

UNDERSTANDING FUNGICIDES TO IMPROVE THEIR USE AND EFFICACY

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Introduction

Fungicides have become a major component of plant disease management plans for agronomic crops. Fungicides are applied to prevent or slow epidemics of disease caused by fungi. Unlike insecticides and herbicides, which are used to kill insects and weeds, fungicides are applied to form a barrier to protect plant organs from infection. Performance of fungicide products can be affected by many factors including timing of application, off-label rates, poor product choice for the pathogen of concern (e.g. active ingredient is not effective against the organism), fungicide resistance, etc.

Don't Forget The Plant Disease Triangle

One of the best ways to improve the efficacy of a fungicide is to use it in conjunction with other cultural practices. A great model to use when considering an integrated disease management approach is to consider the plant disease triangle. The plant disease triangle demonstrates that it takes a virulent pathogen, a susceptible host, and favorable environment occurring at the same time for the development of a plant disease. If any one of these components is missing a plant disease will not occur. Likewise, if a component of the triangle is manipulated in some way, the magnitude of a disease can be affected. For instance, the host component can be manipulated by using plants that have genetic resistance against the pathogen of interest. Also, managing plant stress and using hybrids/varieties that are well adapted to an area equates to plants that are less likely to be predisposed to a plant disease. Manipulating the environmental component of the triangle can be much more difficult. However, the environment immediately around a plant (microenvironment) can be changed, to a certain extent. For example, managing soil fertility can provide an environment favorable for plant growth and reduce plant disease. Changing plant population and spacing or reducing irrigation can change the microenvironment and can also reduce plant disease. The pathogen component can be manipulated in several different ways. Excluding a pathogen from an area is an excellent way to control plant diseases. Using certified pathogen-free seed and cleaning field implements between fields could prevent the introduction of a pathogen to a non-infested field. Eradication can also be applied to pathogens. This strategy can be very difficult because it can be nearly impossible to remove all infested plants and/or soil from an area to completely rid it of a pathogen. Sanitation can be widely utilized too, whereby pathogen infested plant material is removed or buried. As mentioned previously, fungicides are also used to manipulate the pathogen.

Fungicides, Fungicide Mode of Action, and Fungicide Mobility

The word 'fungicide' implies that a chemical will kill a fungus. This can be misleading as many of the products used to control fungi are actually only fungistatic (meaning they simply inhibit the growth or reproduction of a fungus and are not directly toxic to the organism).

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Fungicide mode of action defines how the product actually affects the fungal organism. For instance, the demethylation inhibitor (DMI) fungicide group (contains the triazoles) inhibits a specific enzyme in fungi that plays a role in sterol production. Sterols are necessary for the development of cell walls in fungi. Therefore, the application of DMIs results in abnormal fungal growth, repressed growth, and in some cases death. All fungicides within the DMI group have this same mode of action. One of the strategies to manage fungicide resistance development is to rotate fungicide mode-of-action. Considering the example of using DMI fungicides above in a proper rotation, the crop manager must choose a fungicide that is not in the DMI group for a subsequent application. This is analogous to a pitcher in baseball. Pitchers don't typically throw the same style of pitch each time. They rotate fastballs, with screwballs, with sliders, etc. This same approach should be adopted when developing a fungicide program. Care should also be taken during the development process to identify products with pre-mixed active ingredients in different mode-of-action groups. For instance if a pre-mix product is chosen that contains a Fungicide Resistance Action Committee (FRAC) 3 (DMI compound) and also a FRAC 11 (strobilurin compound) then the next fungicide application should ideally be a product that does not contain either a FRAC 3 or 11 compound.

Fungicide mobility is separate from fungicide mode of action. By understanding mobility and mode of action and how the two work in unison to control a fungus in a crop plant, the better the disease management decision-making process can be for plant management practitioners. Fungicides have one of two types of mobility: contact or penetrant. Regardless of the mobility, fungicide products work best when applied prior to symptom development and pathogen reproduction (spore production). Applying fungicides close to the onset of an epidemic will yield the best control of diseases caused by fungi.

Contact fungicides are applied to the surface of a plant and do not move into plant tissue. They can be washed from the plant and degrade by exposure to the weather. Therefore, contact fungicides must be reapplied regularly to re-establish protection on previously treated plant organs, or applied to protect new plant growth. Contact fungicides act by forming a protective barrier against fungal invasion. Therefore, they must be applied prior to fungal infection.

Penetrant fungicides can move into plants after being applied to the surface. Due to the movement of the fungicide into the plant, these fungicides are generally considered 'systemic' fungicides. This can be misleading as the degree of systemicity can vary among fungicides. *Local penetrant* fungicides move just short distances, such as into the waxy plant cuticle and remain in that location. *Translaminar penetrants* can move through the cuticle between cells toward the opposite side of the leaf. *Acropetal penetrants* are xylem-mobile (xylem elements are the water conducting vessels of plants) and move between cells along a water potential gradient. Acropetal penetrants only move upwards in plants. *Systemic penetrants* move through cells and follow sugar gradients in plants. Therefore, systemic penetrants can move upward and downward in plants. Very few fungicides are considered systemic penetrants. Regardless of the level of systemicity, penetrant fungicides have very limited 'curative' ability. Penetrant fungicides will only stop or slow infections within the first 24- to 72-hours after fungal penetration. Therefore, best control of fungal infections with penetrant fungicides will be achieved when these products are applied on a preventative schedule.

Fungicide Resistance in Fungi

Fungicide resistance results from genetic adjustment of the fungus, which leads to reduced sensitivity to a fungicide. Genetic mutations in fungi that result in fungicide resistance are thought to occur at low frequency and can be governed by a single gene or multiple genes. Mechanisms that lead to reduced sensitivity to a fungicide can vary, but include a change in the target site, active export of the fungicide out of the fungal cell, breakdown of the fungicide active ingredient, and reduced fungicide uptake. Fungicide resistance occurs when the frequency of resistant fungal strains in the population outnumbers the fungicide-sensitive individuals. This arises through repeated and exclusive use of fungicides with high-risk for fungicide resistance development. Selection pressure can be high when repeated fungicide applications are used to control many of the foliar diseases of field crops. Risk of fungicide resistance development is low for seed treatments and soilborne pathogens, which require just one or two applications per season for control.

Practices that Result in Fungicide Resistance

Application of fungicide at the wrong time (ex. after the fungus has begun sporulating) or with inadequate coverage can result in poor control of a pathogen and lead to reapplication thereby resulting in many fungal individuals being exposed to fungicide. Using inadequate rates can also lead to poor control necessitating the need to apply fungicides frequently, exposing many fungal individuals to fungicide. Excessive application of fungicide where a need is not justified can also lead to higher risk of fungicide resistance. Other practices that result in exposure of unnecessarily high populations of fungal individuals to many fungicide applications include using susceptible hybrids/varieties, inadequate or excessive fertilization, excessive and/or frequent irrigation, continuous cropping, and poor sanitation.

References

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