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Vegetable Diseases

# *Fungicide Resistance Management for Indiana Vegetables*

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Proper fungicide use is essential for controlling potentially devastating diseases in almost all commercial crops. Understanding the factors that contribute to fungicide resistance is a critical part of creating successful disease management programs for vegetable crops.

This publication will provide you with basic information about fungicide resistance and what you can do to minimize fungicide resistance in your vegetable crops. If you would like to learn more about fungicides and fungicide resistance, there are several excellent references at the end of this publication.

## Fungicide Resistance Basics

Imagine that Farmer Brown looks out into his watermelon field one day and notices that his field is completely covered with symptoms of gummy stem blight. For several years Farmer Brown has regularly sprayed his watermelons with a particular fungicide that worked perfectly. Could Farmer Brown be dealing with fungicide-resistant fungi?

To answer this question, it's important to understand how fungicides can fail. Fungicides can fail for many reasons, including:

1. The severity of the disease is too high for fungicides to provide acceptable control
2. The spraying equipment was improperly calibrated
3. The fungicide application had poor coverage
4. The fungicide was applied at the improper rate
5. The fungicide that was applied was not labeled for the particular crop or disease

If you rule out these and similar factors and still cannot control a disease with a particular fungicide, then you may be dealing with fungicide resistance.

Fungicide resistance is observed in a field when the majority of the pathogen population becomes resistant (insensitive) to a particular fungicide (Figure 1). When certain fungicides are applied continuously, it allows an individual fungus that is fungicide-insensitive to survive and reproduce in the population (Figure 2). Over time, the majority of fungi in the population will be resistant to this particular fungicide, which means the fungicide fails to control the disease and the crop could potentially suffer losses. This phenomenon has been observed in many pathogenic fungi because of the intensive use or misuse of certain types of fungicides.

You can compare fungicide resistance to playing baseball.

Let's say a pitcher only throws one pitch: a 100 mph fastball. During the first few innings, the pitcher strikes out every batter except the one or two players who happen to be excellent fastball hitters. The more innings the pitcher plays, the more the opposing manager includes fastball hitters in the lineup. Eventually, the entire lineup contains fastball hitters and the pitcher is ineffective.

Now let's say that the manager replaces that pitcher. If the replacement throws curveballs he will strike out the fastball hitters. However, if the replacement is another fastball pitcher, the hitters will continue to get hits and the pitcher will be ineffective.

If a pitcher can throw several types of pitches, he is more likely to continue to be effective against the opposing team, regardless of what types of hitters are in the lineup.

This comparison is useful for thinking about fungicides: when a fungal population develops resistance to a fungicide that targets a specific aspect of fungal physiology (a single-site mode of action fungicide) they often are resistant to other fungicides that function in the same manner — much like replacing one fastball pitcher with another.

When fungicides have multi-site activities (that is, they target several aspects of pathogen physiology simultaneously) they are more like the pitcher who can throw several types of pitches. Alternatively, if fungicides with different single-MOAs are alternated in sequence, it would be as if pitchers with different pitches were used one after the other.

## The Fungicide Resistance Action Committee

The Fungicide Resistance Action Committee (FRAC) deals with fungicide resistance issues. FRAC places each fungicide into a group according to its mode of action (how the fungicide acts on the fungus). Fungicide FRAC groups are synonymous with a fungicide mode of acton (MOA). In many Purdue Extension publications, FRAC and MOA numbers are used interchangeably.

Certain fungicide modes of action have a history of fungicide resistance issues, including FRAC groups 1 (benzimidazoles), 2 (dicarboximides), 3 (DMIs), 4

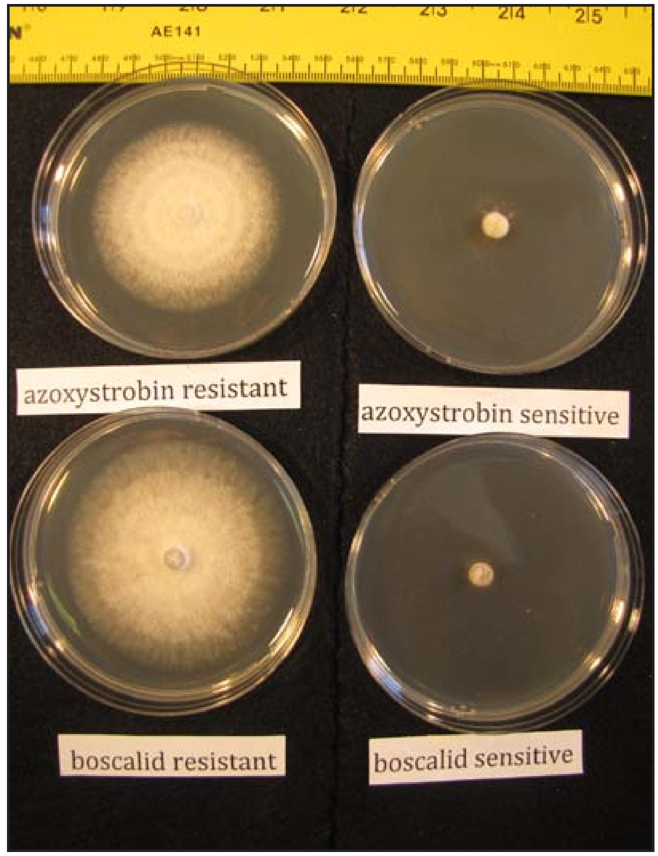


**Figure 1.** Fungicide-sensitive isolates of the gummy stem blight pathogen (right) and insensitive isolates. The isolates on the left are unaffected by the fungicide azoxystrobin (top) and Boscalid® (bottom).

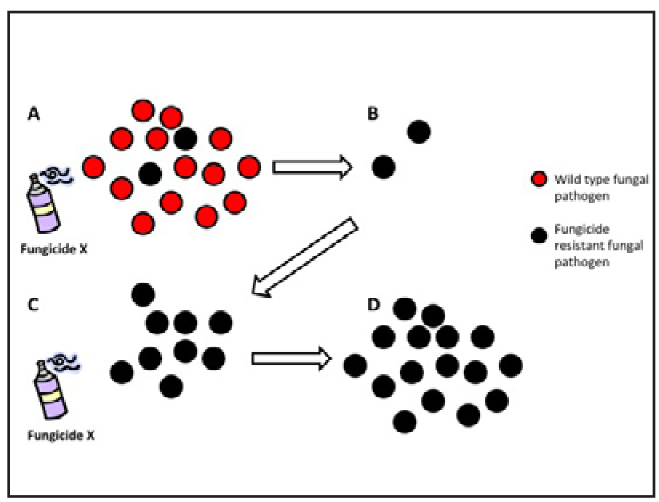


**Figure 2**. A simplified example of how fungicide-resistant individuals may eventually build up in a population. In any fungal population, there may be an individual fungus that is resistant to Fungicide X (A). After Fungicide X is applied (B), the resistant individuals survive and reproduce until they are a majority of the population (C), and Fungicide X no longer controls the fungal population (D). A wild type of an organism is the most common form, appearance, or strain that exists in the wild.

(phenylamides), and 11 (strobulurins). If we return to the baseball metaphor, these fungicides can only throw one type of pitch.

The FRAC website (www.frac.info) provides guidelines for managing resistance among these high-risk fungicides, and updates fungicide risk levels frequently. Table 1 lists high-risk pathogens, fungicides with reported resistance issues, and some alternatives.

## Practices to Reduce Fungicide Resistance Risk

Although some fungicide resistance issues are unavoidable, growers can significantly reduce their chances of experiencing major resistance problems if they (1) follow sound fungicide management strategies, and (2) implement management practices that help reduce disease. These recommendations differ with the crop and cropping system. In Indiana, your Purdue Extension specialist or educator can help you tailor a fungicide resistance management program to your vegetable crops.

### *Fungicide Management Strategies*

1. **Properly time fungicide applications to increase their efficacy.** Timing is crucial for proper disease management. Timing decisions may depend on the type of fungicide used, the type of disease, and environmental conditions. Product labels include general instructions for timing and application intervals. And some crops have forecasting systems in place — for example, MELCAST for muskmelons and watermelons (btny.agriculture.purdue.edu/melcast) and Cucurbit Downy Mildew Forecasting (cdm.ipmpipe.org). USPEST forecasts multiple diseases including potato late blight (uspest.org). These systems use environmental information to inform growers when to apply fungicides to best control major pathogens. Using these systems may increase fungicide efficacy and reduce overall fungicide use.
2. **Read and follow all fungicide label instructions.** Many labels include FRAC group information and have specific instructions for avoiding resistance. These are instructions, not suggestions.
3. **Tank-mix fungicides.** Growers who want to use a single mode of action fungicide may tank mix that fungicide with a different fungicide that has a multi-site mode of action — this can reduce the chance of resistance development. For example, you can tank mix Pristine® (which has two single-site active ingredients) with a chlorothalonil product such as Bravo® (which has multiple modes of action). To use a cucurbit example: The fungicide Pristine® will provide good control of gummy stem blight in situations where there is negligible fungicide resistance — it will also control anthracnose and powdery mildew. In situations where the gummy stem blight pathogen is resistant to both the active ingredients in Pristine®, a chlorothalonil product will provide back up control of these populations.
4. **Alternate fungicides that belong to different FRAC groups.** After applying a product with a single mode-of-action, the next application should use a product with a different mode of action (FRAC group) or have multiple modes of action. Always make sure to only use fungicides that are labeled for the crop and disease in question.
5. **Avoid high-risk fungicides.** Minimize your use of fungicides that have high levels of resistance risk, particularly if you do not tank mix with a multiple site fungicide. More information is available in the Fungicide Resistance Management Table of the *Midwest Vegetable Production Guide for Commercial Growers* (Purdue Extension publication ID-56 — available from the Education Store, www.the-education-store.com).

### *General Practices to Reduce Diseases*

1. **Plant resistant varieties/cultivars.** Many crops have varieties/cultivars that provide complete or partial resistance to specific diseases. Growers can reduce disease issues and fungicide use by using plants that have genetic resistance to the disease. This management practice may not be practical for certain high-value vegetable varieties or cultivars. For example, many popular varieties of pumpkin provide resistance against powdery mildew; however, if you are interested in only growing older, classic varieties with low resistance to powdery mildew, you will have to rely more on other management practices.

2. **Understand disease history and identification.** Scout fields and greenhouses frequently for disease symptoms. Knowing the history and recognizing the signs of infection will allow you to select and apply fungicides in a timely fashion that will provide adequate protection of your crops before diseases become a problem. Furthermore, it is essential that you understand the diseases that cause major problems for the particular crops you work with, and (if needed) consult your Purdue Extension specialists to help you correctly identify diseases. The Purdue Plant and Pest Diagnostic Laboratory can also diagnose diseases (for details, visit www.ppdl.purdue.edu). If you do not properly identify the disease, you may unnecessarily apply an ineffective or high-risk fungicide to your crops.

3. **Implement effective sanitation practices.** Remove diseased or dead plants, properly dispose of inoculum sources, and manage weeds and plants that may be reservoirs or alternate hosts for pathogens. Proper sanitation will help minimize disease by reducing the survival of inoculum and the threat of disease in subsequent seasons. In turn, this should reduce the amount of fungal individuals that may develop fungicide resistance and the amount of fungicide applications required throughout the growing season. More information about sanitation is available in *Commercial Greenhouse Nursery Production: Sanitation for Disease and Pest Management* (Purdue Extension publication HO-250-W), available from the Education Store, www.the-education-store.com.

4. **Minimize plant stress.** Maintain appropriate soil moisture levels. Ensure that soil is properly drained and that plants receive adequate (but not excessive) nutrition. Stressed plants are easier for pathogens to attack successfully. Specific nutrient and water recommendations differ with the crop and pathogen.

5. **Rotate crops when possible.** Crop rotation will help reduce inoculum levels because many plant pathogens only infect specific crops. When the crop is rotated, the fungus is less likely to survive or reproduce. Preventing some diseases may require longer rotations than others. For example, early blight of tomato is a disease that can be managed in part by a three- to four-year crop rotation. Management of Phytophthora blight, which affects many crops, may be more successful with crop rotations of more than four years since the Phytophthora blight fungus survives many years in the soil. Other examples can be found in the *Midwest Vegetable Production Guide for Commercial Growers*.

6. **Deep plow fields when appropriate**. Burying diseased plant material with deep plowing may help reduce inoculum levels in the field and decrease the chance of disease development. Disking often is not sufficient to reduce inoculum levels in the soil.

By taking the necessary precautions, it may be possible to extend the amount of time that a fungicide can be used before resistance builds up in a fungal population. It is much easier to take a proactive approach to fungicide resistance management rather than to manage resistant populations after they have built up to a level that is detectable in an area.

## References

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**Table 1.** Vegetable crop and fungicide combinations that have reported resistance issues in Indiana.[1]

| Crop | High-risk Pathogens | | High-risk Fungicides | | Suggested Alternative Fungicides (FRAC group)[2] |
|---|---|---|---|---|---|
| | Causal Agent | Disease Name | Active Ingredient | FRAC Group Number, Group Name | |
| muskmelon, pumpkin, watermelon | *Didymella bryoniae* | Gummy stem blight black rot | azoxystrobin, pyraclostrobin | 11, strobilurins | chlorothalonil (M), mancozeb (M), tebuconazol (3), cyprodinil (9), difenoconazole (3), fludioxonil (12) |
| muskmelon, pumpkin, watermelon | *Didymella bryoniae* | Gummy stem blight black rot | boscalid | 7, carboxamides | chlorothalonil (M), mancozeb (M), tebuconazol (3), cyprodinil (9), difenoconazole (3), fludioxonil (12) |
| cucumber, muskmelon, pumpkin, watermelon | *Pseudoperonospora cubensis* | Downy mildew[3] | azoystrobin, pyraclostrobin, fenamidone trifloxystrobin | 11, strobilurins | chlorothalonil (M), mancozeb (M) cymoxanil (27), zoxamide (22), fluopicolide (43), propamocarb (28), cyazofamid (21), mandipropamid (40) |
| muskmelon, pumpkin | *Podosphaera xanthi* | Powdery mildew | azoystrobin, pyraclostrobin, trifloxystrobin | 11, strobilurins | tebuconazol (3), cyprodinil (9), difenoconazole (3), fludioxonil (12) triflumizole (3), quinoxyfen (13), myclobutanil (3) |
| muskmelon, pumpkin | *Podosphaera xanthi* | Powdery mildew | thiophanate-methyl | 1, methyl benzimidizole carbamates | tebuconazol (3), cyprodinil (9), difenoconazole (3), triflumizole (3), fludioxonil (12), quinoxyfen (13), myclobutanil (3) |
| tomato, potato | *Alternaria solani* | Early blight | azoystrobin, pyraclostrobin | 11, strobilurins | chlorothalonil (M), mancozeb (M), boscalid (7), cyprodinil (9), difenoconazole (3), pyrimethanil (9), fludioxonil (12), cymoxanil (27) |

[1]Always contact your local extension specialists with specific questions. Always refer to product labels to make sure all uses of any fungicide are legal.

[2]These products may be used as alternatives to, in tank mixes with, or in alteration/tank mixes with products that have resistance issues. Some products may only be available in pre-mixes. Always check fungicide labels. More information about fungicides and fungicide resistance can be found in tables 26 and 27 of the *Midwest Vegetable Production Guide for Commercial Growers* (Purdue Extension publication ID-56).

[3]Downy mildew does not overwinter in Indiana, so the fungicide resistance of the fungus may vary from year to year.



12/11