COLLEGE OF AGRICULTURE & NATURAL RESOURCES

Anthracnose in Strawberries

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What is strawberry anthracnose?

- A major fungal disease on strawberries, caused by species within ***Colletotrichum acutatum*** & ***C. gloeosporioides*** complexes.
- Disease infection is usually favored by **extended moisture** and **warm** conditions
- The pathogen is not a general necrotroph on all tissues, but it is significant as a necrotroph causing **severe fruit rot (AFR)**.
- Symptoms normally referred to as **black spot** on upper parts of the plant. **Bright orange** sporulation typically occurs on mature fruit.
- **Roots and crowns** can also be infected, causing severe stunting or plant death (**ACR**)

Photo by Madeline Dowling
http://phytographics.com/

Strawberry anthracnose in the field

Attacking mature & immature fruit

Photo: Tim Elkner

Flower infection

Photo: Tim Elkner

Photo: David Liker

Photo: Meng-Jun Hu

Characteristic sunken lesion on the fruit

Anthracnose crown rot

Photo: Frank Louws

Where does it come from and how it spreads?

Dispersal

Conidia of *C. acutatum* spp. are usually produced in acervuli on host tissue and are typically **rain-splash dispersed**; On low-growing crops such as strawberry, conidia are **spread over short distances** (Peres et al. 2005).

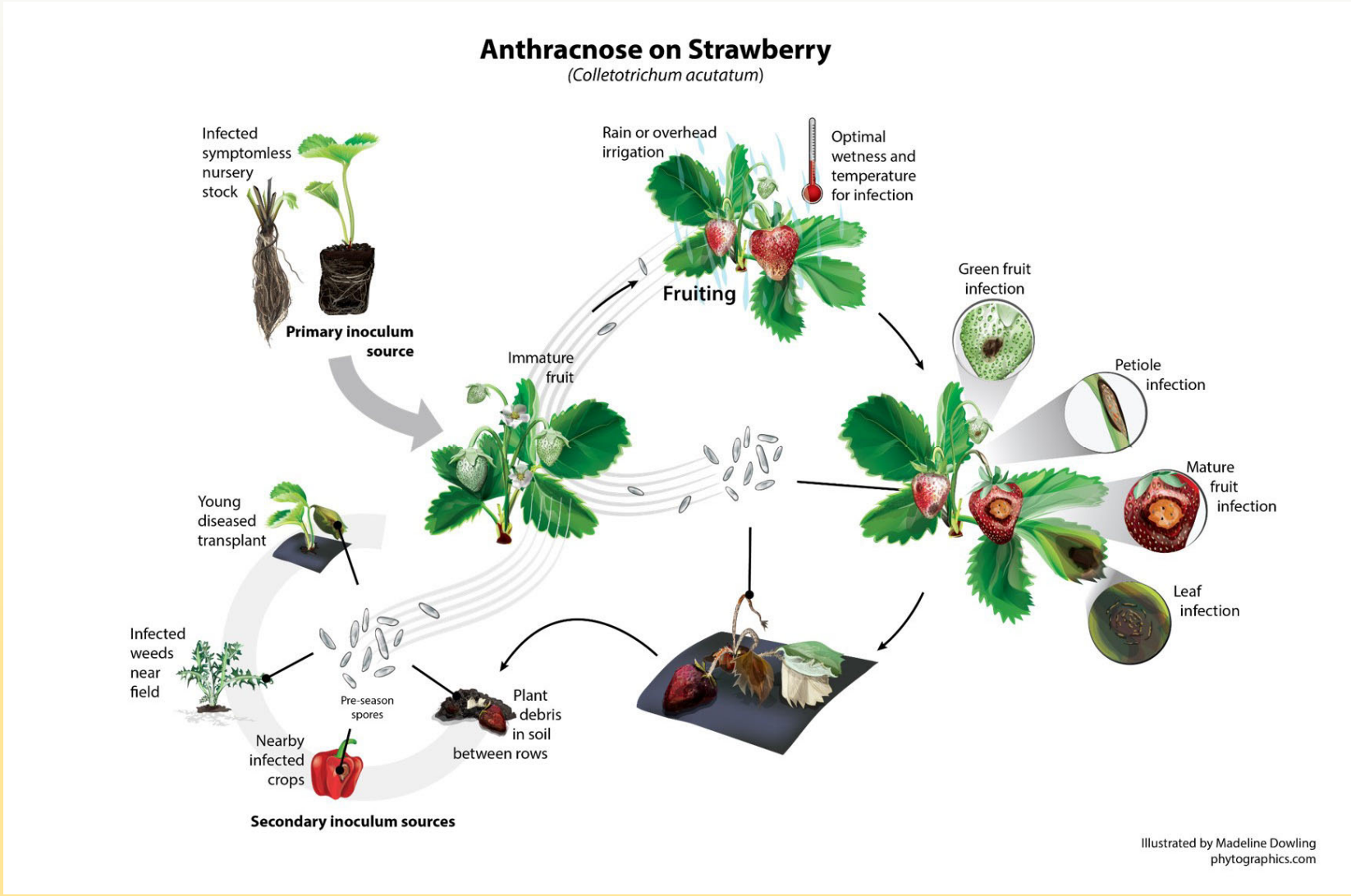
The possible source of infection

- **Nursery transplants**
  - **Facts:** *Colletotrichum* species have both biotrophic and necrotrophic stages. Symptoms may not develop for some time due to the biotrophic phase that typically occurs early in the infection process (Curry et al. 2002)
  - Soon after planting in fruiting fields, conidiation can occur on the surface of vegetative tissues when weather conditions are favorable, and this can serve to augment inoculum levels to infect flowers and fruit (Leandro et al. 2003)

The possible source of infection (continued)

- **Weeds**
  - **Facts:** the fungi seem to live on weeds as an endophyte or remain quiescent, which unlikely to produce acervuli or conidia needed for dispersal; however, certain herbicide treatments have been shown to stimulate sporulation.
- **Survivals in the soil**
  - **Facts:** not a typical soil-borne pathogen, but can survive in the soil for up to 12 months under dry conditions. Survival of conidia and sclerotia declined rapidly under moist conditions.
  - At 11% soil moisture content, the time required for 95% loss of viability was 70 to 75 days. In soil at field capacity (22% moisture), a 95% reduction in population recorded within 4 to 10 days

Life Cycle of Strawberry Anthracnose



Control of strawberry anthracnose

- **Chemical control**

- A major pillar in the IPM of strawberry anthracnose
- Strobilurin fungicides (QoIs; FRAC 11) are the most effective but resistance has been reported.
- MBCs (FRAC 1) are effective against *C. gloeosporioides* only, but their use is also challenged by resistance.
- Other fungicides such as Captan (FRAC M4) and Switch (FRAC 12) are helpful.

Effective fungicides for strawberry anthracnose control

Trade Name	Active Ingredient	FRAC Code	Efficacy
AFTERSHOCK	Fluoxastrobin	11	E
AZAKA	Azoxystrobin	11	E
ABOUND	Azoxystrobin	11	E
Cabrio	Pyraclostrobin	11	E
Evito	Fluoxastrobin	11	E
Gatten	Mandestrobin	11	E
Luna Sensation	Fluopyram, trifloxystrobin	7, 11	E
Merivon	Fluxapyroxad, pyraclostrobin	7, 11	E
Pristine	Boscalid, pyraclostrobin	7, 11	E
Quadris Top	Difenoconazole, Azoxystrobin	3, 11	E
QuiltXcel	Propiconazole, Azoxystrobin	3, 11	E
Switch	Cyprodinil, Fludioxonil	9, 12	G
Miravis Prime	Pydifumetofen, Fludioxonil	7, 12	G
Captan	Captan	M4	G
Captec	Captan	M4	G

Resistance to FRAC 11 is a major concern

E: excellent
G: good

- **Cultural-based control methods**

- Sanitation of infected plants/fruit
- Living mulches (such as wheat, rye, or ryegrass) or organic mulches (wheat straw)
- Increasing plant density

*Anthracnose was found less severe when water is supplied to plants using drip irrigation rather than overhead irrigation

Research updates on strawberry anthracnose in the Mid-Atlantic

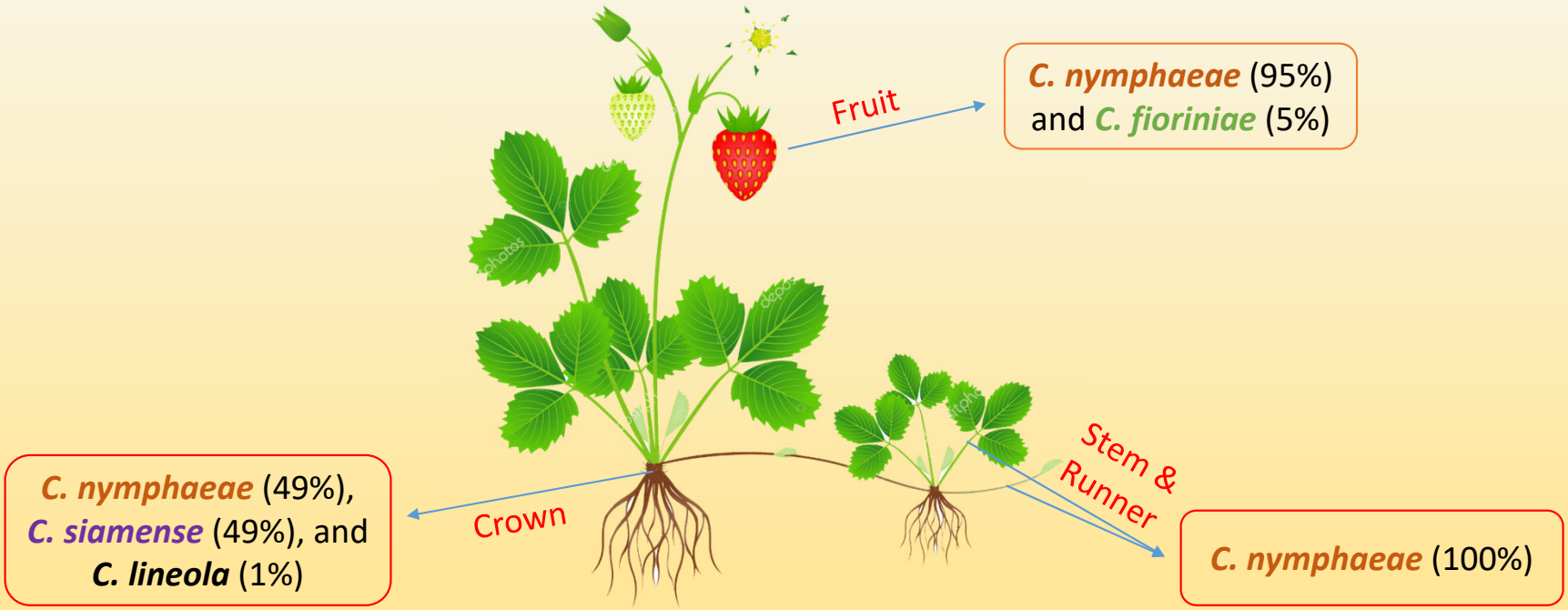
Colletotrichum species identified in Mid-Atlantic strawberry fields

Number of Colletotrichum spp. isolates from different states

	C. acutatum complex		***C. gloeosporides complex***		
States	***C. nymphaeae***	***C. fioriniae***	***C. siamense***	***C. lineola***	**Total**
Maryland	121	6	2	0	129
Pennsylvania	36	2	3	1	42
Virginia	10	0	6	0	16
North Carolina	13	0	0	0	13
Total	180	8	11	1	**200**

Note:
Isolates were collected from the fruit, crowns, petioles, and runners
Species were identified through multi-locus sequence: ITS/G3PDH/CAL

Colletotrichum species recovered from different organs of strawberry plant

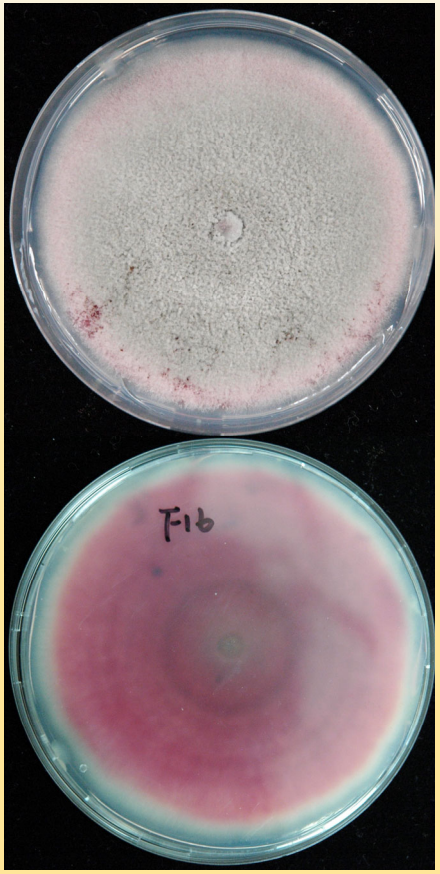


- Out of the 200 isolates, majority (85%) was obtained from strawberry fruit, whereas 12, 1.5, and 1.5% of the isolates were obtained from the crown, runner, and petioles.

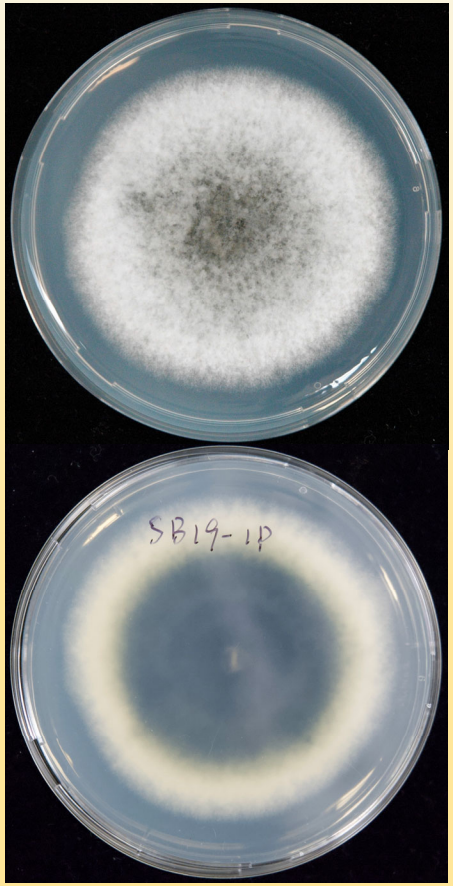
Frorq|#p ruskrorj|

C. nymphaeae

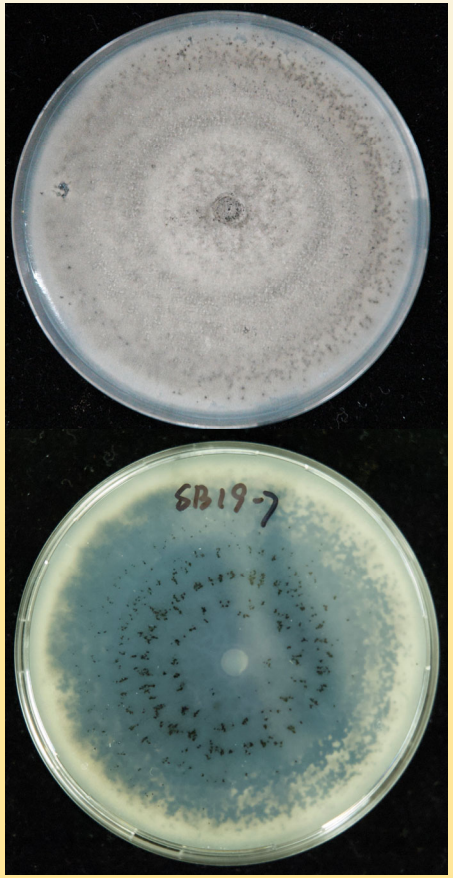
C. fioriniae



C. siamense



C. lineola



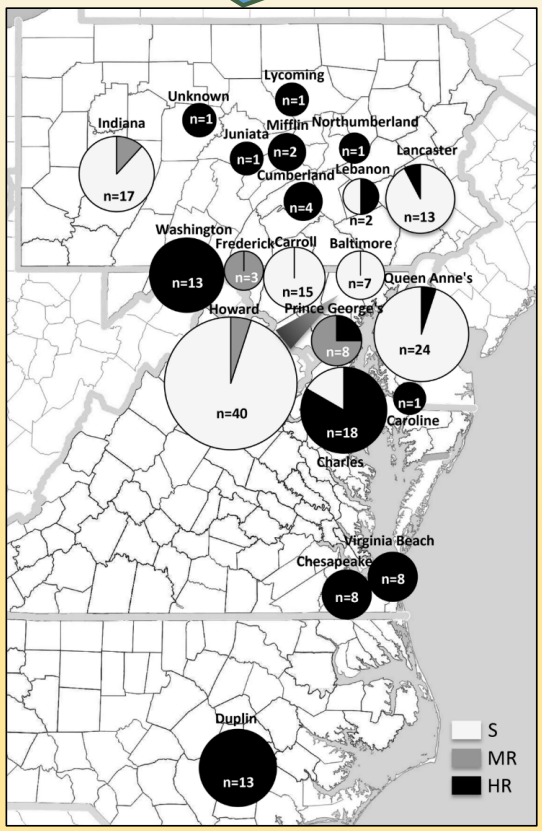
Fungicide Resistance in Virginia

All *C. fioriniae* isolates are moderately resistant to QoI fungicide

The overall resistance frequency is 39.6% for Azoxystrobin

Number of *Colle* **phenotypes for azoxystrobin**

Phenotype	*C. acutatum* *C. nymphaeae*	*C. fioriniae*	*C. gloeosporioides* *C. siamense*	Total
Resistant	71	0	6	76
Moderately Resistant	5	8	0	13
Sensitive	102	0	0	102
Total	178	8	6	192



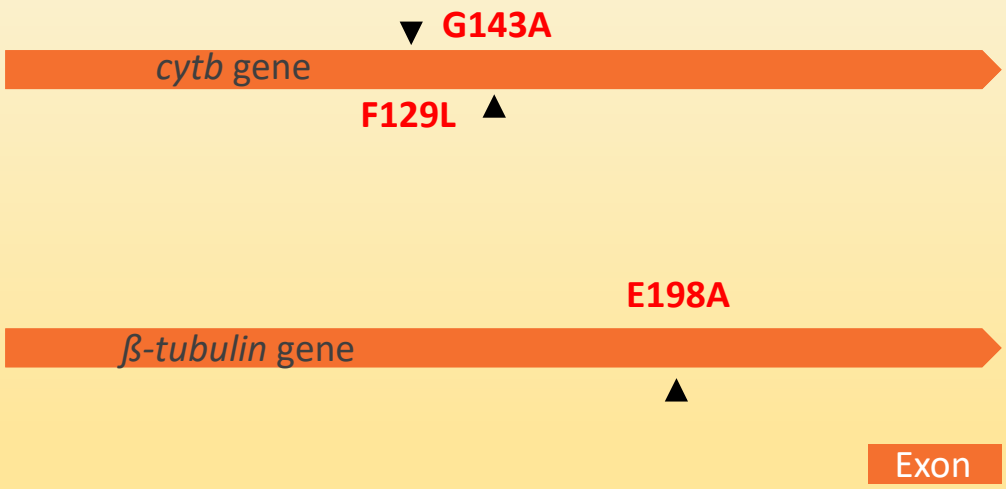
Luo et al, 2021

Number of *C. siamense isolates* with different resistant phenotypes for thiophanate-methyl

Phenotype	*C. gloeosporides* *C. siamense*
Resistant	7
Moderately Resistant	0
Sensitive	4
Total	11

The overall resistance frequency is 63.6% for Thiophanate-methyl

Uhvlvwdqfh#z dv#frqihuuhg#e|#jhqhwlf#p xwdwlrqv



Vxp p du

01 **At least 4 *Colletotrichum* species were found associated with strawberry anthracnose**

- The majority of isolates from fruit was *C. nymphaeae* (*C. acutatum* species)
- Both *C. nymphaeae* and *C. siamense* (*C. gloeosporioides*) were frequently isolated from the crown
- *C. fioriniae* seemed to ONLY infect the fruit, with low occurrence (5%)

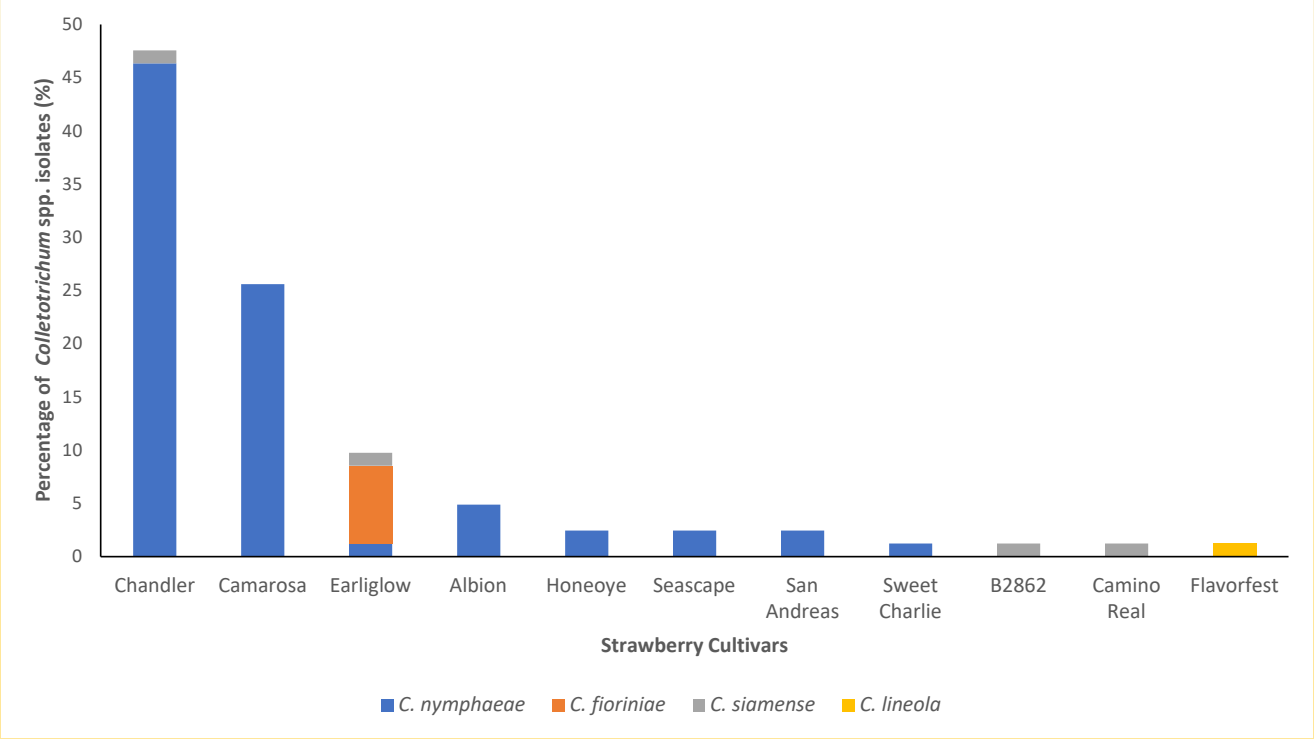
02 ***C. siamense was first found in the Mid-Atlantic region; C. lineola was not described as a cause of strawberry anthracnose previously.***

03 ***Resistance to QoI and MBC fungicides in Colletotrichum spp. is widespread, and resistant isolates were found from various host tissues.***

Are there any anthracnose resistant cultivars?

- Very few cultivars are resistant to anthracnose crown rot (ACR)
- Some cultivars are known to be more susceptible to anthracnose fruit rot (AFR; e.g. Chandler, Albion, and Camarosa)

Colletotrichum spp. isolates collected from different strawberry cultivars in the Mid-Atlantic



Any new or existing fungicides that may offer some efficacy?

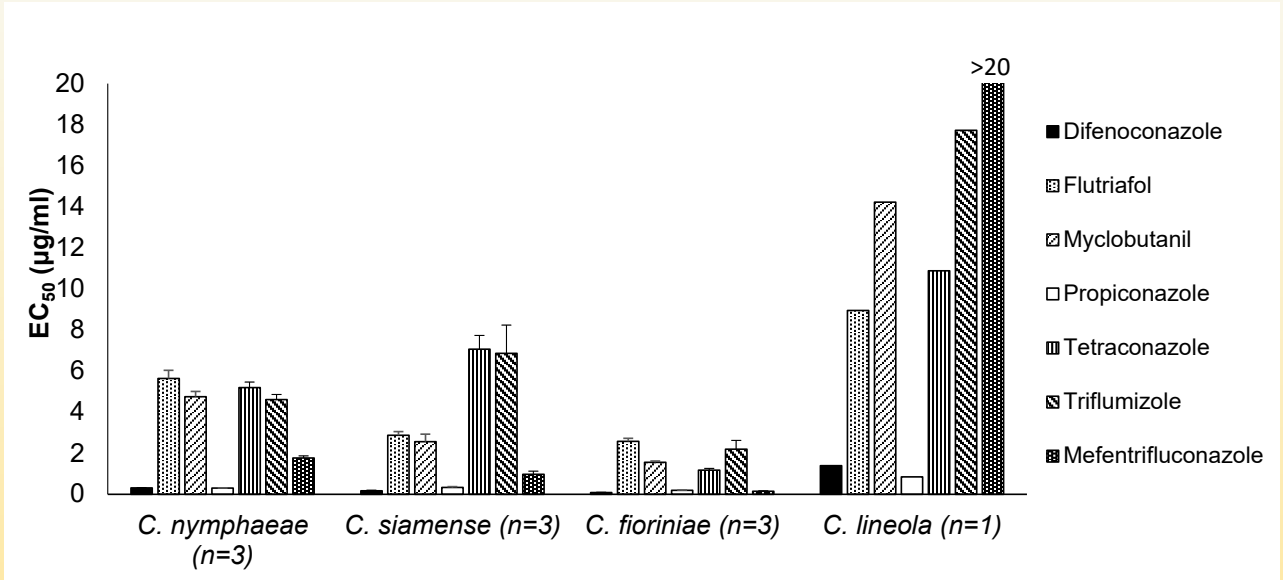
Colletotrichum spp. affecting strawberries

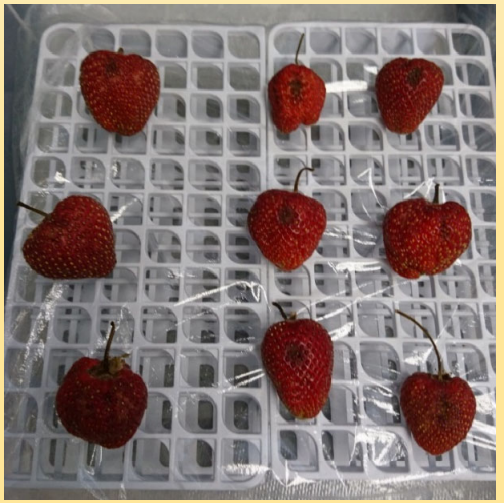
- ***Colletotrichum acutatum*** [a, b]
  -C. nymphaeae
  Resistant to FRAC 11
  -C. fioriniae
  Resistant to FRAC 11
  [a]Inherently resistant to FRAC 1
- ***Colletotrichum gloeosporioides*** [b]
  -C. siamense
  Resistant to FRAC 1 & FRAC 11

Major chemical classes of fungicides labelled on strawberry

- ~~FRAC 1: (Thiophanate-methyl; Topsin M)~~
- ~~FRAC 2: (Iprodione; Rovral)~~
- FRAC 3: (a variety of a.i. available; Rally, Tilt, Mettle etc.)
- FRAC 7: (multiple a.i. available; Pristine, Fontelis etc.)
- ~~FRAC 11: (multiple a.i. available; Pristine, Abound etc.)~~
- FRAC 12: (fludioxonil; Switch and Miravis Prime)

Sensitivity to FRAC 3 (DMI) fungicides





Fungicide treatment	Lesion diameter (mm)
Control (water)	14.1 a
Propiconazole	2.8 c
Triflumizole	14.1 a
Mefentrifluconazole	13.3 a
Triflumizole + Mefentrifluconazole mixture 1:10	6.6 b
Switch	0.00 d

Schoeneberg and Hu (JPP, 2022)

Any new or existing fungicides that may offer some efficacy?

Sensitivity of *Colletotrichum* isolates to FRAC 7 (SDHI) fungicides (mycelial growth)

Species and isolates	EC_{50} (µg mL^{-1}) of fungicide:				
	Bos-	Fluxapy-	Penthio-	Fluopy-	Benzovin-
C. gloeosporioides					
Niitaka 3	>100	>100	2.6	>100	0.2
5-2-1	>100	>100	1.9	>100	<0.1
5-2-2	>100	>100	1.8	>100	<0.1
Nagasaki 1	>100	>100	0.8	>100	<0.1
Nagasaki 2	>100	>100	0.7	>100	<0.1
19002	>100	>100	1.6	>100	<0.1
Cg_RR12-1	>100	>100	1.2	>100	<0.1
Cg_SE12-2	>100	>100	1.1	>100	<0.1
Cg_EY12-2	>100	>100	2.6	>100	<0.1
Cg_RR12-4	>100	>100	1.1	>100	<0.1
Ca_EY12-1	>100	>100	2.0	>100	<0.1
C. acutatum					
GC2-1	>100	>100	0.3	>100	<0.1
AAU811-3	>100	>100	0.5	>100	<0.1
CO4-35	>100	>100	1.2	>100	<0.1

- Bos: Pristine
- Fluxapy: Merivon
- Penthio: Fontelis
- Fluopy: Luna series
- Benzovin: Aprovia (not labeled on strawberry)

Ishii et al., 2016
(Pest Manag. Sci.)

Controlling Anthracnose Crown Rot

Potential New Pre-Plant Dip

Sublabel C: All Crop Groups Agricultural Use – Preplant, transplant & at plant treatment (nonfood use pattern)

Natamycin L

(alternate brand name: Zivion™ S)

Now registered in Florida, California, South Carolina, North Carolina, and Virginia

For use as a pre-plant, transplant and at plant treatment as a broad spectrum pre-harvest biofungicide to control Anthracnose, Gray Mold, Black Mold, Powdery Mildew, Verticillium Wilt, Rhizopus Rot, Mucor Fruit Rot, Fusarium Wilt, Charachol Rot, Smut, White Rot, Southern Blight, Crown & Root Rot, Storage Rot, and common Leaf Spots, in all crop groups.

For 2020 contact John.Faragher@DSM.COM to order product

Active Ingredient:	
Natamycin	10.34%
Other Ingredients:	89.66%
Total:	100.00%

This product contains 0.93 pounds of

Zivion S

Adapted from Dr. Chuck Johnson
2021, strawberry pre-plant meeting

Controlling Anthracnose Crown Rot

Potential New Pre-Plant Dip

	Mean Fruit Wt (g)/replication			
	Trial #1		Trial #2	
Treatment, Rate/100 gal	**QoI-Sensitive**	**Qoi-Resistant**	**QoI-Sensitive**	**Qoi-Resistant**
Water Control	125 cde	102 ab	993 cd	813 c
Switch, 8 oz	190 bc	255 a	1,999 ab	1,652 ab
Zivion, 1.0 g/l	161 bc	145 ab	1,738 ab	1,671 ab
Zivion, 0.5 g/l	162 bc	262 a	1,827 ab	1,980 a
Abound, 8 fl oz	378 a	16 c	1,946 ab	683 c
Untreated Control	24 f	81 bc	835 d	641 c

Haak, et al, 2018. Plant Disease 102:1687-1695

Adapted from Chuck 2021, strawberry pre-plant meeting

Take-Home Message

- Resistance to QoI (FRAC 11) or MBC (FRAC 1) is common, use of these two fungicide classes may no longer be effective
- Captan should be included in every spray during fruit ripening
- Certain DMIs (e.g. Tilt and Quadris Top) and Fontelis may be useful
- Any practices that keep water/rain off the plant WILL be of great benefit

Accepting strawberry gray mold (Botrytis) samples for fungicide resistance detection

We accept gray mold from **flowers and/or dead leaves** (**early season**)

Obtain 20 to 40 **dead** strawberry flowers from each strawberry field you would like to have tested. Sometimes the fungus is in dead leaves. Send as many dead leaves as you like in addition to the flowers.

Mail the flowers with information about the origin of the sample (Farm name), your name, phone number, and e-mail to:

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2125 Plant Sciences Building
University of Maryland
College Park 20742

Good luck in 2023-2024 season!