Choosing Fungicides for Botrytis Control
Part 1

Making fungicide decisions is more complicated than we may appreciate. This article will share the knowledge that you need to make the decisions that will result in the best possible control of Botrytis blight while minimizing the fungicide resistance of the Botrytis spore population in your greenhouse.

1. **Know the history of fungicide applications made to your plants**

   At this moment, you have a population of Botrytis spores in your greenhouse. Those spores have varying degrees of resistance to various fungicides (this is called the Resistance Profile). The resistance profile depends on what fungicides have previously come into contact with the fungus, thus after repeated exposure to a fungicide, fungicide-resistant mutants are present in the pathogen population.

   If you are growing roses in a greenhouse for multiple years, then the only fungicides that the fungi in your greenhouse have been exposed to are the ones that you have applied. In this scenario, no new plants carrying spores are being introduced into the greenhouse, so you are not affected by the fungicides applied by other growers, although you might have migration of spores from neighboring crops.

   In contrast, if you purchase URCs or RCs to start the crops in your greenhouse, Botrytis spores and/or tissue-embedded with mycelium that will eventually producing spores will be coming along for the ride on those cuttings. The fungicide-resistance profile of those spores will be determined by the stock plant grower or the propagator that supplied the young plants. Consequently, greenhouses that start their production schedule with young plants supplied by other businesses are dealing with a continuously changing and unpredictable fungicide-resistance scenario.

2. **Identify the efficacy of the fungicides in your pesticide cabinet**

   It would be helpful if we knew the resistance profile of the spores in our greenhouses. Several options for evaluating fungicide resistance and efficacy include:

   a. **Lab Method.** Spores can be collected from your greenhouse and sent to commercial laboratories for analysis. This involves the collection and shipment of symptomatic plant material that is placed under high humidity to promote sporulation. Alternatively, spores can be collected from sporulating tissue with cotton swabs that are placed individually in paper envelopes and sent for analysis. Commercial labs exist in Colombia, while some universities in the U.S. offer testing services.

   b. **In situ Petri Dish Trap.** Petri dishes containing a culture media that will allow Botrytis spores to germinate and grow can be placed at strategic locations in the greenhouse. A different
fungicide is placed in each dish at an appropriate dose (called ‘discriminatory dose’*).
The open-faced dishes are placed in the greenhouse for 2-4 hours to allow air-born spores to land on the surface of the dishes. If no Botrytis grows in the dish, the fungicide is effective, and resistance is not an issue for that fungicide. If Botrytis does grow, fungicide resistance is a concern and that active ingredient and mode of action (FRAC code) should be avoided since fungicides that have the same mode of action are usually considered to be at risk of cross-resistance. The use of control Petri dishes containing culture media without fungicides is important to verify that you actually have Botrytis spores landing and growing in the media. Different fungicides might require the use of different media. This method will take some time and effort to develop, but it has been successfully implemented in commercial greenhouses.

c. Detached Tissue Assay Method. Botrytis spores are generated from infected tissues by placing the latter into a Ziploc bag to allow for spore formation. Sometimes sporulating tissue is already present in the greenhouse and can be used directly. From these spores, a solution containing a known concentration of Botrytis spores is created. Then, susceptible plant tissues, such as flower petals, are collected, surface sterilized with a 10% bleach solution and then treated in two ways:

i. Petals are sprayed with a fungicide at label rate, allowed to dry, sprayed with a solution containing Botrytis spores (called a ‘suspension’), kept at high relative humidity for at least 12 hours, and examined for disease two or three days later. This method demonstrates whether the fungicide is protecting the plant tissue from Botrytis spores that land on the surface.

ii. Petals are sprayed first with the Botrytis spores and allowed time for the infection to begin. Then the petals are sprayed with fungicide. This method demonstrates how effective the fungicide is for reducing the fungal growth in already infected tissue.

Ideally, both of the above techniques are performed simultaneously to provide a useful analysis of fungicide efficacy on the spores that populate your greenhouse.

*Guidelines for determining a discriminatory dose have been published in research journals.

Note 1: As with any lab procedure, the results are more meaningful and reliable as you have more experience and more data. Fungicide resistance monitoring could be incorporated into your in-house testing procedures much like most growers did with pH and EC monitoring 20 years ago. It does require a commitment of time and resources as well as technical lab expertise, but these techniques have been tested and proven in commercial greenhouses. Contact us if you want more details on these procedures.

Note 2: Fungicide resistance is a dynamic situation, i.e., it is in a constant state of flux. Every fungicide application changes the spore population’s resistance profile. Thus, each test provides
only a glimpse into your specific situation. Like pH and EC measurements, the value is
gained as the procedures are repeated over time.

3. Characteristics of multi-site fungicides
Synthetic fungicides fall into one of two broad categories, multi-site and single-site
fungicides. Multi-site fungicides inhibit multiple essential pathways of the pathogen while
single-sites are more specific to a certain target in the fungus. Only the latter are vulnerable
to resistance development. Consequently, these fungicides must strategically be used in
your disease management program.

- Multi-site fungicides are designed to not penetrate the plant surface, i.e., they stay on the
plant surface to avoid phytotoxicity while killing fungal spores. Therefore, they are used
preventatively to kill the fungus before penetration. Once the spore has germinated and is
starting to form mycelia (fungal root- and stem-like tissue) inside the plant, they are no longer
effective. Thus, multi-site fungicides should be used prior to infection events.

- Multi-site fungicides have moderate efficacy, i.e., these are not usually the strongest
products available.

- Multi-site fungicides have a low risk of fungicide resistance developing amongst the
Botrytis spore population. Botrytis gains resistance by mutating, but this is more difficult to do
when the fungicide affects several different pathways. The fungus would need to implement
multiple mutations at the same time to cope with this challenge.

Examples of multi-site fungicide include the active ingredients: captan, chlorothalonil,
mancozeb*, thiram, ziram. Of these, only chlorothalonil and mancozeb are labeled for
greenhouse use in the U.S. As you may recognize from this list, these products have been
around for many decades. Chemical companies are no longer developing and introducing
broad-spectrum, multi-site products like these because they are unlikely to receive
registration permits.

4. Characteristics of single-site fungicides

The second category of synthetic fungicides contains single-site products. These
fungicides typically interrupt one single enzyme of the Botrytis fungus. This is called single-site
mode of action. Often the enzyme is specific to fungi or even just certain fungi not affecting
many other animals. This results in lower toxicity for the environment, the handler, and the
customer. Single-site fungicides possess a unique set of characteristics that determine how
these fungicides should be used in a disease management program.

- Single-site fungicides are locally systemic, i.e., to a certain degree they penetrate the
tissues upon which they have been applied. Consequently, these fungicides can be applied
before and after infection. They inhibit not only sporulation on the plant surface, but also
mycelial growth in the plant (up to 48 hours post-infection). Best efficacy is achieved if applied
before or within 24 to 48 hours of infection. Infection is favored by high humidity, wetness, and
moderate temperatures, 15-25°C).

- Single-site fungicides have medium to high efficacy, IF no fungicide resistance is present in
the spore population.

- The risk of fungicide resistance developing is dependent on many factors, including the
pathogen (sexual vs asexual reproduction; asexual modification of genome), the number
of applications, the dose, the mode of action (MOA) of the fungicide, the production type (greenhouse vs. field), resistance strategies applied (mixtures, alternations with other MOA) and whether a mutation carries a fitness cost. Dependent on the mutation, fungicide-resistant spores can possess a lower degree of fitness than non-resistant spores. In this case, the resistant spores will be outcompeted, and resistance will disappear over time if the fungicide is no longer applied. However, resistance is likely to persist in your spore population for several (2-4) crop cycles, so this process is slow and doesn’t occur with all fungicides. The only way to know that fungicide has regained efficacy is to perform one of the three fungicide resistance tests described above.

5. **Single-site fungicide options (FRAC codes)**

The Fungicide Resistance Action Committee (FRAC) has grouped fungicides together based on the target site or specific process in the fungus that the fungicide interferes with. Fungicides categorized into the same FRAC code are at risk for cross-resistance, i.e., a mutation in the fungus that allows for the fungus to resist the action of one fungicide will also allow the fungus to be resistant to other fungicides in the same FRAC code. The FRAC code is different from the mode of action since two fungicides with the same mode of action may have different target sites. Fungicides with efficacy for *Botrytis* essentially fall into just seven FRAC codes (1, 2, 7, 12, 17, 19, 29). Unfortunately, thiophanate-methyl and iprodione (FRAC 1 and 2) have been used for so long that they no longer have many benefits for growers around the world. Fluazinam (FRAC 29) is a new class that is not yet labeled for greenhouse ornamentals in the U.S. This leaves us with two FRAC codes with medium to high efficacy (7, 12) and three FRAC codes with low to medium efficacy (2, 17, 19).

<table>
<thead>
<tr>
<th>Trade Name</th>
<th>Active Ingredient</th>
<th>FRAC Code</th>
<th>Likelihood of resistance development</th>
<th>Current Efficacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleary’s 3336, et al.</td>
<td>thiophanate-methyl</td>
<td>1</td>
<td>High Risk</td>
<td>Not Effective</td>
</tr>
<tr>
<td>Chipco</td>
<td>iprodione</td>
<td>2</td>
<td>Medium to High Risk</td>
<td>Low to Medium</td>
</tr>
<tr>
<td>Astun, Broadform, Mural, Pageant, Orkestra</td>
<td>isofetamid, fluopyram + solatenol + boscalid + fluxapyroxad +</td>
<td>7</td>
<td>Medium Risk</td>
<td>Medium to High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>7 (+11)</td>
<td>Medium to High</td>
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<td></td>
<td>7 (+11)</td>
<td>Medium to High</td>
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<td>7 (+11)</td>
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<td></td>
<td></td>
<td></td>
<td>7 (+11)</td>
<td>Medium to High</td>
</tr>
<tr>
<td>Medallion, Spirato, Palladium</td>
<td>fludioxonil + fludioxonil</td>
<td>12</td>
<td>Low to Medium Risk</td>
<td>Medium to High</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>12 (+9)</td>
<td>Medium to High</td>
</tr>
<tr>
<td>Decree</td>
<td>fenhexamid</td>
<td>17</td>
<td>Low to Medium Risk</td>
<td>Low to Medium</td>
</tr>
<tr>
<td>Affirm</td>
<td>polyoxin D zinc salt</td>
<td>19</td>
<td>Medium Risk</td>
<td>Low to Medium</td>
</tr>
<tr>
<td>N/A</td>
<td>fluazinam</td>
<td>29</td>
<td>Low Risk</td>
<td>Medium to High</td>
</tr>
</tbody>
</table>

This is a somewhat bleak situation. It also underscores the critical need to properly rotate products used in your fungicide program to reduce the probability of creating a population of resistant spores in your greenhouse. One of the keys to avoiding resistance is to spray synthetic
fungicides less frequently by utilizing ‘alternative’ products that provide a moderate level of *Botrytis* control. Using alternative products and multi-site fungicides will help to maintain the efficacy of single-site fungicide applications!

6. **Non-fungicide options**

The two main categories of non-fungicide options that we continue to work on in our lab with the support of the American Floral Endowment are:

i. the use of calcium to strengthen plant tissue and improving tissue resistance to *Botrytis* infection. The bottom line is that we can reduce *Botrytis* infection by increasing the concentration of calcium in plant tissues through increased application rates in our fertilizer program or through spray applications.

ii. The use of biological alternatives. Currently, we are beginning a new three-year study of biological control agents (BCAs) and Systemic Acquired Resistance-inducing compounds (SARs) for control of botrytis blight. These products include beneficial fungi, beneficial bacteria, compounds derived from BCAs, and compounds that enhance the plant’s natural defense mechanisms. These products will be tested for efficacy on floriculture crops (cut flowers and bedding plants) to determine how they can be effectively incorporated into an IPM program while reducing fungicide resistance in greenhouse spore populations.

PART 2: The next newsletter will discuss how to pool all of this information together to develop a strategic approach to Botrytis blight control.