Stealth pathogens:

The sooty blotch and flyspeck complex

Mark Gleason

November 10, 2020

Stealthy:
"Slow, deliberate, and secret"

1. Taxonomy
2. Biogeography
3. Management
4. Phenology
5. Evolutionary phylogeny
6. Adaptation to niche

Sooty blotch and flyspeck (SBFS)

- A common fungal disease of apple fruit.
- Colonizes surfaces of many plants.

4 to 10 fungicide sprays per year.

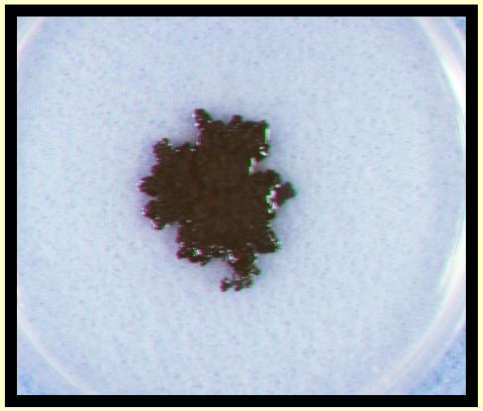
1832: First SBFS publication

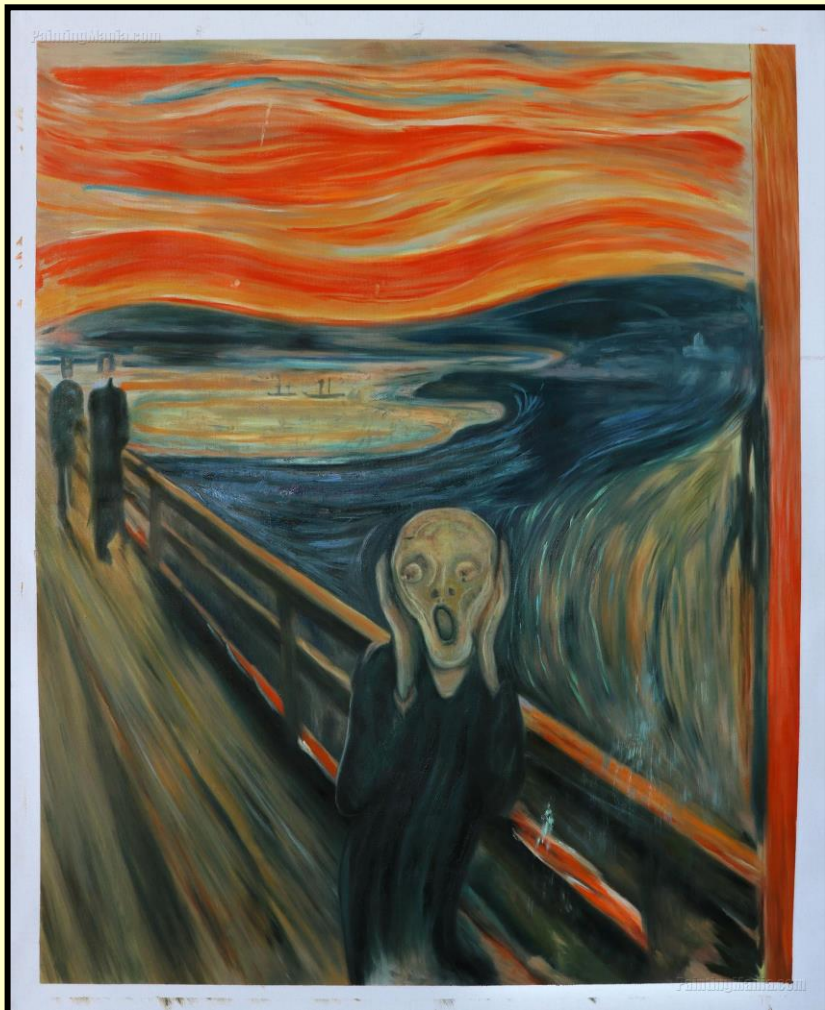
Mycology was morphology-based.

1832-2005:
173 years of SBFS frustration

One problem:
They grow slowly.

1 cm in 3 months!





Another problem: Cryptic species

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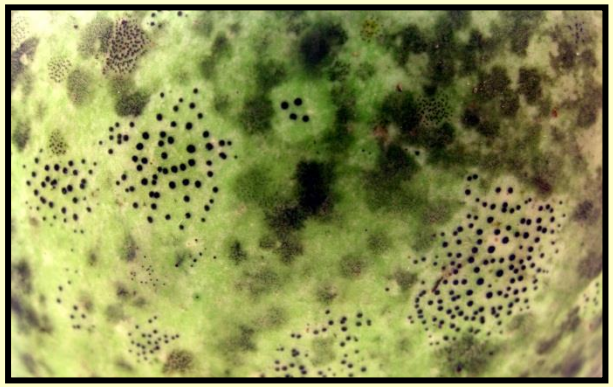
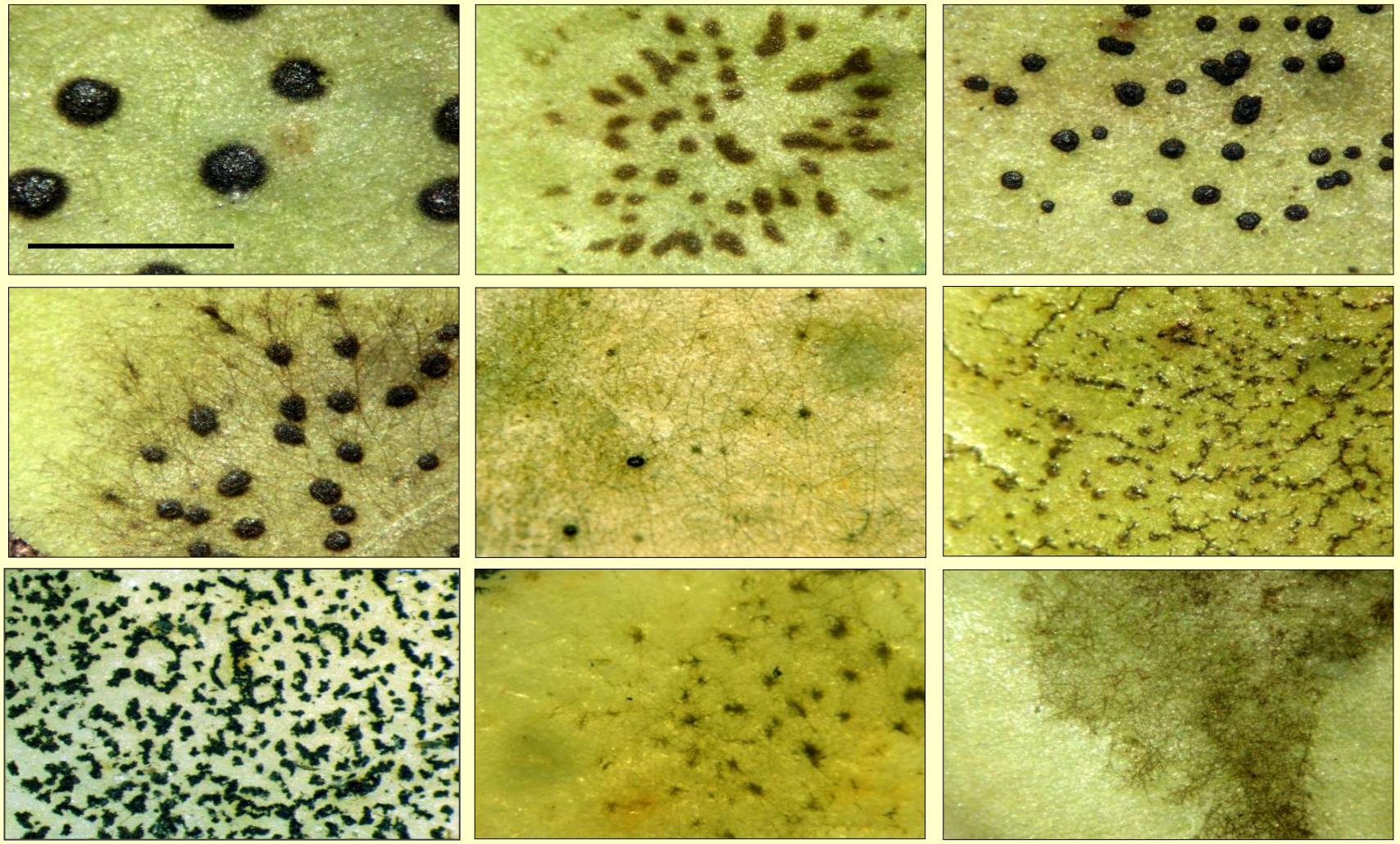
Many look alike.



1) SBFS taxonomy



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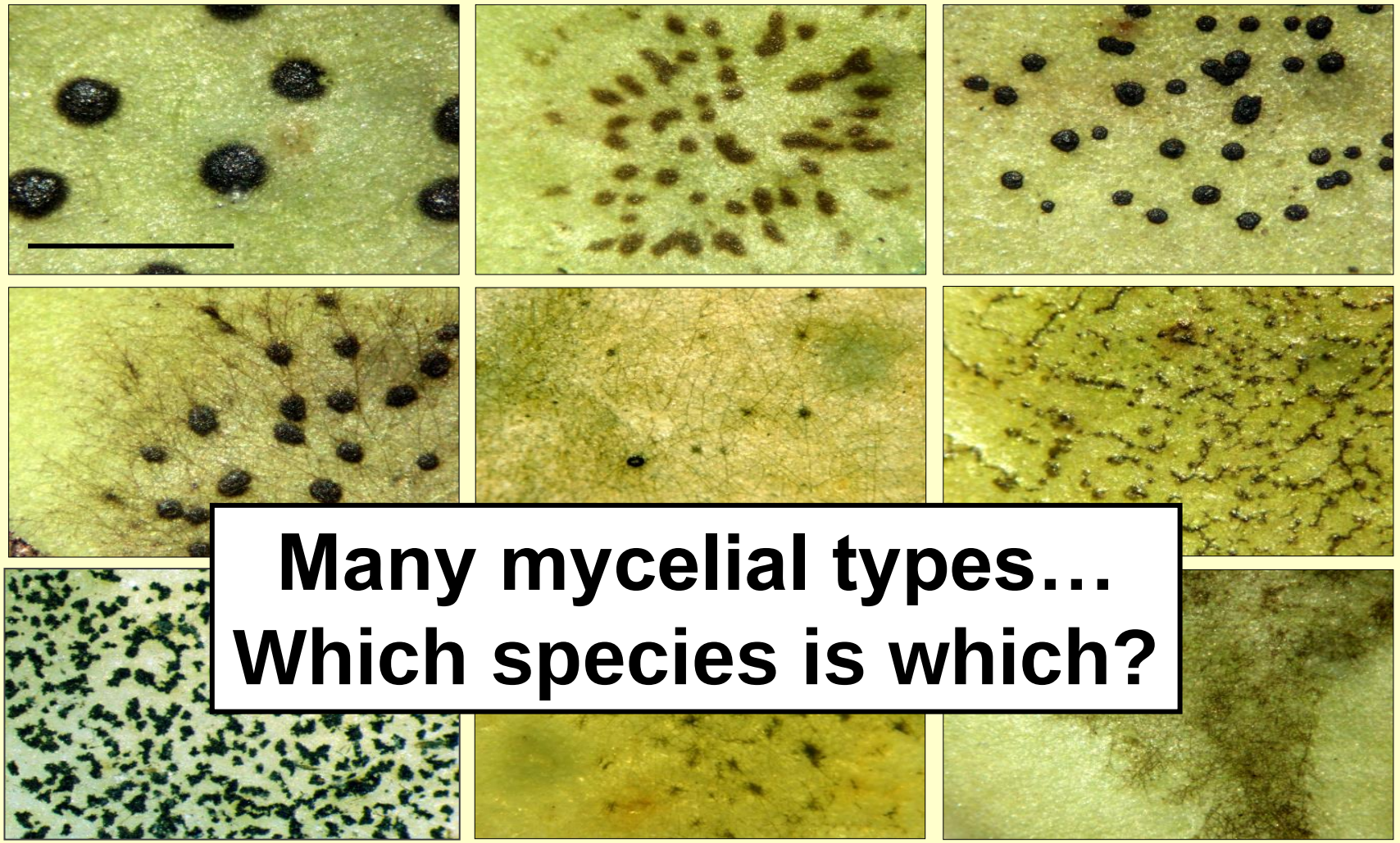
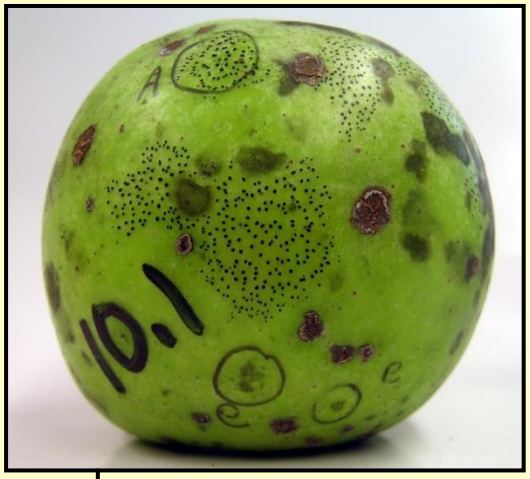


Many mycelial types…
Which species is which?

Tools of molecular genetics unlocked secrets of SBFS.

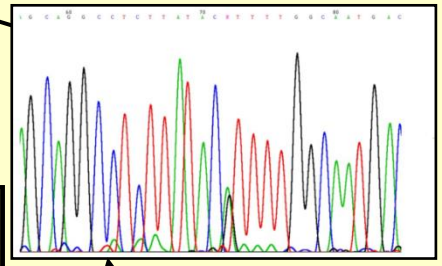
Orchard Surveys

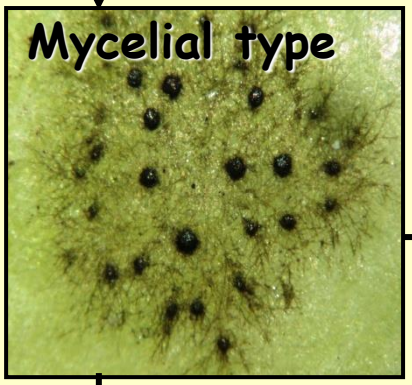


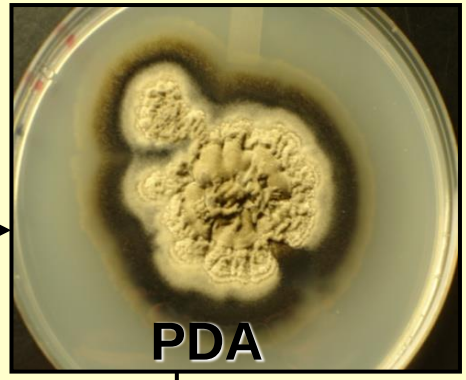
- 40 apples/orchard
- Counted colonies

>GA2-38A1a
TCATTAGAGGAAGTAAAAGTCGTAACAAGGTCTCCGTAGGTG
AACCTGCGGAGGGATCATTACCAGAGACGCCTCGGCGGAA
ACGCCGGGGCCTTTGTCCAACTTTGTGAACGTATCTCTATT
GCCCCGGGGGAACCCGCCTGTCATGGGCGTGGGCCCCCGG
TGGCCAACTCAAACTCTGTTTTTATTGCCGTCCGAGTAACCAA
CCAATCAAAACAAAATTTCAACAACGGATCTCTTGGTTCTGG
CATCGATGAAGAACGCAGCGAAATGCGATAAGTAATGTGAAT
TGCAGAATTCAGTGAATCATCGAATCTTTGAACGCACATTGCG
CCCCCTGGTATTCCGGGGGGCATGCCTGTTCGAGCGTCATTA
CAACCAATCCAGCCCCTCGCGGTATTGGGCGTCGCGGCCTG
CCGCGCGCCTCAAAGTCTTCGGCGAAGCCGCCCGTTCCTCT
GCGTGATGACACATCGTCGCTTGGGACACGGGGGTGCGCCC
GGAAAACATCGGCGGAGACGTCGACTCAAGGtTGACCT

ITS-1
5.8s
ITS-2

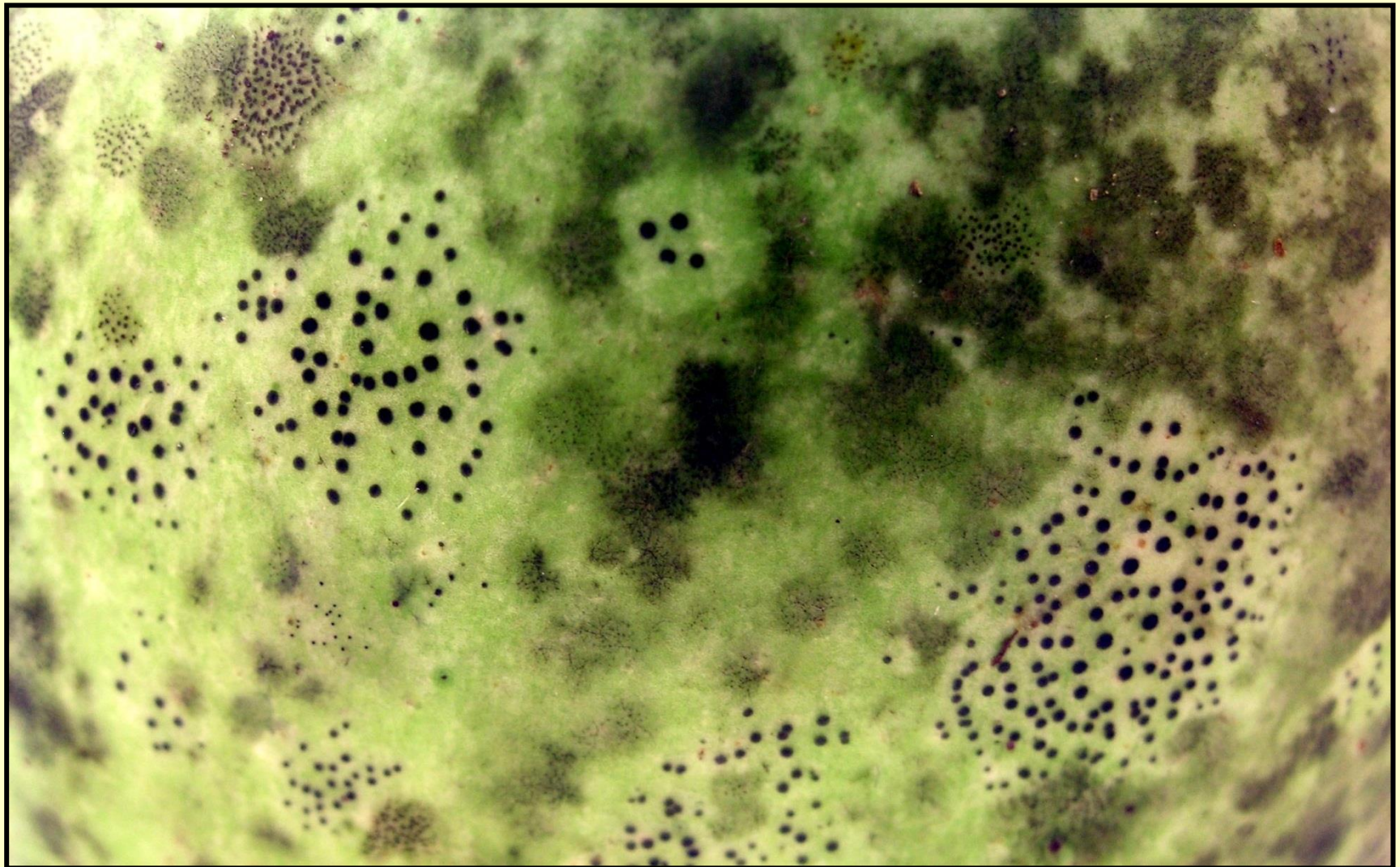






Describe conidia

SBFS diversity

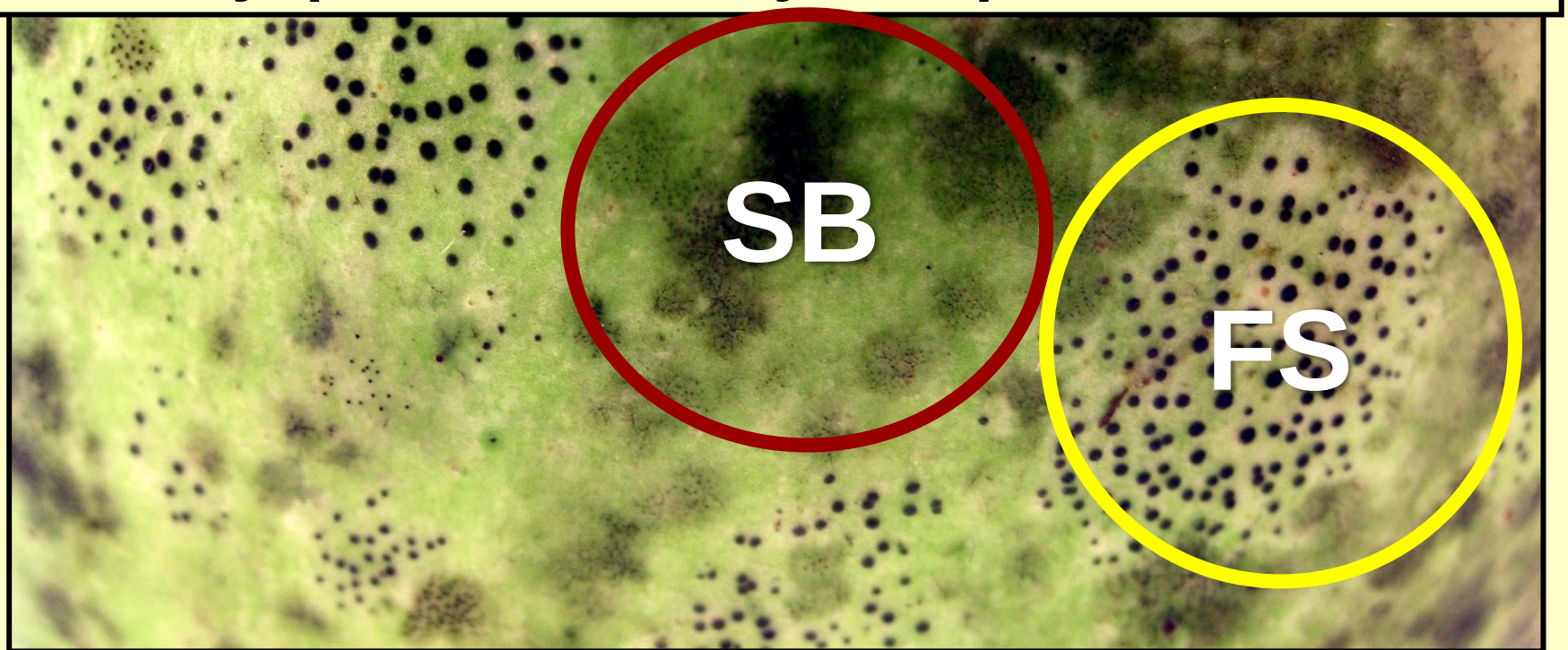


SBFS diversity

1920-1997: 2 diseases, 1 sp. each

Sooty blotch: *Gloeodes pomigena*

Flyspeck: *Schizothyrium pomi*



SBFS diversity

1920: 2 diseases, 2 species

Sooty blotch: *Gloeodes pomigena*

Flyspeck: *Schizothyrium pomi*

1997: 2 diseases, but 4 species

Sooty blotch: 3 species

Flyspeck: *Schizothyrium pomi*

SBFS diversity

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1997: 2 diseases, 4 species

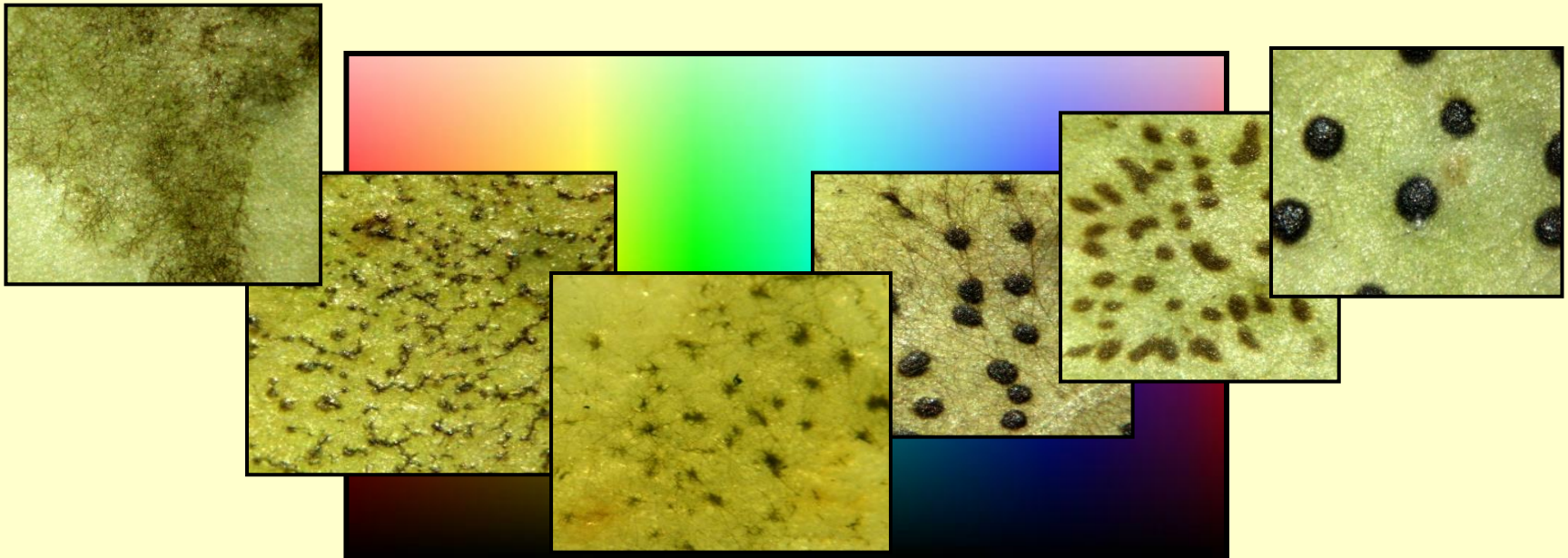
Sooty blotch: 3 species

Flyspeck: *Schizothyrium pomi*

2020: More than 100 species

New paradigm

- Not a pair of diseases
  - "Sooty blotch" and "flyspeck"
- **A multi-species complex**



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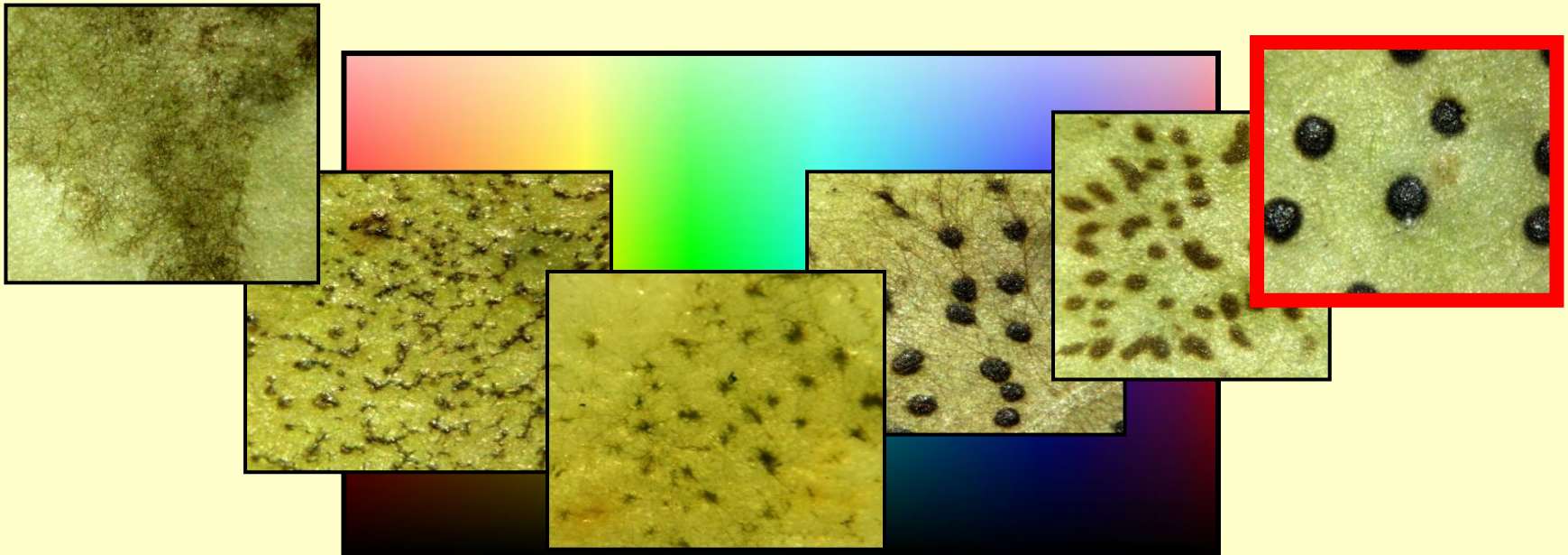

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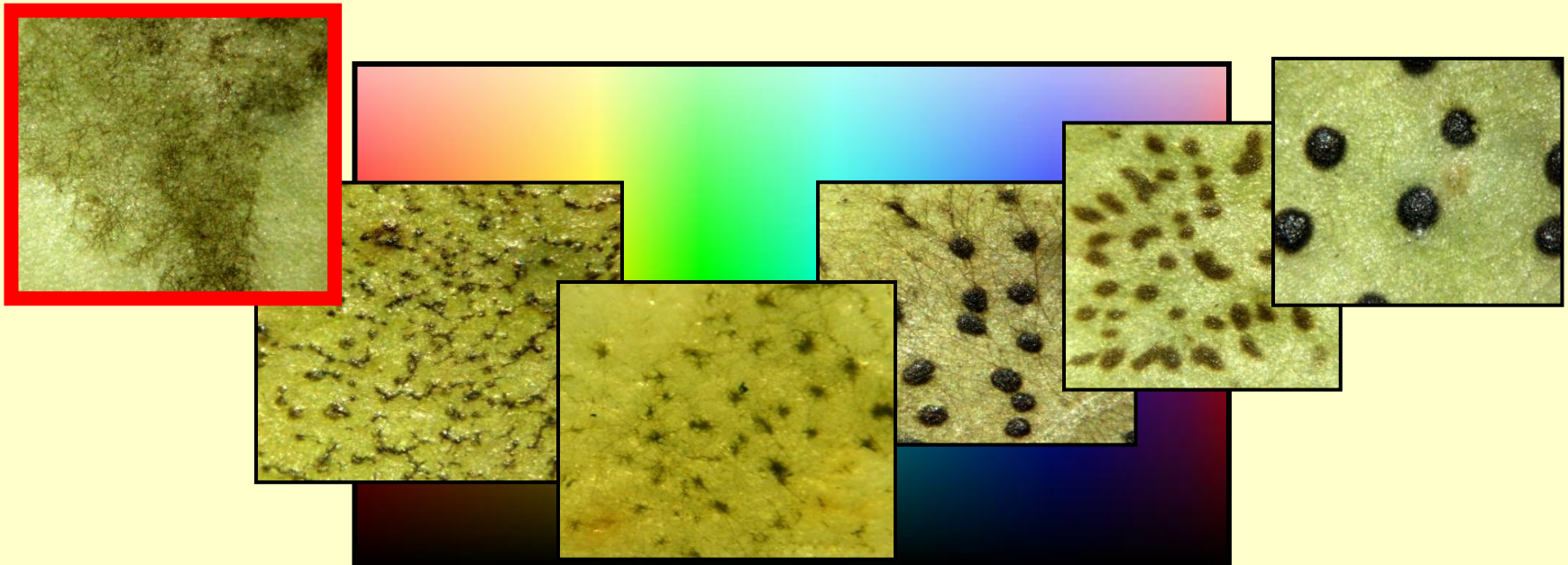

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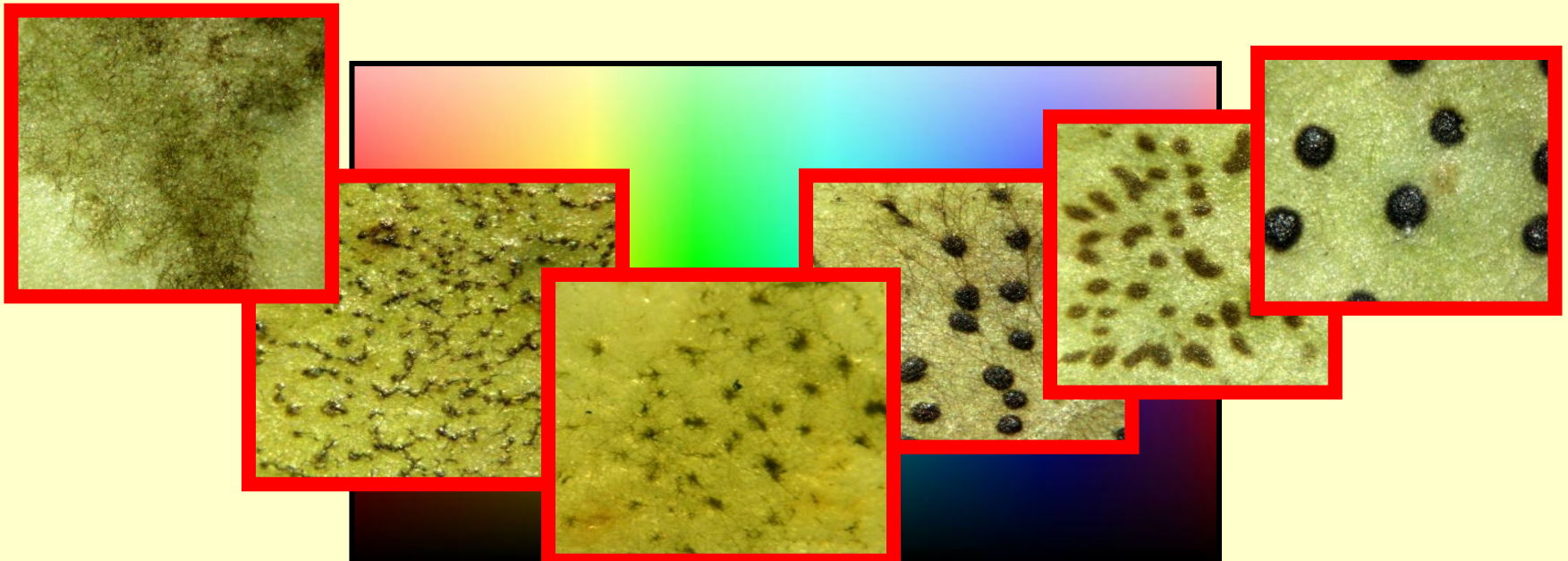

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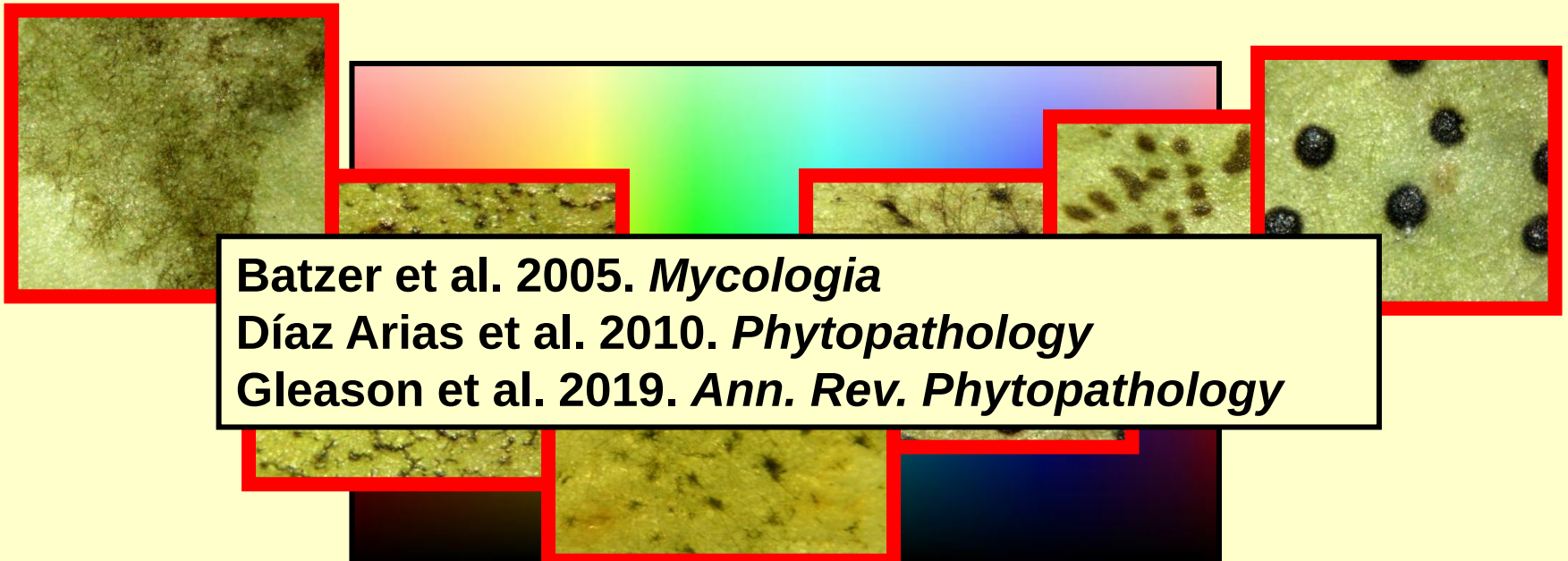
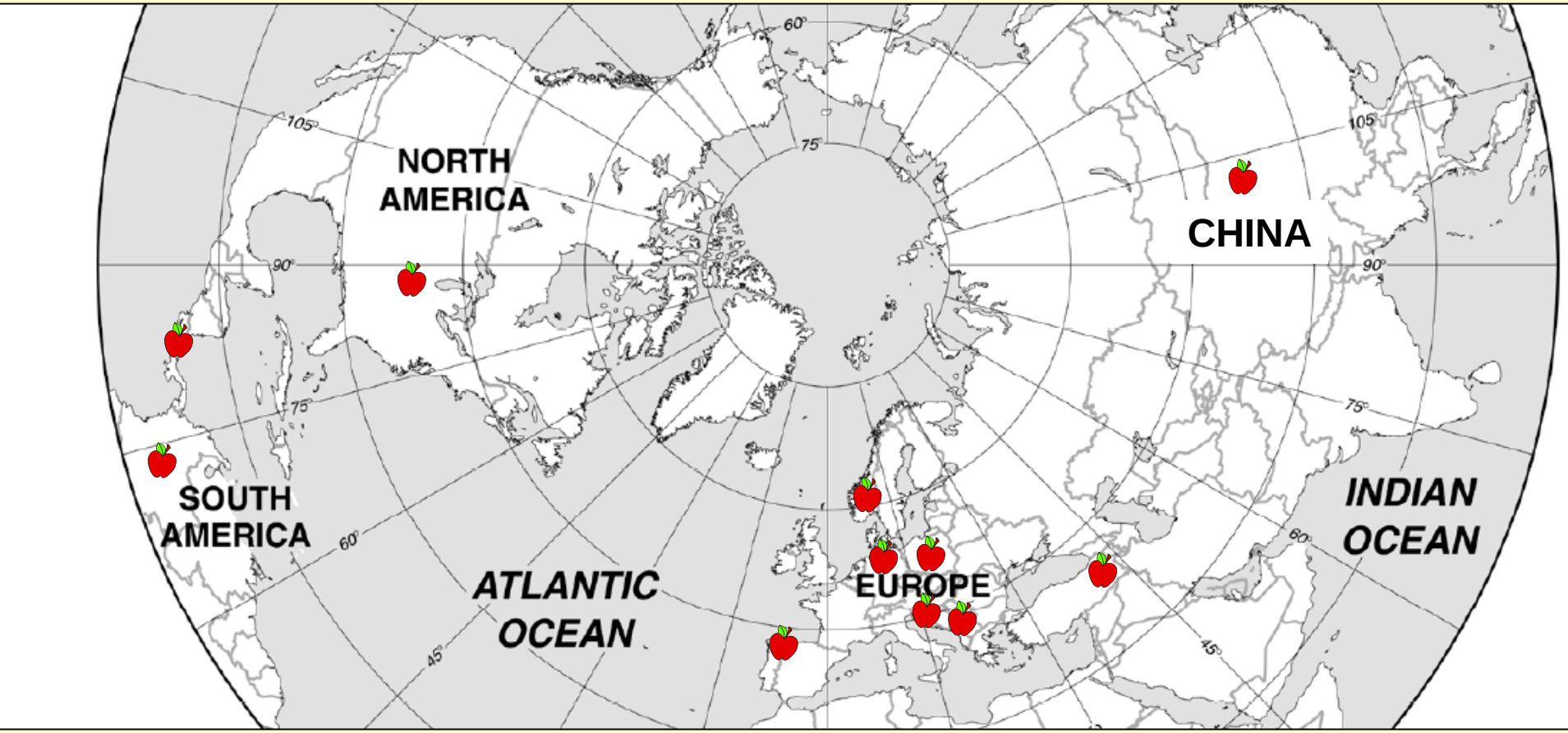


Batzer et al. 2005. *Mycologia*
Díaz Arias et al. 2010. *Phytopathology*
Gleason et al. 2019. *Ann. Rev. Phytopathology*

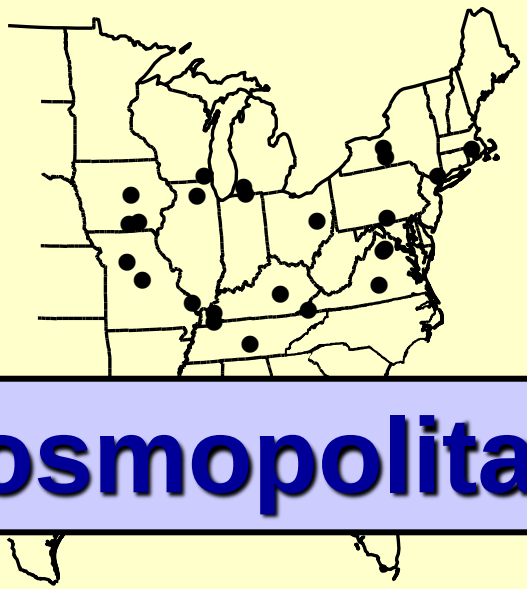
2) Biogeography



Survey results

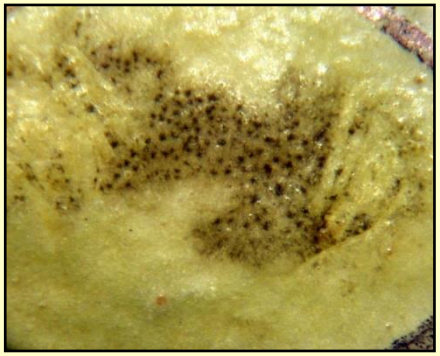
Schizothyrium pomi

***Pseudocercosporella* sp. RH1.1**



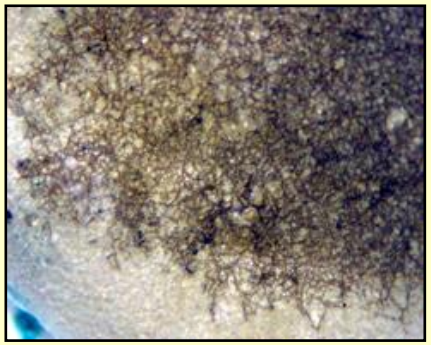
Cosmopolitan

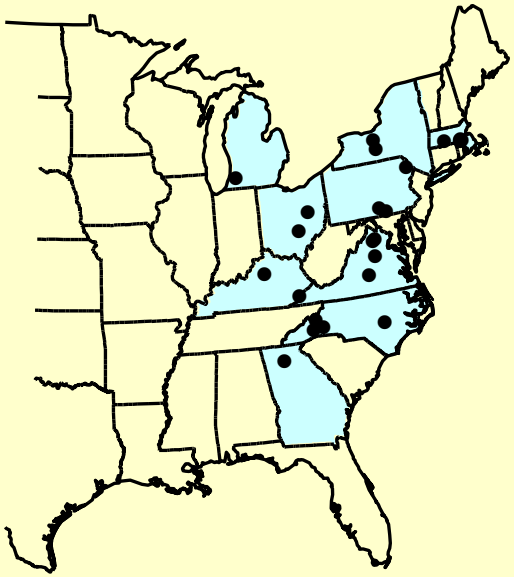
Peltaster fructicola



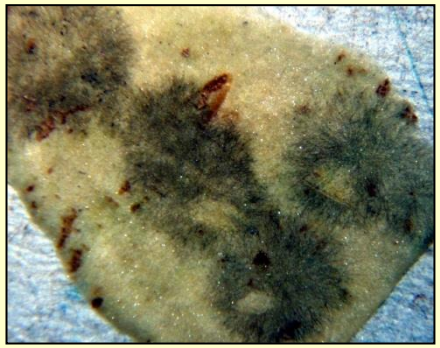
Survey results

Geastrumia polystigmatis

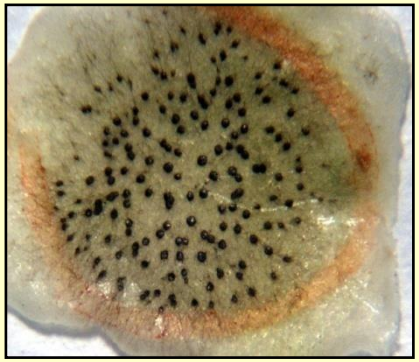




Phialophora sessilus



***Stomiopeltis* sp. 5.1**



3) Management

Can it be more cost effective?

North Carolina SBFS warning system (1990s)

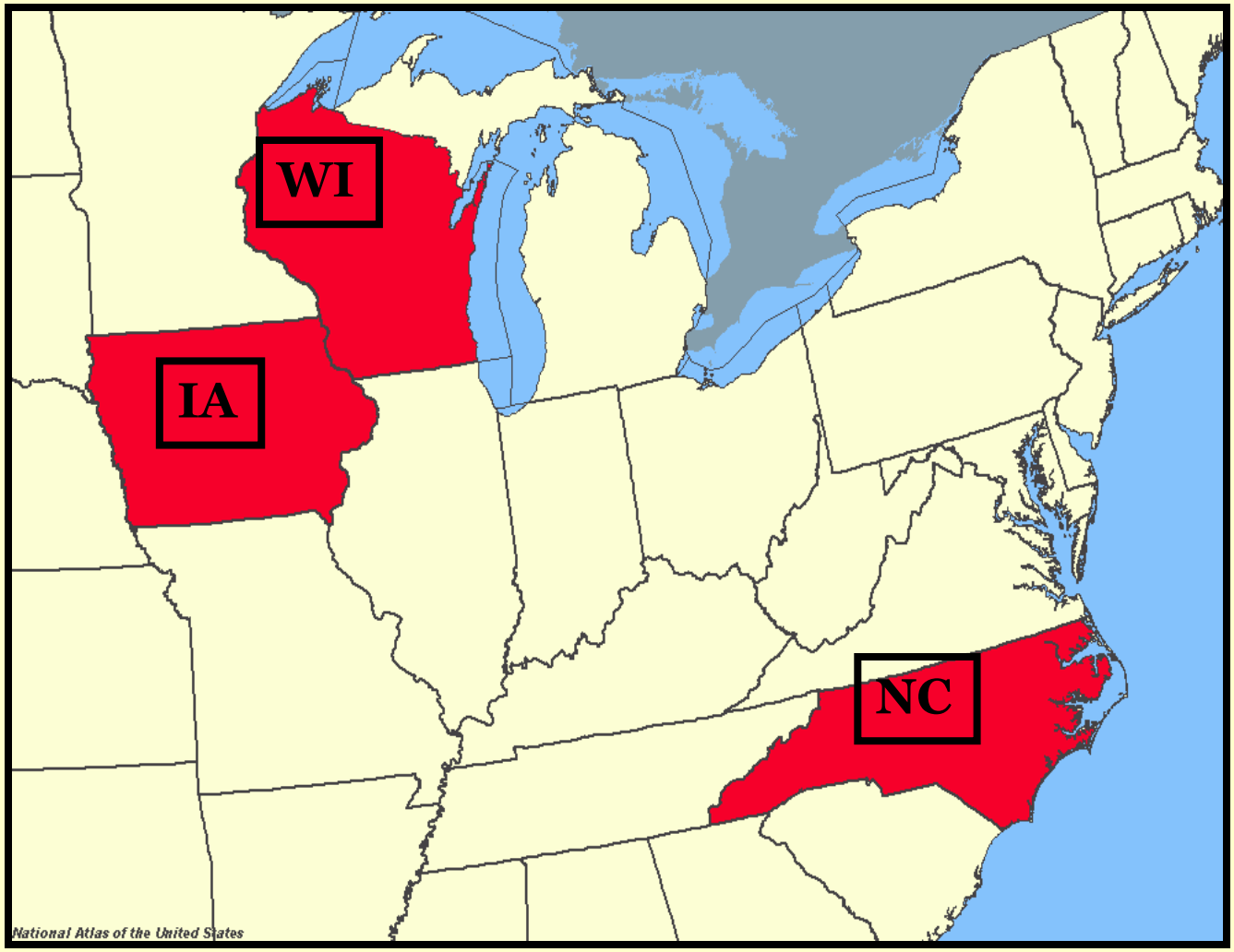
1st-cover spray

2nd-cover spray

175 hours of leaf wetness

Time

Does it work in the Midwest?



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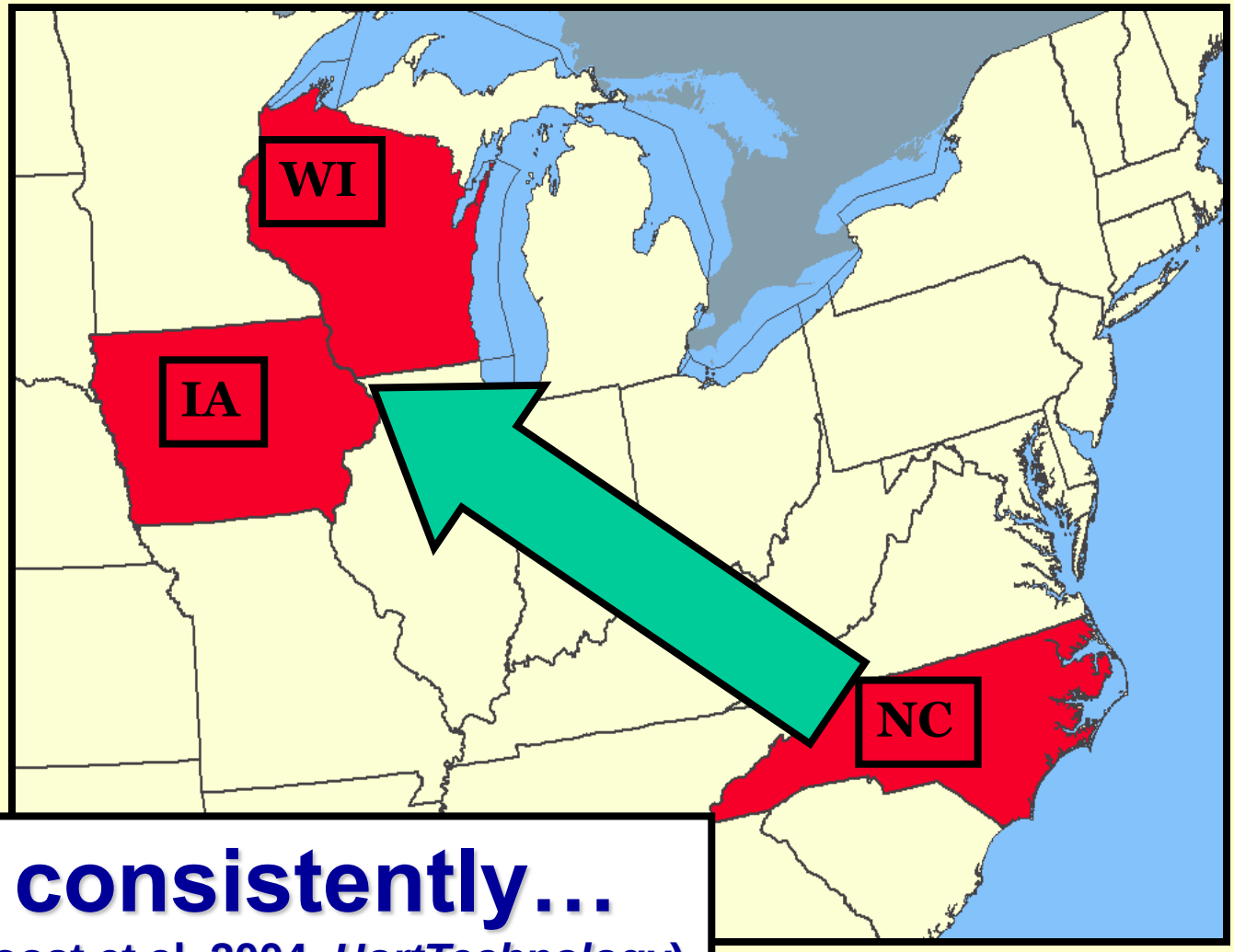
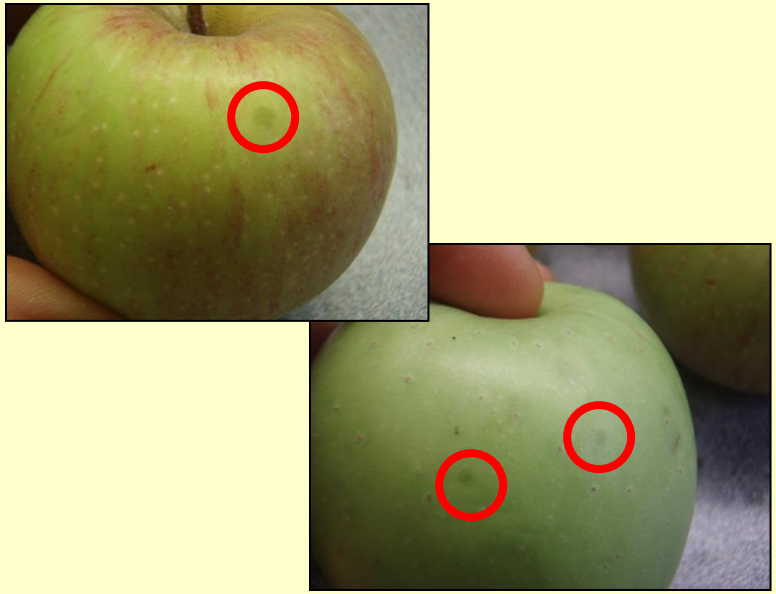


Not consistently…

(Babadoost et al. 2004. *HortTechnology*)

Revising for the Midwest



- **Monitored T, RH, rainfall, LWD**
- **19 orchard-years**
- **Scouted for first SBFS signs**

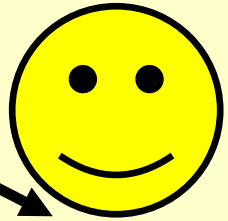
Receiver operating characteristic (ROC) analysis

True positives

False positives

	Observed +	Observed -
Predicted +	+ +	+ -
Predicted -	- +	- -

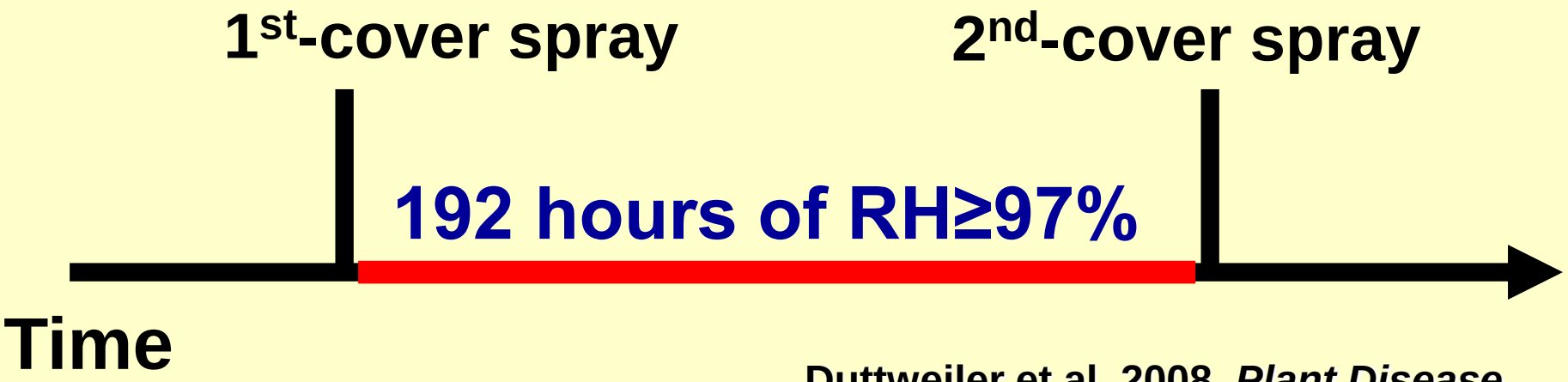
False negatives



True negatives

Proposed Midwest warning system

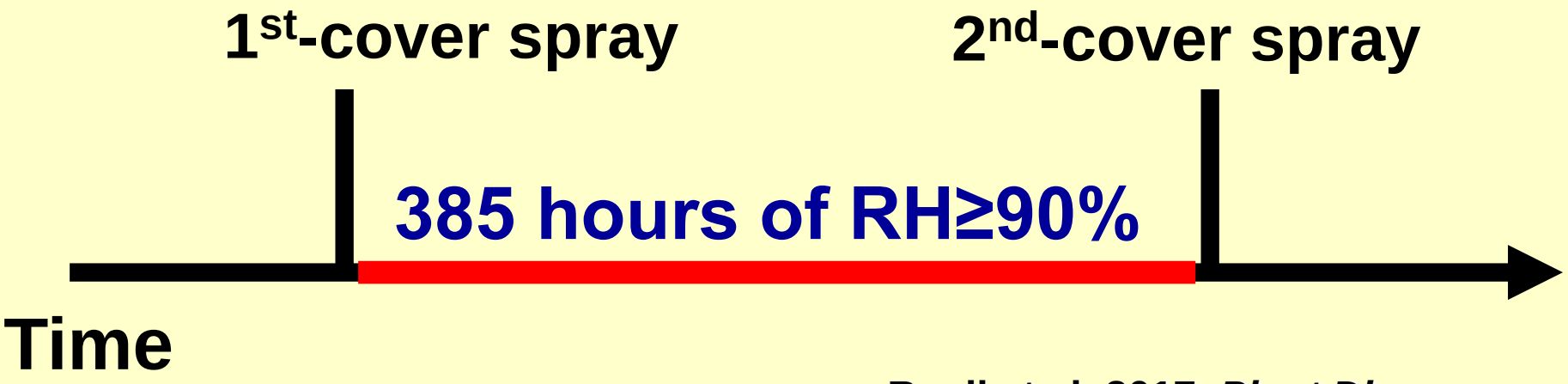
- Monitor **relative humidity**, not LWD.



Duttweiler et al. 2008. *Plant Disease.*

Validating RH-based warning system

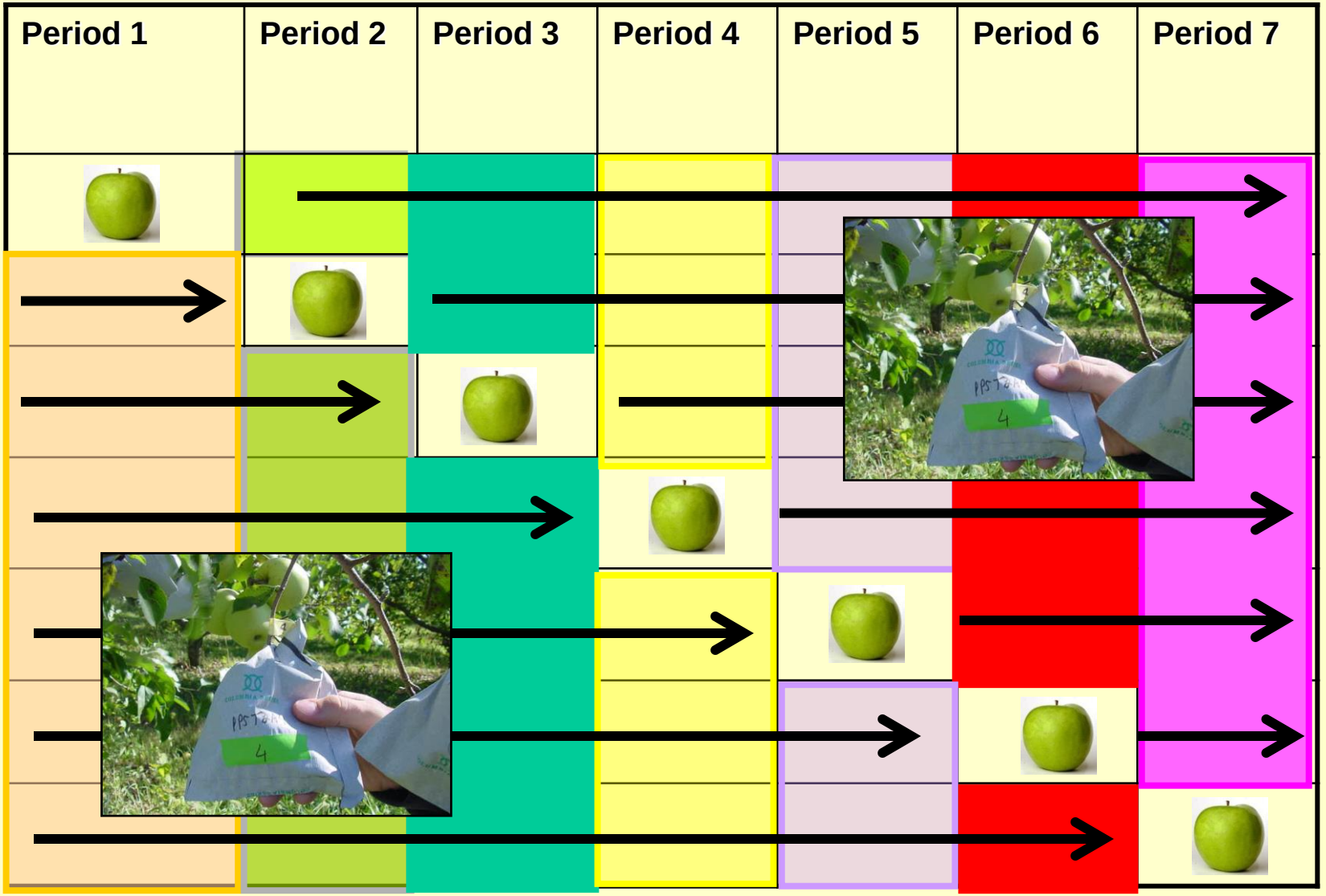
- Field trials (2010-2015)
- Saved 2.5 sprays/year
- Threshold shifted from 97% RH to **90% RH**.



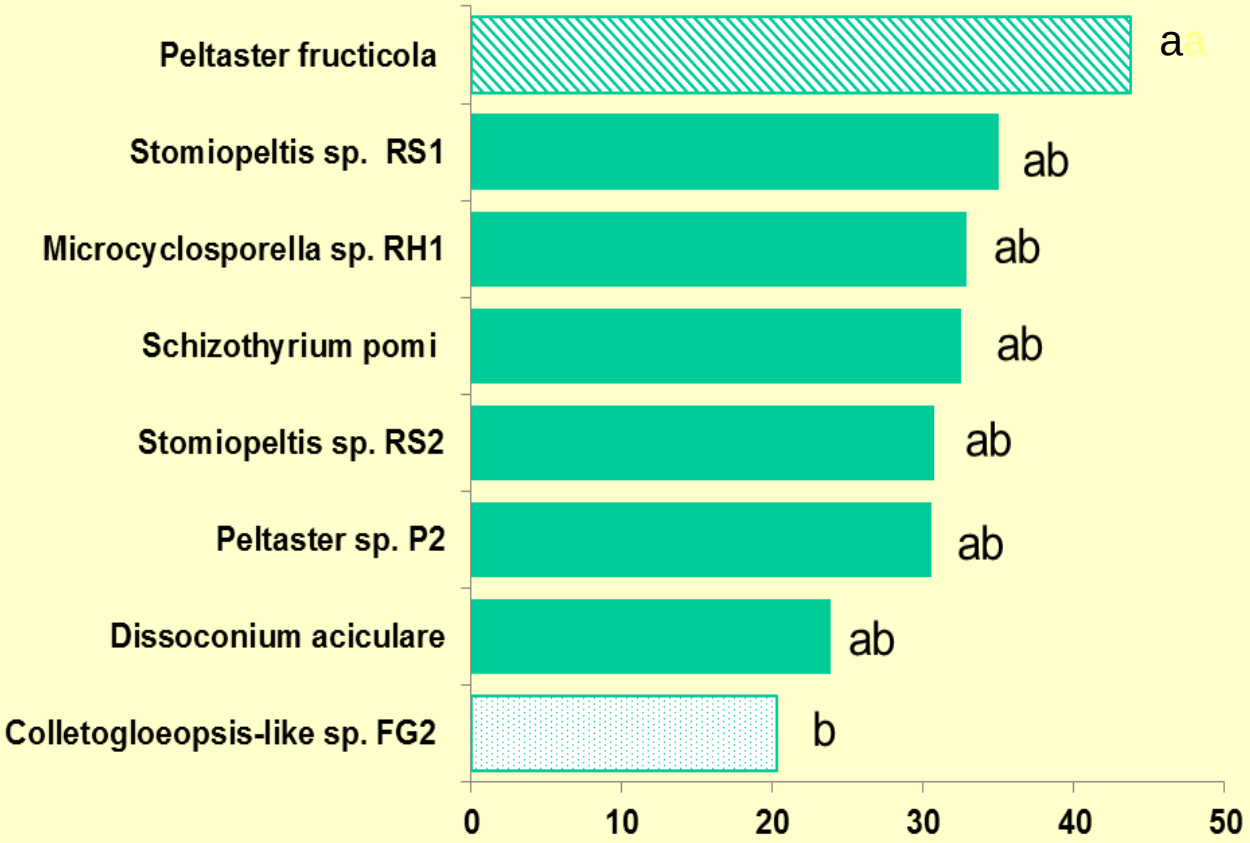
Rosli et al. 2017. *Plant Disease*

4) Phenology

Bagging trials



Phenology of SBFS fungi



Ismail et al. 2016. *Plant Disease*

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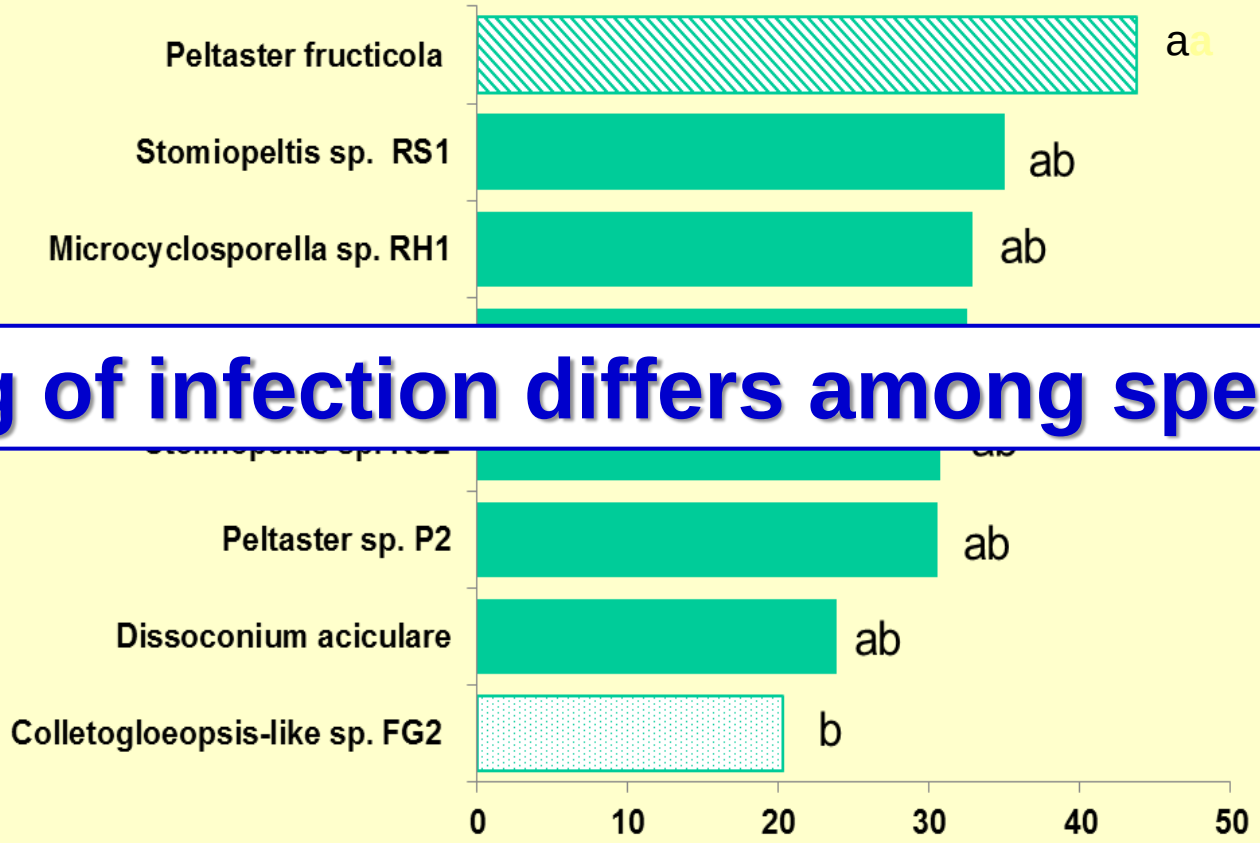
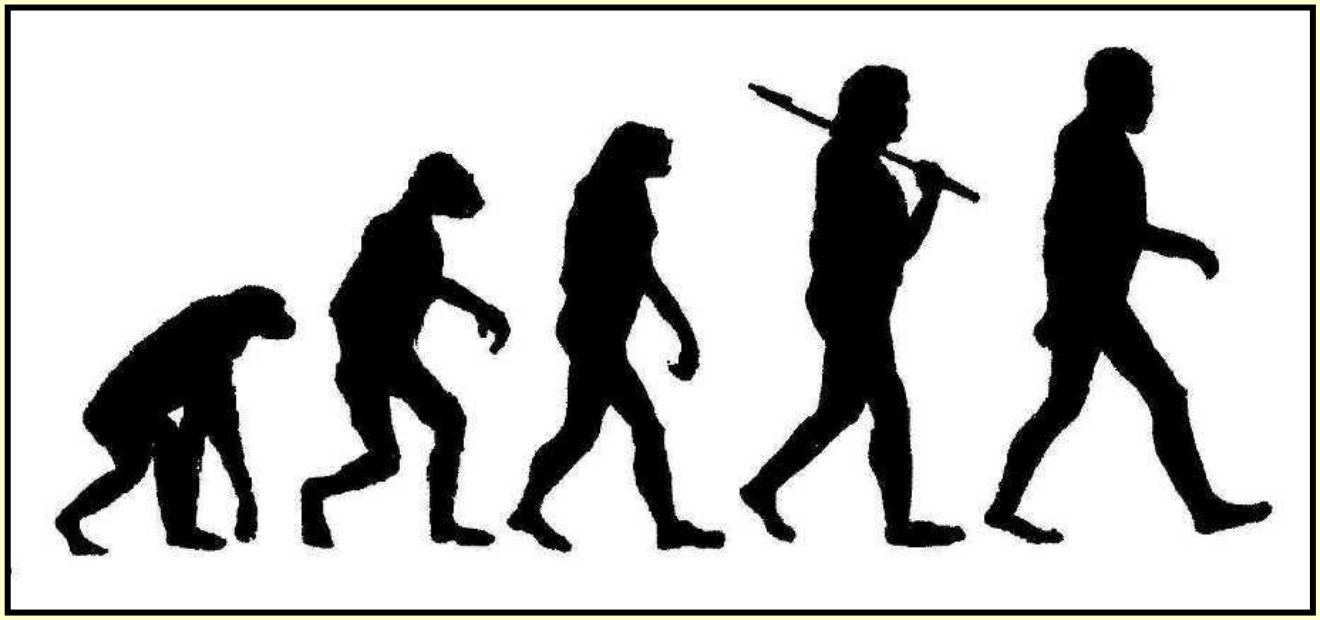
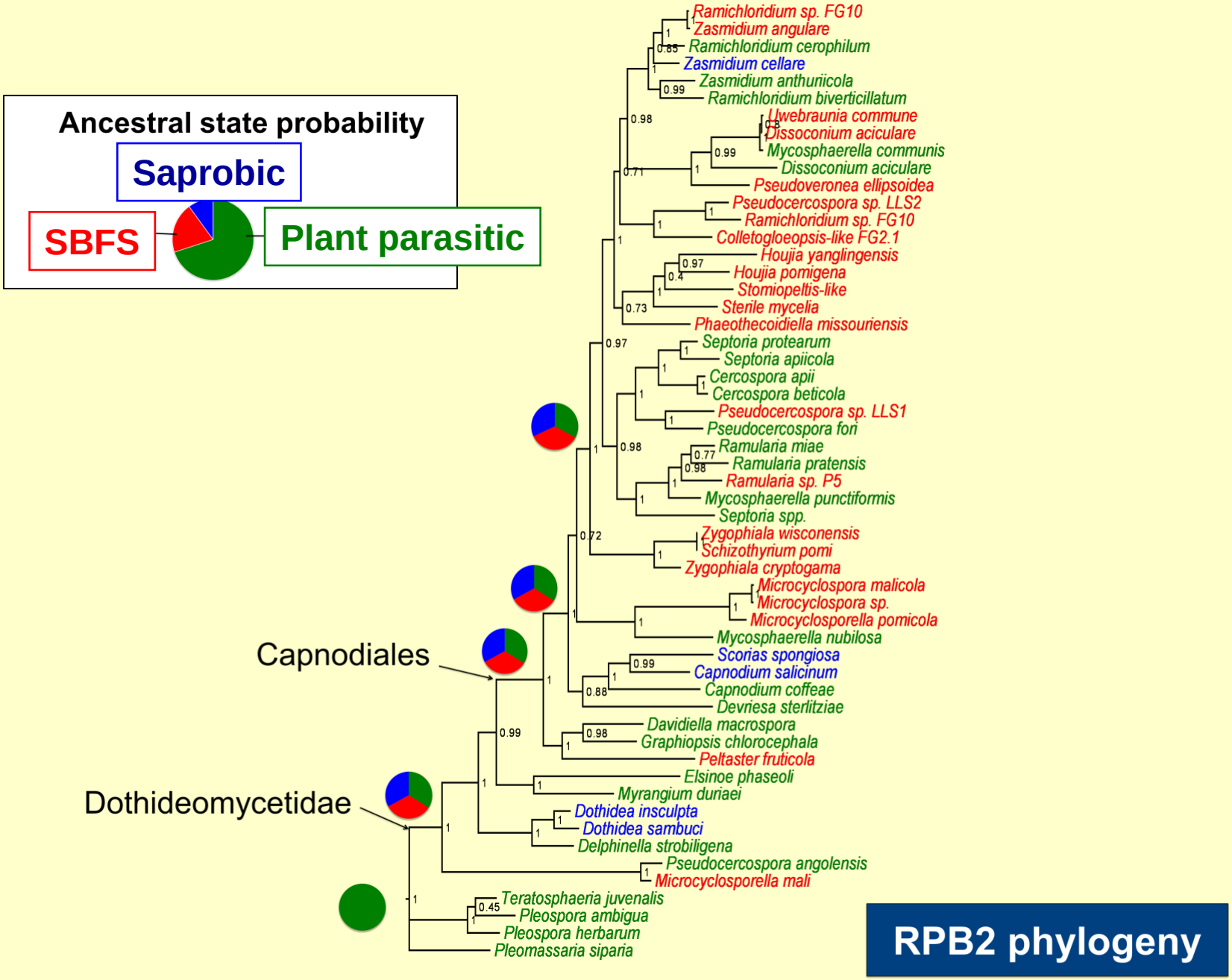


Timing of infection differs among species.

Ismail et al. 2016. *Plant Disease*

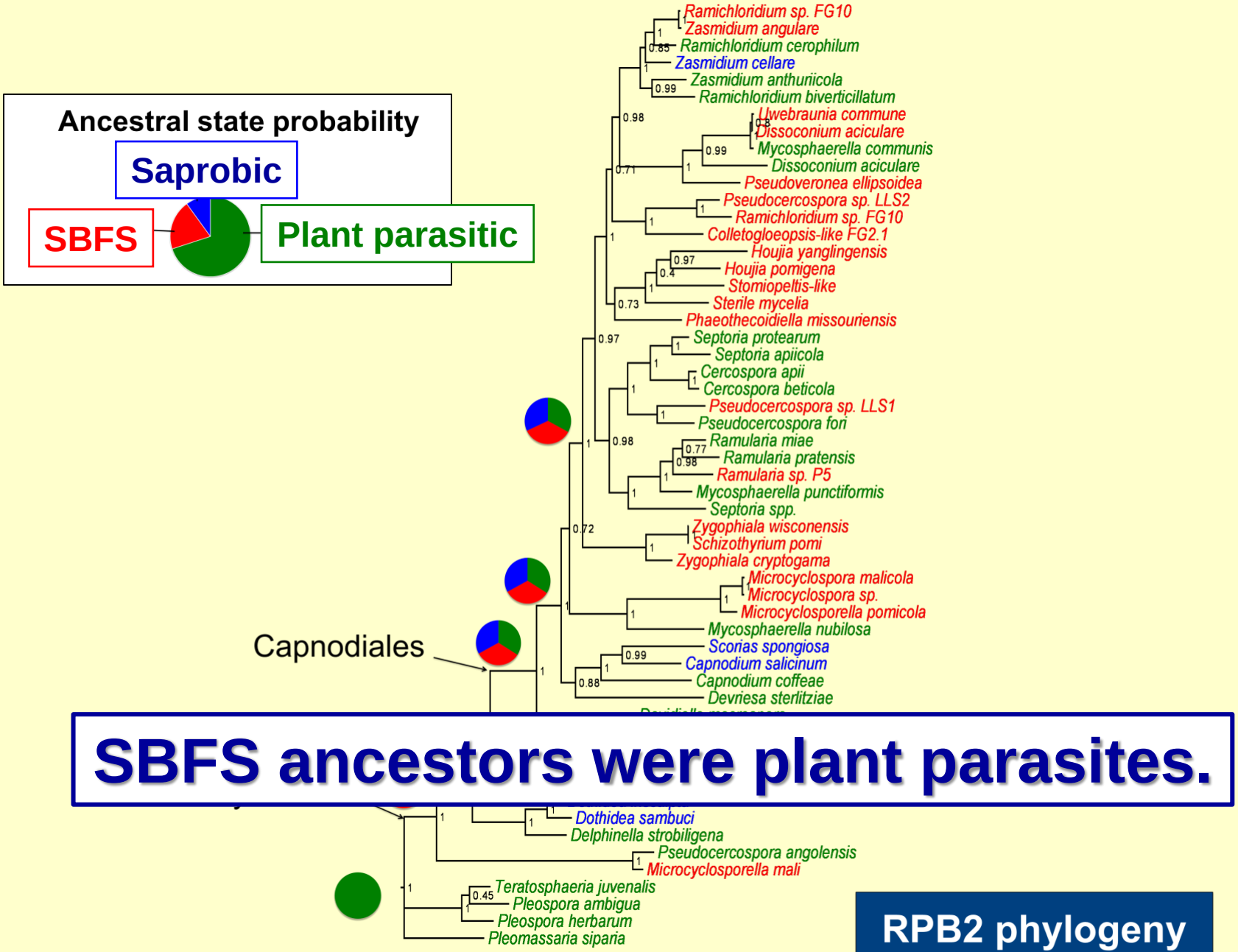
5) Evolutionary origins of SBFS





RPB2 phylogeny

Ismail et al. 2016. *Mycologia*



SBFS ancestors were plant parasites.

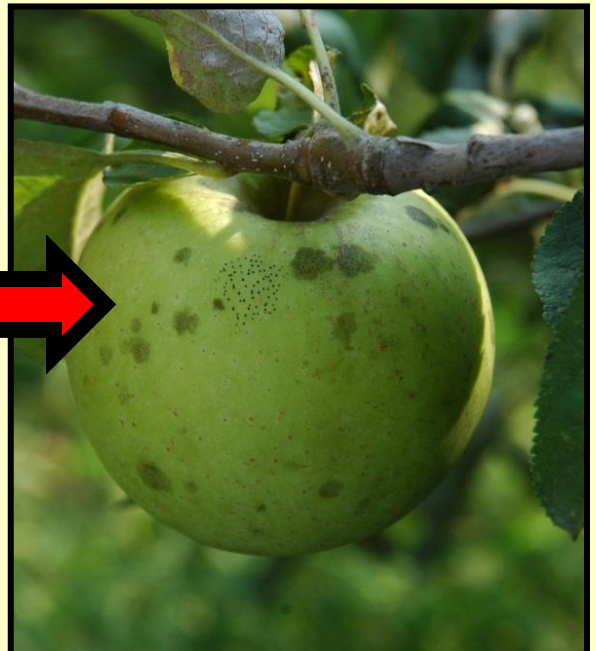
RPB2 phylogeny

Ismail et al. 2016. *Mycologia*

6) Adaptive mechanisms

Parasites

Ectophytes



Ectophytes *vs.* epiphytes

- **Ectophytes – ON and IN plant surfaces**
- **Epiphytes – ON the plant surface**

Xu et al. 2016. *Scientific Reports*

Ectophytes *vs.* epiphytes

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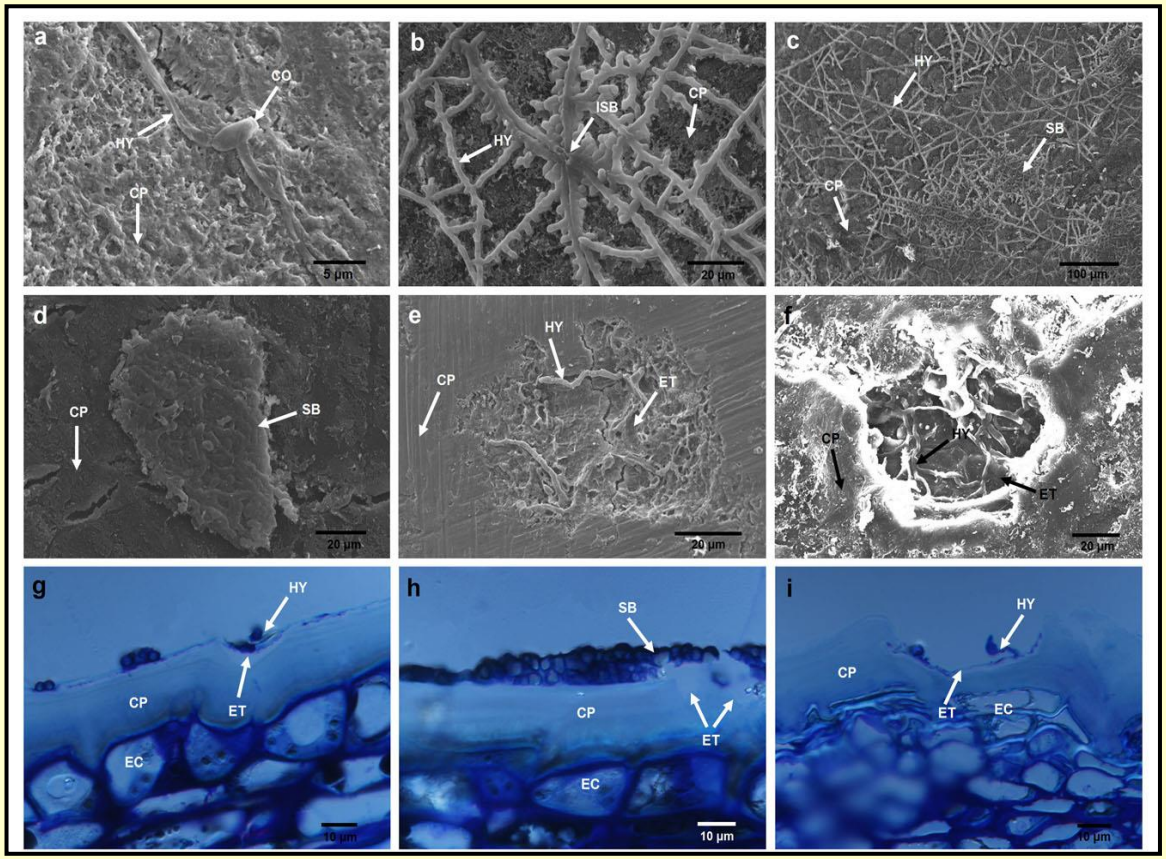

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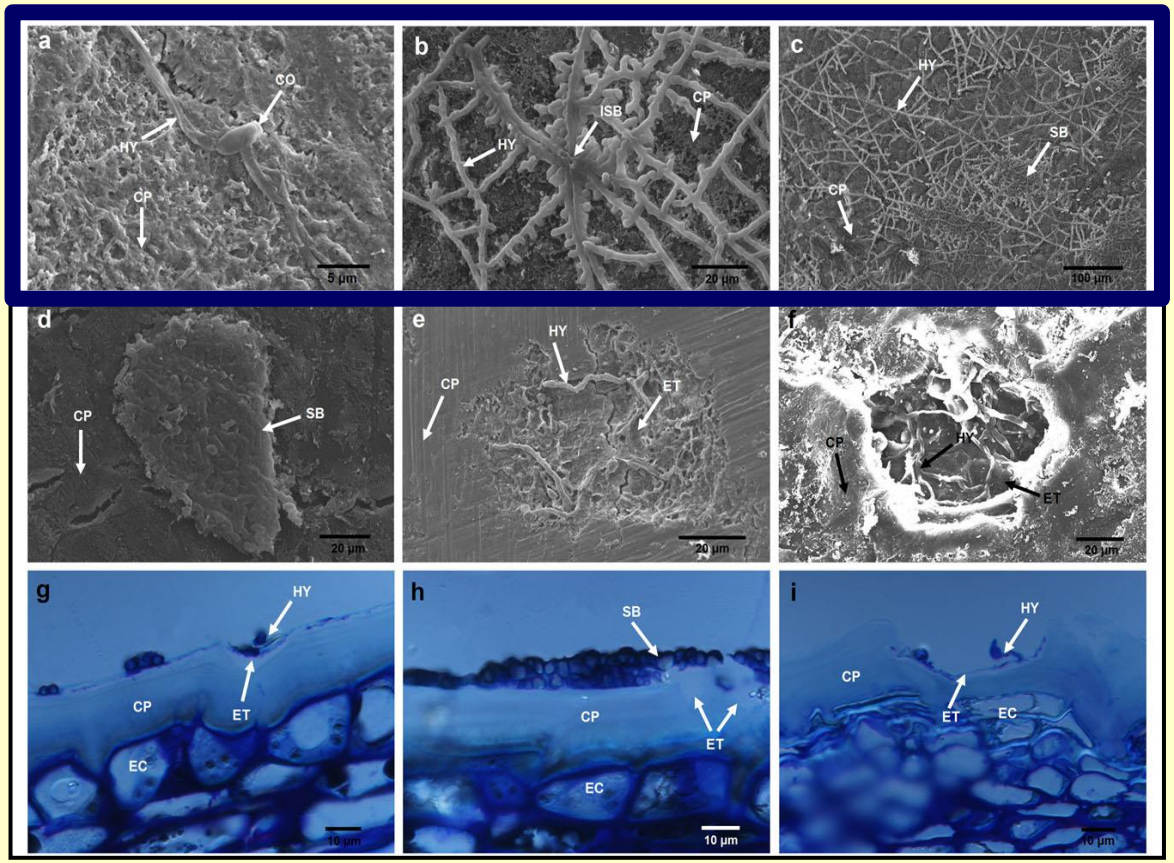

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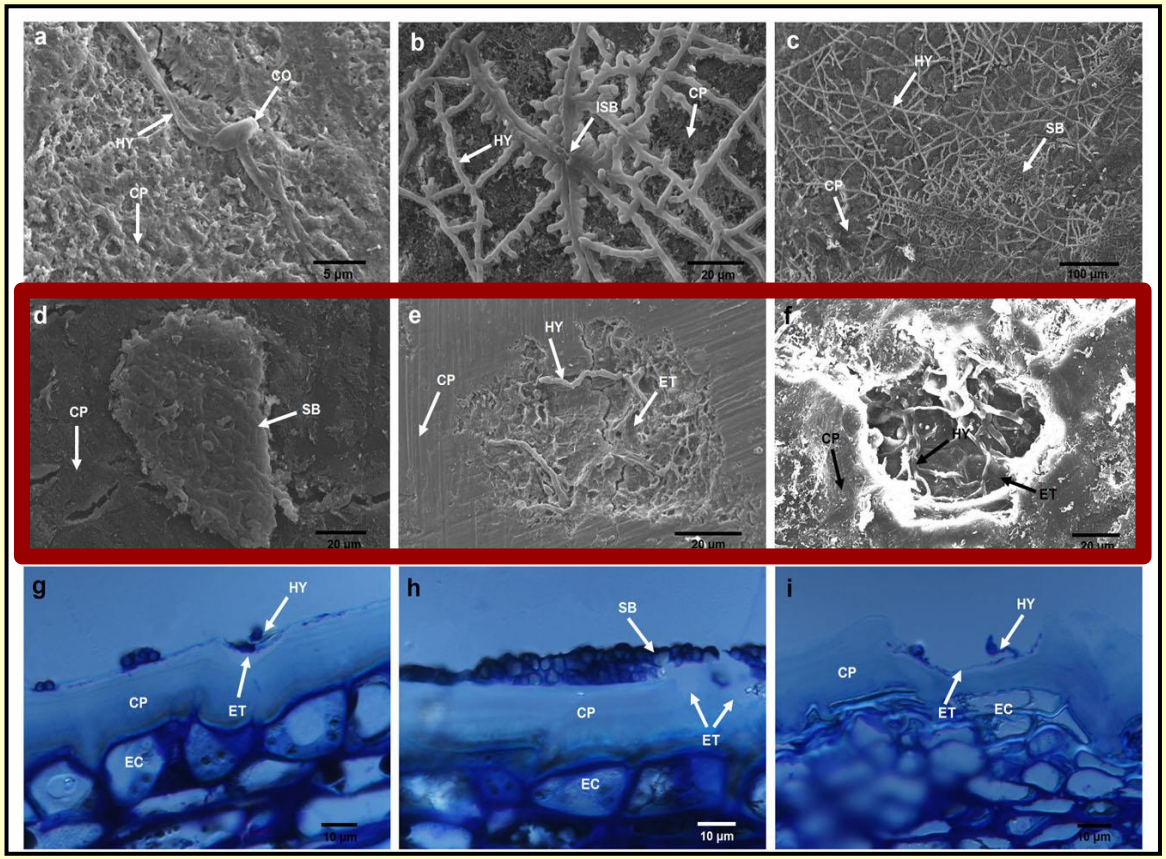

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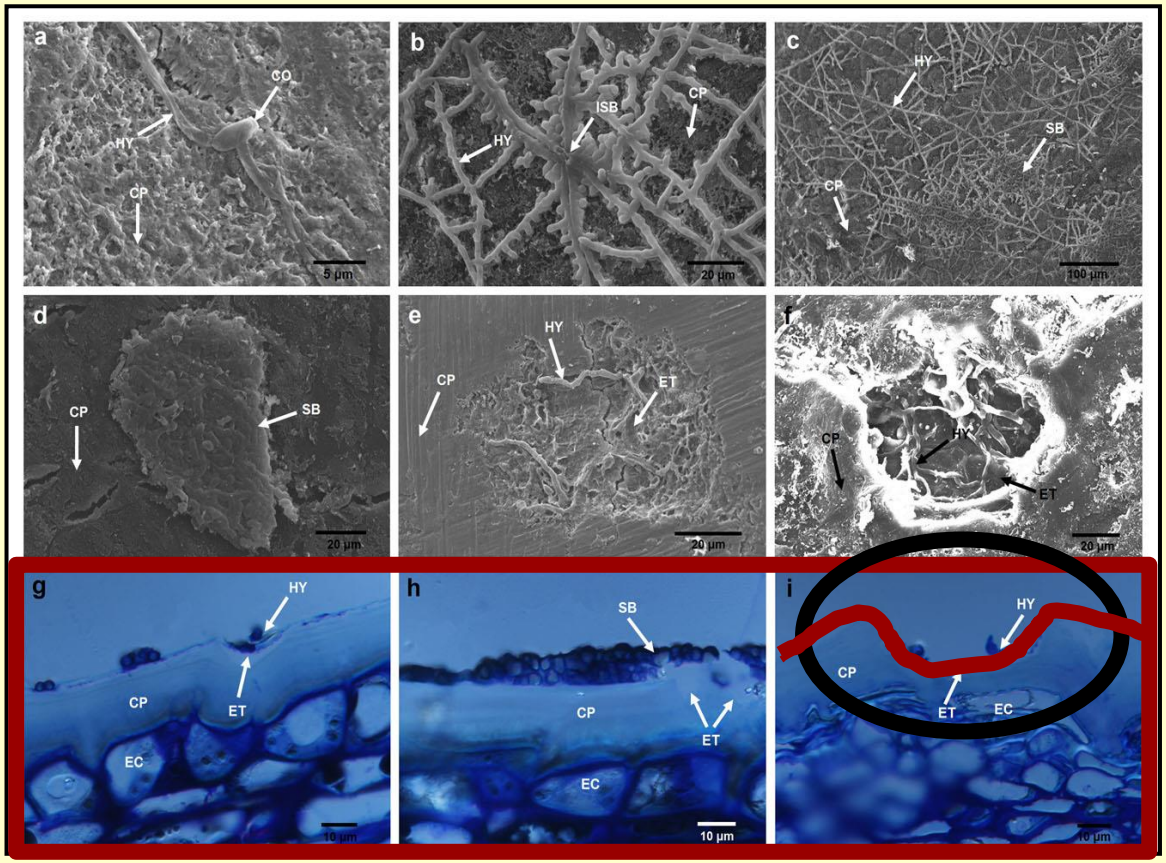
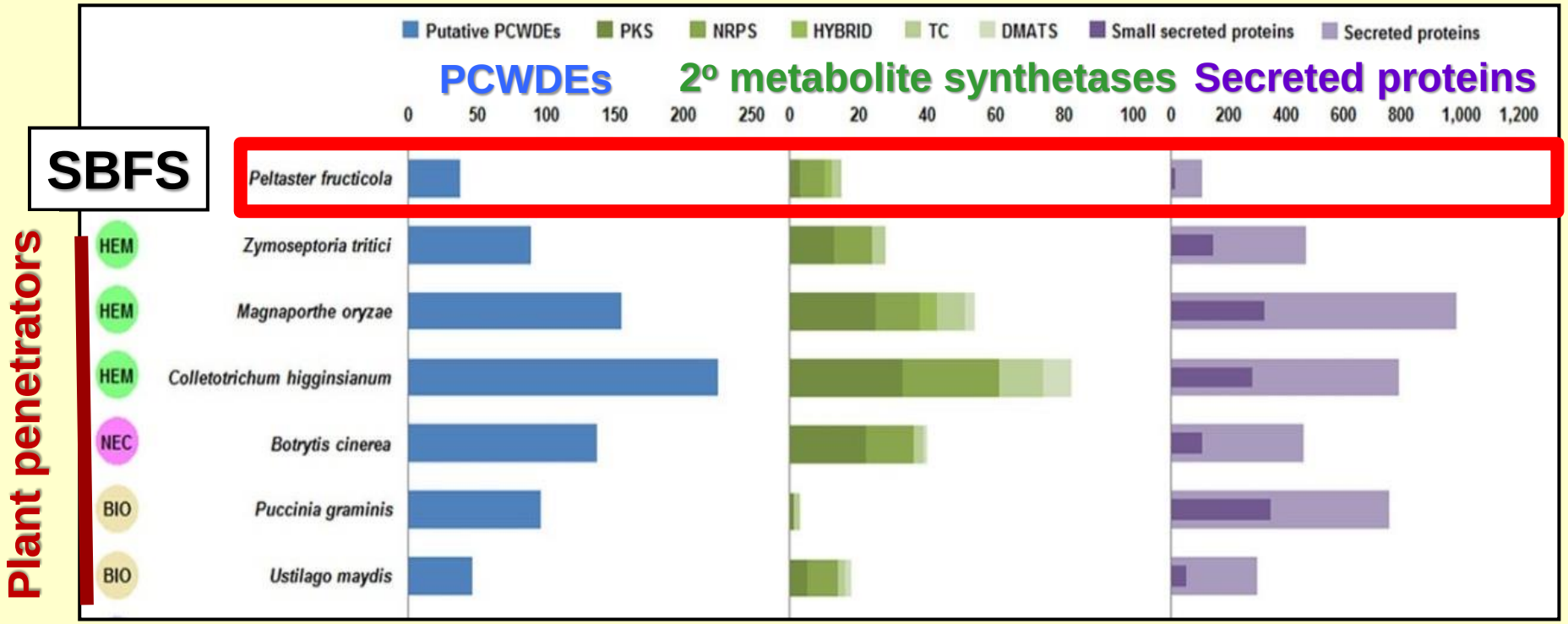


Xu et al. 2016. *Scientific Reports*

Reductive evolution of enzyme systems



Xu et al. 2016. *Scientific Reports*

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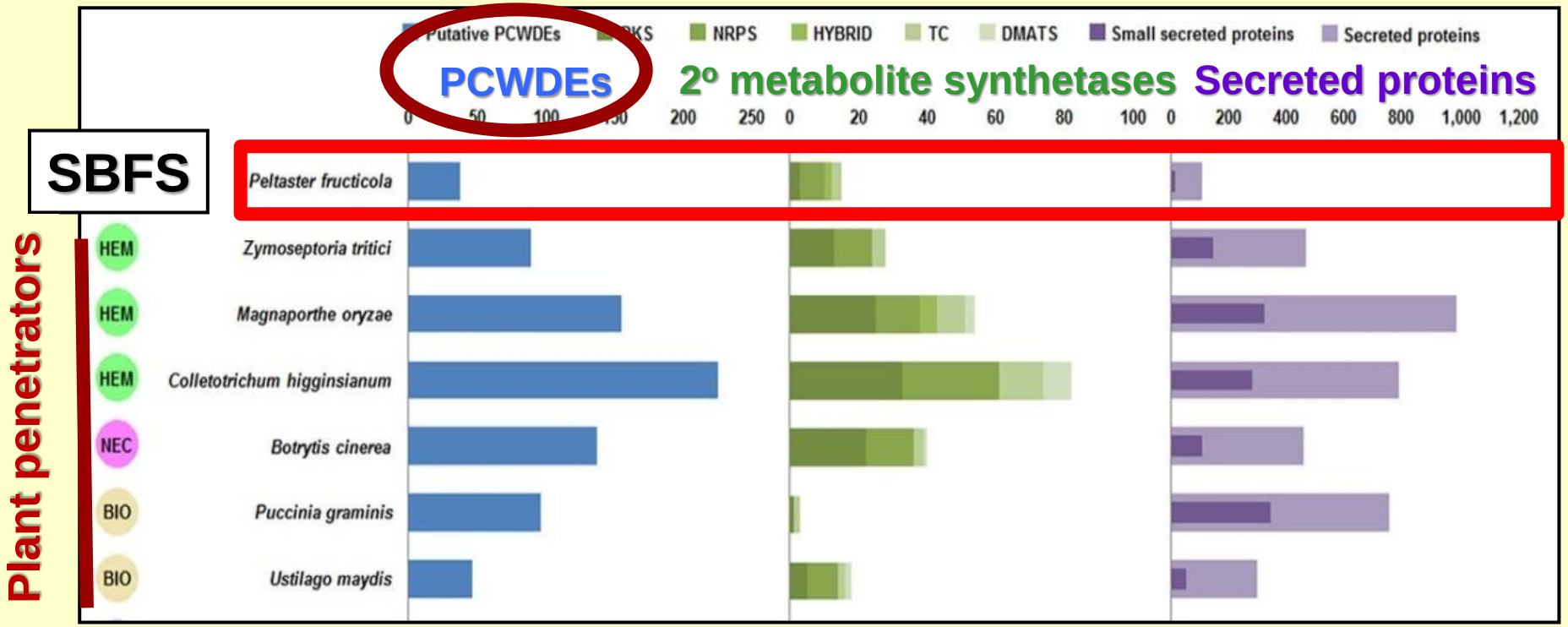

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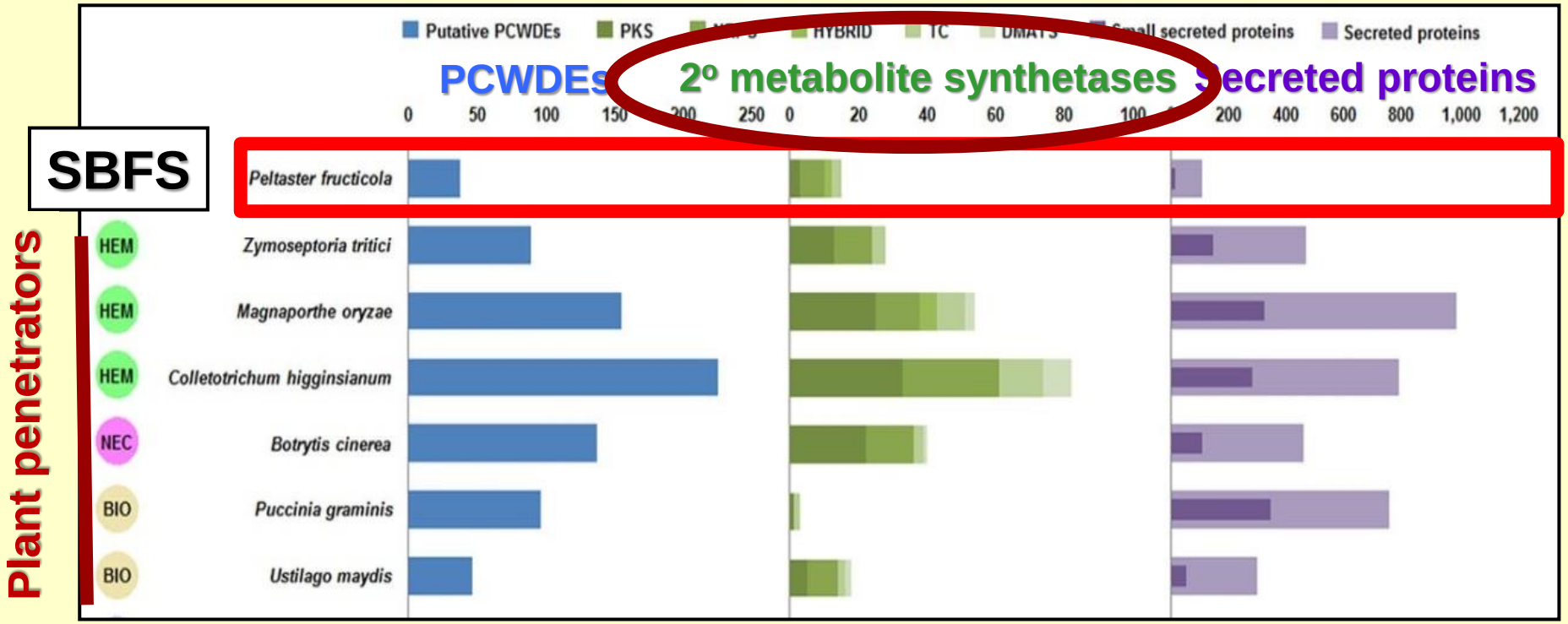

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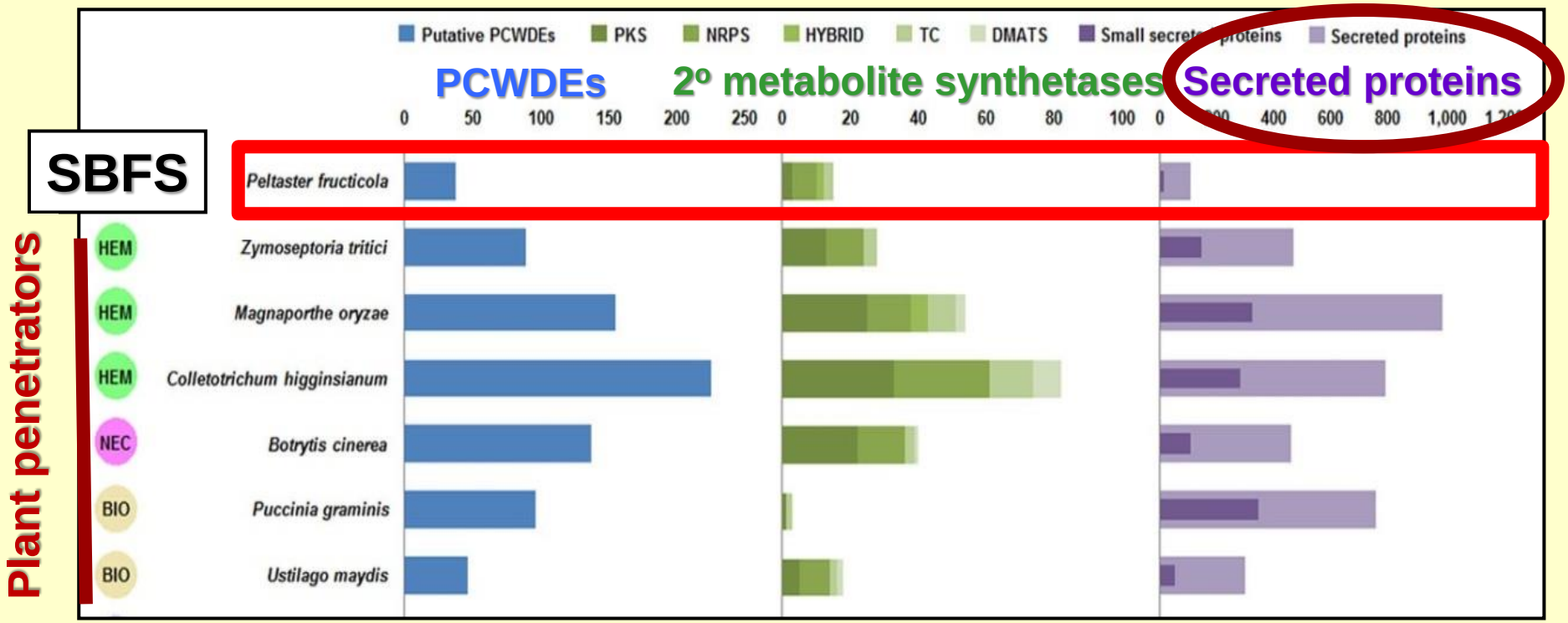
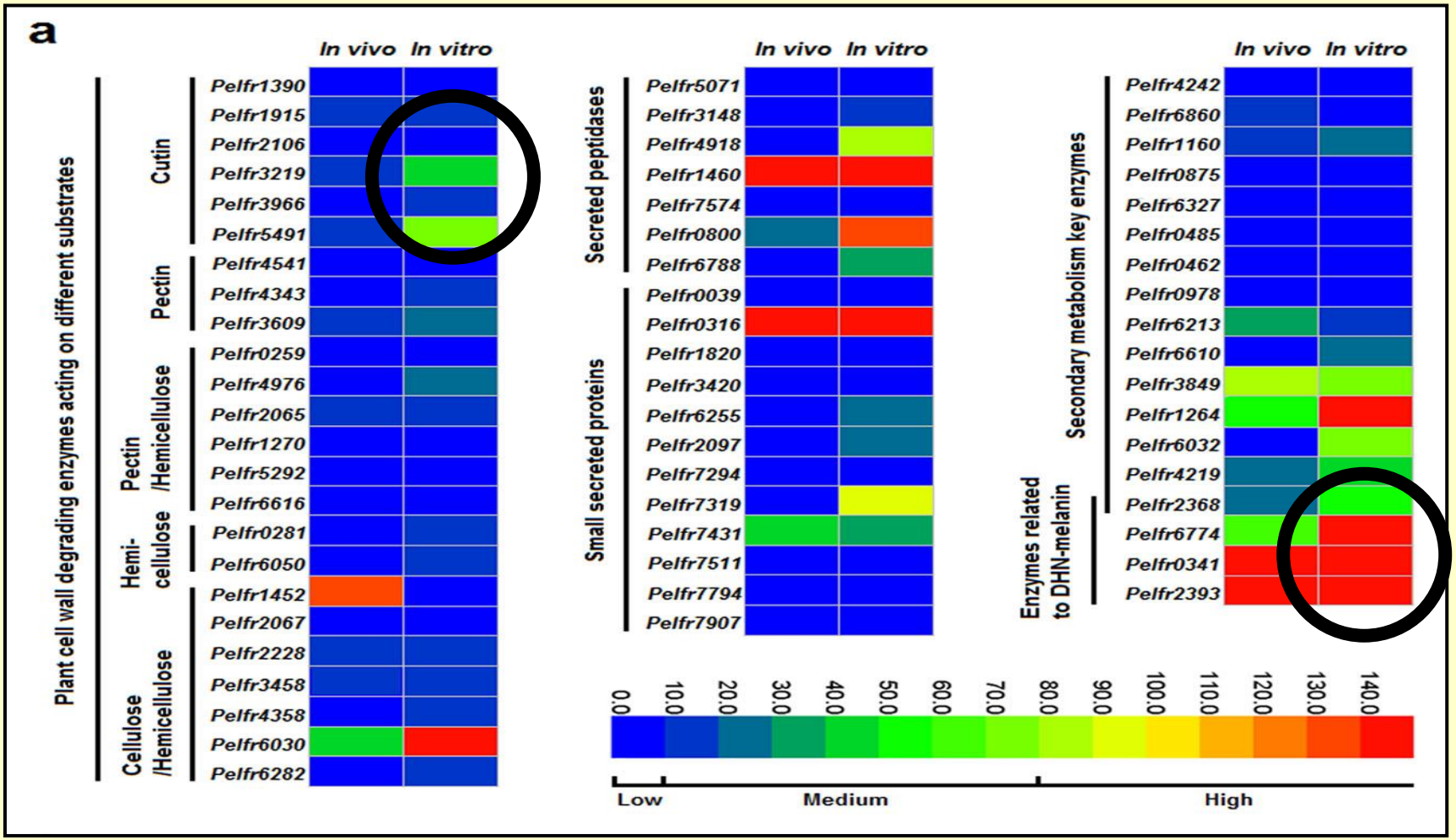
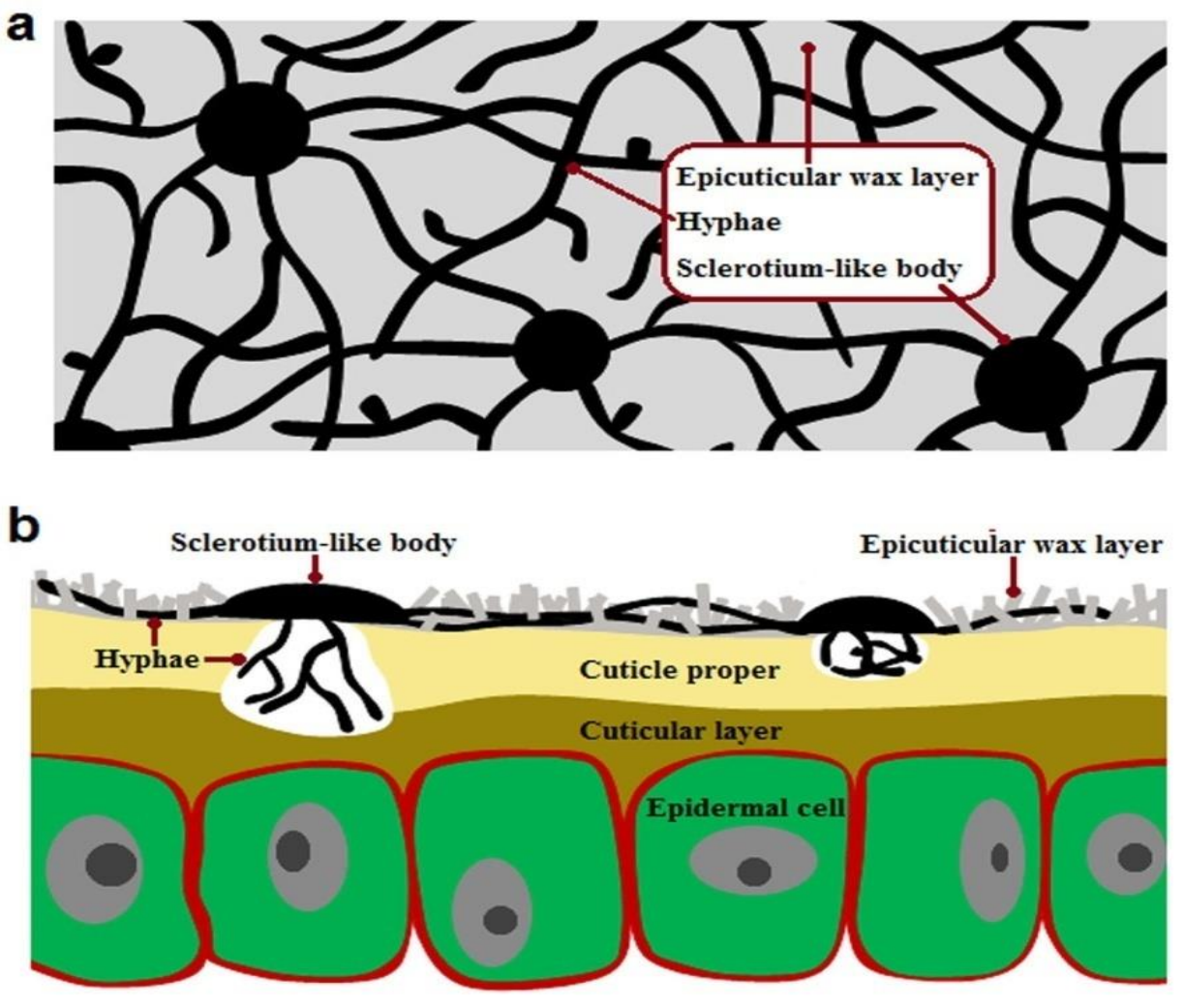


Xu et al. 2016. *Scientific Reports*

Cutinase and melanin production



Schematics of SBFS niche



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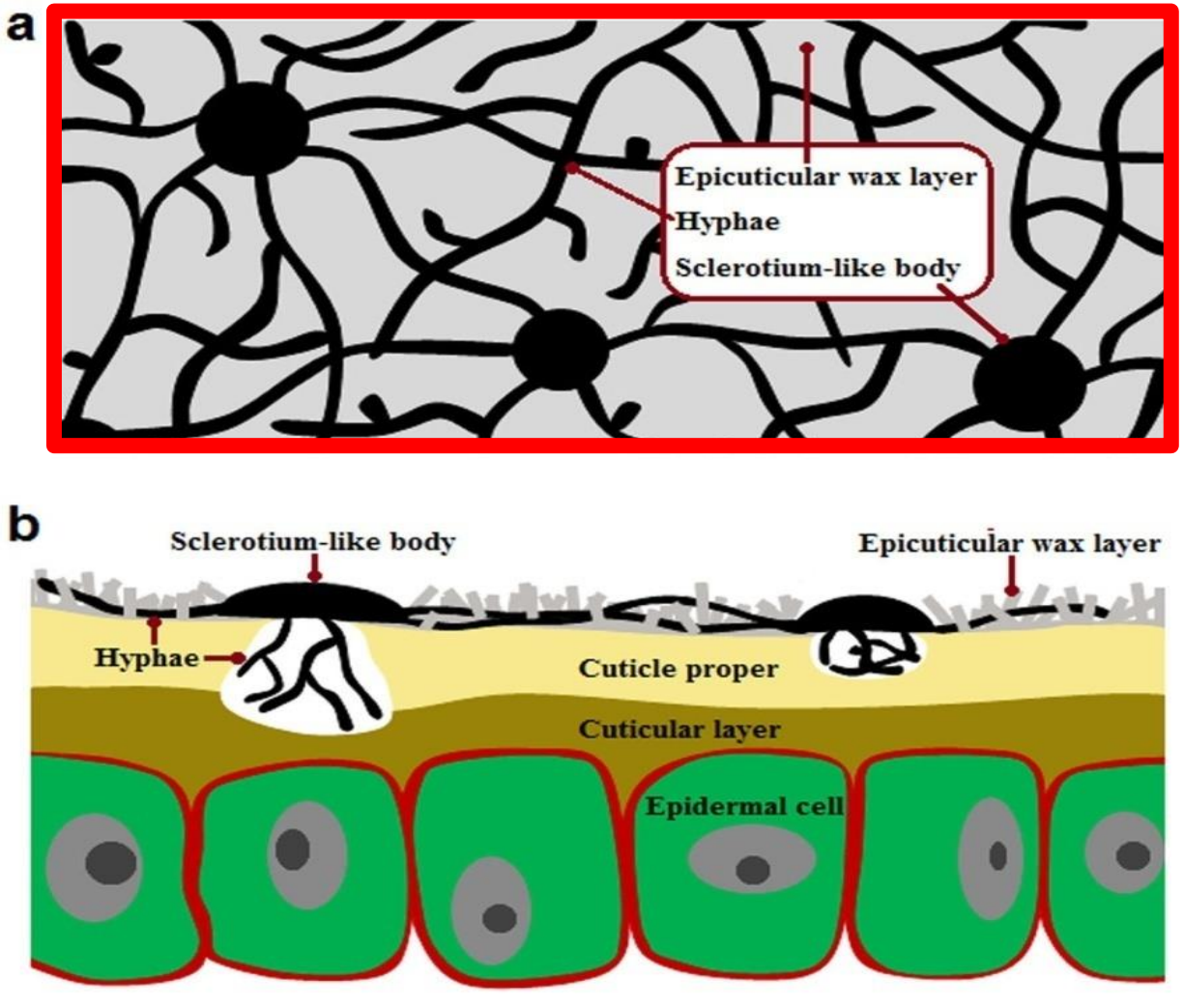
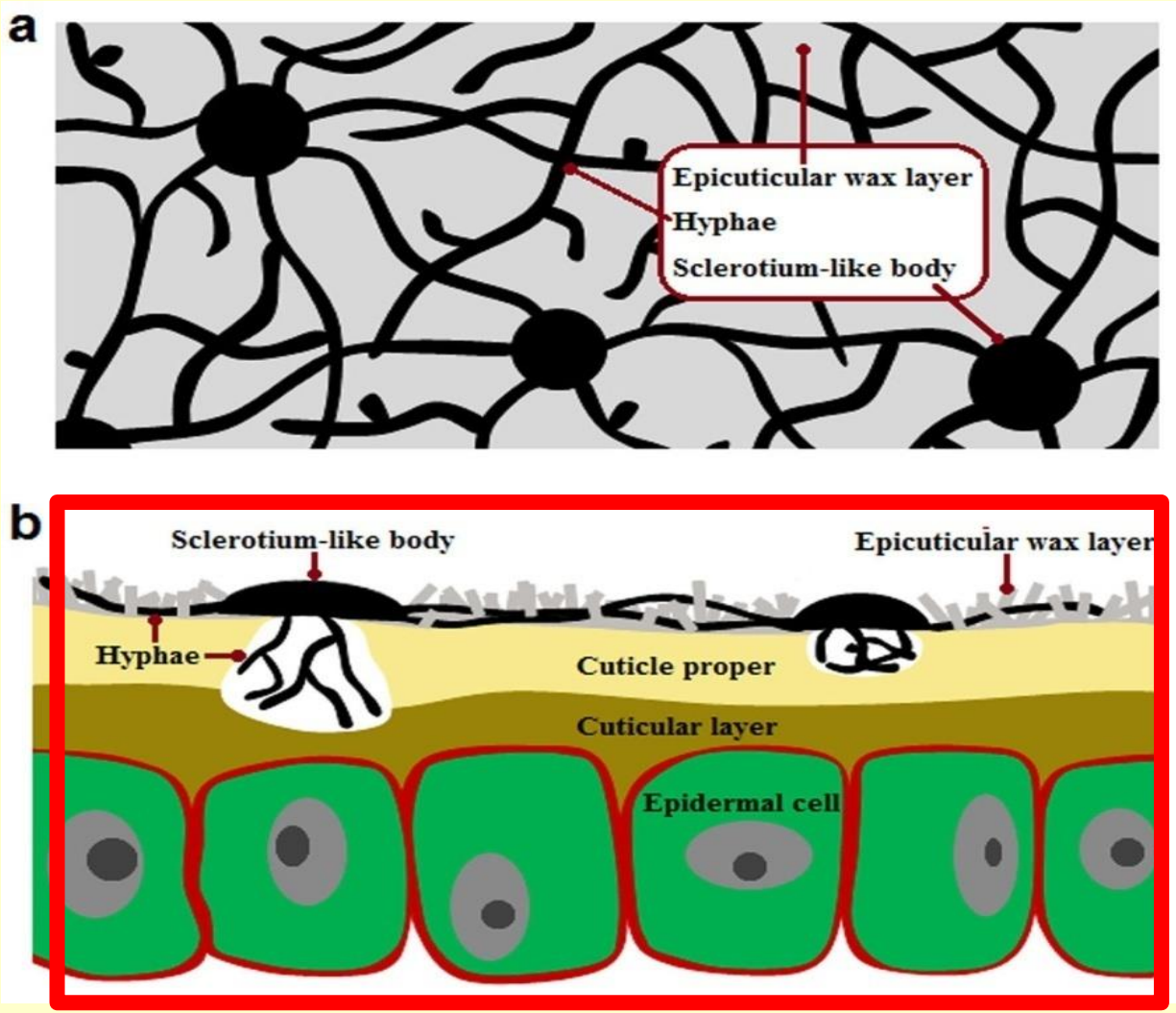


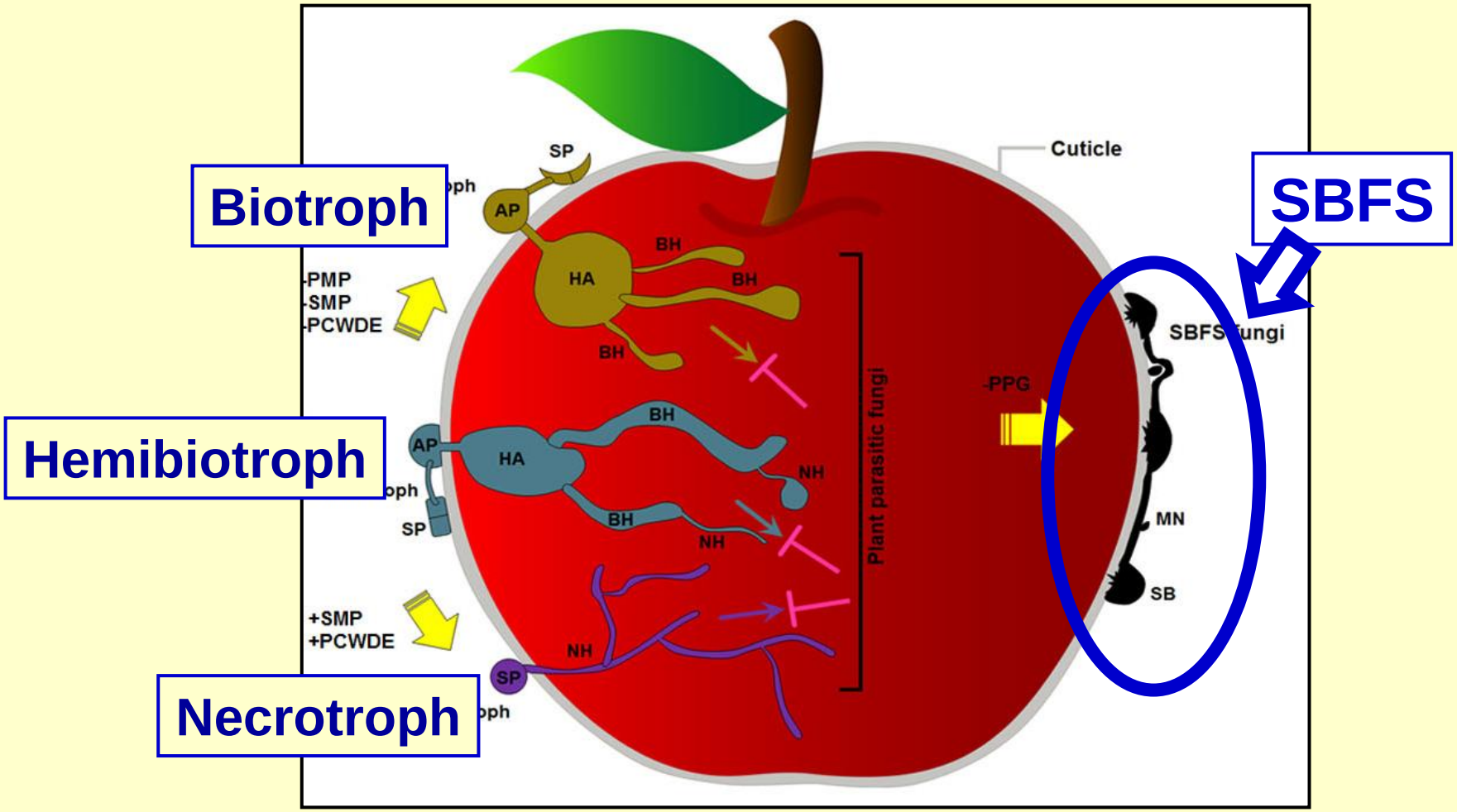
Xu et al. 2016. *Scientific Reports.*

Schematics of SBFS niche



Xu et al. 2016. *Scientific Reports.*

SBFS fungi: stealth pathogens!



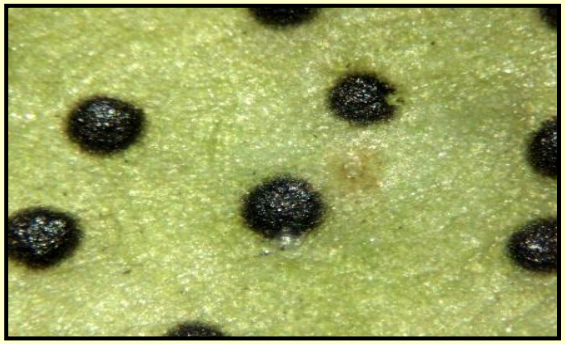
Xu et al. 2016. *Scientific Reports*

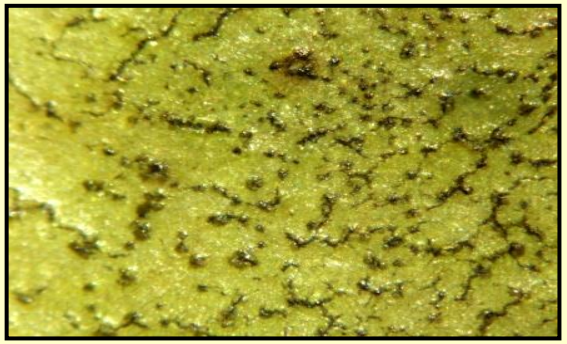
Main points

- A disease complex, not two diseases
  - The most diverse plant disease complex?
- SBFS species differ in:
  - Biogeography
  - Phenology
- Adapted SBFS warning system for Midwest
- SBFS fungi evolved from plant parasites.
- Multiple adaptations to plant-surface niche

Where to go next

- Pin down timing of spore release.
- Clarify genomics of fruit infection.
- Determine host range of SBFS species.
- Sequence genomes of more SBFS taxa.
- Similarities to other surface-adapted fungi?
- Assess biological control potential (yeasts).

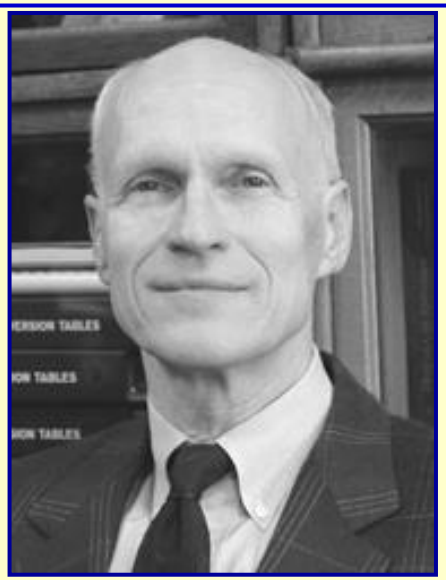




SBFS collaborators

SBFS collaborators

Turner Sutton



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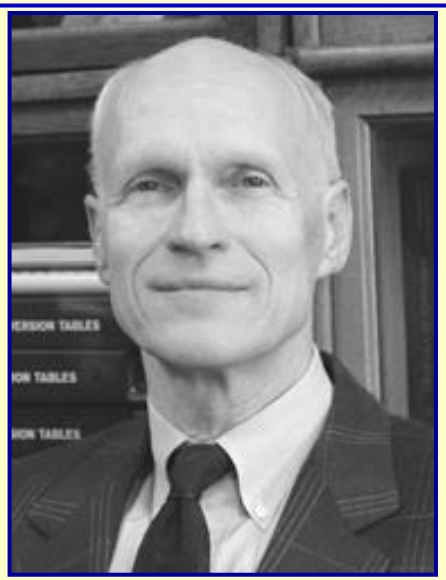

Sun Guangyu

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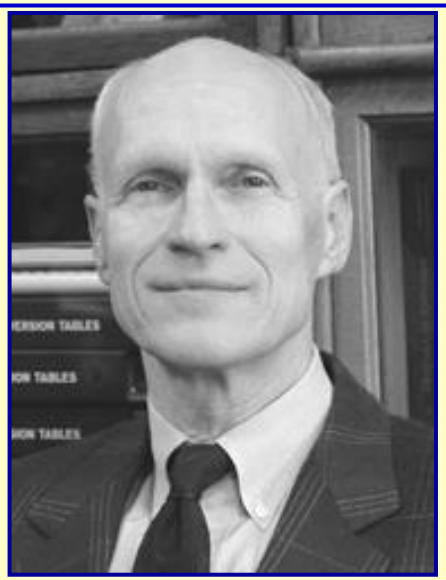

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Questions?