Managing Botrytis in the Greenhouse:
What You Should Know About Fungicide Resistance

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We've all heard about fungicide resistance, and that rotating chemical classes is a good thing, but have you ever sat down and tried to figure out what fungicide belongs to what chemical class? If you have, you probably don't appreciate me reminding you of the massive migraine that ensued. For the diehard chemists among you, I am definitely impressed that you can look at the active ingredient and instantly know the mode of action. But for the rest of us chemically and time-challenged individuals, I thought a quick review and reference chart might be helpful.

Fungicides are placed into chemical classes based on the specific mechanism(s) that is responsible for disrupting or altering the normal growth of the target fungus. This mechanism is referred to as the mode of action. Fungicides in the same chemical class have a similar mode of action. This can be confusing as two chemically diverse fungicides may belong to the same chemical class because they both share the same mode of action. Therefore any genetic change that occurs in a fungus that gives it resistance to a particular fungicide, will usually give it resistance to other fungicides within that same chemical class. Some chemical classes of fungicides are more prone to resistance problems than others. Generally if a fungicide disrupts multiple metabolic processes in the target fungus, resistance is rare. For fungicides that disrupt only one or a few specific ▶

metabolic processes, fungal resistance is much more likely to develop.

Botrytis is one of several plant pathogenic fungi that have developed fungicide resistance. As a result, certain fungicides (benzimidazoles and dicarboximides) previously used to control Botrytis in your greenhouse may no longer be effective. Although you may have been diligent in rotating chemical classes within your own greenhouses, it is still possible that you are dealing with a fungicide resistant population of Botrytis. This is due in part to the extensive movement of plant materials from operation to operation (on plugs, cuttings, and plants), as well as to the presence of low, naturally occurring fungicide-resistant populations of Botrytis. It is important to remember that once you have fungal resistance in your greenhouse, continued use of fungicides with the same mode of action (chemical class) will be ineffective and will allow the resistant fungal population to build up over time.

Preventative steps can be taken to prevent or reduce the chance of fungicide resistance. These include avoiding long term, continuous use of fungicides with similar modes of action; alternating between fungicides from different classes or using tank mixes of non-systemic, low-risk fungicides; minimizing the number of preventative fungicide applications; using the label recommended rates; and practicing good integrated pest management (IPM) that utilizes all cultural and biological control practices available.

How many times have you heard "sanitation, sanitation, sanitation?" While sanitation is the first and most critical component in successfully managing most plant diseases, sanitation alone cannot control Botrytis in the greenhouse (can't you just see the grins on those chemical reps faces?). However without good sanitation and humidity control, fungicides won't work well by themselves either.

Botrytis is considered to be a relatively weak pathogen as it generally requires a food source before it can invade a plant. As such you have probably noticed that wounded or

Table 1. Chemical mixture recommendations for Botrytis control.

Common Names of Active Ingredients
mancozeb+chlorothalonil
copper+chlorothalonil
mancozeb+copper

Chemical recommendations by Dr. Gary Moorman (The Pennsylvania State University) as presented at the 2001 Southeast Greenhouse Growers Conference.

senescing tissue is the first to become colonized by this fungus, which is why it is so important to remove spent flower heads and protect plant wounds. This fungus, as well as many others, requires high humidity to sporulate. Increasing the space between plants, utilizing horizontal airflow, watering from below, heating and venting the greenhouse at sundown, and funneling heat under the benches so it rises through the crop will all help to reduce the humidity. Botrytis survives from crop-to-crop on living plants or plant debris, so try to avoid placing older and newer plants together and keep the greenhouse free of plant debris. Cuttings can become infected, and not show symptoms for several weeks, so preventative measures are prudent under high disease pressure.

Dr. Gary Moorman, professor of plant pathology at The Pennsylvania State University, has done extensive research on fungicide resistance and Botrytis control. Many of you may have had the privilege to hear Gary speak on this topic at the Southeast Greenhouse Growers Conference in June 2001. Gary offered his recommendations for managing Botrytis, and I'd like to share this information with you. Gary's research has shown that using a tank mix of two non-systemic fungicides with different modes of action (**Table 1**) gives excellent control, and is consistently better than either fungicide used alone. In addition, he found that using half-rate of each fungicide in the tank mix also gave good control. He cautions, however, to be certain the crop you wish to treat is listed on both labels and that you first test for phytotoxicity on a small population before treating the entire crop.

This seems simple enough, but as you will note in **Table 2**, over thirty different brands of fungicides, belonging to eleven different chemical classes, are registered for Botrytis control on greenhouse ornamentals. Included in this group are both old and new chemistries that have shown excellent control in various trials by researchers across the country. Some of these most promising fungicides are considered to be "at risk" fungicides. That means, without necessary ▶

precautions, there is a higher chance of the target fungus developing resistance to these fungicides. But in addition to the risk of fungicide resistance, there are other factors to consider. Fungicides are generally considered to be protectants or curatives (although many products are both). This is important information to know as a protectant might work wonderfully as a preventative, but offer very little control once infection has occurred. The re-entry interval should also be considered, especially during busy times of the year.

If it has been awhile since you evaluated your fungicide program for Botrytis control, this might be a good time to start.

Table 2. Fungicides registered for Botrytis control on greenhouse bedding and flowering plants[a].

Chemical Class	Common Name of Active Ingredient	Trade Names	Risk of Resistance
Strobilurins	azoxystrobin	Heritage (P+C)	High risk fungicides. Resistance management required.
	trifloxystrobin	Compass (P+C)	
Aromatics (Chloronitrile)	chlorothalonil	Daconil Ultrex, Echo[b], Exotherm Termil, Manicure T/O[b], Pathguard[c] (P)	Low risk group with no sign of resistance developing to majority of fungicides.
Aromatic Hydrocarbons (Chlorophenyl)	dicloran	Botran (P)	Low risk, but resistance is known for some fungi.
Hydroxyanalid	fenhexamide	Decree (P+C)	Higher risk fungicide. Resistance management required.
Phenylpyrrole	fludioxonil	Medallion (P)	Resistance management required
Ethylene bisdithiocarbamates	mancozeb	Dithane T/O, Fore, Junction[d], Mancozeb DG, Protect T/O (P)	Low risk group with no sign of resistance developing to majority of fungicides.
	maneb	Pentathlon (P)	
Mycopesticides	*Streptomyces griseoviridis*	Mycostop (P)	None
Inorganic Protectants	potassium bicarbonate	Armicarb, FirstStep (P)	Low risk
	copper compounds	Junction[d], Kocide, Nu-Cop, Phyton 27 (P)	
Sterol Inhibitors (Imidazole)	triflumizole	Terraguard[e] (P+C)	Moderate risk. There may be cross-resistance.
Benzimidazoles	thiophanate-methyl	Cavalier, Clearys 3336, Domain, FungoFlo, SysTec (P+C)	High risk. **Resistance to these fungicides is common in greenhouses.** Resistance management required.
	thiophanate-methyl + mancozeb	Zyban (P+C)	
Dicarboximides	iprodione	Chipco 26019 (P+C)	**Resistance to these fungicides has been found in ~50% of greenhouses.** Resistance management required.
	vinclozolin	Curalan, Vorlan, Touché (P+C)	

[a] Not all commercially available products may be listed. Recommendations for the use of agricultural chemicals are included in this publication as a convenience to the reader. The use of brand names and any mention or listing of commercial products does not imply endorsement by North Carolina State University nor discrimination against similar products not mentioned. Individuals who use agricultural chemicals are responsible for ensuring that the intended use complies with current regulations and conforms to the product label. Be sure to obtain current information about usage regulations and examine a current product label before purchasing and applying any chemical.

[b] Discoloration on blooms has been noted on certain petunia varieties when applied during flowering.

[c] Avoid applications during bloom period on plants where flower injury is unacceptable.

[d] Product contains more than one active ingredient.

[e] Do not apply to impatiens plugs, reduce rate for impatiens transplants.

(P+C) = Preventative +Curative, (P) = Preventative