# Agronomic Spotlight

Seminis grow forward

## Protectant and Systemic Fungicides

» Protectant fungicides prevent new infections from occurring, are usually non-systemic, have multisite modes of action, and are active on a broader range of fungal pathogens.

» Systemic fungicides provide some control in the early post-infection period, can move to protect unsprayed plant tissues, often have single-site modes of action, and may have narrower spectra of activity.

### Fungicide Classifications

Fungicides are classified based on whether or not they move through the plant after application, what groups of pathogens they control, if they have any curative activity, and by what mode of action they inhibit the pathogen, indicated by their FRAC group. Fungicide FRAC groups have been established by the Fungicide Resistance Action Committee to group fungicides by their modes of action and their risk for cross-resistance.[1] It is common to see protectant fungicides compared to systemic fungicides. While these terms technically belong to different classification systems, the terms are useful for describing two types of fungicides with common characteristics.

### Contact and Systemic

Contact and systemic are terms used to indicate where on or in the plant fungicides are active.[2] Contact (non-systemic) fungicides remain on the plant surface (Figure 1A). They do not penetrate into plant tissues. As a result, they are only effective before the pathogens infect the plant.[2] Because they are not absorbed into the plant, contact fungicides are susceptible to being washed off of plant surfaces by rain or overhead irrigation. The rainfastness of a product will depend on its chemical characteristics and the addition of any adjuvants such as spreader-stickers. However, a commonly used guideline is that one inch of rain will remove approximately 50% of fungicide residue, and two inches of rain will remove most of the residue of a contact fungicide from a plant surface.[3] Contact fungicides are also susceptible to degradation from other environmental factors, such as UV light, heat, and microbial activity. Plant tissues that grow after a contact fungicide is applied will not be protected.[3] **Most protectant fungicides are contact fungicides**.

Systemic fungicides are absorbed into the plant to some degree (Figure 1B).[2] However, most fungicides are not truly systemic in that they are not translocated throughout the plant. There are different degrees of systemic movement. Some products are **locally systemic**, meaning that they are absorbed into the plant and move only a short distance from the point of application.[2] When a fungicide is able to spread from one side of a leaf (the upper leaf surface) to protect the other side of the leaf (the lower leaf surface) it has translaminar movement (Figure 1B). **Xylem systemic** fungicides are able to move within the leaf, usually toward the leaf tip, or move upward in the plant toward the shoot tips. They do not move downward in the plant toward the roots. **Highly systemic** fungicides are able to move throughout the plant from their point of application, both upward toward the shoot tips and downward toward the roots. Only a few fungicides are classified as highly systemic.[2,3]

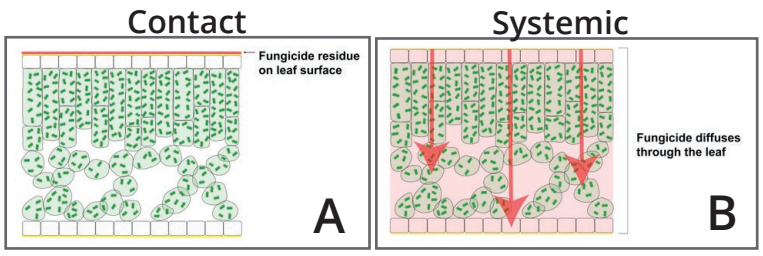


**Figure 1. Leaf cross-sections showing the difference between contact and systemic fungicides. (A) Contact fungicides form a layer of residue on the leaf surface. (B) Systemic fungicides are absorbed into the leaf tissue.**

Systemic fungicides are less susceptible to being washed off the plant because they are absorbed into the plant tissue. However, some dilution of the fungicide occurs as it is redistributed within the plant and as the plant grows. Many systemic fungicides are curative, providing some post-infection activity against the fungal pathogen.[2,3]

### Protectant and Curative

Protectant (preventative) fungicides act as a protective barrier for the plant, killing or inhibiting fungal spores and hyphae before infection occurs. Protectant fungicides are only effective if applied before infection because they do not have any post-infection effect on the pathogen within the plant.[2,3]

Most protectant fungicides are also contact fungicides and broad-spectrum fungicides. Broad-spectrum fungicides work against a wide range of fungal pathogens, often because they have multisite modes of action. The active ingredient acts on several metabolic sites of the fungus. Multisite fungicides are in FRAC groups M-01 through M-12. For example, copper-based fungicides are in FRAC group M-01.[1] The copper

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molecules in the fungicide denature proteins in cells, and they act against many kinds of proteins. Copper fungicides do not affect proteins in the plant because the fungicide remains on the plant surface. Sulfur-based fungicides are in FRAC group M-02. These fungicides disrupt the electron transport system in the mitochondria of the cell. In other words, they disrupt the cell's ability to use energy. Sulfur fungicides often help manage fungal diseases by inhibiting spore germination.[4] Other broad-spectrum, protectant fungicides include mancozeb (FRAC group M-03), captan (FRAC group M-04), and chlorothalonil (FRAC group M-05). Multisite, protectant fungicides are often mixed with systemic fungicides to help reduce the risk of developing fungicide resistant strains of fungal pathogens.[2,4,5]

Fungicides that are able to stop established infections and minimize further symptom development have "curative" activity. These fungicides can kill spores and fungal hyphae after the pathogen has penetrated the plant. This effect is also referred to as kickback or eradicant activity. Curative activity is usually limited to the early infection period of the disease, often within 24 to 72 hours of initial infection, depending on the fungicide and the rate of application.[2,3] Curative fungicides are systemic fungicides by nature. The fungicides are absorbed into the plant, where they kill or inhibit the fungus and stop the infection process. Some systemic fungicides have both preventative and curative activity.[2]

Many curative fungicides have single-site modes of action, meaning that they act against single points of function in a metabolic pathway of a fungus. The chemical/biological bases for the modes of action are numerous and result in damage to cell membranes, inactivation of enzymes, disruption of energy production/respiration, inhibition of nucleic acid synthesis, and disruption of growth and development.[2] Fungicides that have similar modes of action and belong to the same FRAC group may or may not have similar chemical structures. Many curative fungicides have narrower spectra of activity (effective against a smaller range of pathogens), as compared to protectant fungicides. For example, phenylamide fungicides, such as metalaxyl, are used almost exclusively to manage oomycete organisms, including *Pythium* and *Phytophthora*. Single-site fungicides may be at higher risk for enhancing the development of fungicide resistance in pathogens. Resistance management programs are often recommended to prolong the effectiveness of these types of fungicides.[2]

Some curative fungicides also have antisporulant activity, meaning that they inhibit the ability of the fungus to produce spores. The fungal pathogen may be able to continue to grow in the plant tissue and cause symptoms. However, the fungus is not able to produce spores, which limits the ability of the pathogen to spread to other plants or other locations on the same plant.[1]

**Table 1. Some commonly used contact and systemic fungicides.[1,5,6]**

| FRAC Code | Fungicide Group | Example Active Ingredients |
|---|---|---|
| **Contact (Protectant) Fungicides** | | |
| M 01 | inorganic copper | copper hydroxide<br>copper oxychloride |
| M 02 | inorganic sulfur | sulfur |
| M 03 | dithiocarbamates | mancozeb |
| M 04 | phthalimides | captan |
| M 05 | chloronitriles | chlorothalonil |
| **Systemic Fungicides** | | |
| 1 | methyl benzimidazole carbamates (MBC) | thiabendazole<br>thiophanate-methyl |
| 2 | dicarboximides | iprodione |
| 3 | demethylation inhibitors (DMI) | propiconazole<br>prothioconazole |
| 4 | phenylamides | metalaxyl<br>mefenoxam |
| 7 | succinate dehydrogenase inhibitors (SDHI) | fluopyram<br>boscalid |
| 9 | anilino pyrimidines (AP) | cyprodinil<br>pyrimethanil |
| 11 | quinone outside inhibitors (QoI) | azoxystrobin<br>trifloxystrobin |
| 28 | carbamates | propamocarb |
| 33 | phosphonates | aluminum tris |
| 40 | carboxylic acid amides (CAA) | dimethomorph<br>mandipropamid |

**Sources:**


[1] FRAC Code List ©*2021: Fungal control agents sorted by cross resistance pattern and mode of action. https://www.frac.info/knowledge-database/knowledge-database.

[2] McGrath, M. 2016. What are fungicides? The Plant Health Instructor. DOI: 10.1094/PHI-I-2004-0825-01. https://www.apsnet.org/edcenter/disimpactmngmnt/topc/Pages/Fungicides.aspx.

[3] Schilder, A. 2010. Fungicide properties and weather conditions. Michigan State University. https://www.canr.msu.edu/news/fungicide_properties_and_weather_conditions#:~:text=Since%20systemic%20fungicides%20are%20absorbed,the%20outside%20of%20the%20plant.&text=Also%2C%20fungicides%20and%20formulations%20differ,to%20adhere%20to%20plant%20surfaces.

[4] Wyenandt, A. 2021. Understanding protectant fungicides (FRAC groups M01-M11). Plant & Pest Advisory, Rutgers Cooperative Extension. March 10, 2021.

[5] Phillips, B. and Hausbeck, M. 2019. Broad-spectrum fungicides for vegetables. Michigan State University, MSU Extension. https://www.canr.msu.edu/news/broad_spectrum_fungicides_for_vegetables.

[6] Phillips, B., Maynard, E., Egel, D., Ingwell, L., and Meyers, S. 2019. Midwest vegetable production guide for commercial growers 2021.


Websites verified 5/6/2021

**For additional agronomic information, please contact your local seed representative.**

**Performance may vary** from location to location and from year to year, as local growing, soil and weather conditions may vary. Growers should evaluate data from multiple locations and years whenever possible and should consider the impacts of these conditions on the grower's fields. The recommendations in this article are based upon information obtained from the cited sources and should be used as a quick reference for information about vegetable production. The content of this article should not be substituted for the professional opinion of a producer, grower, agronomist, pathologist and similar professional dealing with vegetable crops.



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