Methods for Minimizing Fungicide Resistance in Plasticulture Strawberry Systems

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Systemic Fungicides

- Not as systemic as you may think.
- When fungicide is sprayed on one leaf, it is not readily moved to other unsprayed leaves.
 Coverage is still very important.
- Systemic fungicides can move within the xylem (transpiration stream) in a leaf, resulting in more uniform distribution than that achieved by the initial deposit.

Principles of Disease Management; Fry (1982)

Principles of Resistance Management

- Alternating sprays with fungicides from different classes (different modes of action) is an important means of resistance management.
- Tank-mixing of different fungicides is also an acceptable method of resistance management, and both methods are employed.
- Many fungicides are limited to a set number of applications per year in order to improve their long-term survival. Follow the label recommendations.

Tank Mixing Fungicides for Resistance Management

- Good resistance management tool.
- Do not use half rates of a systemic and a contact, since disease control would be poor and resistance management would be poor (unless known synergy occurs).
- Contact usually works very quickly, and systemic may have moderately delayed action, so combination is sometimes good.
- Alternation is a good resistance management scheme, and the cost issue is avoided.

Resistance Management

- Use the fungicidal rate which results in complete kill or deactivation of the fungus.
- Reducing rates is a dangerous game, since the end result may be a "training" of resistant strains.

Combined risk: 1 = low, 2-6 = medium, 9 = high							
benzimidazoles dicarboximides phenylamides	h i g h (3)	3	6	9			
carboxanilides DMIs phosphorothiolates anilinopyrimidines phenylpyrroles strobilurins	m e d i u m (2)	2	4	6			
coppers dithiocarbamates melanin inhibitors phthalimides sulphur SAR-inducers	1 0 w (1)	1	2	3			
basic	1	low (1)	medium (2)	high (3)			
risk dise risk	ic ease c	seed-borne (eg. <i>Pyrenophora,</i> <i>Ustilago</i>) soil-borne (eg. <i>Phytophthora</i>), cereal eyespot cereal rust rice sheath blight	barley <i>Rhynchosporium</i> wheat <i>Septoria</i>	apple scab banana <i>Sigatoka</i> , cereal powdery mildew, grape <i>Botrytis</i> , potato blight, citrus <i>Penicillium</i> , rice blast			



R = resistant S = sensitive

Evolution of fungicide resistance: quantitative resistance



Deising H et al. Brazilian Journal of Microbiology (2008) 39:286-295

Evolution of fungicide resistance: qualitative resistance







1. Use cultural practices to reduce carryover inoculum.





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- 2. Bring in clean, disease-free plants.

Phytophthora crown and root rot

Botrytis gray mold



Powdery mildew

FRAC Code	Trade Name Examples	Primary Target
1	Topsin M	Gray mold
2	Rovral	Gray mold
7	Fontelis	Gray mold
7/11	Pristine	Gray mold and anthracnose
	Merivon	Gray mold and anthracnose
9	Scala	Gray mold
9/12	Switch	Gray mold and anthracnose
11	Abound	Anthracnose
	Azaka	Anthracnose
	Cabrio	Anthracnose
17	Elevate	Gray mold

Spray Strategically. If applications are needed prior to bloom, <u>thiram</u>, <u>captan</u>, and maybe biologicals should be used. During bloom, stick with <u>captan</u> as much as possible and use the 'at risk fungicides' (including FRAC 1, 2, 7, 9, 11, 12, and 17) only when the weather is favorable for disease development (Table 1).

Schnabel and Perez

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- 3. When possible, use fungicides which are not prone to resistance development, such as Captan and Thiram.

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- 4. Check the resistance status of your pathogens (when possible).

Collecting gray mold from fruit



Plar	Plant Molecular Diagnostic Lab								
Home	Research	Diagnostic Se	ervices	Fungicide Resista	nce Test	Submission Procedu	res Submissi	on Form 🔻	
Out of St	tate & Interna	tional sample	Payment	Personnel	Lab News	Publications 🔻	Join the Lab	Contact	

Fungicide resistant test

A. Fungicide resistance profiles in Botrytis cinerea from strawberry

MDL at the University of Georgia, Tifton is now providing fungicide resistance profiles in *Botrytis cinerea* from strawberry. We accept gray mold samples from flowers, leaves, and fruit. You may send cotton swabs with spores from fruit for analysis as shown below:



- Please send 20 to 40 dead strawberry flowers OR 150 healthy flowers (it is much harder to get the fungus out of healthy flowers) from each strawberry field you would like to have tested. Send as many dead leaves as you like in addition to the flowers. Make sure your specimens (flowers/leaves/fruits/swabs)/ isolates are spread out and represent the entire field.
- Collection of gray mold from fruit, obtain cotton swabs from a local pharmacy. Collect spores with swabs from 10 individual berries with fresh gray mold lesions. Use a fresh cotton swab for each berry and carefully rub one side of the swab on the diseased portion of each berry without getting strawberry juice on the swab. The swab should look lightly gray (lower right). A tiny bit of gray color is sufficient for analysis.
- Please fill the resistant test form and provide the information as much as you can.
- Payment for Botrytis profiling:10 isolates/specimens/samples will be considered as 1 sample and the cost would be \$250/sample; if more than 5 samples (50 or more specimens/isolates) it will be \$200/sample. After testing, MDL will send an invoice to the submitter via email. As soon as we receive the payment (either credit card or check), we will send the result. Please do not hesitate to contact us/MDL director (#2293867230 or #229386-3070 or alimdl@uga.edu) if you have any questions about fees or free trial prior to sample submission.

B. Fungicide (QoI) resistance testing for anthracnose from strawberry

MDL is also providing fungicide resistance testing for anthracnose from strawberry. Please send us 10 to 20 symptomatic strawberry fruits that represent the entire field. Place each collected sample (each fruit) separately in a zip-lock bag and label bags clearly so that samples can be differentiated.



Please fill the resistant test form and provide the information as much as you can.

Payment: 10 isolates/infected fruits will be considered as 1 sample and the cost would be \$100/sample (Only for QoI

testing). After testing, MDL will send an invoice to the submitter via email. As soon as we receive the payment (either credit card or check), we will send the result. Please do not hesitate to contact us/MDL director (#2293867230 or #229386-3070 or alimdl@uga.edu) if you have any questions about fees or free trial prior to sample submission.

Address for the sample submission:





Summary

Monitoring results from 8 states, 2012



Plant Health Brief

Sensitivity of *Colletotrichum* Isolates Collected from Strawberries in Georgia to Pyraclostrobin, a Quinone Outside Inhibitor (QoI) Fungicide

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Keywords: Colletotrichum spp., fungicide, pyraclostrobin, strawberry, small fruit, resistance

Anthracnose fruit rot disease, caused by *Colletotrichum acutatum*, is the most significant disease problem of commercial strawberry (*Fragaria* \times *ananassa*) production in the southeastern United States Gunnell and Gubler 1992; Leandro et al. 2001). In addition to comparison of morphological characteristics, 20 randomly selected isolates from 108 *Colletotrichum* spp. were further verified via PCR



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- 2. Bring in clean, disease-free plants.
- 3. When possible, use fungicides which are not prone to resistance development, such as Captan and Thiram.
- 4. Check the resistance status of your pathogens (when possible).
- 5. Avoid fungicides which are exceptionally prone to resistance development.

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1	Topsin M	Gray mold
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	Azaka	Anthracnose
	Cabrio	Anthracnose
17	Elevate	Gray mold

- Avoid FRAC 1 fungicides
- Use FRAC 7/11 premixtures (Merivon, Pristine) ONLY if gray mold AND anthracnose are a threat BUT NOT for routine gray mold control.
- Use FRAC 11 solo products (Abound, Cabrio) only for anthracnose control
- Do not use FRAC 7/11 premixtures or FRAC 11 solo products more than twice per season.

Schnabel and Perez

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- 5. Avoid fungicides which are exceptionally prone to resistance development.
- 6. Spray as little as possible.

Strawberry Advisory System (SAS)



2020 Southeast Regional Strawberry Integrated Pest Management Guide For Plasticulture Production

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Recommendations are based on information from the manufacturer's label and performance data from research and Extension field tests.

Because environmental conditions and grower application methods vary widely, suggested use does not imply that performance of the pesticide will always conform to the safety and pest control standards indicated by experimental data.

This publication is intended for use only as a guide. Specific rates and application methods are on the pesticide label, and these are subject to change at any time. Always refer to and read the pesticide label before making any application! The pesticide label supersedes any information contained in this guide, and it is the legal document referenced for application standards.

Photo: Frank Louws

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PYDIFLUMETOFEN	GROUP	7	FUNGICIDE
FLUDIOXONIL	GROUP	12	FUNGICIDE



×X Miravis[®] Prime



Fungicide

An ADEPIDYN[™] brand fungicide

Active Ingredients: Pydiflumetofen*:	
Fludioxonil**:	
Other Ingredients:	65.8%
Total:	100.0%
*CAS No. 1228284-64-7	



Early Bloom	(10%) and into	o Harvest: Diseas	e Management	ţ		
Pest/Problem	Management Options	Amount of Formulation per Acre	Effectiveness	REI	РНІ	Comments
Botrytis fruit rot	*** SEE RESIST	ANCE MANAGEMENT	RECOMMENDAT	TONS ON	N PAGES	19 AND 34.***
(cont'd)	fenhexamid + captan (CaptEvate 68 WDG)	3.5 to 5.25 lb	Е	24 hr	0 days	Do not make more than 2 consecutive applications before switching to a fungicide with a different mode of action. Do not apply more than 21.0 lb per acre per season. With plastic mulch, do not apply within 16 ft of naturally vegetated or aquatic areas. <i>Note: CaptEvate 68 WDG is no longer being manufactured but may still be available for purchase at some locations.</i> FRAC 17 + M04.
	pydiflumetofen + fludioxonil (Miravis Prime)	9.1 – 13.4 fl oz	E*	12 hr	0 days	Do not make more than 2 consecutive applications of product or of FRAC 7- or FRAC 12-containing products. Do not make more than 2 applications at the maximum application rate per year. Do not apply more than 26.8 fl oz of product per acre per year. Do not apply more than 0.268 lb of pydiflumetofen or 0.9 lb of fludioxonil per acre per year. The minimum application interval is 7 days. See label for additions use restrictions. *Indicated efficacy ratings is tentative based on the performance of similar products and laboratory studies. FRAC 7 + 12.
	*** SEE RESIST.	ANCE MANAGEMENT	RECOMMENDAT	TONS ON	V PAGES I	19 AND 34.***
	thiram (Thiram SC)	2.6 qt	G	24 hr	1 day	Make 3 to 5 applications at 10-day intervals. Thiram is a broad-spectrum fungicide similar to captan. Do not apply more than 5 applications per year west of the Mississippi River or more than 12 applications per year east of the Mississippi River. Do not apply more than 2.73 lb thiram
			6			(active ingredient) per acre. FRAC M03.

Early Bloom (10%) and into Harvest: Disease Management

The primary diseases of concern at early bloom and into harvest are **Botrytis fruit rot** (BFR) and **anthracnose fruit rot** (AFR). Most growers rarely experience anthracnose problems and may not need an anthracnose management program. Several **key principles** should be kept in mind:

- Abound, Cabrio, Inutity, Merivon, Pristine, and Luna Sensation belong to the same family of chemicals (QoIs; FRAC 11). Pyraclostrobin (Cabrio, Merivon, and Pristine) has offered better control of AFR in recent research efforts. **<u>No more than two applications of a FRAC 11 fungicide should be made per</u> <u>season for resistance management.</u>** Strategic timing is necessary. Pristine, Luna Sensation, and Merivon also have a second chemical that has good broad-spectrum activity against a number of diseases, especially those caused by *Botrytis*. QoI resistance has been found in 'acutatum' populations in the south. The problem tends to be plant-source-aassociated.
- 2. Captan (FRAC M04), thiram (FRAC M03), and Switch (FRAC 9+12) offer a broad spectrum of disease control. Switch is modest against AFR in NC research.
- 3. Polyoxin D zinc salt (FRAC 19; Ph-D and OSO 5%SC) is as effective as captan for *Botrytis* at high label rates and can help reduce reliance on fungicides that have resistance concerns.
- 4. ** Elevate should not be used more than twice per season due to resistance concerns. ** It is effective against Botrytis but no other fungal pathogens.
- 5. **High risk fungicides of the same chemical class (FRAC group) should not be applied in consecutive applications.**
- 6. CaptEvate is a premix of captan (FRAC M04) and fenhexamid (FRAC 17; Elevate) which has good broad-spectrum activity. Note: CaptEvate 68 WDG is no longer being manufactured but may still be available for purchase at some locations.
- 7. Bloom sprays are the most important for managing *Botrytis*, because 90% of fruit infection occurs through the flower at bloom. Recent research suggests bloom sprays are also critical for AFR control.
- 8. Fruit rot diseases develop rapidly during wet periods or in poorly ventilated locations. Control is easier when initiated before the problem develops. Spray coverage is important and dependent on nozzle condition, tractor speed, pressure, and plant density. Spray coverage can be checked with water sensitive cards.

Fungicide Selection for Botrytis and Anthracnose Fruit Rot Management

Management of Botrytis fruit rot (**BFR**) and anthracnose fruit rot (**AFR**) caused by *"Colletotrichum acutatum"* has become more complex. Growers need to use products that work against resistant strains of BFR and manage AFR. We developed a new table to help with the decision process (see table on page 36).

The table (right) shows our current understanding of the efficacy of fungicides for the Southeastern US (north of Florida). Efficacy in the table is indicated as follows: E = excellent, VG = very good, G = good, F = fair, P = poor. A large number of

Product	FRAC Group	BFR	Botrytis Resistance	AFR
Captan; Captec	M04	G	None	G
CaptEvate	M04 + 17	E	Prevalent for 'Elevate'	G
Thiram	M03	G	None	G
Fracture	BM01	Р	No data	No data
Topsin M	1	Not effective	Widespread	Not effective
Rovral	2	G	Prevalent	Not effective
Tilt; generics	3	Not effective	Not applicable	F
Fontolis	7	F	Provalent	F

Path Forward

(1) Continue and expand monitoring for resistance.

(2) Incorporate new fungicides with different modes of action, and determine efficacy of other fungicides and combinations.

(3) Incorporate novel approaches to management, such as timing sprays.