# 1.3: FUNGICIDE LABELING AND TERMINOLOGY

There are several important concepts to consider with fungicides including nomenclature, classification criteria, and fungicide terminology. Understanding these concepts helps provide clarity among educators, applicators, and other agricultural professionals. Also, fungicide labels use specific terminology to convey information to users, highlighting the importance of understanding the meanings of these words.

Fungicides are required by law to have a product label, which becomes a legal document. It is a violation of Federal law to use a product in a manner inconsistent with its labeling. A fungicide label provides details about the fungicide and how to properly apply the product. Information as it relates to the label includes the crops a fungicide may be used on, diseases managed, application rate, applicator safety, and numerous other important statements regarding the product or products contained within the fungicide. Fungicide labels are organized in a similar fashion, making it easy to quickly identify the most important information. Although there is a lot of information present on a label, there are a few especially important parts to carefully consider (Figure 1.3).

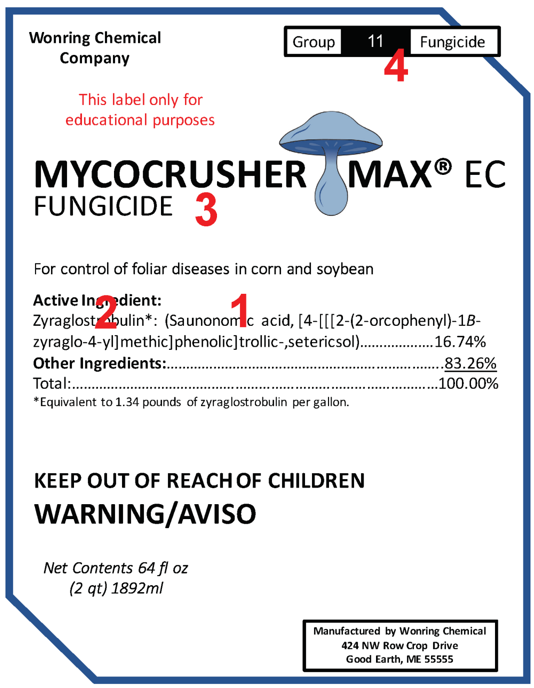


**Figure 1.3.** All fungicide labels contain the same key information. The specific information is important for proper application, user safety, resistance management, and many other things. Vital information includes: 1) chemical name, 2) common name, 3) trade name, and 4) Fungicide Resitance Action Committee (FRAC) code.

# Fungicide Nomenclature

Three terms are used to differentiate fungicides: the chemical name, common name, and trade name(s). These names help farmers, scientists, and applicators to reference fungicide products for ease of identification and classification, depending on the specific audience. These names are found on the fungicide product label (Figure 1.3).

**Chemical name:** designates the fungicide active ingredient (e.g., carbamic acid, [2-[[[1-(4-chlorophenyl)-1H-pyrazol-3-yl]oxy]methyl]phenyl]methoxy-, methyl ester).

**Common name:** less technical reference for fungicide active ingredient (e.g., pyraclostrobin).

**Trade name(s):** registered reference to a commercially available product containing the fungicide active ingredient (e.g., Headline®). Several different trade names may exist for a single active ingredient.

# Characterizing Fungicides

Different criteria are used to characterize fungicides including mobility within the plant (phytomobility), mode of action, chemical class, FRAC (Fungicide Resistance Action Committee) code, metabolic activity, role in plant protection, and selectivity. Other methods of fungicide characterization also exist, such as bioavailability.

## Phytomobility

After application, fungicides that come into contact with plant tissue either remain in place or have the ability to move within plant tissue or between plant parts. Potential movement of a fungicide within plant tissue is termed "phytomobility," and should not be confused with mode of action (see below). Fungicides can be broadly classified into two groups based on phytomobility: contacts or penetrants/systemics.

**Contact**, or non-systemic fungicides do not move into plant tissues. Products consisting of or containing contact fungicides stay on the surface of the plant that was sprayed and are not absorbed. Contact fungicides may re-distribute over the target area (i.e., leaf) due to wetting events such as irrigation, rain, or dew. Contact fungicides are more prone to being washed off the plant by rain compared to penetrant fungicides. Additional fungicide applications may be required if protection of new plant growth is needed later in the season.

**Penetrant/Systemic** fungicides are absorbed into plant tissues. However, these fungicides are not all equally mobile within the plant. Systemic fungicides can be further classified into three subgroups, based on their mobility within the plant (phytomobility): acropetally mobile fungicides, ambimobile fungicides, and locally systemic fungicides.

- **Acropetally mobile** fungicides move along a water potential gradient and are distributed between cells (Figure 1.4, top). These types of fungicides are mobile in the xylem (water-conducting vessels in the plant) and are moved upwards toward leaf tips.
- **Ambimobile** fungicides have the ability to move upward AND downward in plants (Figure 1.4, bottom). Ambimobile fungicides can move through live protoplasts and cells along a sugar gradient. These gradients run from high concentration in fully expanded leaves to low concentration in roots and new leaves. Ambimobile fungicides, such as phosphorous acid fungicides, are rare in field crops.
- **Locally systemic** fungicides have more limited mobility compared to acropetal or systemic penetrants. They are typically attracted closely to waxy compounds, thus diffusing mostly in the waxy cuticle of the plant surface. Some fungicides can move from the cuticle of the upper leaf surface through the leaf to the cuticle of the lower leaf surface, or vice versa (translaminar movement; Figure 1.5). However, most of the active ingredient stays near where it is applied.

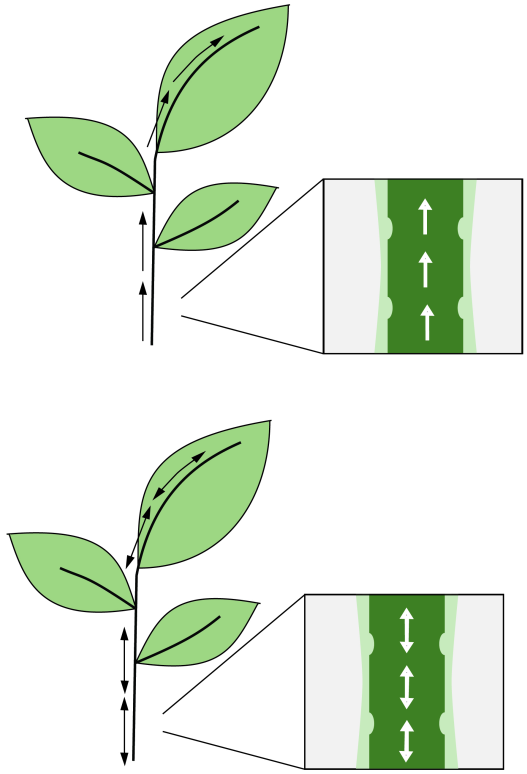

**Figure 1.4.** Acropetally mobile fungicides (top) move upwards in the plant while ambimobile fungicides (bottom) can move up and down within the plant.

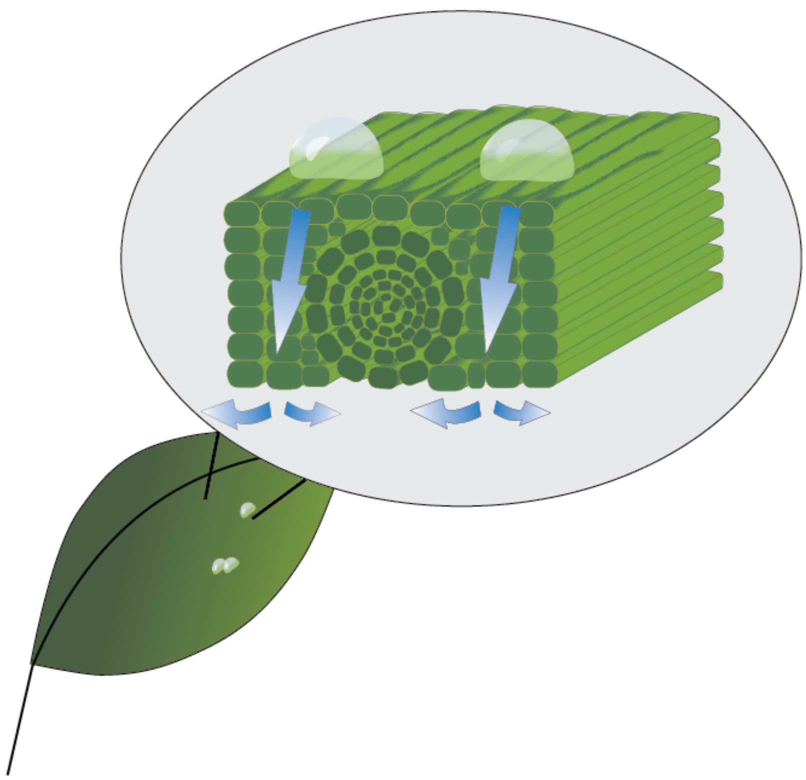

**Figure 1.5.** Translaminar movement of fungicides occurs when the chemical moves through the leaf from the side of application to the opposite side.

## Mode of Action

The mode of action is defined as the target and process the fungicide possesses to inhibit or reduce growth of fungal or fungal-like pathogens. Mode of action is different than phytomobility. Fungicide modes of action include interfering with fungal respiration and energy production, impairing cell membranes, and inactivating important proteins and enzymes. Details of specific modes of action of various fungicides are included in Section 2.1. Mode of action also helps define several other characteristics of a fungicide including chemical class and FRAC group, metabolic activity, role in plant protection, and selectivity. These characteristics are further defined below.

## Chemical Class and FRAC Code

Fungicides with the same biochemical mode of action belong to specific chemical classes. Chemical structure may differ among fungicides within the same group or class. In an effort to understand the important issue of chemical classification and the development of fungicide resistance based on class, the Fungicide Resistance Action Committee (FRAC) was developed. The committee created the FRAC code to help fungicide applicators easily distinguish products with different modes of action groups. FRAC codes are composed of letters and/or numbers such as 11 (pyraclostrobin), M3 (mancozeb), or M5 (chlorothalonil). See Section 1.4 for additional details on FRAC codes.

## Target Site (Biochemical Mode of Action)

Fungal and fungal-like pathogens, like other living organisms, have metabolic pathways essential for life. Metabolic pathways consist of multiple chemical reactions that can be disrupted by fungicides to cause harm to the fungal pathogen.

A **single-site fungicide** disrupts one function or point of a single metabolic pathway. The fungicides contained within this particular metabolic group may also be active against a single protein or enzyme critical to development. Fungicides with single-site metabolic activity are at increased risk of fungicide resistance development in the target fungus (Figure 1.6, left).

A **multi-site fungicide** disrupts more than one fungal metabolic site. These types of fungicides typically make it harder for a fungus to develop resistance, as it is more difficult to overcome disruption to multiple sites versus one target (Figure 1.6, right)

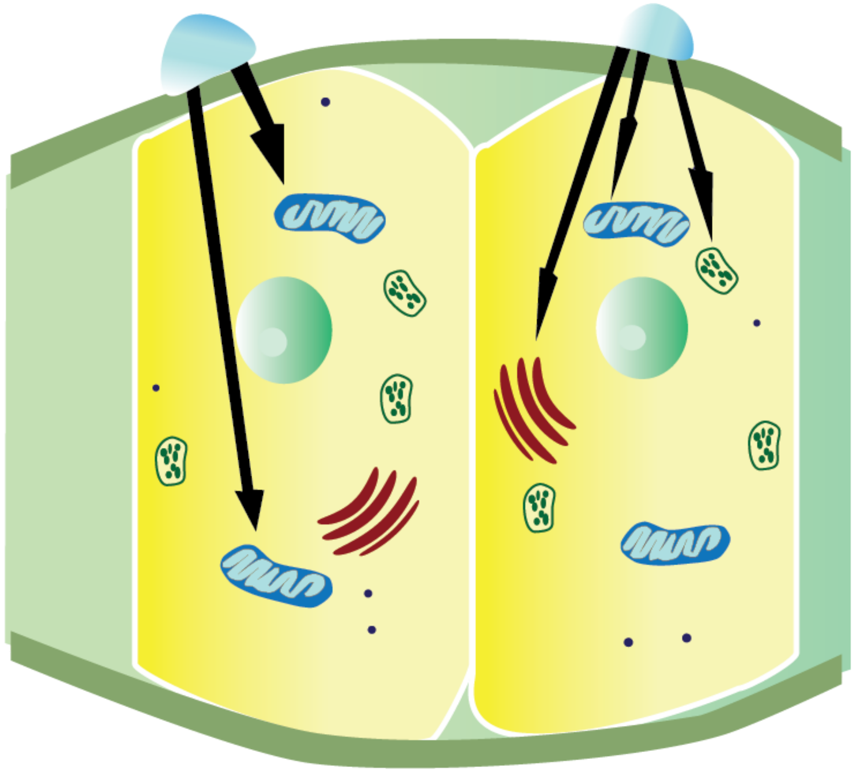

**Figure 1.6.** Single-site fungicides disrupt one function within the plant (left droplet) while multi-site fungicides disrupt more than one plant function (right droplet).

## Role in Plant Protection

Fungicides protect plants by preventing infection, inhibiting early pathogen development, and preventing spore production (antisporulant). Some fungicide products exhibit more than one of these types of protection (mixed chemical class products).

Fungicides with **preventive** activity act as a barrier to fungal infection, and must be present before pathogen arrival or initiation of disease development. Preventive activity is also referred to as protective activity.

Some fungicides have the ability to inhibit early fungal development. Depending on the fungicide, this type of activity is effective from 24-72 hours post-infection. This type of activity is also called **curative** or kickback activity, although fungicides do not "cure" the plant once infection has occurred. Fungicides that have this ability usually also have preventive activity, and effectiveness is maximized if applied prior to infection.

**Antisporulant** activity fungicides prevent spore germination. Spores often contain essential lipids and carbohydrates in stored forms. Thus, fungicides that inhibit the formation of these compounds in fungi effectively inhibit spore germination.

## Selectivity

Selectivity refers to the ability of a fungicide to be active on a specific targeted pathogen without having a detrimental effect on the host, non-target animals, or the environment. Mode of action and fate determine the selectivity of a fungicide. Some fungicides are active on a specific biochemical pathway that only exists in some organisms and not others. The level of selectivity often leads to influencing the spectrum of activity of a fungicide. That is to say some fungicides are effective on a wide range of pathogens, while others have an extremely narrow spectrum of activity, only affecting a limited number of specific organisms within a particular fungal (or oomycete) family.

## Bioavailability

Fungicides can be categorized in other ways, including their bioavailability, which affects how they are absorbed into and translocated within the plant and their half-life.

Uptake and translocation within the plant are influenced by lipophilicity (logP) of the active ingredient, which is the ability of an organic compound to dissolve in fats, oils, lipids, and non-polar solvents. The greater the logP, the less movement within the leaf (Zhange et al., 2018). Translocation within the plant is a passive process and is affected by the active ingredient's polarity. The logP and polarity of active ingredients can be used to calculate the "translocation stream concentration factor", which is an indication as to how readily fungicides can move within the plant (Briggs et al., 1982). The half-life of fungicides and logP values, as well as many other properties, can be found on the University of Hertfordshire Pesticide Properties DataBase (PPDB). The properties for fungicide active ingredients can vary widely (Table 1.3), which can affect how well products work in different situations.

**Table 1.3.** Translocation stream concentration factor, typical half-life in soil, and lipophilicity (logP) of some common fungicides used on field crops.

| Fungicide | TSCF[1] | Typical half-life in soil (days)[2] | LogP[2] |
|---|---|---|---|
| **Mefentrifluconazole** | 0.267 | 268 | 3.40 |
| **Tetraconazole** | 0.214 | 61 | 3.56 |
| **Difenconazole** | 0.051 | 130 | 4.36 |
| **Tebuconazole** | 0.173 | 63 | 3.70 |
| **Cyproconazole** | 0.388 | 142 | 3.09 |
| **Metconazole** | 0.135 | 142 | 3.85 |
| **Prothioconazole** | 0.142 | 14 | 3.82 |
| **Propiconazole** | 0.168 | 72 | 3.72 |

| | | | |
|---|---|---|---|
| **Flutriafol** | 0.701 | 1358 | 2.3 |
| **Fluxapyroxad** | 0.371 | 183 | 3.13 |
| **Bixafen** | 0.304 | 500 | 3.3 |
| **Fluopyram** | 0.304 | 309 | 3.3 |
| **Boscalid** | 0.443 | 200 | 2.96 |
| **Penthiopyrad** | 0.106 | 32 | 3.99 |
| **Benzovindiflupyr** | 0.026 | 121 | 4.62 |
| **Pydiflumetofen** | 0.12 | 2416 | 3.8 |
| **Pyraclastrobin** | 0.099 | 32 | 3.99 |
| **Trifloxystrobin** | 0.038 | <1 | 4.5 |
| **Picostrobin** | 0.202 | 24 | 3.6 |
| **Fluoxastrobin** | 0.486 | 59 | 2.86 |
| **Azoxystrobin** | 0.634 | 78 | 2.5 |
| **Kresoxim-methyl** | 0.267 | 16 | 3.4 |

[1]Translocation stream concentration factors were calculated using the Briggs, Bromilow, and Evans equation (Briggs et al., 1982). [2]Values for typical half life and logP can be found on the University of Hertfordshire Pesticide Properties Database (PPDB).