Strategies for Effective Management of Botrytis and Anthracnose Fruit Rot in Strawberries

Dr. Mengjun Hu, Univ. of Maryland, and Kathy Demchak, Penn State Extension

Managing gray mold (Botrytis) on strawberries is increasingly challenging because of fungicide resistance development, plus a new Botrytis species that is less susceptible to fungicides is becoming common in the mid-Atlantic region. Resistance to certain fungicides is also a problem in management of anthracnose fruit rot. This article describes disease management strategies designed to slow further resistance development, while also providing specifics for managing our two most common fruit rots.

First, what's new with Botrytis. There are at least 4 species of Botrytis that can infect strawberries, but only two of them have been commonly found in the region. *Botrytis cinerea*, the species traditionally infecting strawberries, is present nearly everywhere and affects many horticultural crops. Recently another species, *Botrytis fragariae*, has also been found and as its name indicates, is more specific to strawberry plants. It appears to overwinter on strawberry plant tissue, and preferentially colonizes blossoms early in the spring, causing them to "turn brown and dry up". While sometimes only one of these species is present, both can be present at the same time in a field and even in the same blossom. Using certain fungicides selects for resistant strains of either species, and also preferentially selects for one species over the other. This means that both species have resistance to multiple fungicide groups, and both species can survive in fungicide-treated fields.

How can you tell if the newer species of Botrytis might be present in your fields? While *B. cinerea* (the traditional species) is often isolated from both flowers and fruit, *B. fragariae* (the new one) is often isolated from flowers, and it has been shown that *B. fragariae* infection was much more aggressive on strawberry flowers than fruit. If you see larger-than-usual numbers of blossoms turning brown and shriveling (not to be confused with frost damage, which blackens the center of the flower), it may be prudent to choose fungicides as if *B. fragariae* presence had been confirmed in your field. If you see no more symptoms on the flowers or buds than usual, you may be able to assume that the new species isn't present, or at least not to a great extent.

Which fungicides work for each botrytis species and which ones don't? Our traditional Botrytis species, (*B. cinerea*), is frequently resistant to iprodione (FRAC code 2, Rovral), fenhexamid (FRAC code 17, Elevate), boscalid (FRAC code 7, one of the active ingredients in Pristine), and cyprodinil (FRAC code 9, one of the active ingredients in Switch). Notably, *B. fragariae* seemed to be more tolerant/resistant to fludioxonil (FRAC code 12, the other active ingredient in Switch and also in Miravis Prime) and polyoxin D zinc salt (FRAC code 19, Ph-D or OSO), but it is less resistant to the above active ingredients with a high *B. cinerea* resistance frequency.

Thus far, no resistance to SDHI fungicides (active ingredients in FRAC code 7) has been detected in the newer Botrytis species *B. fragariae*. These include pydiflumetofen (the other active ingredient in Miravis Prime besides fludioxinil, which has little effect), isofetamid (Kenja), penthiopyrad (Fontelis), and fluopyram (Luna series). Boscalid, one of the active ingredients in Pristine has less intrinsic activity on botrytis species in general compared to other newer group 7 (SDHI) fungicides and as mentioned, resistance within *B. cinerea* is high. Strobilurins (FRAC code 11) and DMIs (FRAC code 3) are ineffective against Botrytis.

All of the active ingredients above are single-site fungicides, as indicated by a single number in their FRAC code, aka activity group, or simply "group" as they appear on labels. They target a single step in the fungus' processes, so simply put, the fungi find it rather easy to develop workarounds. Thiram, which works for Botrytis (and Captan) are multi-site fungicides as indicated by the "M" in their FRAC

codes, so workarounds are less likely. Both play an important role in delaying resistance development to single-site fungicides. They are protectants, meaning that they form a protective layer on the surface of plant tissues, thus preventing diseases from growing into the plant. However, new growth that does not have this protective layer is vulnerable, and while the materials may simply be redistributed with light rains, heavy rains may wash the fungicides off.

More information related to fungicide resistance and categorization of products can be found at the Fungicide Resistance Action Committee web site (https://www.frac.info/).

What can you do to manage Botrytis and anthracnose? First, use all cultural methods that you can to minimize inoculum and maximize foliage drying. Having less inoculum around means less disease on your plants, and also fewer chances for resistance development. So, remove those dead and half-dead leaves from plasticulture strawberry plants in the spring, and if at all possible, remove the debris from the field. Keep weeds under control as much as possible. Weedy fields stay wet longer, and Botrytis of any type loves that moisture. The optimum temperature for growth of Botrytis is 65 to 72 degrees F – great temperatures for strawberry growth too, resulting in lots of tender easy-to-infect tissue. If foliage stays wet for 14 hours or longer, Botrytis infections are favored and spores are produced that easily waft around infecting blossoms, fruit, and leaves. Anthracnose is favored by wet conditions of 7 hours or longer, and its optimum temperatures for development are warmer (75 to 82 degrees F). Since its spores are produced in a liquid slime, it is primarily a rain-splashed disease that does not get spread over long distances unless extreme wind-driven rains occur, such as with hurricane events.

Second, target Botrytis early in the season (i.e., during bloom) when applying fungicides and anthracnose later when temperatures are warmer using these strategies: 1) Use multi-site fungicides as the backbone of your spray program to minimize resistance development to the single-site fungicides mentioned above. Maintain continuous use of thiram (more effective for gray mold) and captan (more effective for anthracnose) during the critical disease control periods of bloom and fruit ripening. Use these products alone during drier spells when disease pressure is lower. Apply *before* rain events to have the material affixed onto the foliage before the rain occurs. 2) Add single-site fungicides only when disease pressure is high (extended periods of moisture). Recommended single-site fungicides during bloom for either Botrytis species are newer category 7 (SDHI) fungicides (Merivon, Kenja, Fontelis, and certain products in the Luna series). They can also be applied during ripening if needed. If conditions conducive to anthracnose development occur earlier than usual, products effective against anthracnose may be applied. 3) Save Switch or Miravis Prime for late-season *Botrytis* management since gray mold fruit rot is mainly caused by *B. cinerea* – and these products also have good effectiveness against fruit anthracnose. Other fungicides effective on anthracnose appear in the table below. Ph-D or OSO is another good choice for *B. cinerea* control during harvest. While strategies numbered 2 and 3 are helpful in targeting specific species/diseases, strategy 1 improves fungicide resistance management.

Overall, how you deploy these strategies will vary with your production system. Growers in plasticulture with anthracnose-susceptible varieties may need to focus more on anthracnose management, while growers using matted row production with anthracnose-resistant cultivars may need to focus on controlling Botrytis. Growers with anthracnose-susceptible day-neutral cultivars, which continually bloom and fruit over a long period, should try to focus on using the multi-site protectants thiram and captan prior to major or consecutive rain events.

All growers should use single-site fungicides only when necessary, such as when protectant sprays were missed prior to rain events. Rotate chemistries carefully, and minimize fungicide use during warm dry spells when fungicides are less likely to be needed.

Here is a diagram of what these management strategies would look like for June-bearing cultivars:

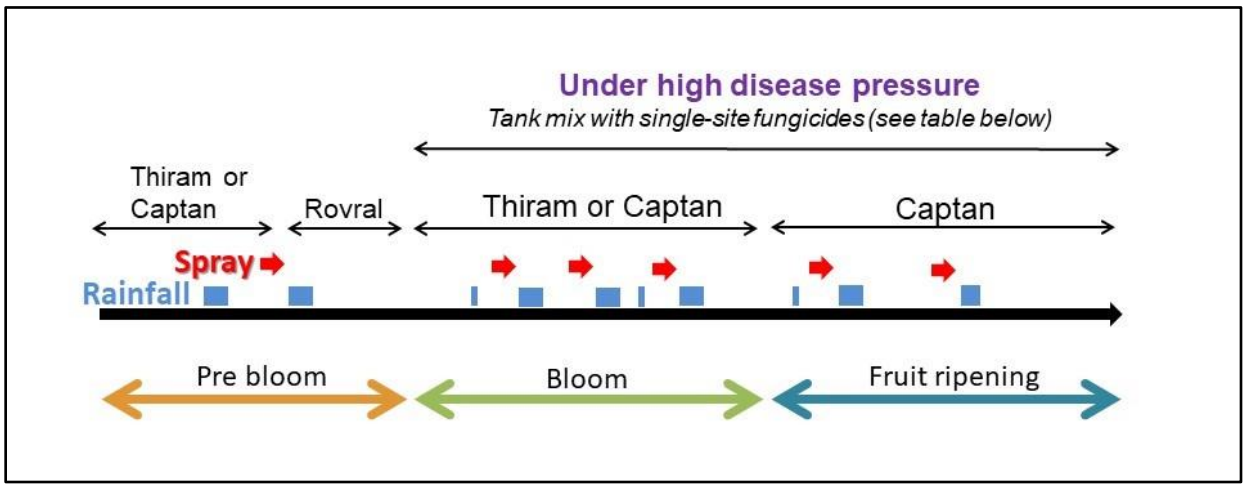

Diagram credit: G. Schnabel, Clemson Univ.; used with permission.

The table below summarizes the information presented in this article with details on specific recommended fungicides, considerations for making the best use of them while minimizing resistance development, and their activity groups. Check individual product labels for rates, pre-harvest intervals, re-entry intervals, and any other restrictions before applying (for example, Fontelis may not be applied on 'Jewel', 'Clancy', or 'L'Amour') and make sure the products are registered for use in your state. Specimen labels can be found at CDMS (http://www.cdms.net/LabelsSDS/home) and Agrian (https://home.agrian.com/label-lookup/), in addition to company web sites.

Early Bloom →		Late Bloom →	Green Fruit →	Early Harvest →		Late Harvest
Maintain continuous coverage with thiram (group M3) or captan (group M4)*						
thiram or captan	thiram or captan	thiram or captan	thiram or captan	captan	captan	captan
*If in matted row production and gray mold is the major concern, utilize thiram more and captan less. If in plasticulture and when growing anthracnose-susceptible varieties, captan may be needed to a greater extent.						
If weather is wet, add one of the following single-site fungicides to the above, making not more than 2 applications of any activity group over the season.						
Primarily for early season gray mold control				*Save for use during harvest*		
- Fontelis, group 7, or				*For gray mold and anthracnose fruit rot:*		
- Kenja, group 7, or				- Switch, group 9 + 12, or		
- Luna Tranquility, group 7 + 9, or				- Miravis Prime, group 7 + 12, or		
- Merivon Xemium, group 7 + 11**, or				- Luna Flex, group 7 + 3		
- Luna Sensation, group 7 + 11**						
**While these products can be used for gray mold, their use will increase selection pressure for anthracnose resistance to group 11 materials.				*For gray mold but not anthracnose fruit rot:*		
				- Ph-D or OSO, group 19		
				For anthracnose fruit rot but not gray mold:		
Alternatives to group 7 fungicides if needed:				- Tilt, group 3		
- Rovral, group 2 (pre-bloom only)***, or				- Inspire Super, group 3 + 9		
- Elevate, group 17***				- Cabrio, group 11***		

		- Pristine, group 7 + 11***
		- Quadris Top, group 11 + 3***
		- Quilt Xcel, group 3 + 11***
***May be used once per season if resistance to active ingredients in these products is known to be low on your farm. Do not, however, make more than 2 applications of any activity group over the course of a season.		