



Lessons from the Citrus Industry

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Alternaria Brown Spot

The importance of resistance management

Fungicide Resistance

- Where the target population is no longer sensitive enough to a fungicide for sufficient control
- Occurs in response to the repeated use of a fungicide or related fungicides
 - Field resistance
- Often becomes apparent with sudden total failure of control

Qualitative Resistance

 \circ Sudden and marked loss of control

 Presence of two separate populations of resistant and sensitive pathogen isolates

- Usually a stable form of resistance
 - Lasts for decades
 - Occasionally will gradually diminish over time but returns rapidly when fungicide is reapplied without precautions

Quantitative Resistance

- Resistance appears less suddenly
 - Decline in sensitivity of pathogen population and control can be observed
- Population tends to revert to sensitive if the fungicide is less used or is alternated with other MOAs

Where does it come from?

- A minute proportion of the population carries a modified version of a gene before the use of a fungicide
- Without the fungicide, there is no advantage to growth or survival of the fungus from the mutation
 - Could even be deleterious

 Mutation could spontaneously disappear and reappear several times





Strobilurins (QoI)



Introduced in the late 1990's

Tim Zurkowski

- Derived from secondary metabolites of a mushroom
- \circ Very broad spectrum
 - Ascomycetes/Deuteromycetes, Basidiomycetes and Oömycetes
- Systemic that has mild eradicant abilities
- \circ Very specific target that blocks respiration

Alternaria Brown Spot



- Causal agent: *Alternaria alternata*
- 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 2 inch in diameter

Alternaria Brown Spot Disease Cycle Caused by *Alternaria alternata*



Young leaves, fruit, and stems

Proportion of Population Sampled

○ 2008 - 2012
○ n = 817





Effect of Application Number



Strobilurin (QoI) Resistance

- A specific amino acid replacement in the cytochrome b (involved in respiration), confers resistance
- Three amino acid substitutions:
 - Glycine to alanine (G143A) highly resistant
 - Phenylalanine to leucine (F129L) moderate
 - Glycine to arginine (G137R) moderate
- $\,\circ\,$ Only the G143A substitution found in population
- Resistance found to be very stable in *A. alternata*

Difference in Level of Control

- Greenhouse
 trees
 - Water control or Abound at 242
 mg a.i. /liter
 (equivalent to 15.5 fl oz./acre)
 - Applied one day before inoculation



Sensitive

Summary

- From 2008-2012, 58% of isolates tested were resistant to strobilurin fungicides
- Strobilurin resistance was widespread among Florida counties
- Amino acid substitution G143A leading to resistant phenotype
- \circ Very stable form of resistance
 - Likely to never disappear from groves
- We recommend to growers manage Alternaria brown spot as if strob-resistance is present.



Postbloom Fruit Drop

Importance of control measure timing



Post-bloom Fruit Drop

- Fungal disease cause by Colletotrichum acutatum
- First described in Belize in 1979
 - Spread in Central and South America as well as Caribbean
- First Florida report of PFD was 1983
 - Spread to rest of state by 1988
- Last major outbreak in Florida occurred in '90's
 - Re-emerged in 2014 throughout state

Post-bloom Fruit Drop

- Preferred climate is humid, subtropical
- Fungus moves with rain-splash, wind-borne rain
 - Human activities such as equipment movement and workers with petals can also move fungus
- Disease more severe in areas with multiple blooms
 - Multiple blooms promoted by other diseases

Symptoms









PFD disease cycle Colletotrichum acutatum



Disease cycle highlights

- Fungus survives on leaf surfaces, twigs, and buttons in specialized structures
- Structures germinate and form new spores with moisture and petal extracts
- Spores are dispersed to new flowers via rain splash
- Germinate with moisture in 12-24 hours, infect in 24-48 hours
 - New symptoms and spores in 4 to 5 days

Ideal phenological timing



Application timing



- Timing specific to grove situation
- Highly weather dependent
- Disease will not wait for the next time sprayer available
- http://pfd.ifas.
 ufl.edu/



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Postbloom fruit drop (PFD), caused by the fungus Colletotrichum acutatum, affects all species and cultivars of citrus. It is often a serious disease in most humid citrus areas of the Americas. The PFD-Fungicide Applications Decisions System is designed to advise growers in all citrus areas as to the need to apply fungicides for control of PFD. Decisions are based on the previous history of PFD in the grove, the weather conditions, and the current disease situation.



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HOME | SYSTEM | DIAGRAM | PUBLICATIONS | LINKS | CONTACTS

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Needed information

- Should be scouting bloom several times a week during bloom
 - Including off-season bloom
 - Bloom intensity
 - Bloom stage
 - Pin-head
 - Popcorn bloom
 - Open flowers



Other Information Needed

\circ Disease history

- How much inoculum is present in grove
- Are there declining trees
 - Often lead to off-season bloom and greater inoculum
- Rainfall in 5 previous days
 - Indication of if there has been an infection event
 - If so greater inoculum in grove
- When was last fungicide application
 - Limits on application numbers
 - Potentially less inoculum

Timing Trial - 2001 Brazil

Treatment	Spray dates	Buttons/12 brch/tree	Fruit/12 brch/tree	Application cost/ha	Fungicide cost/ha	Total
Control		91	23.9	0	0	0
PFD-FAD	8/24	54	29.2	\$8.70 (x1)	\$32.50	\$41.20
PFD Model	7/27-30 8/23-24	45	32.9	\$8.70 (x2)	\$65.00	\$82.40
Grower Program	7/26-27 8/22-24 8/28-29	46	31.3	\$8.70 (x3)	\$97.50	\$124
LSD (<i>P</i> > 0.05)		28	5.0			

Summary

o Application timing critical!

- More important that product
- Can waste time and money if with no attention to timing
- \circ Need to be proactive for PFD
 - Regular scouting for symptoms
 - Train employees to recognize buttons and flower symptoms
 - Need to be able to react quickly if necessary



Citrus Black Spot Leaf Litter Sanitation



Black spot

Causal agent: Guignardia citricarpa
 Asexual name: Phyllosticta citricarpa

Hosts: Citrus species and hybrids



- Symptomatic: Sweet oranges, mandarins and tangerines, lemons, grapefruit
- Rind spots cause the economic damage
 Internal quality unaffected
- Causes premature fruit drop reducing yield

Tree health

- Declining trees are more symptomatic
 - More susceptible to disease
- Declining trees should be removed
 - Cause of decline unimportant
- Anything that can maintain tree health good practice
 - Nutritional
 - Pest and disease control



Classical black spot disease cycle



Leaf Litter Management?

- Inoculum formed in leaf litter
- Inoculum reduction to enhance fungicides
- 5% urea best treatment in small plots
- Large scale trials on-going



Large Scale Field Trial

- o 20 year-old Valencia
- o 3 treatments
 - Urea (20.8 lb/acre)
 - Soil-set (4.80 fl oz/acre)
 - a compost accelerator
 - Untreated control



- Applied with herbicide booms at 50 gal/acre in a 10 ft strip
- Three rows treated per rep, middle row evaluated for disease

Large Scale Field Trial

- Data taken spring
 following
 treatment
- Disease incidence
 lower in 2015,
 2016 post-trt for
 Soil-set
- Disease severity matched incidence data





Plant Debris Movement

- Likely means of long distance movement between groves
- \circ Needs to be minimized to reduce spread
 - Human activity likely prime means of movement
 - Tarping is still necessary
- \circ All vehicles and equipment
 - Canker decontamination materials (quat) will work
- \circ Fruit loads if possible as well
 - Noticing greater twig breakage during harvest recently

Summary

- Leaf litter appears to be an important inoculum source
 - Even without the aerial ascospores
- Controlling the amount of available inoculum through sanitation can improve fungicide efficacy
- For many diseases of perennial plants, plant debris is an important source of inoculum
 - It should be managed to reduce inoculum load

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 \odot Alternaria brown spot

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