solution, but it is always a good idea to mix products thoroughly before putting them into the spray tank. In contrast to the granular formulations, the liquid formulations usually measure the amount of active ingredient in pounds per gallon. An example of this is Turfcide 400 4F, which has 4 pounds of active ingredient per gallon of product. On the label you will notice that the percent is also included. By knowing the amount of active ingredient in each product, you can determine cost per area applied, and use it for cost comparison-shopping.

Table 1. Formulation Types and AI Measurement Method

Formulation	Abbreviation	AI Measurement
Granular	G	% AI/lb
Dry Flowable	DF	% AI/lb
Dry Granular	DG	% AI/lb
Extruded Granular	EG	% AI/lb
Wettable Granular	WG	% AI/lb
Water Dispersible Granular	WDG	% AI/lb
Wettable Powder	WP	% AI/lb
Water Soluble Packet	WSP	% AI/lb
Emulsifiable Concentrate	EC	Lbs/Gal
Microencapsulated Concentrate	MC	Lbs/Gal
Aqueous Suspension	AS	Lbs/Gal
Soluble Concentrate	SC	Lbs/Gal
Flowable	F	Lbs/Gal

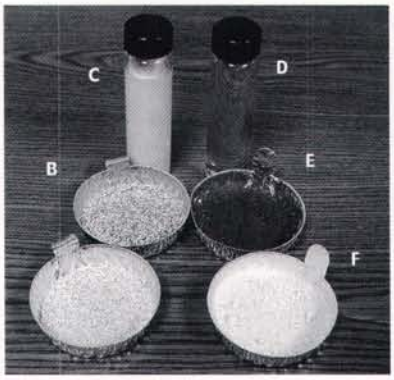

Figure 1. Formulations of fungicides; (A) extruded granular, (B) Water dispersible granular, (C) flowable, (D) microencapsulated concentrate, (E) dry flowable, and (F) wettable powder.

Tank Mixing

Even before the first chemical goes into the spray tank, be sure that you have read the entire label. Many tank mixtures have been evaluated in the past, and because of these evaluations labels usually have recommendations or restrictions when it comes to tank mixtures. Restrictions are imposed because some chemicals are not compatible together and can cause anything from mixtures that gel up to chemicals loosing their efficacy.

Before tank mixing you will want to perform a jar test. This simple test consists of putting all the components desired in the tank mix in a jar and evaluating the mixture. The jar test will only tell you if there are physical changes in the mixture, so you will have to rely on the label to provide any chemical reactions that might be detrimental to the mixture.

When tank mixing, it is good to use the following mixing order. When mixed in this order, there is less of a chance or incompatibilities and the mixture should be more uniform.

Mixing Order

1. Granulars (WDG, WG, EG, DG, DF)
2. Wettable powders (WP, WSP)
3. Flowables (SC, F, AS)
4. Solubles (MC, EC)

Topical Modes of Action

Topical mode of action is simply how the fungicide reacts with the plant to protect it from the fungus. Generally, topical modes of action are divided into five groups: contact, local penetrant, acropetal systemic, systemic, and the most recent addition, mesostemic. Most of these groups share similar modes of protection, but there are some differences among the groups.

Contacts

Contacts have the simplest mode of action. When applied to turf they provide a protective barrier on the outside of the plant. The re-wetting of the plant via rain or irrigation can redistribute the chemical on the outside surface of the plant (see Figure 2.). Since none of the chemical actually gets into the plant, the chemical is subjected to the elements, and therefore has a short life span. Most contacts have a life span of around 14 days, but based on the weather this could be much shorter.

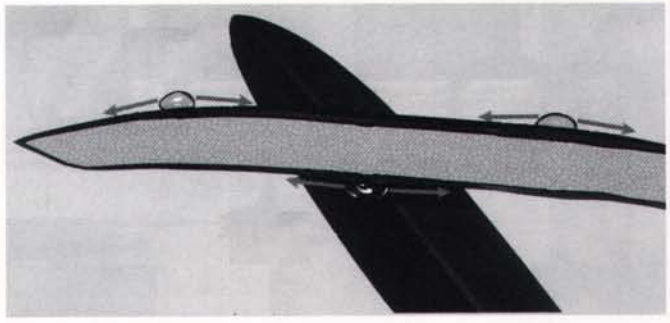

Figure 2. How a contact protects a turfgrass plant. (A) Movement of the contact fungicide is limited to the exterior surface of the leaf, but can be redistributed with irrigation or rain.

Contact fungicides usually have several biochemical modes of action (the biological pathway or process that the fungicide inhibits resulting in growth inhibition of the fungus). Because of this, resistance to the fungicide is unlikely, and these chemicals can play a vital role in preventing fungicide resistance.

Because contacts only provide protection on the outside of the plant, the fungicide will not affect existing infections inside the plant. Contact fungicides will, however, prevent the spread of disease to neighboring plants. It may be common to apply a contact fungicide, or any fungicide, and have lesion or mycelium develop the following day. This does not mean that the fungicide is not working, but the timing of the application was a little late. You can be assured that symptoms will subside in a day or two.

Fungicides that have a contact topical mode of action are chloroneb, chlorothalonil, ethazol, mancozeb, maneb, PCNB, and thiram.

*It should be noted that most other fungicides, when on the outside of the plant, will provide contact control of turfgrass pathogens. The other topical modes of actions also enter the plant and provide additional protection from within the plant.

Mesostemic

The mesostemic mode of action is a relatively new type of protection. Currently there is only one chemical that is in this category, trifloxystrobin. While having all the protection properties of a contact, this group adds some unique modes of action.

A mesostemic fungicide's most unique characteristic is its ability to redistribute by vapor movement. In simpler terms, the chemical goes into a vapor phase and will enter neighboring plants and other parts of the same plant where it will provide protection. Mesostemics can also penetrate the waxy cuticle of the leaf and provide a barrier against a fungus infection. The chemical can also enter the plant via translaminar flow. Translaminar flow is simply movement from one side of the leaf to the other by traveling through the intracellular space. So if the top of the leaf has chemical from an application, translaminar movement will also protect the underside of the leaf.

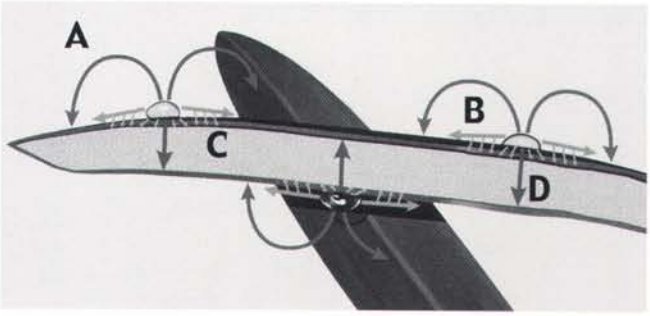

Figure 3. How a mesostemic protects a turfgrass plant. (A) The vapor phase movement, either to other parts of the plant or to neighboring plants. (B) The contact mode of action on the exterior of the leaf. (C) Some of the chemical is able to penetrate the cuticle wax layer and dissipate within it. (D) Limited translaminar flow to the side of the leaf that was not treated.

Mesostemics do have some limited movement into the plant and as a result have some protection from the elements. They have a life span of about 14-21 days. Mesostemics will also control infections already present in the plant; however, they will not prevent symptom expression of preexisting infections.

Trifloxystrobin, unlike the members of the contact classification, only has one biochemical mode of action. Resistance management strategies should be implemented with its use (resistance management strategies will be discussed later in the article).

Local Penetrants

This is the first group discussed that has significant movement into the plant. As stated earlier, this group will also provide protection on the outside of the plant similar to the contact topical mode of action. They also have some limited movement into the plant where it can provide protection. There is no major upward or downward movement in the plant so effective coverage of the plant is required to provide the optimal protection.

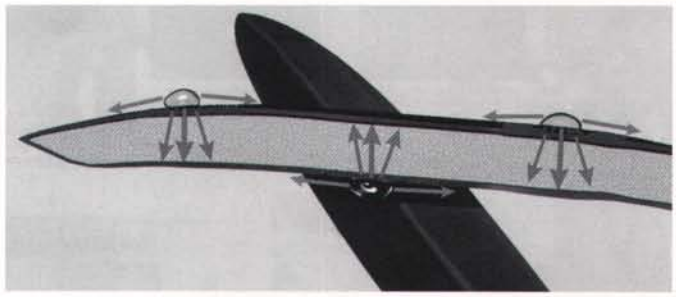

Figure 4. How a local penetrant protects a turfgrass plant. (A) The contact action of the chemical on the surface of the leave. (B) With this mode of action the chemical enters the plant and has limited movement within the plant from the point of entry.

The life span of members of this group ranges from 14-21 days, because of its absorption into the plant. It will also provide some curative properties against existing infections when it enters the plant. Once again, local penetrant chemicals have only one biochemical mode of action so resistance management must be practiced with their use. Documented cases of resistance have been reported on members of this chemical class. Members in this group include iprodione, propamocarb, and vinclozolin.

Acropetal Systemics

Acropetal systemics include the largest group of fungicides. Acropetal movement in a plant is upward

and outward movement, primarily through the xylem. When this type of fungicide is applied it will provide protection to any part of the plant above where it entered. It is usually best to make applications with higher volumes of water to ensure that the chemical enters the plant around the crown of the plant. Therefore, protection will include even newly emerging tissue. Absorption is also possible via the roots of the plant and translocated to the aerial parts of the plant. The root absorption makes these chemicals an ideal choice for root infecting pathogens.

Acropetal systemics, as a general rule, are highly resistant to the elements. In experiments conducted at the UW, some of these chemicals have provided upwards of 65 days of disease protection. But, life span can last anywhere from 14-60+ days depending on coverage and the rate of application.

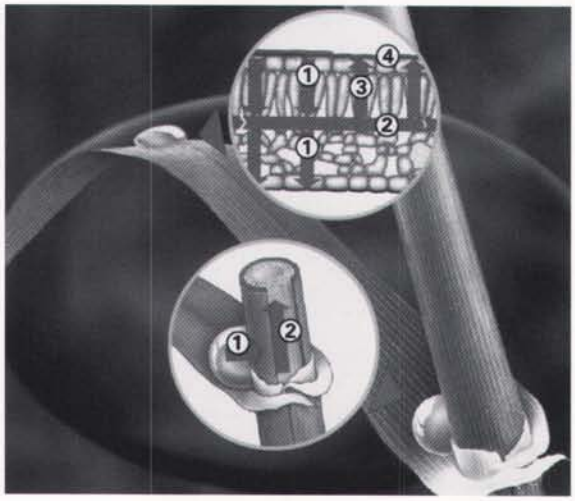

Figure 5. How an acropetal systemic protects a turfgrass plant. 1. Entering the leaf and translaminar movement. 2. Acropetal movement in the xylem of the plant. 3. Movement of the chemical to the surface of the leaf. 4. Contact activity on the surface of the leaf.

Protection against existing diseases is possible because these chemicals enter the plant. As with the other groups, protection of the leaf surface is provided similar to the contacts. Acropetal systemics also has translaminar movement, so that the opposite side of the leaf that receives the chemical application will also be protected.

Most of these chemicals only have one biochemical mode of action, so again resistance management must be practiced. This group is made up of chemicals from several families. These include azoxystrobin, fenarimol, flutolanil, mefenoxam, myclobutanil, propiconazole, thiophanate methyl, and triadimefon.

Systemic

Currently there is only one true systemic fungicide labeled on turf. In order to be classified as a systemic the chemical must be able to move upward and downward within the plant. The only chemical that has a systemic topical mode of action is fosetyl Al. Because of the main biochemical mode of action of this chemical, it will probably provide little protection on the surface of the plant, but it does induce defensive mechanisms within the entire plant.

Systemic chemicals will have some halting properties against existing infections, but may require some time to become effective. Since this group is absorbed into the plant, life span is usually around 14-21 days. Length of efficacy is reduced compared to other systemics because of the pathogens that fosetyl Al is affective against.

Figure 6. How a systemic protects a turfgrass plant. 1. Entering the leaf and translaminar movement. 2. Acropetal and basipetal movement in the xylem and phloem of the plant. 3. Movement of the chemical to the surface of the leaf. 4. Contact activity on the surface of the leaf.

Resistance may or may not be a problem with this group because the primary biochemical mode of action is a chemical induced plant response. But, as with most fungicides, resistance management should be practiced with any fungicide program.

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Illustrations on topical modes of actions were adapted from the following publications:

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