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Managing Fungicide Resistance

Stephen Vann
Assistant Professor - Urban Plant Pathologist

Sherri Sanders
County Extension Agent - Agriculture

Amanda Greer
Plant Pathology Program Technician

Introduction

The use of fungicides can be an effective component in an overall plant disease management program. These products are designed to inhibit infection, development or reproduction of target fungal pathogens and can be very effective in preventing or minimizing the impact of certain plant diseases. Commercial fungicide products are composed of one or more active ingredients, each with a specific mode of action. Choosing the correct fungicide, timing of application and spray coverage are crucial for the material to work effectively.

Most fungicides are applied as a preventative spray to protect healthy plant tissues from infection (Fig. 1). Fungicides are broadly categorized either as ***protectant*** or ***systemic***.

As the name implies, protectant fungicides provide a protective barrier on the surface of the plant to prevent infection by fungal pathogens. Protectant-type fungicides are active only on the surface of plants and may inhibit spore germination of the fungal pathogen or its growth on the surface of leaves, stems and other plant parts. Protectants do not penetrate into plant tissue nor are they translocated in the plant. Because this group of fungicides remains on the plant surface, they are susceptible to weathering (rain events, photodegradation). In addition, because protectants do not move in the plant, new growth is not protected. Because of this, the protectant types of fungicides usually need to be applied frequently.

Systemic fungicides are absorbed into the plant tissue and may be translocated within the plant. Some materials can enter and move within the conducting vessels of the xylem and phloem and are called “true systemic,” whereas others may only move short distances to immediately

FIGURE 1.

Fungicides can be an important component in a disease management program.

(Photo courtesy James Robbins)

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adjacent tissues and are referred to as "locally systemic." In general, systemic fungicides do not need to be applied as often as the protectants, since once they are inside the plant they are less susceptible to weathering. Systemic fungicides offer another advantage because they may actually inhibit pathogens that have already infected plant tissue. This curative action is, however, limited in scope, and both protectant and systemic fungicides perform best when applied preventively before infection occurs. This demonstrates the importance of regular disease scouting for proper timing of applications.

Each fungicide has a specific mode of action, the actual way the active ingredient targets fungal pathogens. Fungicides may impair the ability of a pathogen to grow or its metabolic ability. Some fungicides target only one specific biological action of a fungus (site-specific or narrow spectrum of activity), or they may have multiple target sites of activity against the pathogen (multi-site or broad spectrum of activity).

Improper use of fungicides can lead to development of ***fungicide resistance***, which can be defined as a loss of efficacy against a particular target pathogen. Failure in efficacy is often first recognized when expectations of disease control in a particular crop situation are not met even after the application of the labeled and recommended dosage of fungicide. Loss of fungicide efficacy may gradually increase over time with a slowly increasing loss of disease control, or it may appear suddenly with significant loss of efficacy. The most common way that fungicide resistance develops is due to the repeated and exclusive use of one active ingredient on a population of plant pathogens.

Because fungal pathogens are very diverse genetically and because they have a high reproductive capacity, the probability is high that in any fungal population a few individuals will not be affected adversely by the fungicide that is being used. When the same fungicide is repeatedly used, these individuals will survive and reproduce. As the frequency of these "resistant" individuals increases in the overall population, the effectiveness of the fungicide declines. Because many of our most effective fungicides have a site-specific mode of action, selection of resistant individuals in the population may occur relatively rapidly. Historically, fungicides that affect a single site are more likely to have resistance develop against them than those fungicides that are broad spectrum. This has been documented in several instances since the 1970s, with good examples being the development of resistance in various fungal pathogens to the benzimidazole fungicides and more recently to the strobilurins. Unfortunately, when fungicide resistance develops in pathogen populations across a region or in a major crop pathogen group, the result may be the removal of the product from the marketplace, negating years of research in development of the fungicide and limiting the choices for growers.

Use of site-specific fungicides can lead to a greater chance of resistance developing in the fungal population. If a site-specific fungicide is used frequently over long periods of time, it can lose its efficacy. Because of resistance issues, fungicide use should be managed correctly according to class.

Fungicide Resistance Action Committee (FRAC)

To help prolong the life and usefulness of effective fungicides in commercial use, an organization known as the Fungicide Resistance Action Committee (FRAC) was created. FRAC consists of a group of scientists organized through CropLife International. This international working group is composed of a Central Steering Committee, five Working Groups and three Expert Fora. FRAC originated in 1981 as a result of a course on fungicide resistance in 1980 and an industry seminar in Brussels in 1981.

The purpose of FRAC is to provide fungicide resistance management guidelines to prolong the effectiveness of "at-risk" fungicides and to limit crop losses should resistance occur.

The major objectives of FRAC are to:

1. Identify existing and potential resistance problems.
2. Collate information and distribute it to those involved with fungicide research, distribution, registration and use.
3. Provide guidelines and advice on the use of fungicides to reduce the risk of resistance developing and to manage it should it occur.
4. Recommend procedures for use in fungicide resistance studies.
5. Stimulate open liaison and collaboration with universities, government agencies, advisors, extension workers, distributors and farmers.

Today, FRAC provides guidelines, advice and information on the use of fungicides in such a way as to minimize the development of fungicide resistance in pathogen populations. All registered pesticides are classified by mode of action (MOA), and each mode of action is assigned a group symbol (number or letter). Letters are assigned when the MOA is unknown (U) or multi-site (M). To date, there are over 43 groups, and more are added as new MOAs are identified for the active ingredients of specific fungicides. In 2001, the Environmental Protection Agency (EPA) proposed a labeling scheme that added the FRAC Mode of Action classifications to fungicide labels of all products used in the United States.

The FRAC codes are useful because they are important in identifying "high-risk" fungicides which

have a high probability for fungal resistance to develop if they are misused. Sometimes a fungus that develops resistance to one active ingredient may also be resistant to other similar active ingredients. This situation is known as cross-resistance, and FRAC codes categorize products together that have closely related modes of action. For example, all fungicides with strobilurin chemistries will belong to FRAC code 11, and those belonging to the carbamate group belong to FRAC code 28.

FRAC
FUNGICIDE RESISTANCE ACTION COMMITTEE

FIGURE 2.

Fungicide Resistance Action Committee (FRAC) logo

(Photo courtesy FRAC)

Each year the FRAC group (Fig. 2) publishes a list of FRAC codes for most fungicides and their chemistries. These codes group the fungicide chemistries according to chemical group, common name (active ingredient), target site, MOA and risk of resistance. Although placing the FRAC code on a fungicide label is not mandated by law, currently most companies voluntarily include the FRAC code(s) on their labels.

Finding the FRAC Code on Fungicide Labels

FRAC codes can normally be seen on the front of the label near the top or just below the trade name. They are distinguished by the inverse black-and-white box with the code in the center (Fig. 3). If a particular fungicide contains more than one active ingredient, all of the codes will be listed in the code box (Fig. 4).

Using FRAC Codes to Minimize Fungicide Resistance

By following a few simple guidelines, producers can help reduce the likelihood of resistance development.

- **Obtain an accurate disease diagnosis.** Accurate pathogen identification allows the choice of the correct fungicide to be made and minimizes the chances of applying an ineffective product.
- **Avoid consecutive applications of the same active ingredient or fungicide class.**
- **Rotate fungicide applications between different modes of action.** Consider using multi-site fungicides or utilizing pre-mixes or tank mixes of two chemical classes.

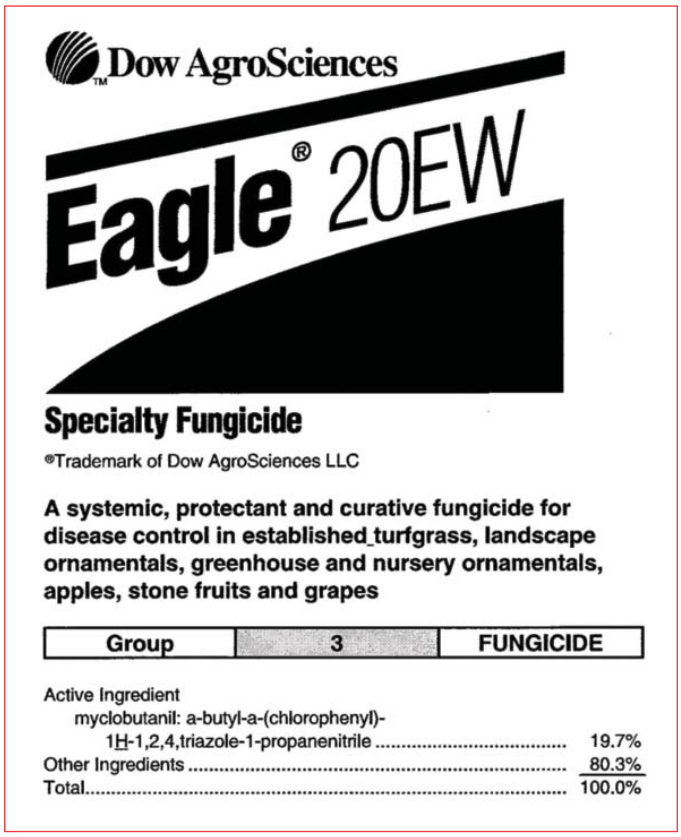

FIGURE 3. Front of Eagle® fungicide label with FRAC code.

(Photo courtesy CDMS)

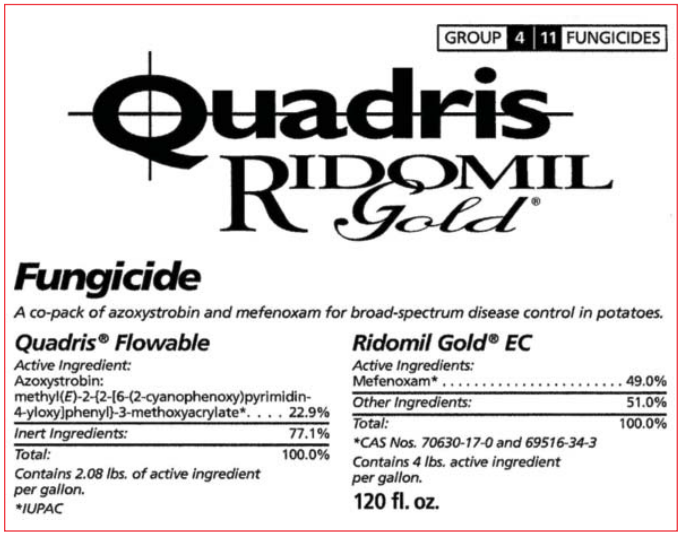

FIGURE 4. Front of Quadris Ridomil Gold® fungicide label with FRAC codes.

(Photo courtesy CDMS)

- ***Always* read and follow the fungicide label directions.** In many instances, companies provide resistance management suggestions on the label which include suggested fungicide partners for rotations and number of sequential applications of the product allowed before switching to another chemistry or mode of action.
- **Use the proper rates as indicated on the label.** Cutting rates can increase selection of resistance pathogens.

Choosing a Fungicide Rotation Sequence

Fungicide rotation means alternating between different modes of action over the course of a treatment period or season. The primary goal of rotating fungicides in a disease management program is to reduce the likelihood of developing resistance in the target organism population. If rotation is not possible, tank-mixing fungicides with different FRAC codes can be effective as well. Some groups of fungicides have a higher risk of resistance development than others. These fungicides often have a single target site or single mode of action. An example of a high risk group of fungicides is those with a FRAC code 11, the strobilurin or Qol group. The risk assessment is given in the "comments" portion of the FRAC chart. Additional restrictions are often placed on their frequency of use and dosage during a season. These restrictions are usually outlined on the fungicide label under the "Resistance Management" section.

Fungicides having multiple target sites or multiple modes of action are at less risk of resistance development; for example, the fungicides listed in FRAC code group M.

To develop a fungicide rotational sequence plan, the grower will first need to know (1) the target organism and (2) a list of available registered fungicides with their respective FRAC codes.

Example of Fungicide Rotation Sequence for Peaches

The following is an example of a fungicide rotation plan for brown rot disease of peach:

- The grower may consider 1-2 applications during pink growth stage of a registered fungicide containing propiconazole (FRAC code 3).
- During full bloom, apply a strobilurin material (FRAC code 11), using no more than 2 sequential applications of Group 11 fungicides before alternating with another FRAC code fungicide.
- At shuck split, the grower may consider a multi-site material such as chlorothalonil (FRAC code M5) with as many as 3 sequential applications, depending on disease pressure.

Always read the fungicide label thoroughly for mixing, handling and application information. Also, see Extension publication *MP154, Arkansas Plant Disease Control Products Guide,* for a comprehensive list of registered fungicides and their respective FRAC codes.

Additional Information

For the most recent FRAC code list and updates, consult the Fungicide Resistance Action Committee (FRAC) web site, http://www.frac.info. This site is updated on a regular schedule and contains information including FRAC codes, various MOAs and fungicide characteristics.

Some fungicide products are only available through commercial pesticide dealers and may not be cost effective or practical for homeowner applications. Consult Extension publication *MP154, Arkansas Plant Disease Control Products Guide*, for available commercial and homeowner fungicides.

An effective disease management program begins with early detection and an accurate diagnosis. A microscopic laboratory exam in conjunction with background information about the disease situation may be required for an accurate diagnosis. For further information about fungicides and their usage, identification of disease organisms and plant sample collection, contact your local county Extension office or the Arkansas Plant Health Clinic at ssmith@uada.edu.

Additional fact sheets are available at http://www.uaex.uada.edu.

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DR. STEPHEN VANN is assistant professor - urban plant pathologist, located in Little Rock; **SHERRI SANDERS** is county Extension agent - agriculture in White County; and **AMANDA GREER** is plant pathology program technician at the Southeast Research and Extension Center, Monticello. All are employees of the University of Arkansas Division of Agriculture.

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