Fungal Diseases of Citrus Fruit and Foliage

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PLP 5115c
Foliar Fungal Diseases to beCovered

- Greasy spot/Rind blotch
- Melanose
- Citrus Black Spot
- Postbloom Fruit Drop
- Alternaria Brown Spot (and leaf spot of rough lemon)
- Scab Diseases
- *Pseudocercospora* Fruit and Leaf Spot
Greasy Spot

- Causal agent: *Zasmidium citri-griseum*
  - Synonyms: *Mycosphaerella citri; Stenella citri-grisea; Cercospora citri-grisea*

- Other similar diseases described around world but caused by other *Mycosphaerellaceae*
  - *Amycosphaerella africana* in Africa and Europe
  - *Mycosphaerella horii* in Japan
  - *M. lageniformis* in California

- Important disease on most types of citrus
- 1915 First described in Florida and Cuba
Greasy Spot cont.

- Also occurs in Texas, the Caribbean, Central and South America, and parts of Asia
- Primary effect is to cause defoliation which can lead to decreases of yield and fruit size
  - Up to 25% on sweet orange in Florida
  - Up to 45% on grapefruit
**Zasmidium citri-griseum** – sexual stage

- Loculoascomycete
  - Pseudothecia up to 90 µm
  - Found in leaf litter
  - Ascospores fusiform and hyaline with one septum (2-3 x 6-12 µm)
Zasmidium citri-griseum – asexual stage

- Conidia are pale olive brown, cylindrical with indistinct septae that can be in chains
- Two types of conidiophores
  - Most common simple, smooth, dark and erect
  - Rare, in clusters (fasciculate) found in necrotic areas on leaves
Mycelium

- Epiphytic hyphae
  - Highly branched
  - Rough walls
  - Olive brown color when young but darken with age and the walls become smooth
- Apressoria formed in stomatal chambers
- Mycelia within leaf grow intercellularly and are not very branched
Tissue Susceptibility

- Highly susceptible cultivars
  - Grapefruit, Pineapple, Hamlin, and Tangelos

- Less susceptible cultivars
  - Valencia, Temple, Murcott, and most tangerines

- Young and mature leaves susceptible to infection

- Immature fruit susceptible
Symptoms
Greasy Spot Disease Cycle Caused by Zasmidium citri-griseum

- **Nov. - Dec.:** Leaf & fruit symptoms
- **Late winter:** Infection through stomates
- **Spring:** Pseudeothecia on decaying leaf
- **Summer:** Underside of leaf Epiphytic growth
- **Dead leaves orchard floor:** Pseudeothecium with Asci
- **Conidia:** Forcibly ejected airborne
### TABLE 1. Effect of the frequency and duration of leaf wetting on the production and maturation of pseudothecia and ascospore production of *M. citri* on grapefruit leaves under laboratory conditions

<table>
<thead>
<tr>
<th>Leaf wetting frequency or duration</th>
<th>Days to pseudothecial initials</th>
<th>Days to &gt;50% pseudothecial maturity</th>
<th>Days to first ascospore discharge</th>
<th>% Leaf weight loss</th>
<th>Time for leaf decomposition (days)</th>
<th>% Leaves with pseudothecia</th>
<th>Pseudothecial density (0 to 10 scale)</th>
<th>Ascospores discharged per leaf (x10³)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Frequency</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 days/week</td>
<td>16 ± 0.6⁠ ⁠</td>
<td>46 ± 1.0</td>
<td>30 ± 0</td>
<td>13.8 ± 0.2</td>
<td>2.⁠⁠²</td>
<td>65 ± 2.0</td>
<td>3.6 ± 0.4</td>
<td>9.5 ± 0.3</td>
</tr>
<tr>
<td>3 days/week</td>
<td>27 ± 3.5</td>
<td>58 ± 7.5</td>
<td>40 ± 10</td>
<td>11.3 ± 0.3</td>
<td>2.⁠⁠²</td>
<td>82 ± 4.5</td>
<td>5.3 ± 0.4</td>
<td>11.7 ± 0.6</td>
</tr>
<tr>
<td>2 days/week</td>
<td>50 ± 6.5</td>
<td>73 ± 1.0</td>
<td>55 ± 5</td>
<td>7.4 ± 0.2</td>
<td>2.⁠⁠²</td>
<td>83 ± 0.0</td>
<td>2.8 ± 0.3</td>
<td>4.2 ± 0.2</td>
</tr>
<tr>
<td>1 day/week</td>
<td>48 ± 9.5</td>
<td>99 ± 24</td>
<td>84 ± 27</td>
<td>4.9 ± 0.2</td>
<td>2.⁠⁠²</td>
<td>52 ± 1.5</td>
<td>1.7 ± 0.2</td>
<td>0.7 ± 0.1</td>
</tr>
<tr>
<td><strong>Duration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 min/day</td>
<td>38 ± 7.5</td>
<td>68 ± 7.5</td>
<td>58 ± 7.5</td>
<td>–</td>
<td>95 ± 5.0</td>
<td>90 ± 0.0</td>
<td>4.3 ± 0.3</td>
<td>12.8 ± 0.4</td>
</tr>
<tr>
<td>30 min/day</td>
<td>38 ± 7.5</td>
<td>67 ± 8.5</td>
<td>53 ± 7.5</td>
<td>–</td>
<td>90 ± 3.0</td>
<td>77 ± 10.0</td>
<td>3.2 ± 0.1</td>
<td>10.5 ± 0.5</td>
</tr>
<tr>
<td>1 h/day</td>
<td>35 ± 5.0</td>
<td>64 ± 6.0</td>
<td>53 ± 7.5</td>
<td>–</td>
<td>84 ± 6.5</td>
<td>64 ± 3.5</td>
<td>2.0 ± 0.0</td>
<td>8.3 ± 0.2</td>
</tr>
<tr>
<td>2 h/day</td>
<td>28 ± 2.5</td>
<td>53 ± 7.5</td>
<td>42 ± 3.5</td>
<td>–</td>
<td>70 ± 5.0</td>
<td>79 ± 8.5</td>
<td>2.6 ± 0.2</td>
<td>8.3 ± 0.1</td>
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<tr>
<td>3 h/day</td>
<td>17 ± 2.0</td>
<td>53 ± 7.5</td>
<td>42 ± 3.5</td>
<td>–</td>
<td>68 ± 7.5</td>
<td>68 ± 2.0</td>
<td>1.5 ± 0.4</td>
<td>7.0 ± 0.4</td>
</tr>
<tr>
<td>No wetting</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>&gt;90</td>
<td>0 ± 0.0</td>
<td>0.0 ± 0.0</td>
<td>–</td>
</tr>
</tbody>
</table>

¹ Grapefruit leaves naturally infected with *M. citri* were collected, air dried for 2 to 3 days at room temperature (≈23 to 27°C), and exposed to the various wetting regimes. In frequency experiments, leaves soaked 2 h per day; in duration experiments, leaves soaked four times per week.

² Pseudothecia containing asci with stained septate ascospores were considered mature.

³ Leaves skeletonized and highly decomposed with no further ascospores were discharged.

⁴ Pseudothecial density was estimated on a 0 to 10 rating scale, where 0 = no pseudothecia and 10 = >50% leaf area covered with pseudothecia.

⁵ Cumulative total for each treatment.

⁶ Means ± standard errors; average of two experiments (Table 4).

⁷ Not produced.
### Pseudothecia Maturation - Temperature

**TABLE 2. The effect of temperature on pseudothecial development and ascospore production of Mycosphaerella citri in grapefruit leaves at ambient humidity**

<table>
<thead>
<tr>
<th>Temperature$^a$</th>
<th>Days to pseudothecial initials</th>
<th>Days to &gt;50% pseudothecial maturity$^a$</th>
<th>Days to first ascospore discharge</th>
<th>Degree of leaf decomposition (0 to 3)</th>
<th>% Leaves with pseudothecia</th>
<th>Pseudothecial density (0 to 10)$^a$</th>
<th>Ascospores discharged per leaf$^a$ ($\times 10^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td>62 ± 1.5$^y$</td>
<td>-</td>
<td>-</td>
<td>1.1 ± 0.1</td>
<td>10 ± 0.0</td>
<td>0.4 ± 0.1</td>
<td>0.0 ± 0.0</td>
</tr>
<tr>
<td>24°C</td>
<td>26 ± 4.1</td>
<td>92 ± 1.5</td>
<td>69 ± 1.5</td>
<td>1.8 ± 0.1</td>
<td>84 ± 11.0</td>
<td>2.9 ± 0.9</td>
<td>0.5 ± 0.1</td>
</tr>
<tr>
<td>28°C</td>
<td>16 ± 1.0</td>
<td>35 ± 5.0</td>
<td>30 ± 0.0</td>
<td>3.0 ± 0.0</td>
<td>90 ± 7.5</td>
<td>4.1 ± 0.6</td>
<td>20.1 ± 2.2</td>
</tr>
<tr>
<td>32°C</td>
<td>11 ± 1.0</td>
<td>-</td>
<td>20 ± 0.0</td>
<td>3.0 ± 0.0</td>
<td>56 ± 4.0</td>
<td>1.5 ± 0.5</td>
<td>1.3 ± 0.7</td>
</tr>
<tr>
<td>20 to 28°C</td>
<td>17 ± 1.5</td>
<td>72 ± 1.5</td>
<td>60 ± 0.0</td>
<td>-</td>
<td>47 ± 6.5</td>
<td>0.8 ± 0.7</td>
<td>0.4 ± 0.0</td>
</tr>
<tr>
<td>24 to 28°C</td>
<td>14 ± 1.5</td>
<td>52 ± 1.5</td>
<td>45 ± 5.0</td>
<td>-</td>
<td>70 ± 3.0</td>
<td>2.4 ± 0.3</td>
<td>15.6 ± 2.9</td>
</tr>
</tbody>
</table>

$^a$ Grapefruit leaves naturally infected with *M. citri* were collected, air dried for 2 to 3 days at room temperature (23 to 27°C), and wetted and dried for 2 h per day and 3 days per week inside incubators held constantly at 20, 24, 28, and 32°C or alternated daily between 20 and 28°C, or between 24 and 28°C at ambient relative humidity (RH) in each chamber: 20°C, 42% RH; 24°C, 62% RH; 28°C, 71% RH; and 32°C, 81% RH.

$^y$ Pseudothecia containing asci with stained septate ascospores were considered mature.

$^x$ Pseudothecial density was estimated on a 0 to 10 scale, where 0 = no pseudothecia and 10 = 50% leaf area covered with pseudothecia.

$^x$ Cumulative totals of 10-day samplings.

$^y$ Means ± standard errors; average of two experiments (Table 4).

$^z$ Not found or determined.
Optimal Temperatures for Ascospore Production

- 20 °C = 68.0 °F
- 24 °C = 75.2 °F
- 28 °C = 82.4 °F
- 32 °C = 89.6 °F

Mondal and Timmer, 2002
Peak Ascospore Ejection

- The peak ascospore ejection period has shifted to earlier in season
  - Why?
  - Is this beneficial?

![Graph showing the percentage of total ascospores by month for different years.](image-url)
Epiphytic Growth

- Occurs during the wet summer months
- Ascospore dose does not determine level of epiphytic growth
- Similar patterns on fruit and leaves

Mondal and Timmer, 2005
Epiphytic Growth and Infection

- Tissue penetrated only through stomata
- High density of penetration required for symptoms
- Requires high humidity
- Symptoms caused by swelling stimulated by hyphae
Cultural Controls

- Reduce leaf litter in winter and early spring
  - Disking
  - Frequent irrigation to promote decomposition
  - Mulch leaf litter
  - Put urea or lime on the leaf litter

- Problem with this approach
  - Not enough of the leaf litter is decomposed
Spray Timing

- Less susceptible cultivars
  - One spray between May and June often sufficient especially in Northern production regions
- In South Florida, more susceptible cultivars and in groves with severe defoliation
  - Two sprays; one mid-May – June, the second once flush has expanded
  - A third and final spray may be needed for fresh grapefruit in a grove that was heavily infested the previous year
Spray Timing Effects

The graph shows the epiphytic mycelial growth over time, comparing different spraying conditions:
- Unsprayed control
- May spray
- July spray
- August spray
- May+June spray

The growth is measured in a y-axis that ranges from 0 to 5. The x-axis represents the months from May to January.
Melanose

- **Causal agent:** *Diaporthe citri*
  - **Synonym:** *Phomopsis citri*
- Disease is present in most citrus producing countries
- Important only where fresh fruit is produced in humid areas
- Causes lesions on fruit and leaves
- All citrus susceptible but grapefruit and lemons are the most susceptible
**Diaporthe citri** – sexual stage

- **Ascospores formed in perithecia**
  - Spherical with flattened base (125-160 µm)
  - Long tapered beaks (200-800 µm)

- **Ascospores are hyaline**
  - 2 cells each with 2 oil droplets (guttulae)
  - 3.2-4.5 x 11.5-14.2 µm
Diaporthe citri – asexual stage

- Pycnidia are dark, ovoid and erumpent with thick walls
  - Found scattered on dead twigs
  - 200-450 µm
  - Spores are extruded in a tendril (cirrhus)
Diaporthe citri – asexual stage cont.

- Two forms of hyaline conidia
  - $\alpha$-conidia are unicellular
    - 2 oil droplets (biguttulate)
    - 2.5-4 x 5-9 µm
  - $\beta$-conidia
    - Filiform and hooked
    - Don’t germinate and are predominant form in older pycnidia
    - Likely a spermatial spore for mating
    - 0.7-1.5 x 20-30 µm
Tissue Susceptibility

- Spring flush usually not severely infected
- On summer flush infection can lead to defoliation especially after dieback
- Leaves become resistant once fully expanded
- Fruit resistant 12 weeks after petal fall and when infection occurs later during the 12 weeks, lesions are smaller
  - Grapefruit are susceptible until 7-10 cm in diameter
Symptoms
Melanose Disease Cycle Caused by Diaporthe citri

- Twig death
- Symptoms twigs
- PYCNIDIA on twigs
- Splash-dispersed to fruit leaves and twigs
- Old dead twigs
- PERITHECIA
- ASCOSPORES
- Infection 10-12h at 77-85°F free water
- Symptoms leaves and fruit

5-7 days
Pycnidia Production

Mondal et al., 2004
Pycnidia Production

- Wetting period, twig diameter, temperature and disease severity on the twig all had significant effects on pycnidia formation
- Formation takes between 3-5 months in field and can occur on dead twigs

Mondal et al., 2004
Conidia Production

- Most of the inoculum is produced on twigs that die between January and April.
- Conidia produced at low %RH are viable for several weeks to months.

Mondal et al., 2007
Infection

- Conidia germinate
  - 6 hrs at 16°C
  - 4 hrs 20 to 28°C
- Literature has varying times and temperatures needed for infection
- Optimum temp determined to be 24-28°C

Agostini et al., 2003
Cultural Controls

- Select younger groves for fresh fruit
  - Less dead wood for inoculum production

- Remove dead wood from canopy

- Clear out brush piles
Spray Timing

- Oranges and Tangerines
  - First spray mid to late April
  - One to two applications sufficient

- Grapefruit (fresh market)
  - First application when fruit $\frac{1}{4}$ to $\frac{1}{2}$ inch
  - Copper to be applied every 3 weeks until fruit resistant in late June to early July
  - There is a model to determine whether copper residues are sufficient to control disease based on weathering of copper and the growth rate of fruit
Black Spot

- **Causal agent:** *Phylllosticta citricarpa*
  - *Synonyms:* Guignardia citricarpa; Phoma citricarpa
- **Hosts:** Citrus species and hybrids
- **Sweet oranges, mandarins and tangerines, lemons, grapefruit**
- ‘Tahiti’ lime and some sour orange cultivars have non-symptomatic infection
Other *Phyllosticta* spp. and citrus

- **Pathogenic species**
  - *P. citriasiana* – Described in 2009 from pomelo (tan spot)
  - *P. citrichinaensis* – Described in 2011 from pomelo, lemon, mandarin, and sweet orange with minor symptoms
  - *P. paracitricarpa* – Described in 2017 in Europe only on lemon leaf litter

- **Endophytic species**
  - *P. capitalensis* - Ubiquitous
  - *P. citribraziliensis* - Described in 2011 from citrus leaves in Brazil
  - *P. paracapitalensis* – Described in 2017 in Europe on *Citrus* spp.

Glienke et al., 2011; Guarnaccia et al., 2017; Wang et al., 2011; Wulandari e al., 2009
Black Spot cont.

- Rind spots cause the most economic damage
  - Internal quality unaffected

- Reduces fruit value for the fresh market

- Restricts export of fresh fruits
  - Mostly to European countries and formerly the U.S

- Causes premature fruit drop reducing yield
  - Particularly with late harvest cultivars
World Distribution

- Occurs mostly in summer rainfall areas or areas with prolonged dew or fog in warm weather
Three Counties with Disease

- Collier
- Hendry
- Polk
- Lee
- Charlotte

Current Quarantine Areas
Phyllosticta citricarpa – sexual stage

- Never found in fruit – in leaf litter
- Form aggregated ascomata - perithecioid pseudothecium
  - 100-175 µm diameter
- Ascopores are aseptate, hyaline, multiguttulate and cylindrical with swollen middles
  - 4.5-6.5 x 12.5-16 µm

Tran et al., 2017
Phyllosticta citricarpa – asexual stage

- Forms pycnidia
  - Dark brown or black
  - Form on fruit, leaves, twigs and fruit pedicles
  - 115-190 µm

- Conidia are obovate, hyaline, aseptate and multiguttulate
  - 5.5-7 x 8-10.5 µm

- Spermatia are dumbbell shaped
  - 5 -8 x 0.5-1

Glienke et al. 2011
Baayen et al. 2002
Tissue Susceptibility

- Hosts include Citrus species and hybrids
- Symptomatic hosts: Sweet oranges, mandarins and tangerines, lemons, grapefruit
- Non-symptomatic host: ‘Tahiti’ lime
  - Produces ascospores from leaves
- Fruit are susceptible for 5-6 months post-petal fall
  - Leaf susceptibility period still uncertain
Symptoms
Black Spot Disease Cycle Caused by *Phyllosticta citricarpa*
Inoculum Basics

- Major source of inoculum: decomposing infected leaves on orchard floor (ascospores)
- Additional source of inoculum: lesions on infected fruits, leaves and branches (conidia)
- Means of spread: Wind (ascospores); Water splash (ascospores and conidia)
Infection Conditions

- Optimal conditions for infection:
  - Temp 21 – 32 °C
  - Wetting period 24 - 48h
- Symptom expression: 1 – 12 months
  - Very long latent period
- Survival of the fungus: leaves, twigs, fruits, peduncles, and leaf litter
What is Needed for Ascospores

- Requirement for two opposite mating types to be present to get ascospores
- Only one mating type found in Florida
  ✓*MAT1-2*

Wang et al. 2016
The Lonely Peninsula

- Wanted to know the proportion of mating types in Florida compared to Queensland, Australia.

<table>
<thead>
<tr>
<th>State, Country</th>
<th>Location</th>
<th>Total number</th>
<th>Number of isolates</th>
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<td></td>
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<td>Collier</td>
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<td>Hendry</td>
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<tr>
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<td>Polk</td>
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<td>0</td>
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<td>Queensland, Australia</td>
<td>Beerwah</td>
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<td>Emerald</td>
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<td>Mundubbera</td>
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<td>8</td>
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<tr>
<td></td>
<td>Tiaro</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>26</td>
<td>12</td>
</tr>
</tbody>
</table>

Wang et al. 2016
Still Only One Mating Type

- Global population study found 2 mating types in all locations except Florida
- Greatest genetic diversity from Australia and China
- South African and Brazil had low genetic diversity
  - Likely founder effect
- Florida population was clonal
- Carstens et al. 2017
Role of *P. citricarpa* Spermatia

- Spermatia are commonly found in culture and leaf litter samples
  - Role in life cycle hypothesized to be male gametes
- First ascospores produced in culture
  - Demonstrated meiosis via multilocus genotyping of ascospores
  - Needed direct contact of isolates carrying opposite idiomorphs or a spermatia suspension
- Tran et al. 2017
Cultural Controls

- Increase air flow in trees to reduce leaf wetness where possible
- Avoid cultivars with significant off-season bloom
  - Older fruit can supply inoculum to infect new fruit
- Reduce leaf litter to reduce inoculum
- Minimize trash when picking to avoid inadvertent movement of the fungus from one location to another
- Clean equipment between groves with disinfestants
  - Quaternary ammonium (2000 ppm) or bleach (200 ppm)
Black Spot Application Timing

- Fruit is susceptible for 5-6 months post-petal fall

Use strobilurins when concerned about copper phytotoxicity
Postbloom Fruit Drop

- **Causal agent:** *Colletotrichum acutatum*
  - Synonyms: *Glomerella acutata; C. abscissum*
  - Formerly thought to be *Colletotrichum gloeosporioides*
- Widespread throughout humid subtropics and tropics of the Americas
- Problematic in years with high rainfall around bloom
- First reported in Belize in 1979
Colletotrichum acutatum

- Conidia are fusiform rather than round
  - Pigmented to give spore mass a salmon color
  - Cultures slower growing than *C. gloeosporioides*
- Borne in an acervulus
  - Few setae on host tissue or in culture
- Apressoria are the survival structures
Host Range

- Affects most citrus cultivars
- Most severe on sweet oranges, lemons, and limes
- Less severe on grapefruit and tangerines
- Is a limiting factor for citrus production in high rainfall areas of Belize, Mexico, Costa Rica, and the Caribbean islands
Susceptible Tissue

- Open flowers are the most susceptible
- Unopened or pin-head bloom much less severe infection
- Does not appear to affect the foliage except that around the calyxes which is distorted with large veins
- Fruitlets abscise at base of ovary to form persistent calyxes or ‘buttons’
Symptoms
Post Bloom Fruit Drop Disease Cycle
Caused by *Colletotrichum acutatum*
Disease Progress

- Inoculum levels most important
- Rainfall is important
- Need infection of early bloom to get inoculum build up
- Optimum temperature for conidia germination is 23°C but over 50% of conidia can germinate between 10-30°C
Cultural Controls

- No overhead irrigation
  - ✓ If necessary only at night

- If there are trees in decline from other diseases such as tristeza, blight, phytophthora root rot, or HLB that promote off season bloom, remove them from your PFD prone block
Predict PFD infection periods

- Citrus Advisory System
- Hosted on Agroclimate.org
  - Under tools/crop diseases
  - Each circle represents a FAWN weather station
  - Florida Agricultural Weather Network
  - https://fawn.ifas.ufl.edu/
Criteria to evaluate

- Need to indicate bloom intensity
  - Will a grower recoup costs if application made?
- Flowering stage
- Last fungicide application
- Simpler than previous PFD forecasting systems
  - Simplification requested by growers

Sufficient bloom

- Many open flowers, some pinhead or button bloom remaining

None

- None
If there is an infection event

- Conditions could allow for infection event
- Still need sufficient bloom
- Fungicide applications minimum 7 days apart
- Recommendations change based on risk level

[Link to current FPG Fungicide recommendations]
Disease simulation tab

- Graphical representation of infection risk
  - Can select time frame
- Forecasted risk (from NOAA weather data) for three days from actual date
  - Help plan if infection will be favored by weather in near term
Infection risk levels

- **High risk (red area)**
  - Index above 0.51; Spray as soon as possible

- **Moderate risk (yellow area)**
  - Index between 0.21 -0.5; Spray recommended

- **Low risk (green area)**
  - Index between 0-0.2; No spray recommended
Weather data

- Available as a daily summary
  - Gives leaf wetness, temperature, PFD index and risk level
    - Weather variables daily average
    - PFD index max. daily value
- Or in 15 minute intervals
  - Temperature, relative humidity, rainfall, leaf wetness
  - Find out when drying periods occur
    - After 4 hours of drying, PFD index resets to zero
Alternaria Brown Spot

- Causal agent: *Alternaria alternata*
  - Synonyms *Alternaria citri* and *A. alternata* pv. *citri*
  - No known sexual stage

- Important disease on tangerines and tangelos
  - Until Huanglongbing, was a production limiting disease in Florida
  - Causes major economic damage in Australia and Spain

- 1903 First described in Australia on Emperor mandarin
Alternaria Brown Spot cont.

- 1974 First identified in Florida
- Also found in South Africa, Turkey, Israel, Spain, Colombia and other countries
- Host specific toxin
  - Isolates from tangerines and tangelos do not infect rough lemon except in rare circumstances
  - Disease on rough lemon same organism with different toxin
  - Considered separate pathotypes of A. alternata
ACT-toxin  Tangerine pathotype of *A. alternata*

ACT-toxin I: R=OH
ACT-toxin II: R=H

ACR-toxin  Rough lemon pathotype of *A. alternata*

Chemical Structures and Specificities of ACT-, and ACR-toxins Produced by Tangerine and Rough Lemon Pathotypes of *Alternaria alternata*
Alternaria alternata

- No sexual stage known
- Necrotrophic
- Conidia are small, thick walled, pigmented and multicellular
- The conidiophores are determinate and pigmented
- Conidia are borne in chains
- Hyphae penetrate host tissue directly
  - No appressorium
Tissue Susceptibility

- Highly susceptible cultivars
  - Dancy, Minneola, Orlando, Sunburst, Murcott, Nova, and Lee
- Leaves susceptible from formation to when fully expanded and hardened
- Fruit are susceptible from petal fall to 5 cm (2 inch) in diameter
Symptoms
Alternaria Brown Spot Disease Cycle
Caused by *Alternaria alternata*
When are the Conidia Released?

- Conidia released by rain events or sudden changes in relative humidity
- In field trapping number of conidia in the air related to leaf wetness duration
- Number of airborne conidia not related to infection severity

Timmer et al., 1988
Infection Conditions

- Optimum temperatures 23-27°C
  - Can get infection between 17-32°C

- Infection can occur with as little as 4-6 hours of leaf wetness but disease severity increases with leaf wetness

Canihos et al., 1999
Cultural Controls

- Disease-free nursery trees
- Careful choice of planting site
  - Air drainage important
  - Wider spacing
- No vigorous rootstocks
- No over-fertilization or over-watering
- Hedge in late March
- No overhead irrigation
Application Timing

- First spray when spring flush ¼-1/2 full expansion
  - If inoculum high, another before full expansion or at petal fall
  - What is the purpose of these applications?
- Rest of the year maintain protective coating
  - What would the best product be for a protective coating?
ALTER-RATER: A Forecasting System

- Weather-based point system to better time fungicide applications
- Points assigned based on:
  - Rainfall and leaf wetness
  - Average daily temperature
- Thresholds vary by cultivar susceptibility
## The ALTER-RATER
### Suggested Threshold Scores

<table>
<thead>
<tr>
<th>Score</th>
<th>Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>Heavily infested Minneola, Dancy, Orlando, Sunburst; Many flatwood groves, East coast, and SW Florida.</td>
</tr>
<tr>
<td>100</td>
<td>Moderately infested Minneola or Dancy, many Murcotts; Ridge and north Florida groves.</td>
</tr>
<tr>
<td>150</td>
<td>Light infestations, any variety, mostly Ridge and north Florida groves.</td>
</tr>
</tbody>
</table>
# ALTER-RATER Daily Points

<table>
<thead>
<tr>
<th>Rain &gt; 0.1 inch</th>
<th>LW &gt; 10 hr</th>
<th>Avg daily Temp</th>
<th>Assigned score</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>+</td>
<td>68-83</td>
<td>11</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>&gt; 83</td>
<td>8</td>
</tr>
<tr>
<td>+</td>
<td>+</td>
<td>&lt; 68</td>
<td>6</td>
</tr>
<tr>
<td>+</td>
<td>_</td>
<td>68-83</td>
<td>6</td>
</tr>
<tr>
<td>+</td>
<td>_</td>
<td>&gt; 83</td>
<td>4</td>
</tr>
<tr>
<td>+</td>
<td>_</td>
<td>&lt; 68</td>
<td>3</td>
</tr>
<tr>
<td>_</td>
<td>+</td>
<td>68-83</td>
<td>6</td>
</tr>
<tr>
<td>_</td>
<td>+</td>
<td>&gt; 83</td>
<td>6</td>
</tr>
<tr>
<td>_</td>
<td>+</td>
<td>&lt; 68</td>
<td>4</td>
</tr>
<tr>
<td>_</td>
<td>_</td>
<td>68-83</td>
<td>3</td>
</tr>
<tr>
<td>_</td>
<td>_</td>
<td>&gt; 83</td>
<td>0</td>
</tr>
<tr>
<td>_</td>
<td>_</td>
<td>&lt; 68</td>
<td>0</td>
</tr>
</tbody>
</table>
Citrus Scab

- **Causal agent:** *Elsinoë fawcettii*
  - Synonym: *Sphaceloma fawcettii*
- Found in most humid citrus production regions
- Important for fresh fruit production
- **Sweet orange scab:** *E. australis*; syn.: *S. australis*
  - Found in southern South America and South Korea
  - Possibly discovered in Texas and Louisiana
Elsinoë fawcettii and E. australis – sexual stages

- Only been found in Brazil
- Distinguished by ascospore size
  - *E. fawcettii* 5-6 x 10-12 µm
  - *E. australis* 12-20 x 15-30 µm
- Function in the disease cycle is unknown but clearly not essential
Elsinoë spp. - Asexual stage

- Conidia are hyaline, single celled and elliptical
  - Indistinguishable between species
  - Can reproduce by budding
- Also fusiform conidia (E. fawcettii)
  - Pigmented
  - Germinate to form hyaline conidia
- Conidia borne in acervuli
Host Range and Tissue Susceptibility

- Young leaves and fruit are susceptible
  - Leaves immune to infection in a few days
  - Fruit remain susceptible up to two months
- Summer flush can be especially badly affected

- The host range of *E. fawcettii* is complicated
- Matter of considerable ongoing phylogenetic research
## Host Range

<table>
<thead>
<tr>
<th>Disease</th>
<th>Pathogen</th>
<th>Pathotype</th>
<th>Hosts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citrus scab</td>
<td><em>Elsinoë fawcettii</em></td>
<td>FBHR</td>
<td>Lemon, grapefruit, Temples, sour orange, sweet orange, Satsuma, many tangerines</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FNHR</td>
<td>Lemon, grapefruit, Satsuma</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tyron’s</td>
<td>Lemon, Cleopatra</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lemon</td>
<td>Lemon</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SRCG</td>
<td>Satsuma, Rough lemon, Clementine, grapefruit</td>
</tr>
<tr>
<td>Sweet orange scab</td>
<td><em>E. australis</em></td>
<td>Sweet orange</td>
<td>Sweet oranges, tangerines</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Natsudaiai</td>
<td>Natsudaiai</td>
</tr>
</tbody>
</table>
Symptoms
Citrus Scab/Sweet Orange Scab Disease Cycles Caused by Elsinoë fawcetti and E. australis
Infection

- Contradictory information in the literature about leaf wetness and temperature
- Optimal temperature range
  - 23.5 to 27 °C
- Optimal leaf wetness
  - Between 12 and 24 hrs

Agostini et al., 2003
Conidia Production

- Conidia can be produced in 1-2 hours with sufficient wetness
- Optimum temperature 24-28°C
- Spores are splash dispersed
- The greater the number of spores, the greater the number of lesions
- Tend to see more disease with low lying areas where there more dew and longer dew periods
Cultural Controls

- Disease-free nursery trees
  - Start clean and problems are unlikely
- Hedge and top badly-affected plantings
  - Does not move far even within trees
- No vigorous rootstocks
- No overhead irrigation
Spray Timing

- Sprays are mainly for groves with a recent history of Scab
- First spray – spring flush ¼ expansion
  - can be omitted if severity was light
- Petal fall
- Three week after petal fall
Pseudocercospora Fruit and Leaf Spot

- *Pseudocercospora angolensis*
- *Syn.: Phaeoramularia angolensis*
  - No known teleomorph
- Serious disease of fruit and foliage in much of Sub-Saharan Africa except South Africa
- First described in Angola and Mozambique in 1952
- Quarantine disease
Host Range

- All citrus species
- Most susceptible
  - Grapefruit, oranges, pummelo and mandarin
- Less susceptible
  - Lemon
- Least susceptible
  - Lime
- Yield losses between 50-100% not uncommon
**Pseudocercospora angolensis**

- Forms dense tufts (synnemata) of light chestnut multi-septate conidiophores
- Emerge from the stromata through stomata on lower leaf surfaces
- Conidia are single or catenulate (2-4)
  - Hyaline, cylindrical and slightly flexuous
  - One to six septate (mostly 3-4)
  - 3-7 x 240 µm
Pseudocercospora angolensis
Susceptible Tissue

- Young leaves are highly susceptible to infection from lesions of older tissues.
- Young fruit up to golf ball size are highly susceptible.
- Not certain whether the fruit have a reduced susceptibility or become immune.
Symptoms
Disease Spread

- So far restricted to humid tropics of Africa between 80-1500 m
- Favoured by prolonged wet weather followed by dry periods with temps between 22-26°C
- Long distance spread by windborne conidia
  - Infected planting material may also contribute to long distance spread
- Within orchard spread by splash dispersed conidia
Environmental Conditions

Pretorius, 2005
Controls

- Inoculum control via collecting and destroying all fallen fruit and leaves in affected orchards
  - Burying or burning
- Plant windbreaks around the citrus orchards
  - Wind is the primary dispersal agent spores
- Discouraging inter-planting in affected orchards with mature producing trees
  - Prevents creation of a microclimate of relatively cool temperatures and high RH
  - Potential inoculum source for young trees

Seif and Hillocks, 1993
Controls cont.

- Judicious pruning of shoots to allow light penetration into aeration within the tree canopy
  - Shorten leaf wetness period, lower RH and moderate temperatures

Seif and Hillocks, 1993
Fungicides

- Alternate benylate and copper sprays every 2 weeks from a week following the onset of rains
- When fruit are golf ball sized an addition 3 copper sprays should be applied followed by another benylate

Table 4. Effect of fungicides on incidence of citrus fruit and leaf spot disease and marketable yield in 1994 (sprays applied at approximately 2-week intervals but only after significant rainfall events)

<table>
<thead>
<tr>
<th>Fungicides</th>
<th>Disease incidence</th>
<th>Marketable yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% infection</td>
<td>% infection</td>
</tr>
<tr>
<td></td>
<td>Foliage</td>
<td>Arsen transf.</td>
</tr>
<tr>
<td>Flusilazole</td>
<td>10.2</td>
<td>18.5</td>
</tr>
<tr>
<td>Chlorothalonil</td>
<td>16.7</td>
<td>24.1</td>
</tr>
<tr>
<td>Benomyl/Copper</td>
<td>12.0</td>
<td>20.2</td>
</tr>
<tr>
<td>Propineb</td>
<td>18.5</td>
<td>25.5</td>
</tr>
<tr>
<td>Copper hydroxide</td>
<td>21.4</td>
<td>27.5</td>
</tr>
<tr>
<td>No-spray A</td>
<td>62.1</td>
<td>—</td>
</tr>
<tr>
<td>No-spray B</td>
<td>78.2</td>
<td>—</td>
</tr>
<tr>
<td>l.s.d.</td>
<td>2.49</td>
<td>1.29</td>
</tr>
</tbody>
</table>

*Fungicide application rates as for Table 3. *Standard treatment but only three copper sprays and two benomyl sprays applied. **Two sets of unsprayed trees; A on downwind edge of trial site, B about 100 m away close to a heavily infected orchard. Neither were included in the ANOVA.
Honeybees can spread Colletotrichum acutatum and C. gloeosporioides among citrus plants


*Pest Pathology, Department of Biochemistry, São Paulo University, São Paulo, SP, 05508-900, Brazil; **Pest Pathology, Institute of Phytopathology, São Paulo University, São Paulo, SP, 05508-900, Brazil.

Introduction

Citrus postharvest fruit drop (PPD) is an important disease that causes up to 80% yield losses during years in which conditions are favorable for the occurrence of epidemics. The conidia of Colletotrichum acutatum and C. gloeosporioides, causal agents of PPD, are wind-dispersed by rain splash. At the beginning of epidemics, the distribution of damaged plants is random and the disease progress rate is very high, which is unusual for pathogens spread by rain splash. As the pathogen produces abundant conidia on damaged plants, pollinating insects may contribute to disease dispersal. This study investigated honeybees (Apis mellifera) as dispersal agents of C. acutatum and C. gloeosporioides among citrus plants. Two experiments were carried out in a greenhouse in which citrus trees were planted (or not) in moist-proof pots. In the presence of inoculated trees, and a honeybee hive was placed on the opposite side. All ungrafted plants showed symptoms of the disease, and the more of the grafted plants evidenced PPD symptoms. The monoclonal model showed a good fit to disease progression in both experiments. Comparisons like structures of Colletotrichum spp. were identified by the honeybees by scanning electron microscopy. These results have revealed that honeybees disperse Colletotrichum among citrus plants.

Keywords: Citrus, citrus mosaic virus, postharvest disease.

Pathogenicity of Phylosticta citricarpa Ascospores on Citrus spp.

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Abstract

Citrin black spot, caused by the fungus Phylosticta citricarpa, is one of the most important fungal diseases in citrus-producing areas with warm temperatures and summer rain, including parts of Australia, Asia, Africa, South America, and North America (Burr et al. 2012; Koral 1981; Schubert et al. 2012; Tran et al. 2013). Most recently, P. citricarpa has been reported in Europe although citrus black spot has never been observed (Guaraccin et al. 2017). Almost all citrus cultivars are known to be susceptible to the disease (Burr et al. 2012; Koral 1981). First can be affected by P. citricarpa in European countries where growth continues for several months after the pathogen enters the plant. On average, these diseases cause up to 80% yield losses during years in which conditions are favorable for the occurrence of epidemics. In this study, we report the pathogenicity of P. citricarpa on citrus cultivars and examine the disease incidence. Surprisingly, in the presence of inoculated trees, and a honeybee hive was placed on the opposite side. All ungrafted plants showed symptoms of the disease, and the more of the grafted plants evidenced PPD symptoms. The monoclonal model showed a good fit to disease progression in both experiments. Comparisons like structures of Colletotrichum spp. were identified by the honeybees by scanning electron microscopy. These results have revealed that honeybees disperse Colletotrichum among citrus plants.

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