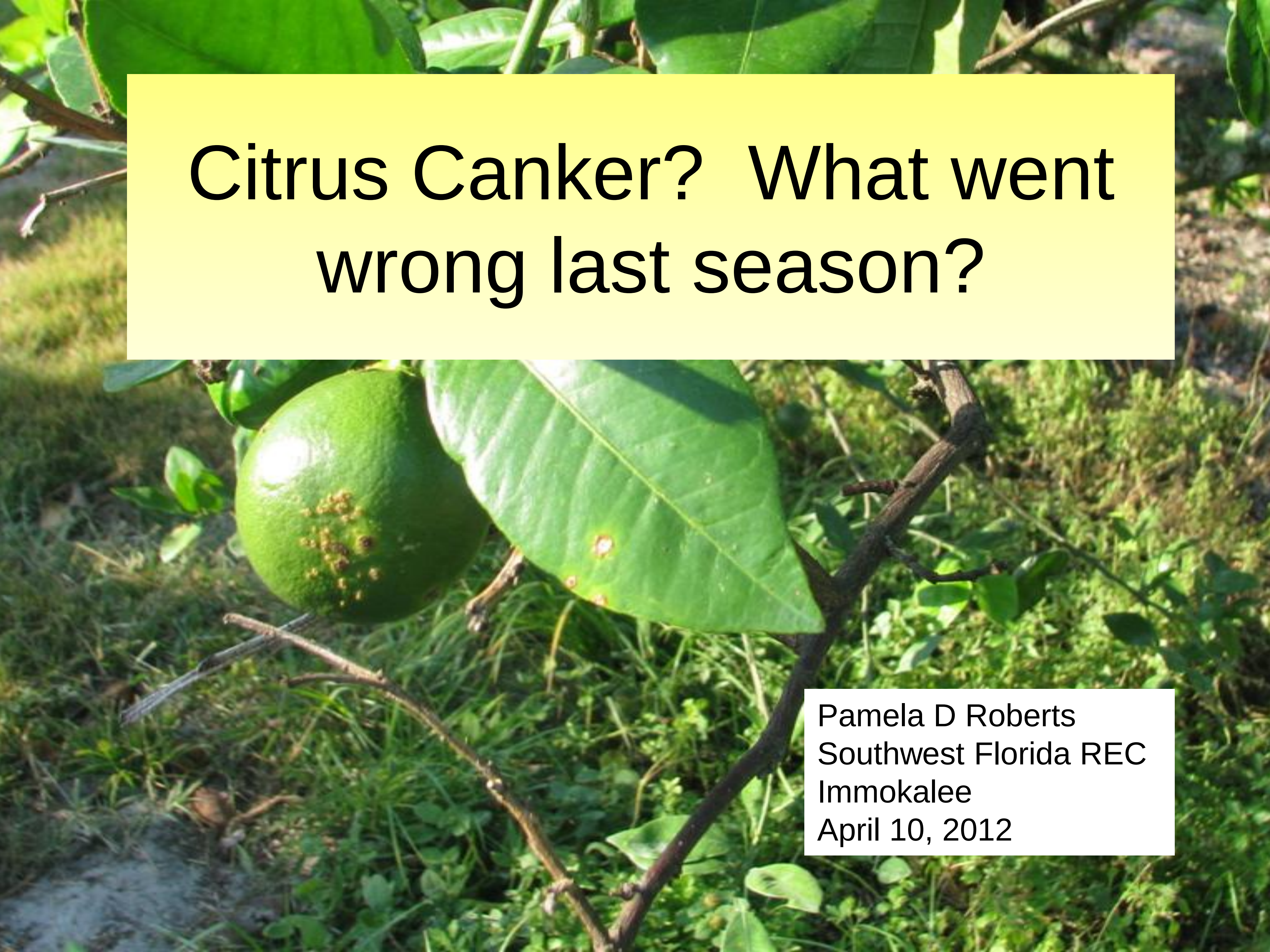
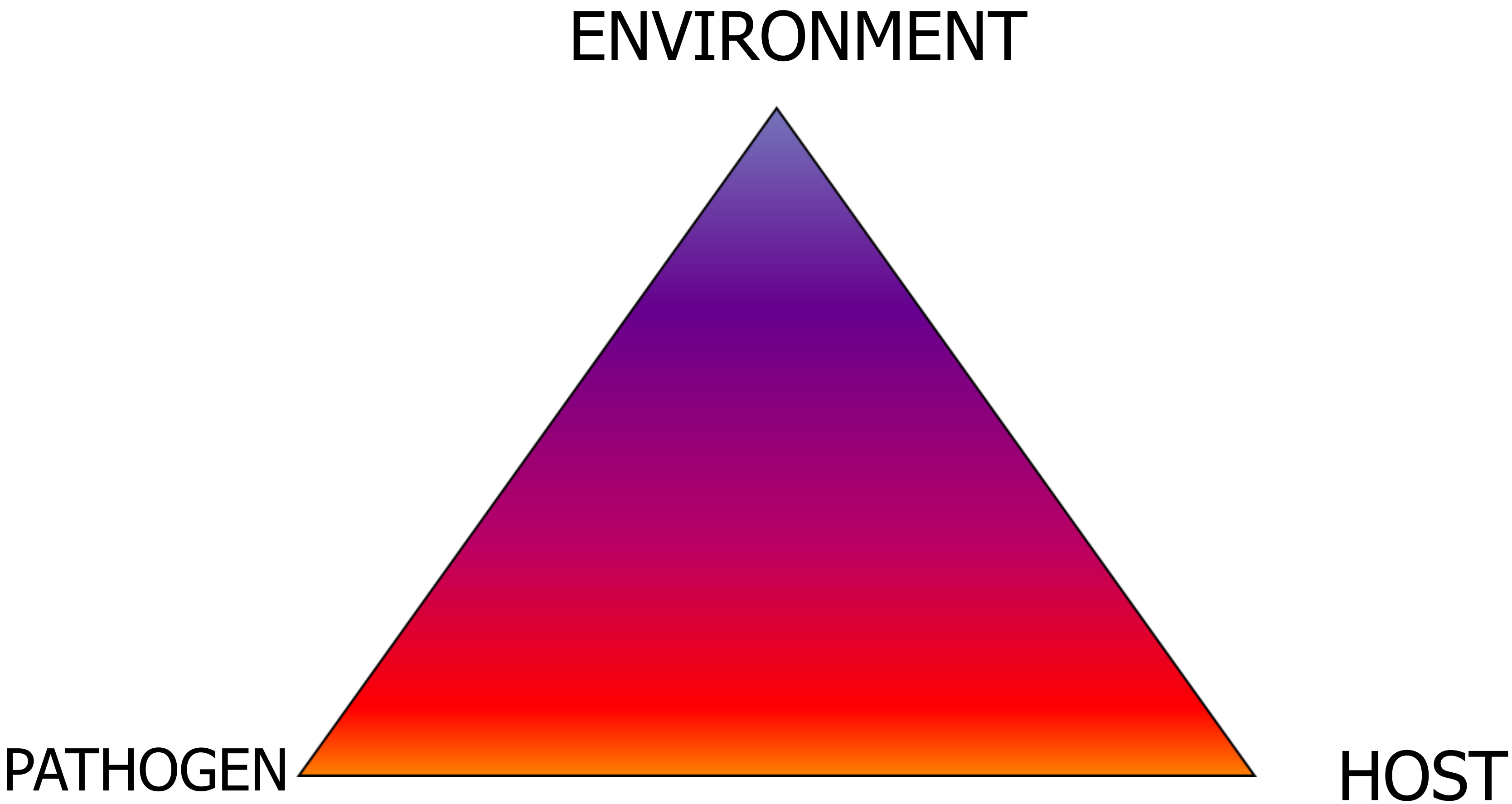


Citrus Canker? What went wrong last season?

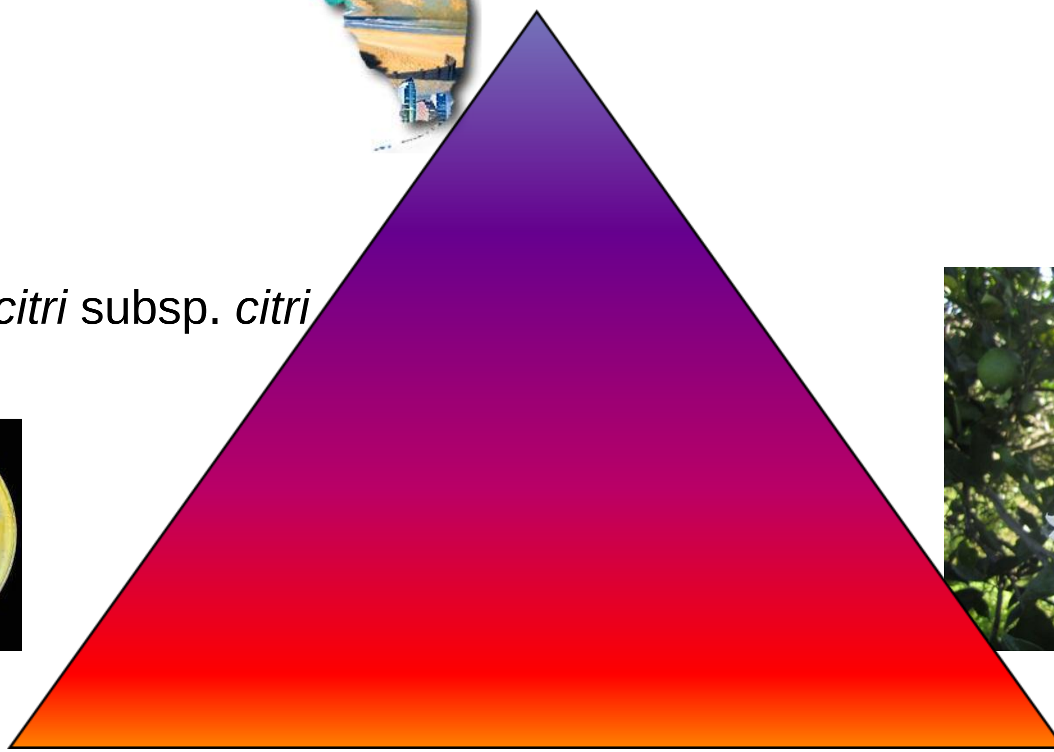
Pamela D Roberts
Southwest Florida REC
Immokalee
April 10, 2012

Disease Triangle



Disease Triangle

ENVIRONMENT

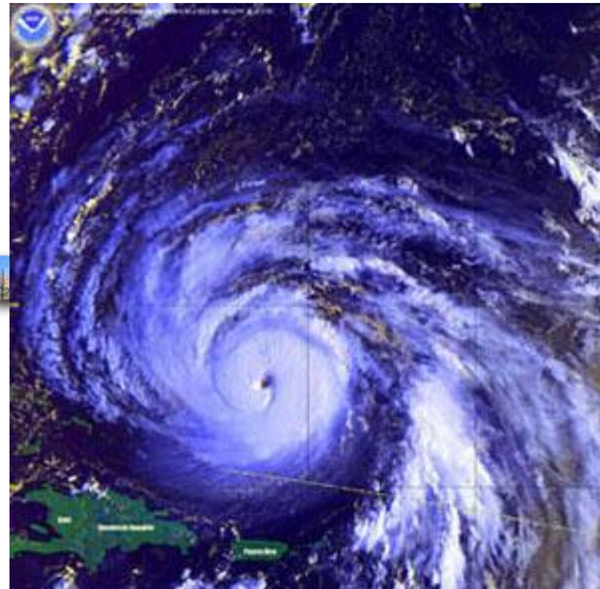


Xanthomonas citri subsp. *citri*

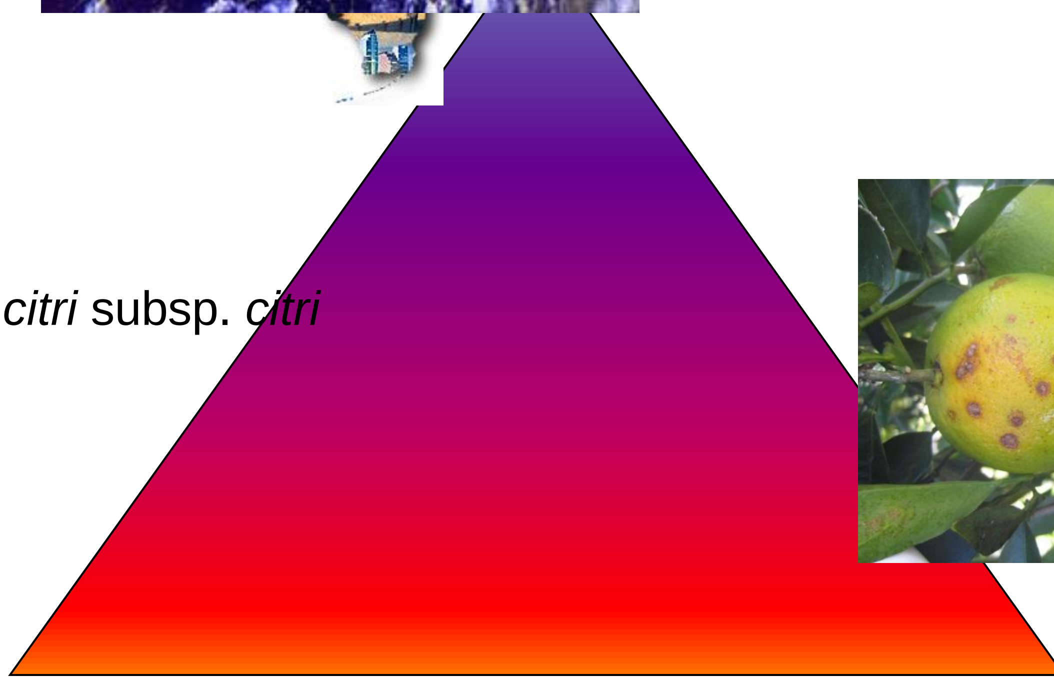
PATHOGEN

HOST

riangle



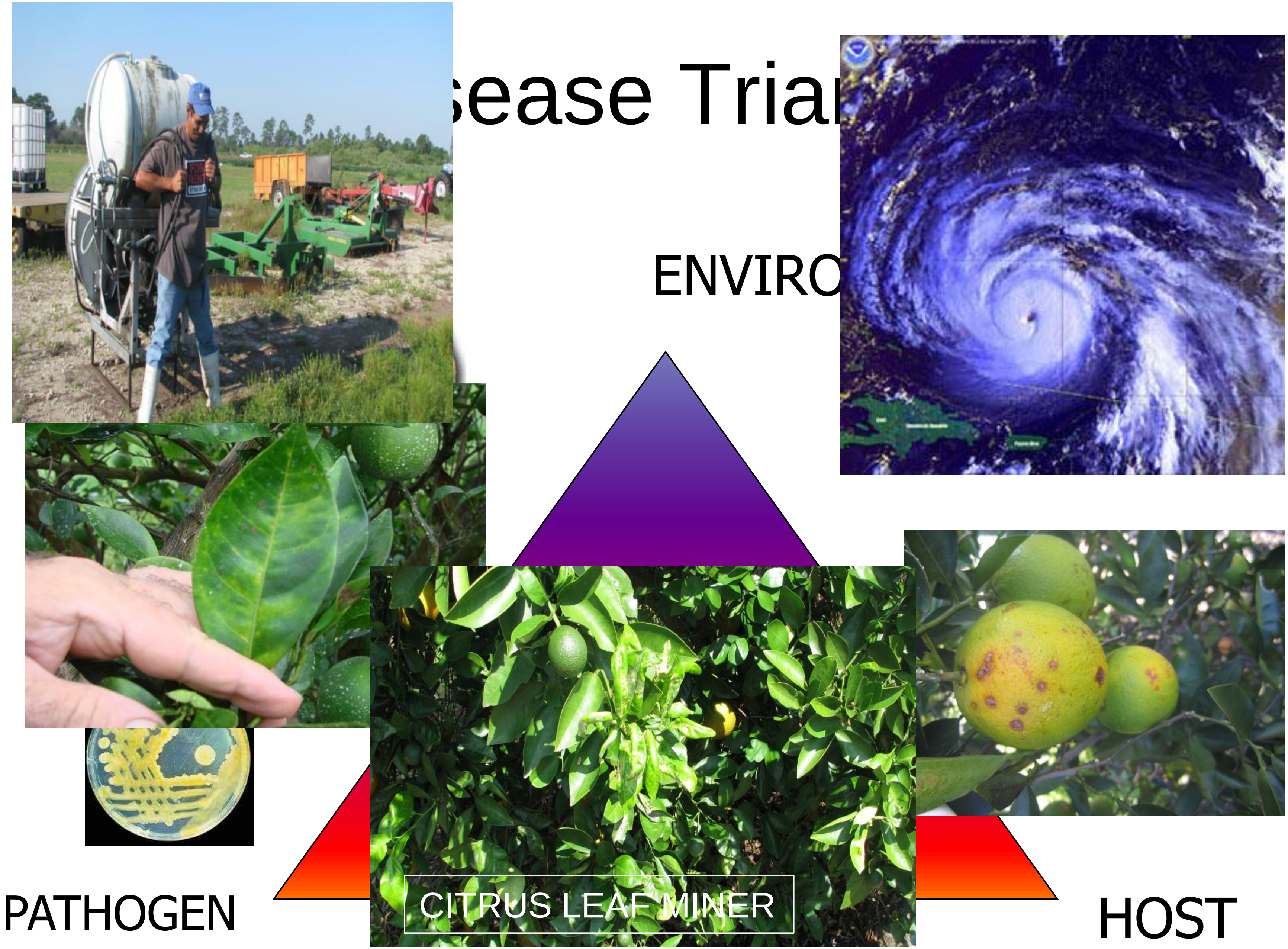
VIRONMENT



Xanthomonas citri subsp. *citri*

PATHOGEN

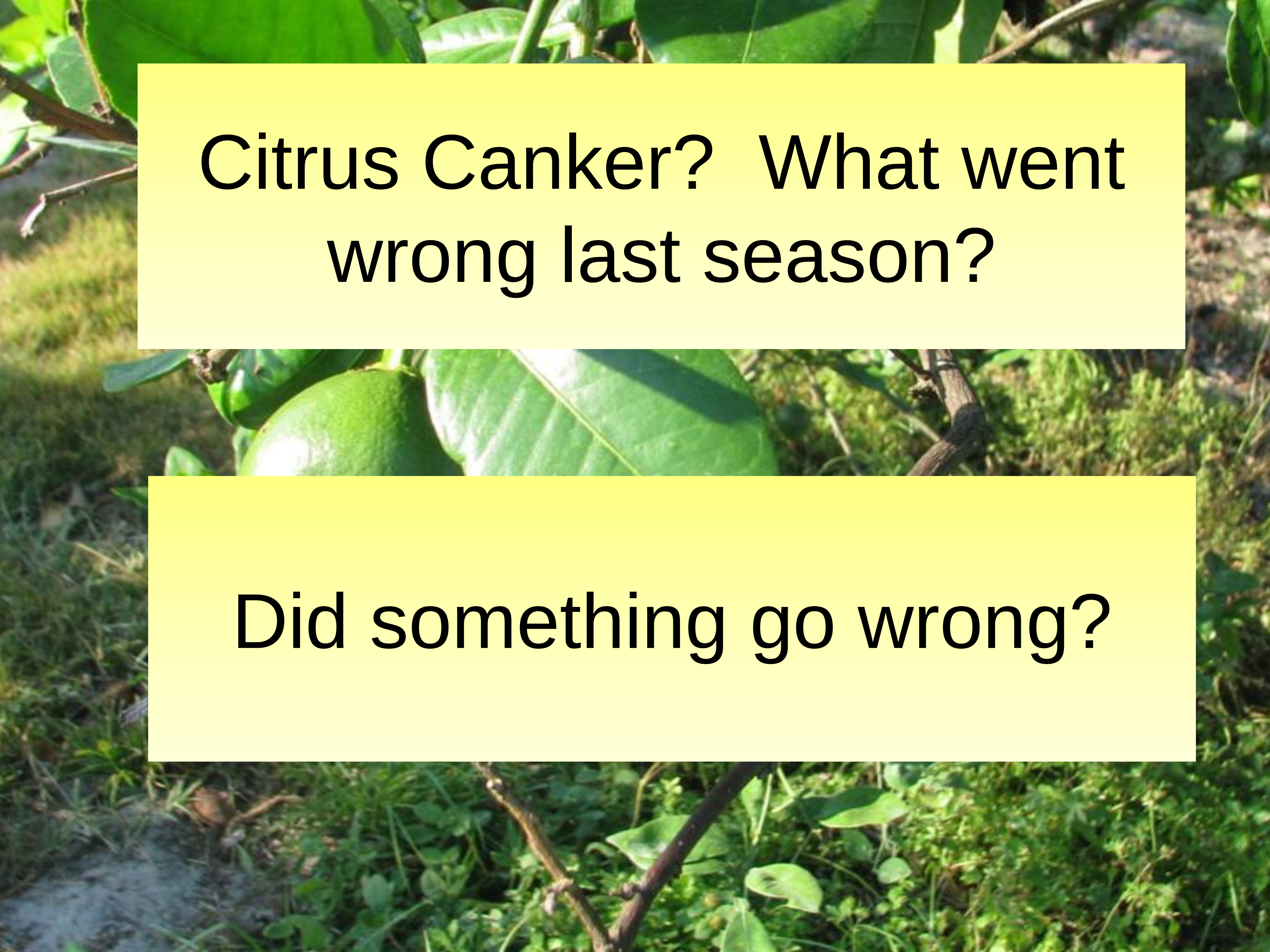
HOST


sease Tria
ENVIRO
CITRUS LEAF MINER
PATHOGEN
HOST

Disease Tri

PATHOGEN

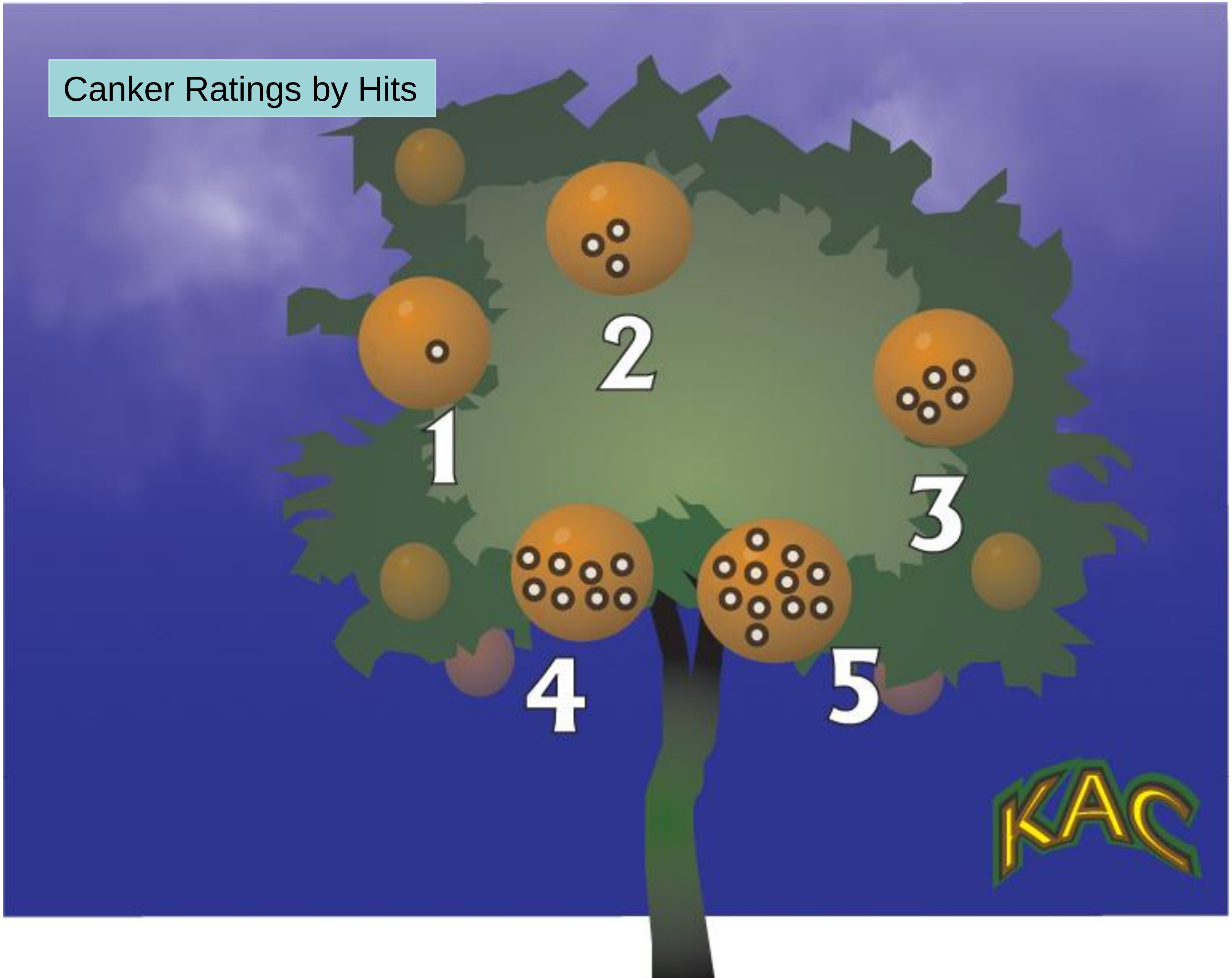
HOST



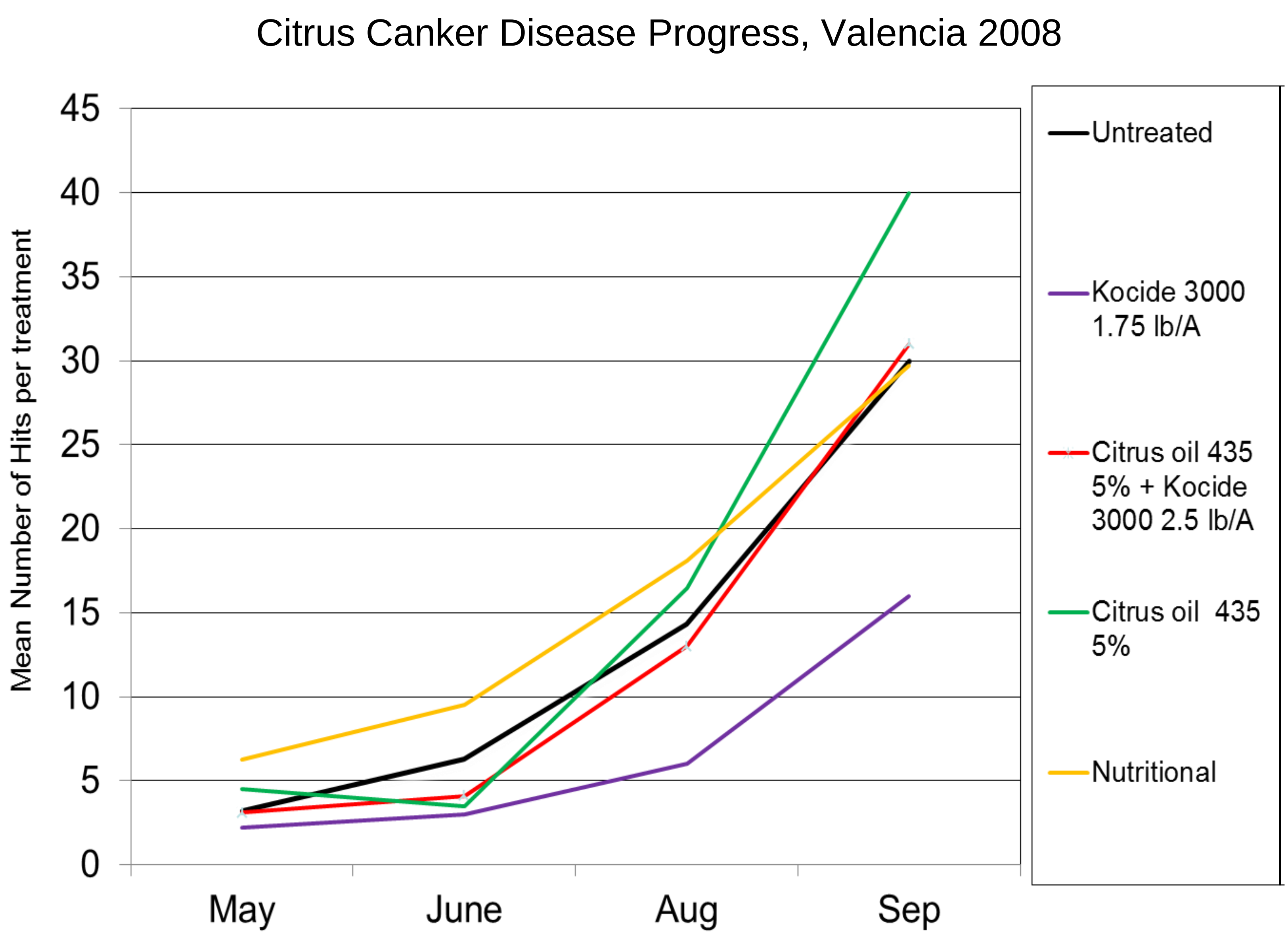
Citrus Canker? What went wrong last season?

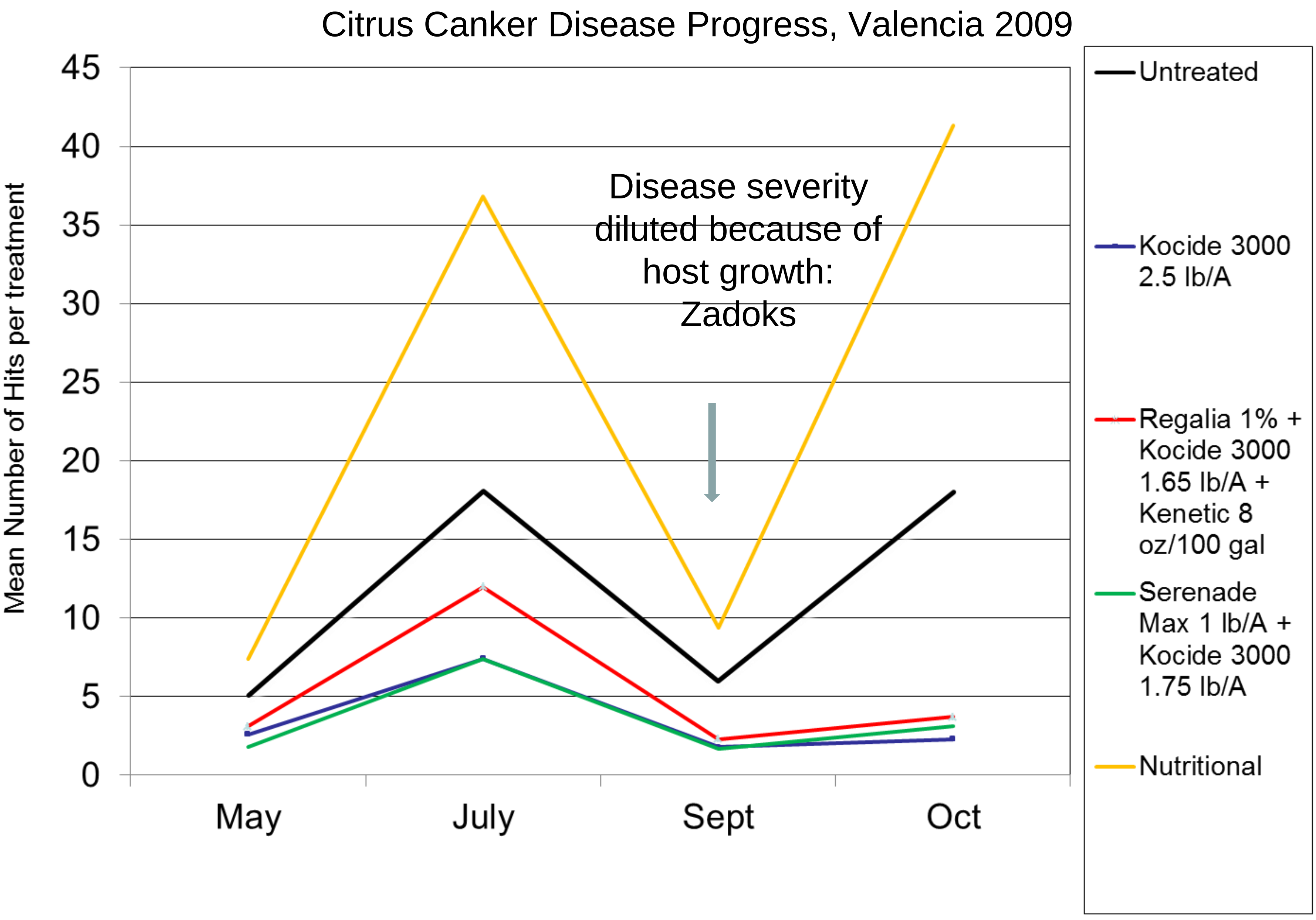
Did something go wrong?

Canker Ratings by Hits

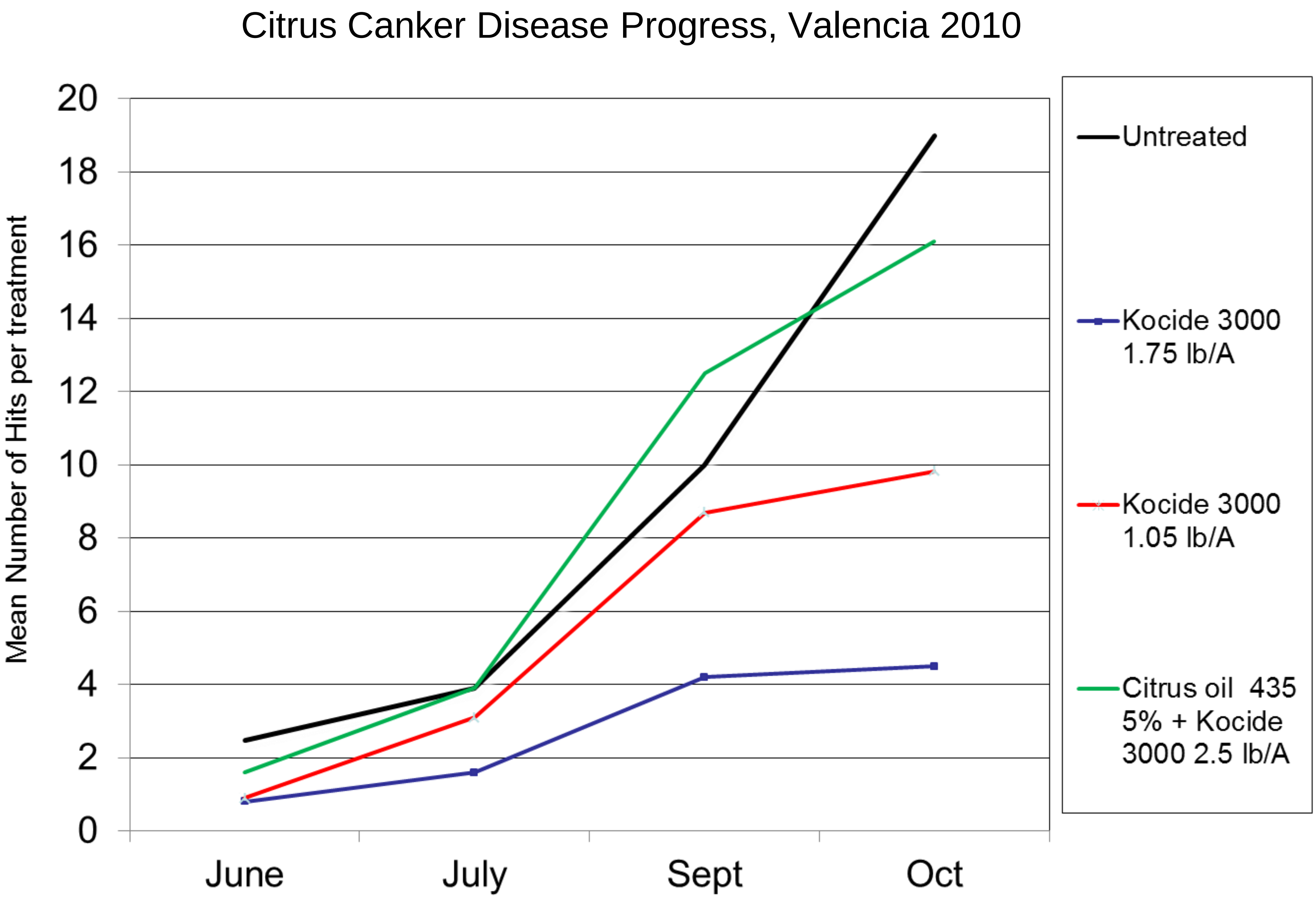



HIT

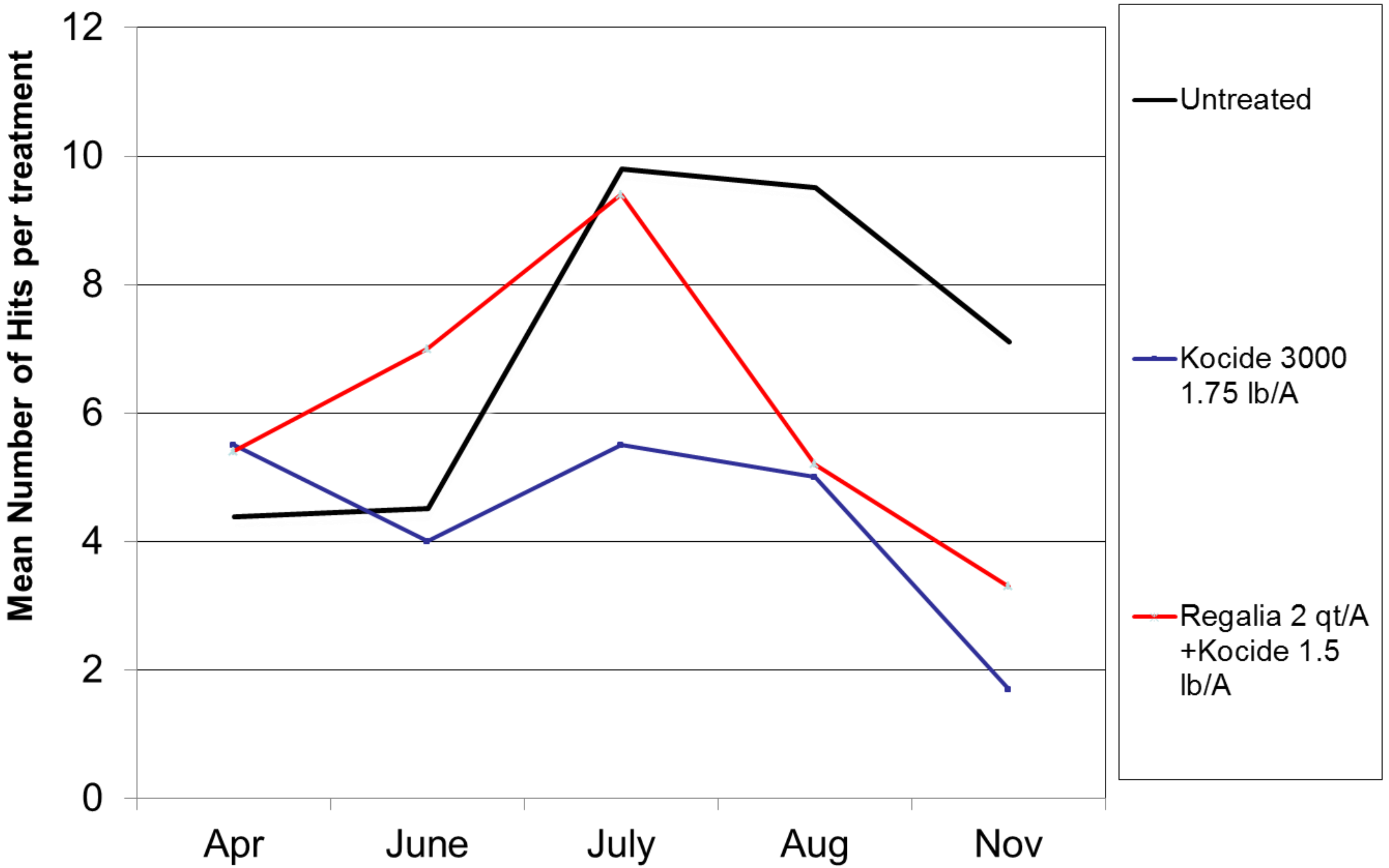

Citrus Canker Disease Progress, Valencia 2008
Mean Number of Hits per treatment
0
5
10
15
20
25
30
35
40
45
May
June
Aug
Sep
Untreated
Kocide 3000 1.75 lb/A
Citrus oil 435 5% + Kocide 3000 2.5 lb/A
Citrus oil 435 5%
Nutritional



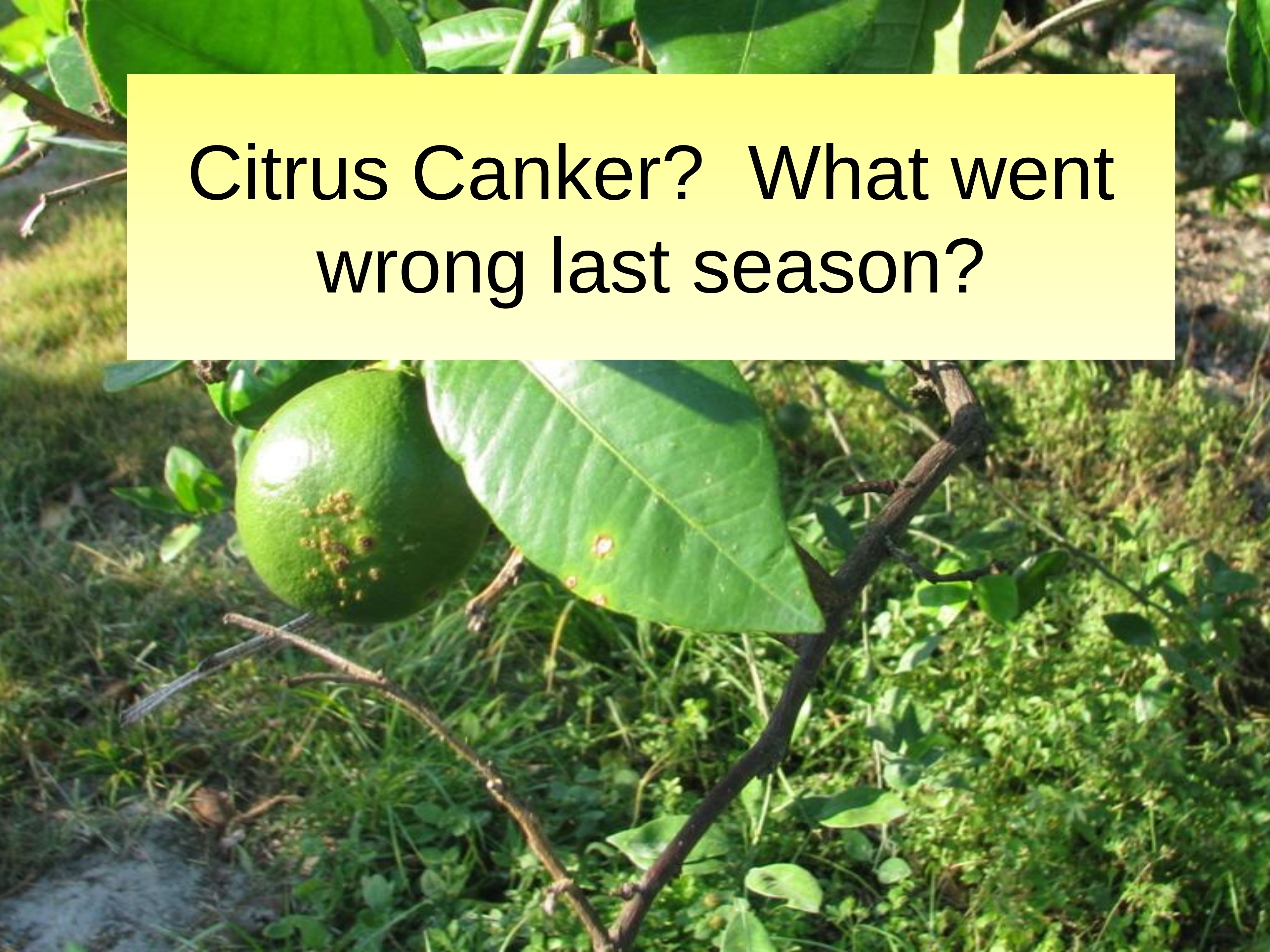
Citrus Canker Disease Progress, Valencia 2009
Mean Number of Hits per treatment
45
40
35
30
25
20
15
10
5
0
May
July
Sept
Oct
Disease severity diluted because of host growth: Zadoks
Untreated
Kocide 3000 2.5 lb/A
Regalia 1% + Kocide 3000 1.65 lb/A + Kenetic 8 oz/100 gal
Serenade Max 1 lb/A + Kocide 3000 1.75 lb/A
Nutritional

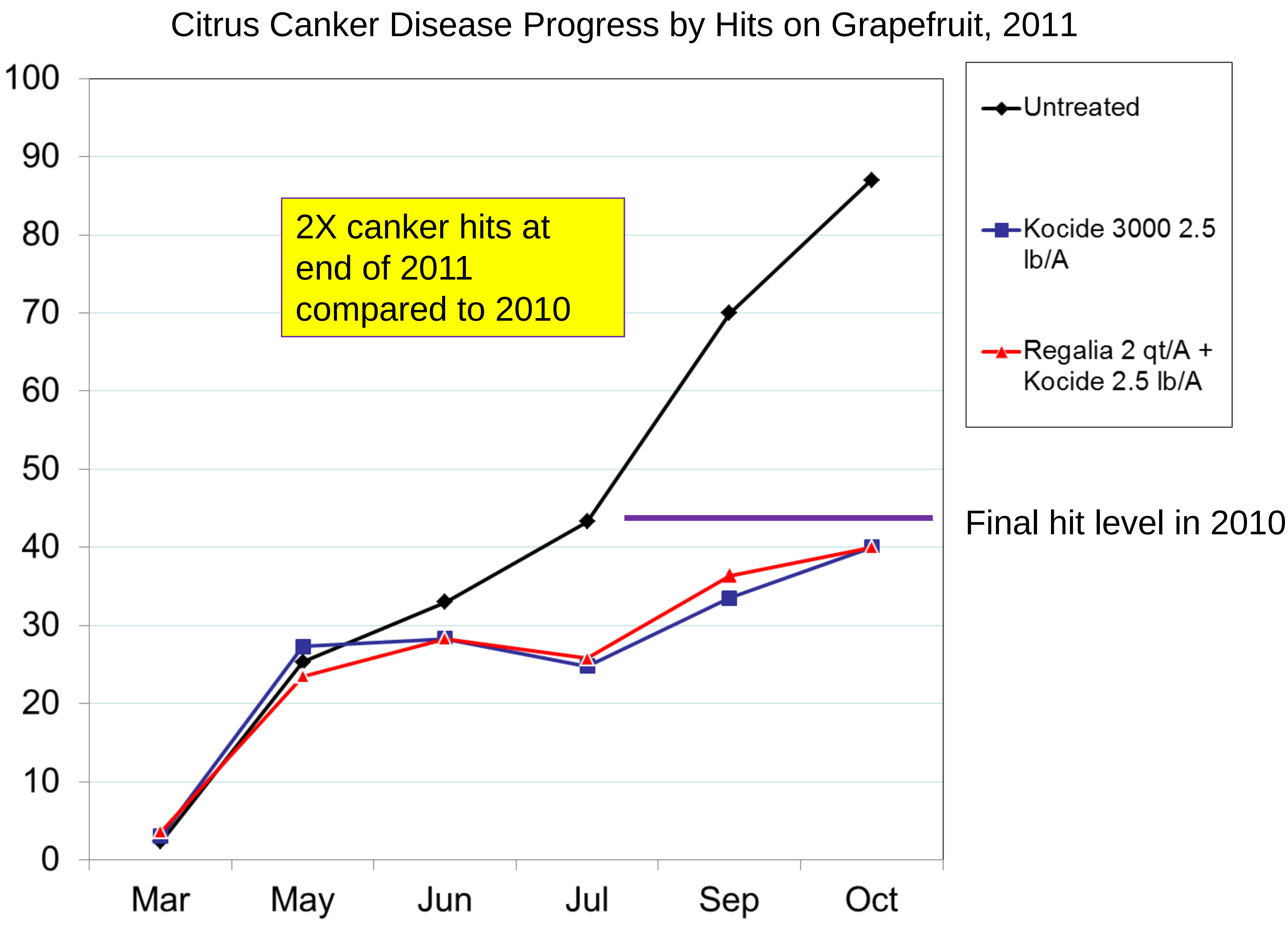

Citrus Canker Disease Progress, Valencia 2010
Mean Number of Hits per treatment
20
18
16
14
12
10
8
6
4
2
0
June
July
Sept
Oct
Untreated
Kocide 3000 1.75 lb/A
Kocide 3000 1.05 lb/A
Citrus oil 435 5% + Kocide 3000 2.5 lb/A

Citrus Canker Disease Progress, Valencia 2011

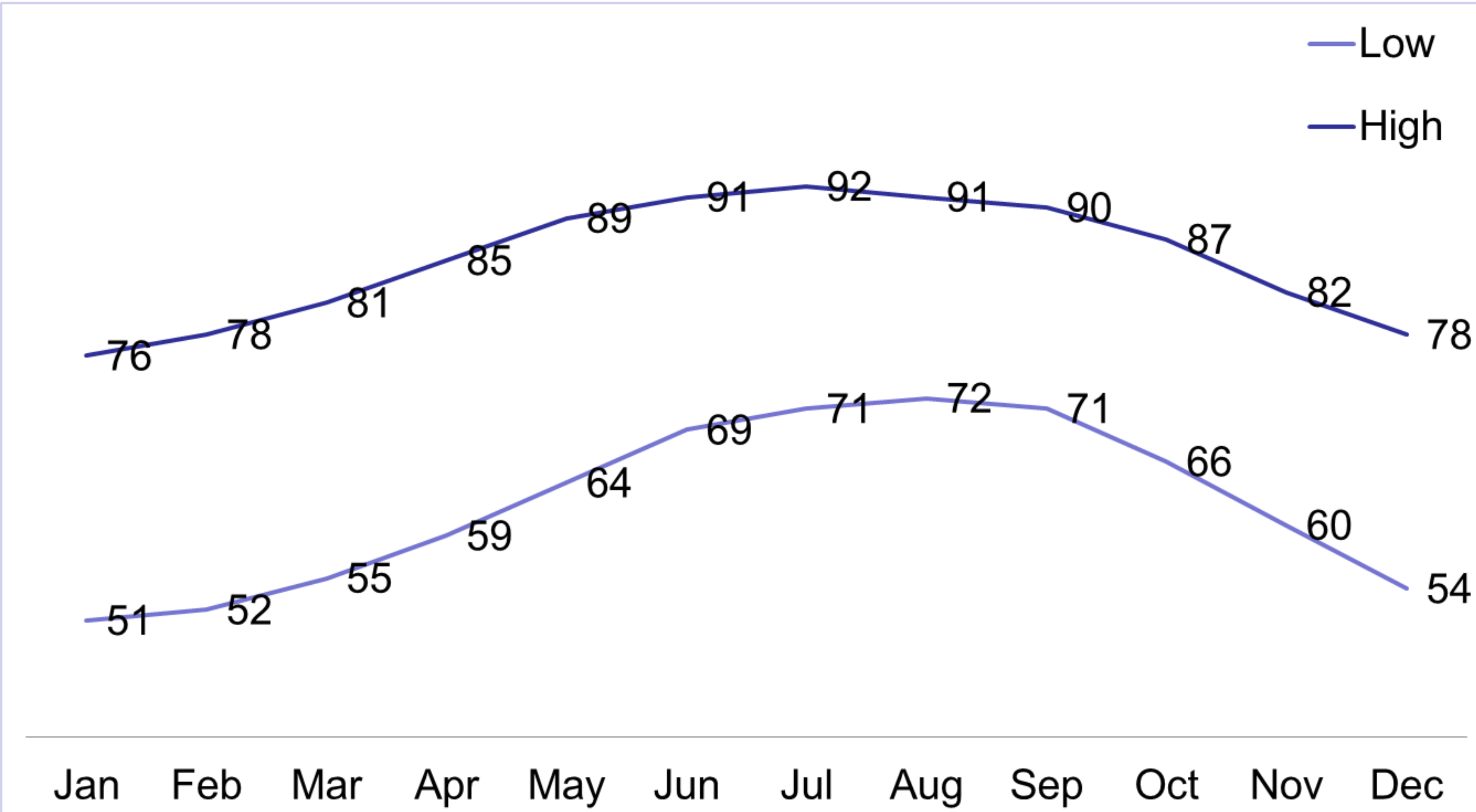


Citrus Canker? What went wrong last season?

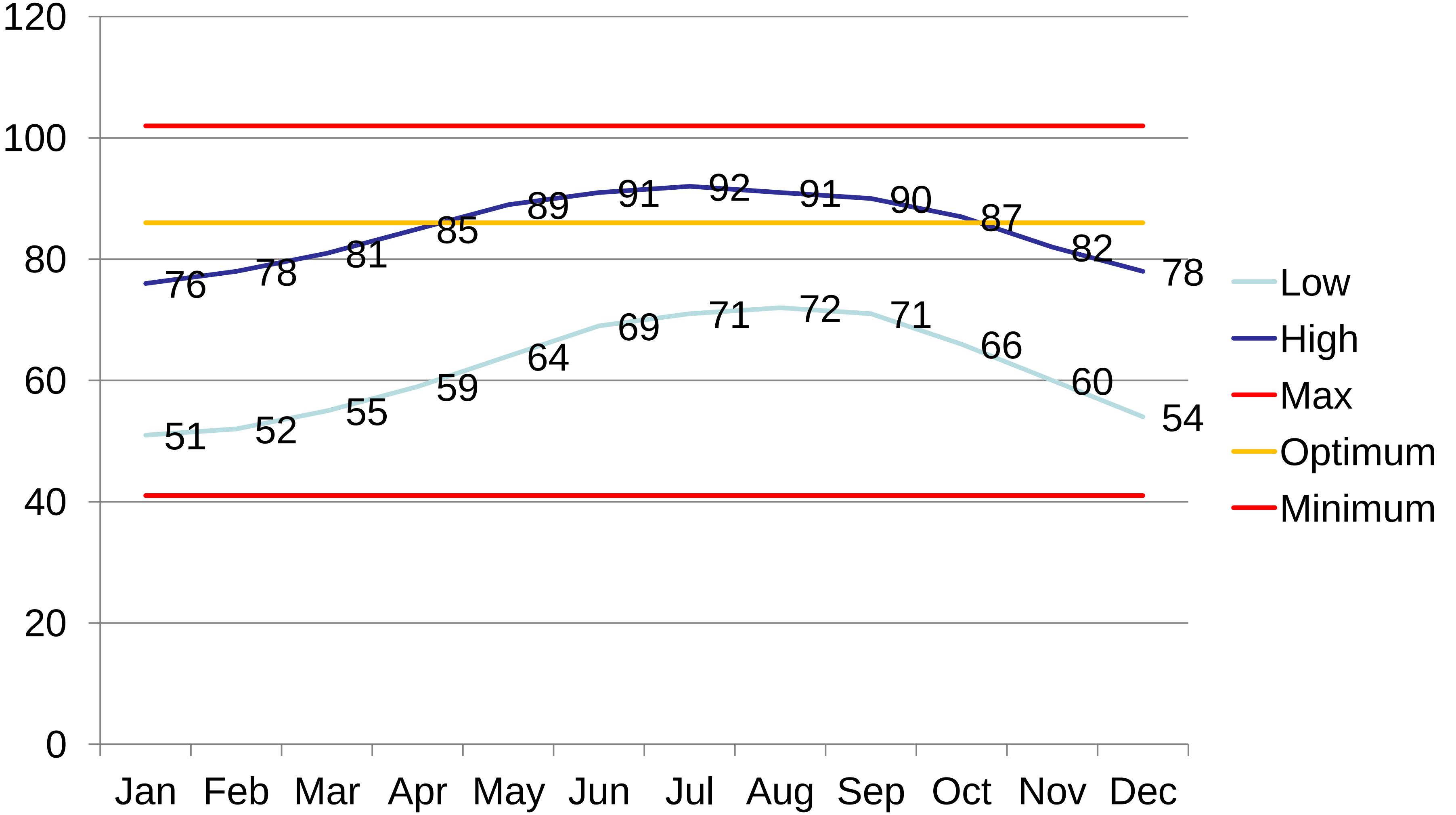



Citrus Canker Disease Progress by Hits on Grapefruit, 2011
100
90
80
70
60
50
40
30
20
10
0
Mar
May
Jun
Jul
Sep
Oct
Untreated
Kocide 3000 2.5 lb/A
Regalia 2 qt/A + Kocide 2.5 lb/A
2X canker hits at end of 2011 compared to 2010
Final hit level in 2010

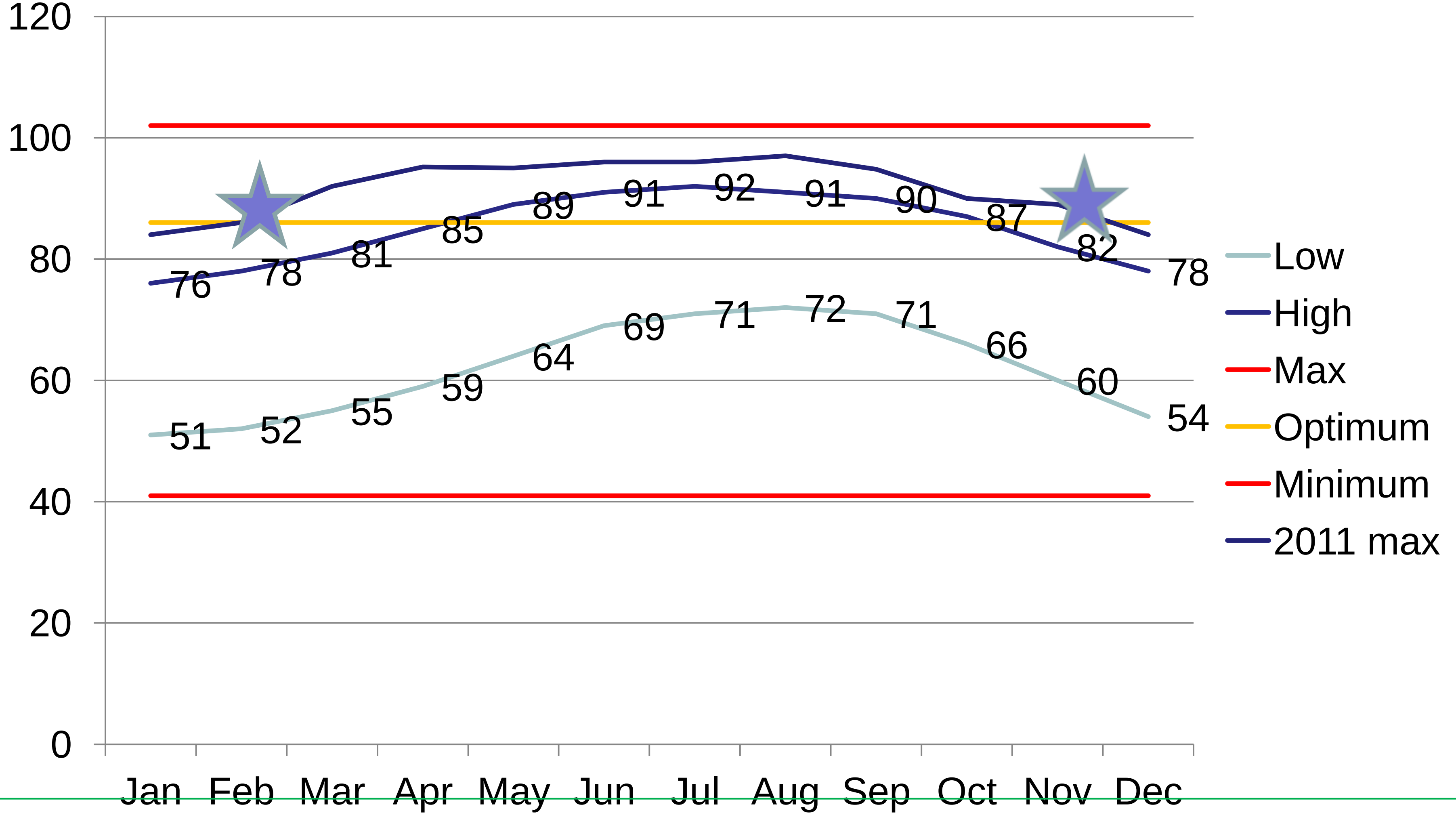
30-year average high and low temperatures (F) for Immokalee



30-year average high and low temperatures (F) for Immokalee and Maximum, Optimum and Minimum Temperatures for *Xanthomonas citri* subsp. *citri*

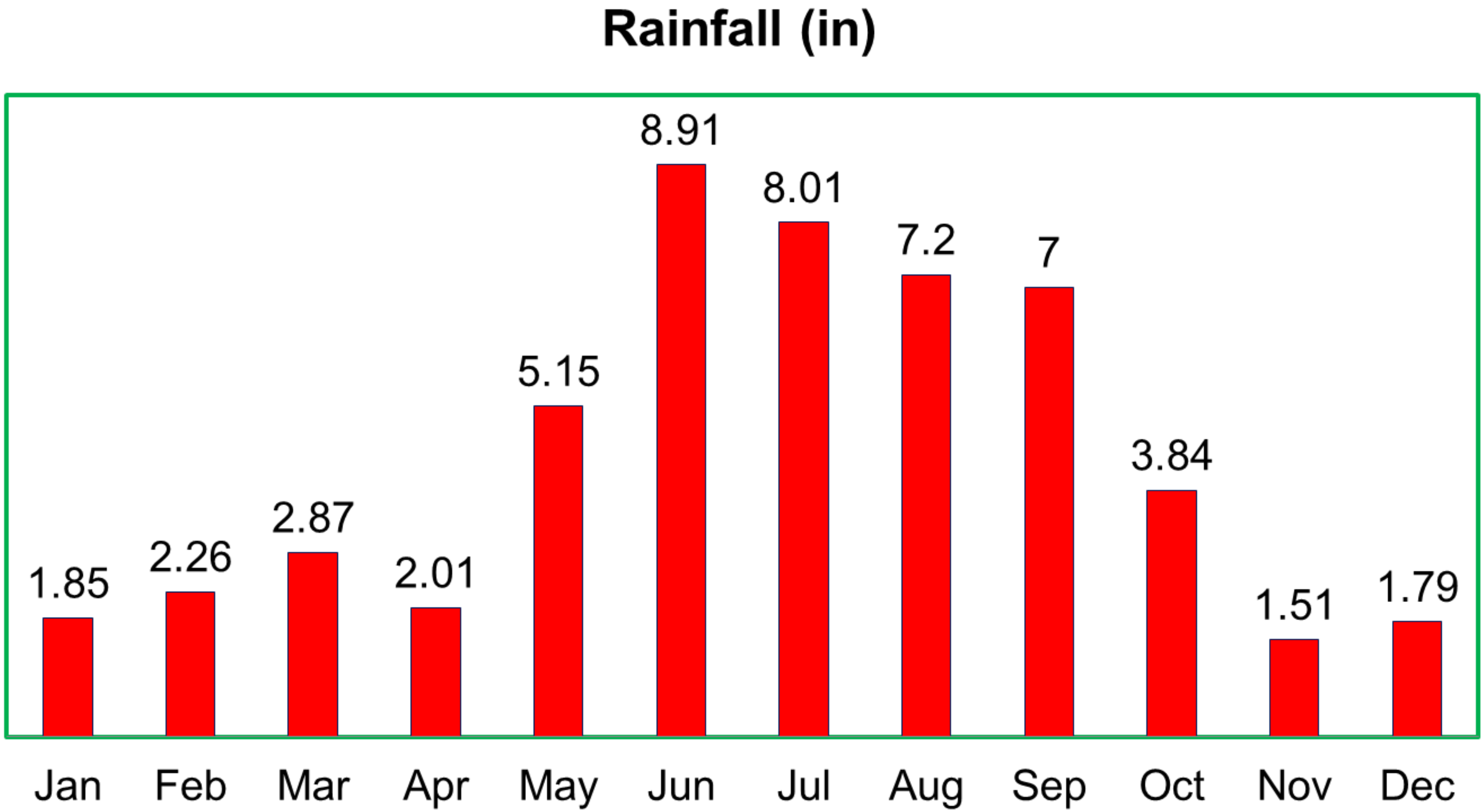


30-year average high and low temperatures (F) for Immokalee and Maximum, Optimum and Minimum Temperatures for *Xanthomonas citri* subsp. *citri*

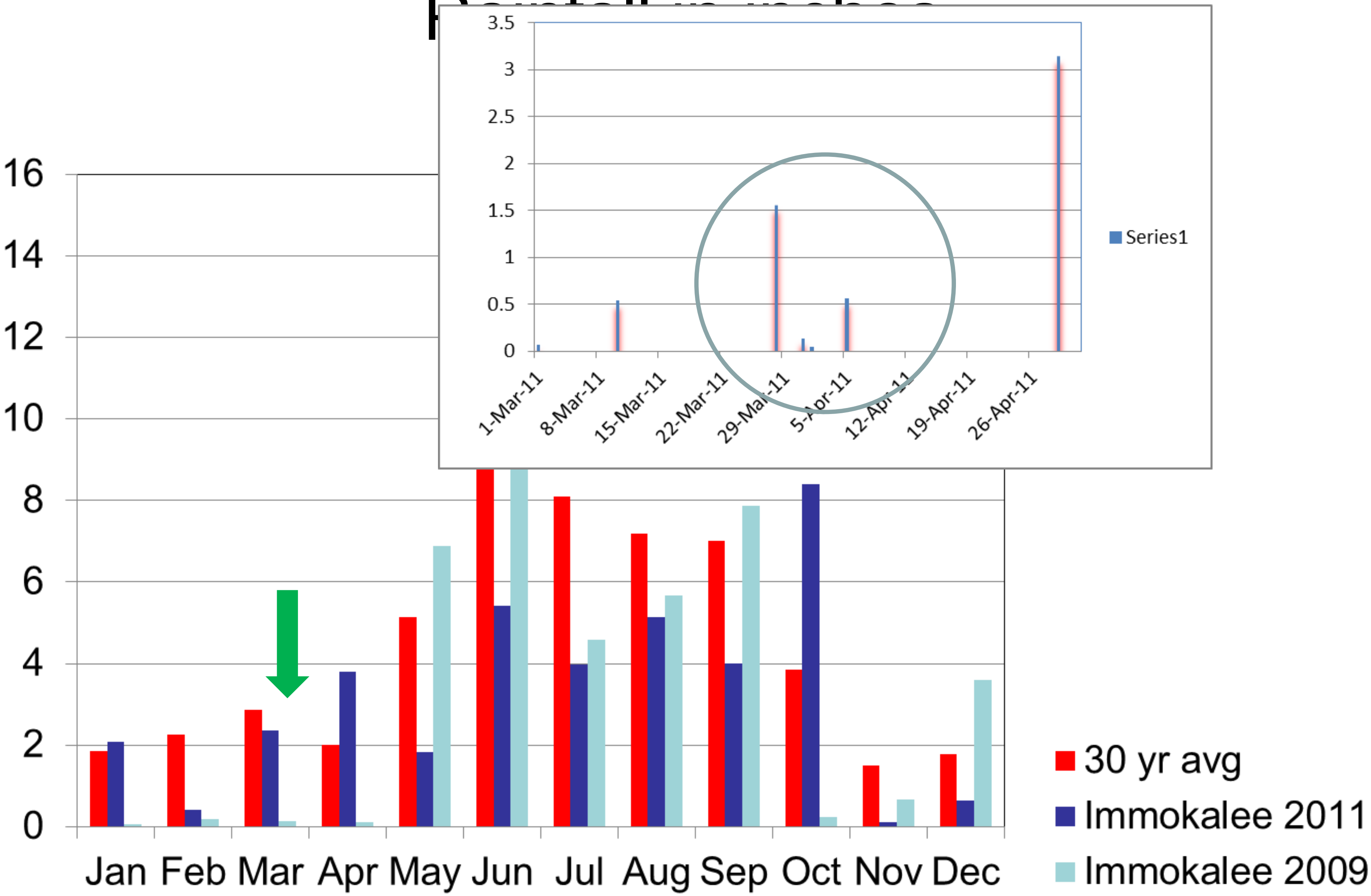


Optimum temperature for *Xanthomonas citri* subsp. *citri* started in Feb and ended in Dec

30-year Average



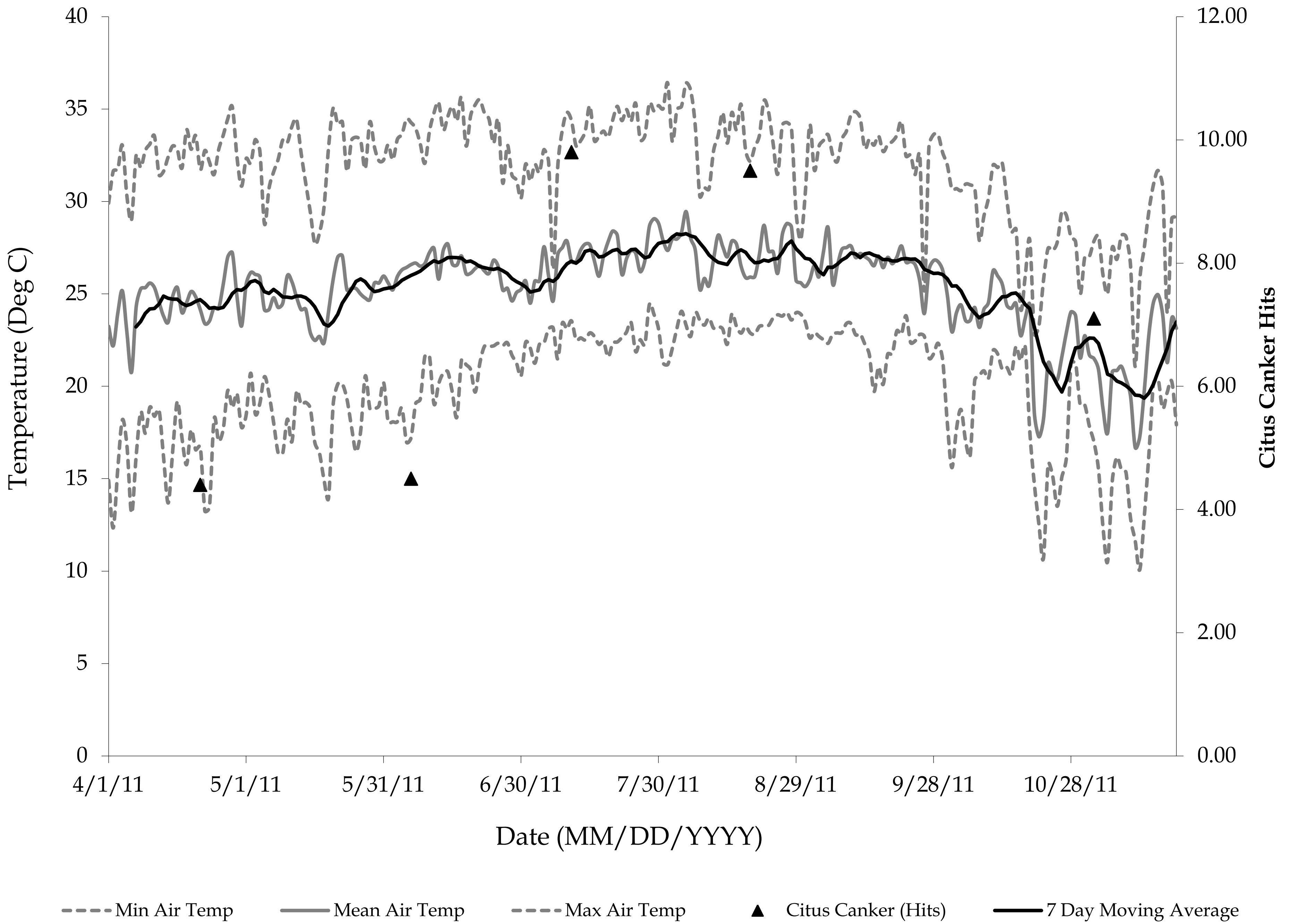
Rainfall in inches



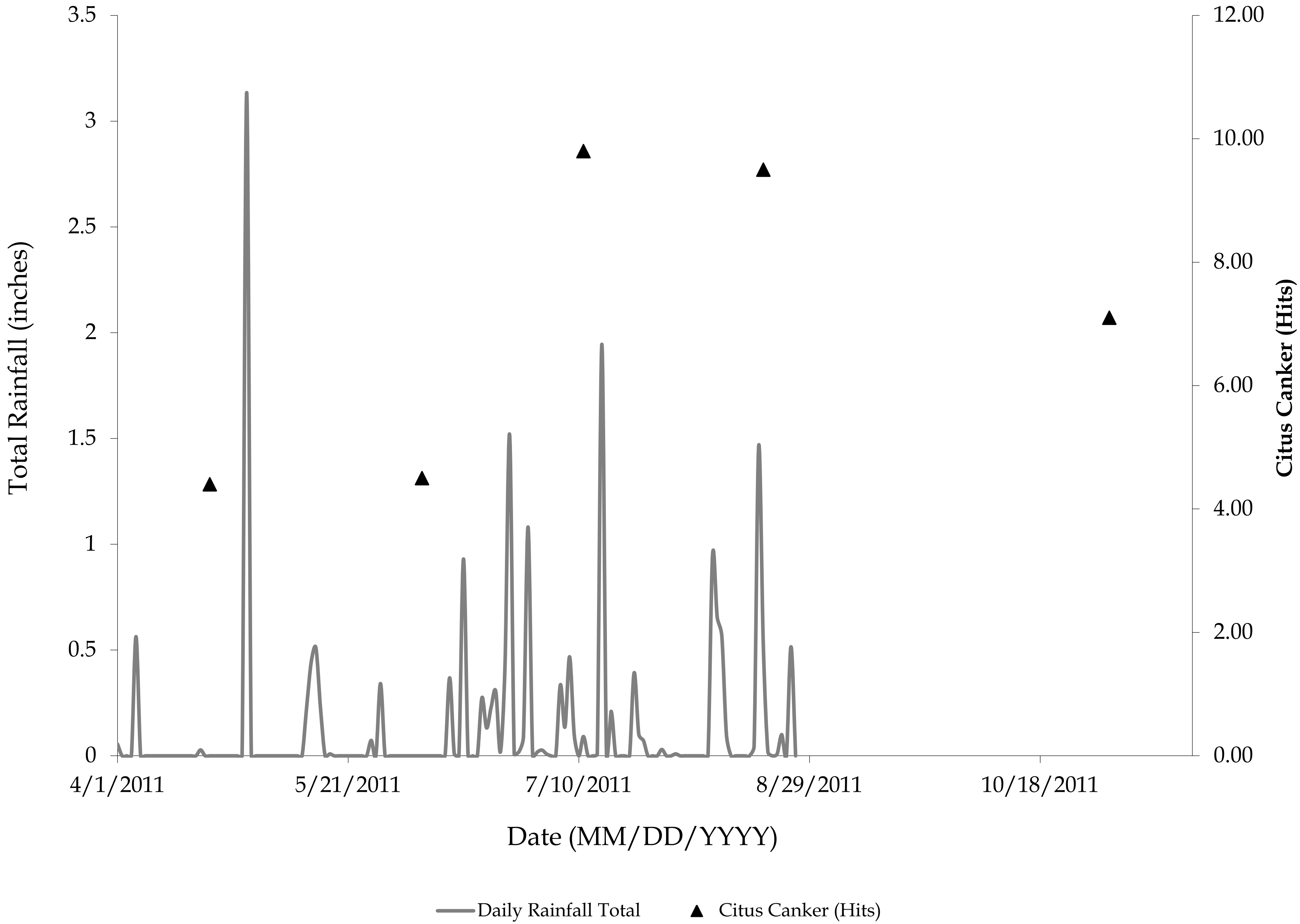
Rainfall and Temperature: significant?

- Canker Trials 2011
  - Canker on Valencia
    - Air Temperature Plot (Min, Avg, Max and 7 Day moving Average).
    - Rainfall Totals
    - Dew point temperature Plot (Min, Avg, Max and 7 Day moving Average).
    - Regression Plots
      - Moving average (7 days) air temperature and moving average interpolated canker hits (7 days).
      - Moving total rainfall (7 days) and moving average interpolated canker hits (7 days).
      - Moving average (7 days) dew point temperature and moving average interpolated canker hits (7 days).

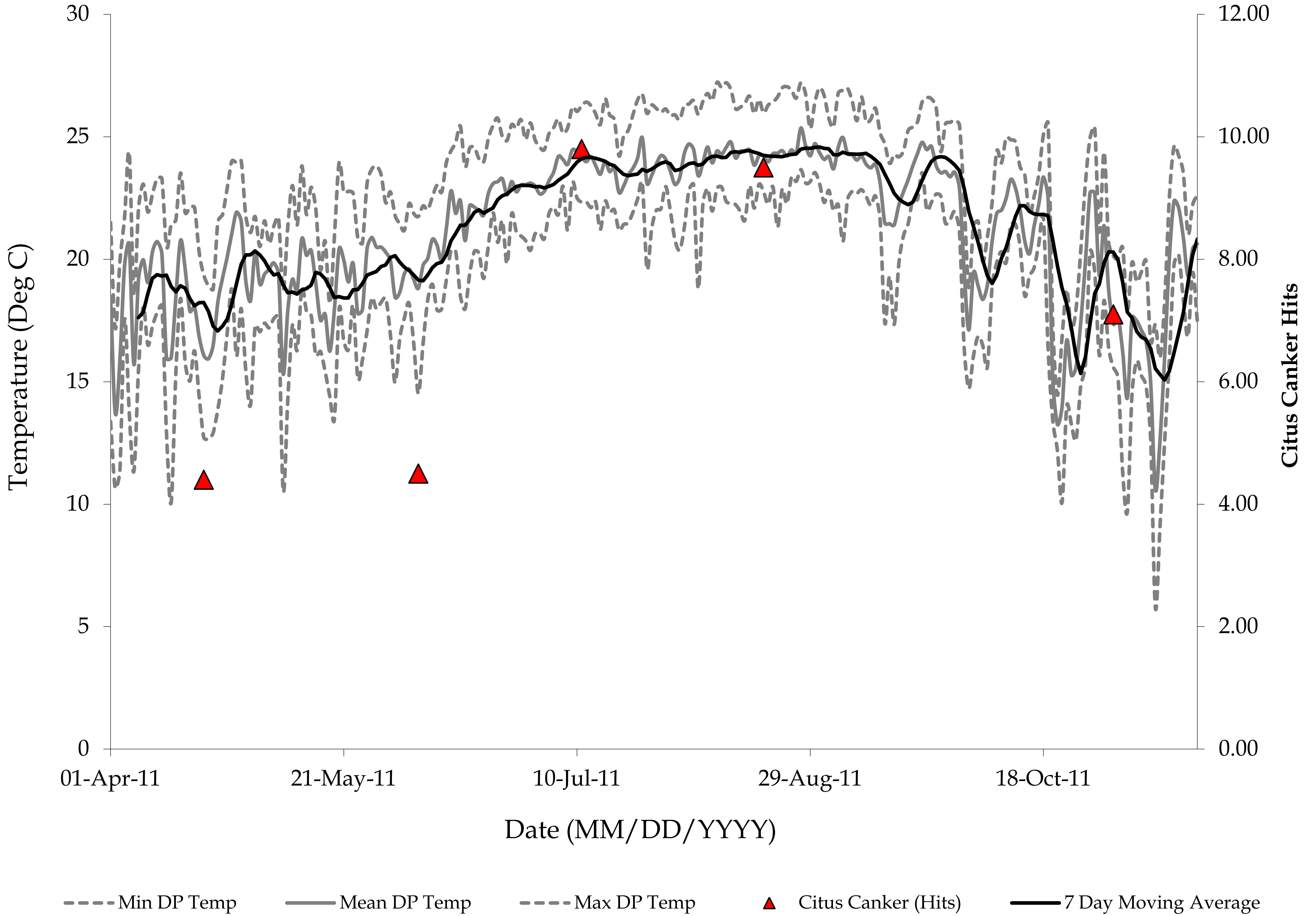
Valencia 2011 Trial



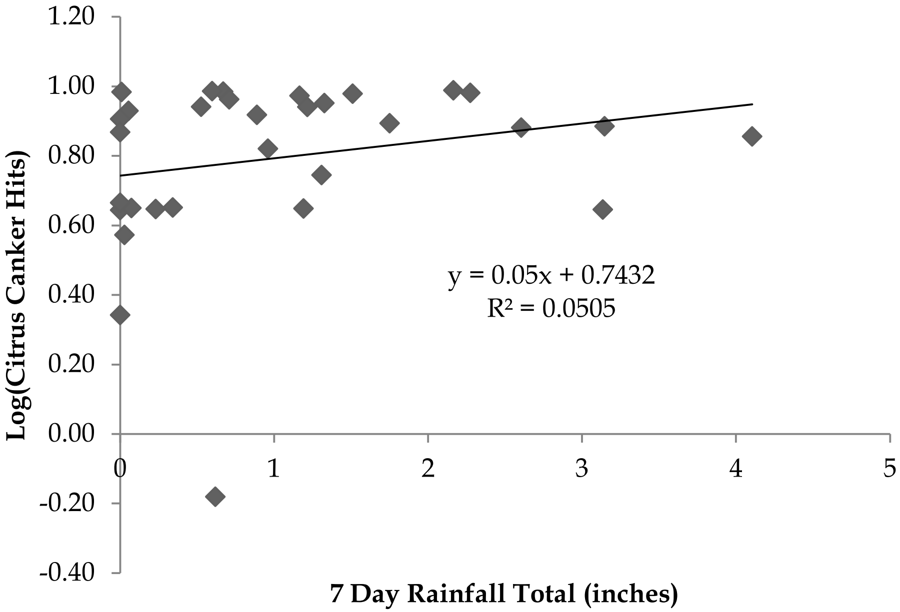
Valencia 2011 Trial



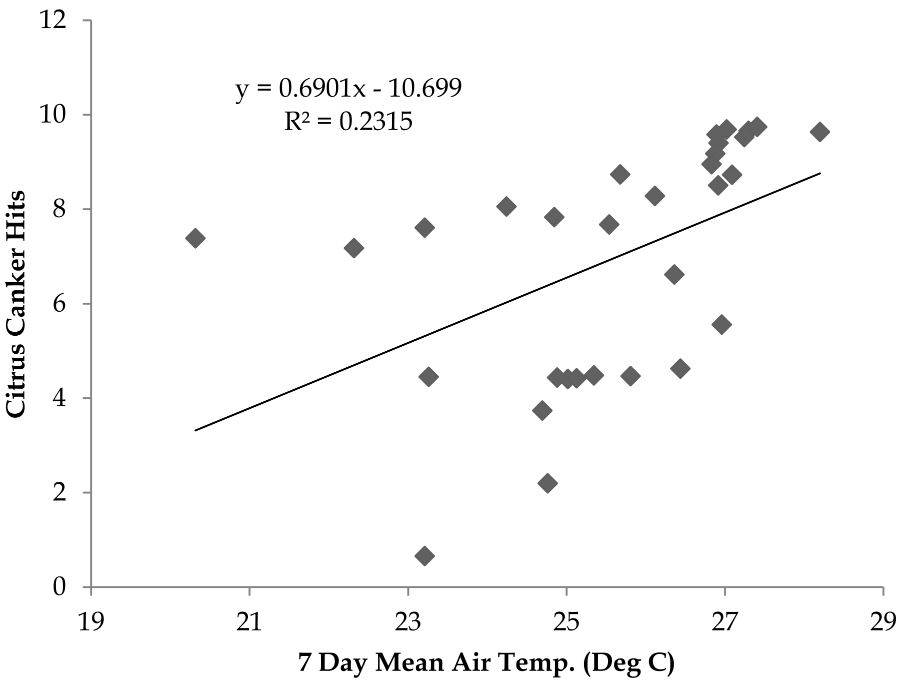
Valencia 2011 Trial



Valencia 2011 Trial

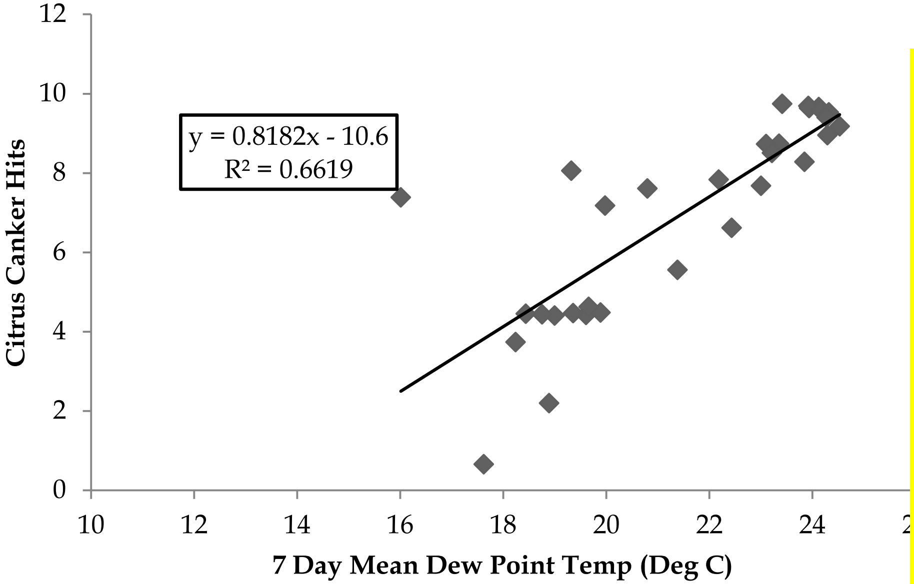


- No statistically significant relationship exists for 7 day rainfall totals verse Log(Canker Hits)
  - DF= 29, F Ratio=1.541, ρ=0.224
  - Low R^2 (0.050) and only improved slightly with non-log transformed data (0.051).



- A statistically significant relationship between 7 day mean air temp and canker hits (non-log transformed) is apparent.
  - DF=29, F Ratio=6.368, ρ=0.017
  - However the relationship has a low R^2 value of 0.232.

Valencia 2011 Trial



- A statistically significant relationship between 7 day mean dew point temp and canker hits (non-log transformed) is apparent.
  - DF=29, F Ratio=56.772, ρ=0.001
  - The relationship has a mid range R^2 value of 0.6619.
  - The relationship did not improve significantly with log transformation canker hits (R^2= 0.4831).

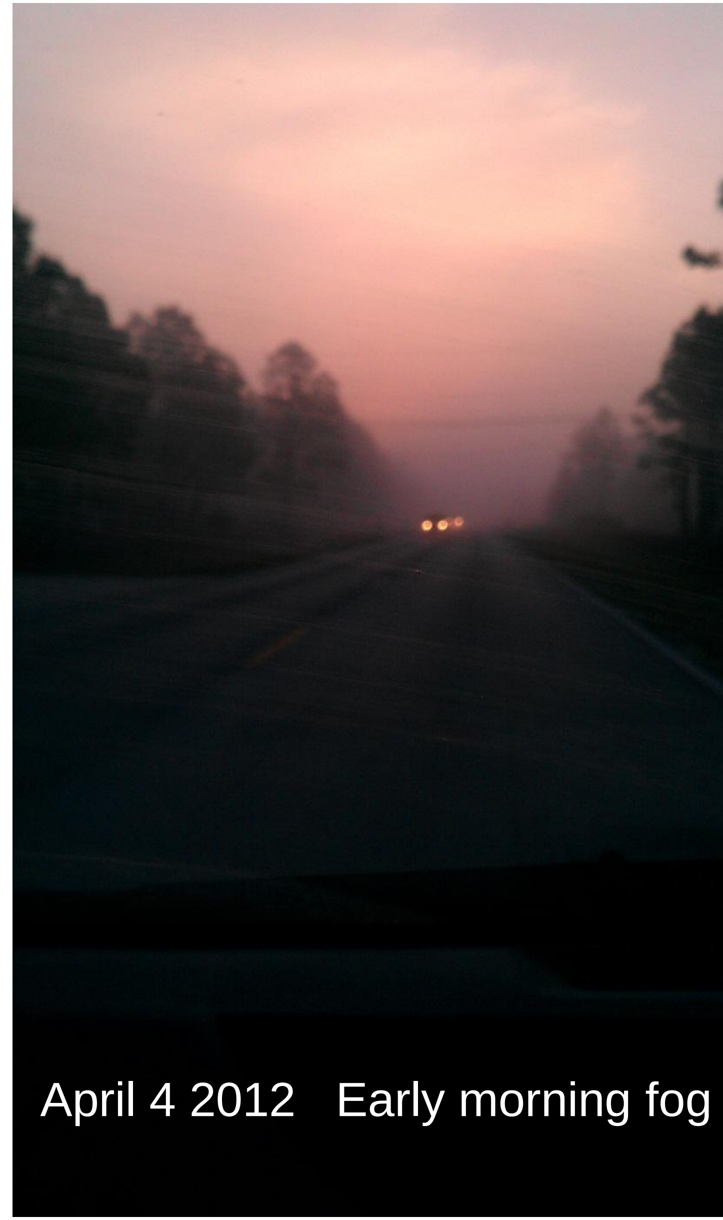
Conclusion: Did something go wrong?

In Immokalee:

2011: Intense rains occurred from late March through October

2011: Temperature was conducive for bacteria growth early in the season and throughout

Mean dew point temperature at which the air becomes saturated seemed to be related to canker in 2011



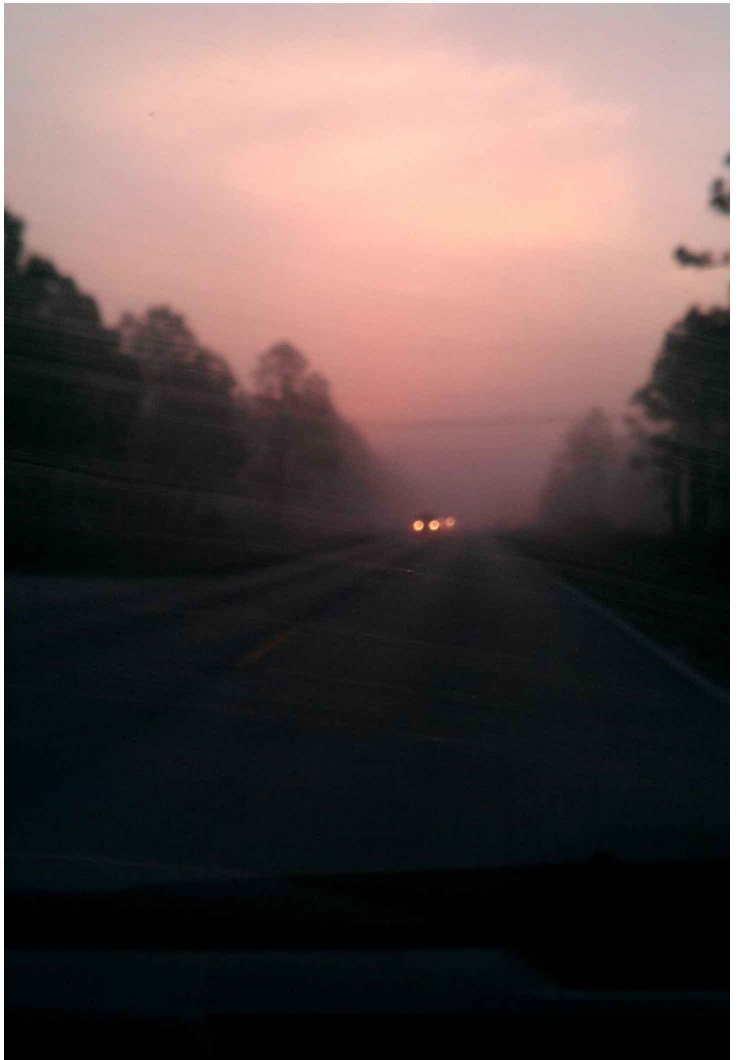
April 4 2012   Early morning fog

2012

Is this year a repeat of 2011?

Warm weather
Isolated rainfall
Dew

Canker lesions developing for several weeks now in south Florida



April 4 2012 Early morning fog

Trials to suppress citrus canker in Immokalee

Background

Trials began in 2007 at the request of a local producer to test claims made by various companies

Test various products and programs to suppress citrus canker

Not timing trials- 21 day calendar

Not to compare different copper materials

Product selection criteria

Trials were initiated in response to grower asking for independent verification of claims

Grower interest

IR-4 program

Other Researchers

My non-citrus trials

- Agrichemical companies

Goals

1. Identify **efficacious** materials to **integrate** into **sustainable management programs**

2. Three applications per year for canker control

Crop Protection 27 (2008) 1519–1526

Contents lists available at ScienceDirect

Crop Protection

journal ho… .com/locate/cropro

Examples of other programs in used in other crops

Evaluation of spray programs containing famoxadone plus cymoxanil, acibenzolar-*S*-methyl, and *Bacillus subtilis* compared to copper sprays for management of bacterial spot on tomato

P.D. Roberts[a,*], M.T. Momol[b,1], L. Ritchie[b], S.M. Olson[b], J.B. Jones[c], B. Balogh[d]

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[b] *North Florida Research and Education Center, Plant Pathology Department, University of Florida – IFAS, 155 Research Road, Quincy, FL 32351-5677, USA*
[c] *University of Florida, 1453 Fifield Hall, Plant Pathology Department, Gainesville, FL 32611-0680, USA*
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ABSTRACT

Bacterial spot caused by *Xanthomonas euvesicatoria* Jones et al. and *Xanthomonas perforans* Jones et al. is a major disease on fresh market commercial tomato in Florida. Fourteen field trials were conducted between 1999 and 2005 (10 in south Florida and four in north Florida) testing famoxadone plus cymoxanil (Tanos 50DF®, E.I. du Pont de Nemours and Company, Wilmington, DE), *Bacillus subtilis* strain QST 713 (*B. subtilis*) (Serenade WPO® or Serenade Max®, AgraQuest, Inc., Davis, CA), and acibenzolar-*S*-methyl (ASM) (Actigard 50WG®, Syngenta Crop Protection, Greensboro, NC) at different rates and in various application programs that were combined and rotated with copper hydroxide and mancozeb for management of bacterial spot. In field applied spray treatments containing famoxadone as a component, all of the programs significantly reduced bacterial spot severity on plants compared to the untreated

Control of Citrus Canker and Citrus Bacterial Spot with Bacteriophages

Botond Balogh, University of Florida, Plant Pathology Department, 1453 Fifield Hall, Gainesville, FL 32611, and The Connecticut Agricultural Experiment Station, 123 Huntington Street, New Haven, CT 06504; **B. I. Canteros,** Instituto Nacional de Tecnología Agropecuaria Estación Experimental Agropecuaria, Bella Vista, Corrientes, Argentina; and **R. E. Stall** and **J. B. Jones,** University of Florida, Plant Pathology Department, 1453 Fifield Hall, Gainesville, FL 32611

ABSTRACT

Balogh, B., Canteros, B. I., Stall, R. E., and Jones, J. B. 2008. Control of citrus canker and citrus bacterial spot with bacteriophages. Plant Dis. 92:1048-1052.

Bacteriophages, alone or in combination with copper bactericides, were evaluated for managing Asiatic citrus canker and citrus bacterial spot incited by *Xanthomonas axonopodis* pathovars *citri* and *citrumelo*, respectively. In a set of five greenhouse experiments, phage treatment provided consistent control of citrus canker, causing an average of 59% reduction in disease severity. However, treatment with phage was ineffective if applied with skim milk, a protective formulation, which increases phage residual activity. In nursery settings, phage treatment also reduced disease but was less effective than copper-mancozeb, a chemical bactericide. The integration of phage and copper-mancozeb resulted in equal or less control than copper-mancozeb application alone. Phage treatments were evaluated in a commercial citrus nursery for reducing citrus bacterial spot caused by natural inoculum. Phage treatment provided significant disease reduction on moderately sensitive Valencia oranges in two trials (48 and 35%); however, on the highly susceptible grapefruit host it was ineffective. In an experimental citrus nursery, phage treatment provided significant control of citrus bacterial spot caused by a phage-sensitive strain, but was equally or less effective than copper-mancozeb. The combination of phage and copper-mancozeb did not increase control compared with copper-mancozeb alone.

Additional keywords: biocontrol, biological control

eral diseases caused by species of *Xanthomonas*, including bacterial spot of peach, caused by *X. campestris* pv. *pruni* (8,27), geranium bacterial blight, caused by *X. campestris* pv. *pelargonii* (9), tomato bacterial spot, caused by *X. euvesicatoria* and *X. perforans*, and xanthomonas leaf blight of onion, caused by *X. axonopodis* pv. *allii* (3,10,19,24,25).

Recently, a considerable amount of research has been conducted on understanding problems associated with phage treatment of bacterial plant diseases and improving its efficacy. The short residual activity of phage, caused mainly by the detrimental effects of sunlight UV irradiation, was identified as a major hindrance to effective disease control (3,14). Strategies that increased phage longevity, such as the use of formulations that attenuate sunlight damage or evening applications to minimize UV irradiation, resulted in enhanced control (3). Phage treatment also per-

Management of Tomato Bacterial Spot in the Field by Foliar Applications of Bacteriophages and SAR Inducers

A. Obradovic and **J. B. Jones**, Department of Plant Pathology, University of Florida, Gainesville 32611; **M. T. Momol**, Plant Pathology Department, North Florida Research and Education Center, University of Florida, Quincy 32351; **B. Balogh**, Department of Plant Pathology, University of Florida, Gainesville; and **S. M. Olson**, Horticultural Sciences Department, North Florida Research and Education Center, University of Florida, Quincy

ABSTRACT

Obradovic, A., Jones, J. B., Momol, M. T., Balogh, B., and Olson, S. M. 2004. Management of tomato bacterial spot in the field by foliar applications of bacteriophages and SAR inducers. Plant Dis. 88:736-740.

Various combinations of the harpin protein, acibenzolar-S-methyl, and bacteriophages were evaluated for controlling tomato bacterial spot in field experiments. Harpin protein and acibenzolar-S-methyl were applied every 14 days beginning twice before transplanting and then an additional four applications throughout the season. Formulated bacteriophages were applied prior to inoculation followed by twice a week at dusk. A standard bactericide treatment, consisting of copper hydroxide plus mancozeb, was applied once prior to inoculation and then every 7 days, while nontreated plants served as an untreated control. Experiments were conducted in north and central Florida fields during fall 2001, spring 2002, and fall 2002. In three consecutive seasons, acibenzolar-S-methyl applied in combination with bacteriophage or bacteriophage and harpin significantly reduced bacterial spot compared with the other treatments. However, it did not significantly affect the total yield compared with the standard or untreated control. Application of host-specific bacteriophages was effective against the bacterial spot pathogen in all three experiments, providing better disease control than copper-mancozeb or untreated control. When results of the disease severity assessments or harvested yield from the bacteriophage-treated plots were grouped and compared with the results of the corresponding nonbacteriophage group, the former provided significantly better disease control and yield of total marketable fruit.

Tomato bacterial spot, caused by *Xanthomonas campestris* pv. *vesicatoria* (Doidge) Dye, remains a constant threat to tomato (*Lycopersicon esculentum* Mill.) commercial production (6,19,25). Control strategies are based on a combination of practices such as use of pathogen-free seed and transplants, elimination of volunteer tomato plants, resistant cultivars, and frequent application of a copper and mancozeb mixture (21,24,38). Chemical control has been used extensively for controlling bacterial spot. In the 1950s, streptomycin was used, but resistant bacterial strains developed and rendered antibiotics ineffective (39). However, these strategies are of limited use, especially in the tropics and subtropics where weather conditions favor infection (26). Four tomato races (T1 to T4) of *X. campestris* pv. *vesicatoria* have been described (23,31). However, only two races (T1 and T3) commonly occur in Florida (22,23), whereas T4 has been found recently at a very low incidence (31). In Florida, T3 has become the most prevalent race (12,17). Although resistance genes have been identified and introgressed into tomato and pepper genotypes with good horticultural qualities, shifts in race populations of *X. campestris* pv. *vesicatoria* compromise breeders' efforts to provide stable resistance in commercial tomato cultivars (23,25).

Chemical control of bacterial spot relies on multiple applications of copper- or streptomycin-based bactericides (26). However, the occurrence of pathogenic strains tolerant to these compounds reduces their effectiveness significantly (29,36,39). As a result of the build-up in copper-tolerant strains, a mixture of copper and ethylene-bis dithiocarbamates was used to control these strains (9,24,29). Although copper-mancozeb combinations reduced bacterial populations on tomato leaves (24) and resulted in improved disease control (9,24), the combination was ineffective when weather conditions were optimal for disease development, and positive yield responses rarely were observed in situations where copper-tolerant strains were present (18). Therefore, alternative disease control strategies are needed that result in improved disease control and yield responses. Alternative strategies that have been tested and which were associated with a reduction in disease severity of bacterial spot and bacterial speck of tomato include activation of natural plant defense mechanisms by systemic acquired resistance (SAR) inducers (28,35,37) and plant growth-promoting rhizobacteria (PGPR) (14,33), and application of antagonistic bacteria (41,42) and bacteriophages (3,10,20).

Although biological control agents have been used successfully for control of crown gall, caused by *Agrobacterium tumefaciens* (7), and fire blight of pear, caused by *Erwinia amylovora* (27), their application to xanthomonads has been tested only in a limited manner. *Bacillus* spp. provided complete control of black rot on crucifer (1,2). In greenhouse studies, *E. herbicola* and *Bacillus subtilis* suppressed *X. campestris* pv. *vignicola* on cowpea and *X. campestris* pv. *vignaeradiatae* on mung bean (15,16). The only published information on bacterial antagonism by nonpathogenic strains toward the bacterial spot of tomato pathogen is that of Colin et al. (8), who determined in in vitro experiments that *Pseudomonas* spp. were antagonistic toward *X. campestris* pv. *vesicatoria*. Besides nonpathogenic bacteria, plant-pathogenic bacterial strains have been shown to be antagonistic to strains of closely related bacteria (40). T3 strains were shown to be antagonistic to T1 strains by producing bacteriocin-like compounds. The T3 strains were shown to contain at least three different bacteriocins that were inhibitory to T1 strains. Hert (17) demonstrated that two of the bacteriocins were essential for the competitive advantage of T3 strains over T1 strains. The antagonistic nature of the T3 strains (17,40) helps to explain previously published results in which T3 strains were shown to outcompete T1 strains in fields where both strains were present (17).

In order to integrate some of these methods to optimize their benefits in control of tomato bacterial spot, we studied the combined effects of SARs, PGPRs, bacteriophages, and antagonistic bacteria under greenhouse conditions (30). We identified several combinations of SARs and bacteriophages that effectively reduced bacterial spot on tomato. Based on results

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Tech Note

Sulphur as an Alternative to Copper as a Bactericide

March 2008

Bacterial Canker (*Pseudomonas syringae*) is a serious disease in a number of crops including stone fruit, and affects both the tree health and the fruit.

Bacteria are effectively controlled by low rates of copper. Copper is a useful product in that its application both controls both fungal and bacterial diseases.

Over use of any product is not the best management option. Copper treatments have been a traditional means of bacterial control and hence and it is now time to search for alternative treatments.

Research originally out of NZ points to sulphur in combination with coppers at lower rates is a possible alternative to copper for bacterial control. There are however a few cautionary notes to be observed:

- Crop sensitivities have not been established
- Varietal differences/ sensitivities within each crop have not been examined.
- Hot temperatures. Refer to copper and sulphur labels.

For this reason extreme care ought to be applied if spraying sulphur is considered.

Sulphur is also an essential nutrient for plant growth and some soils are deficient, so foliar applications are useful from both a disease management point of view and that of nutrition.

Citrus

us acid salts

, Jeffrey B. Jones

Xanthomonas euvesicatoria toma
other states in the Southeaster
vegetable crop in Florida, acco
market produced in the south
Committee, 2005). However, tom
by bacterial spot, which continu
The tomato industry in the south
1996; Bauske et al., 1998). Altho
gies have been developed rece
lenges and new opportunities to
and subtropical environmen

Corresponding author.
E-mail address: ...@ncsu.edu
Both authors contributed equally

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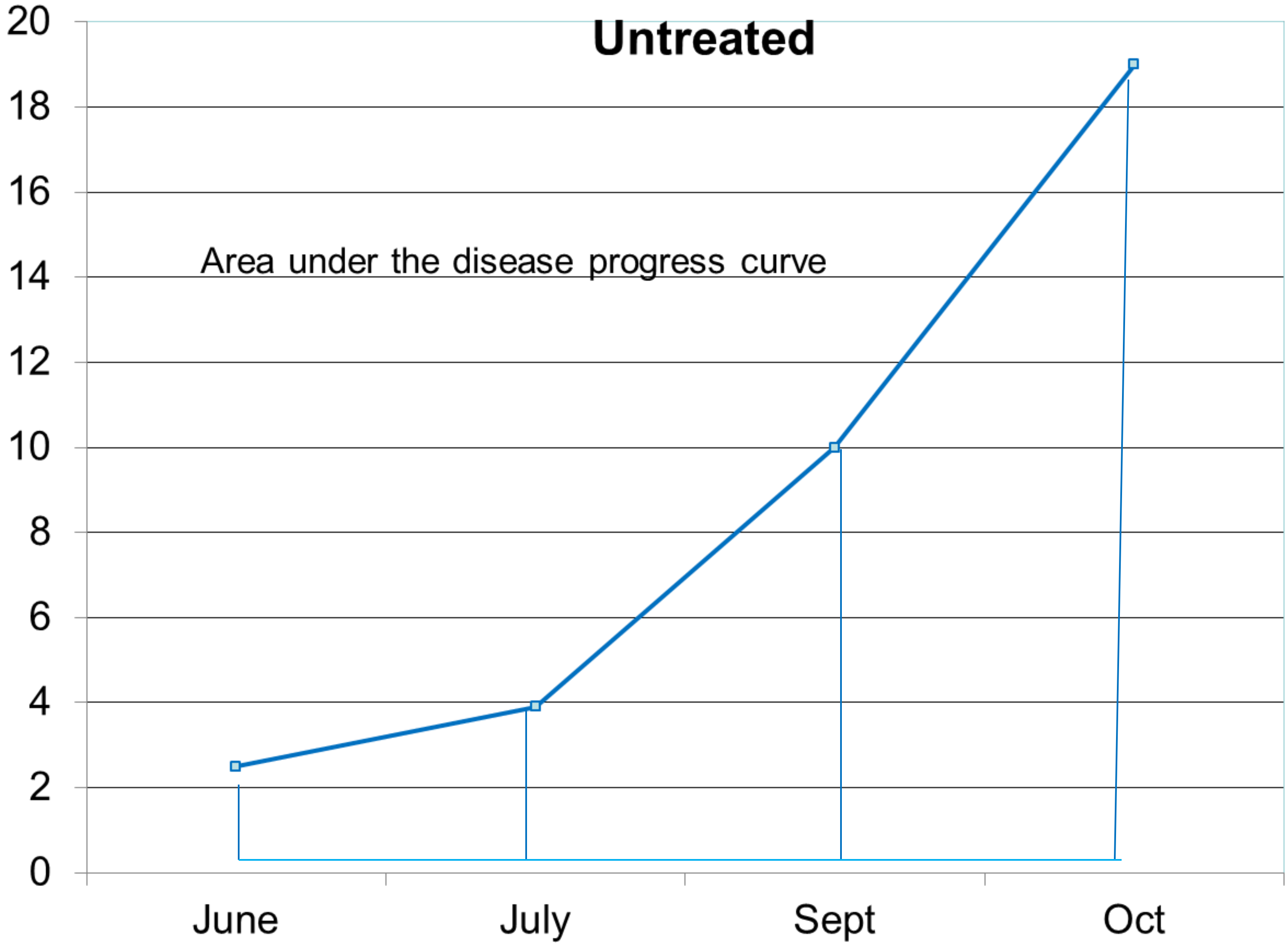
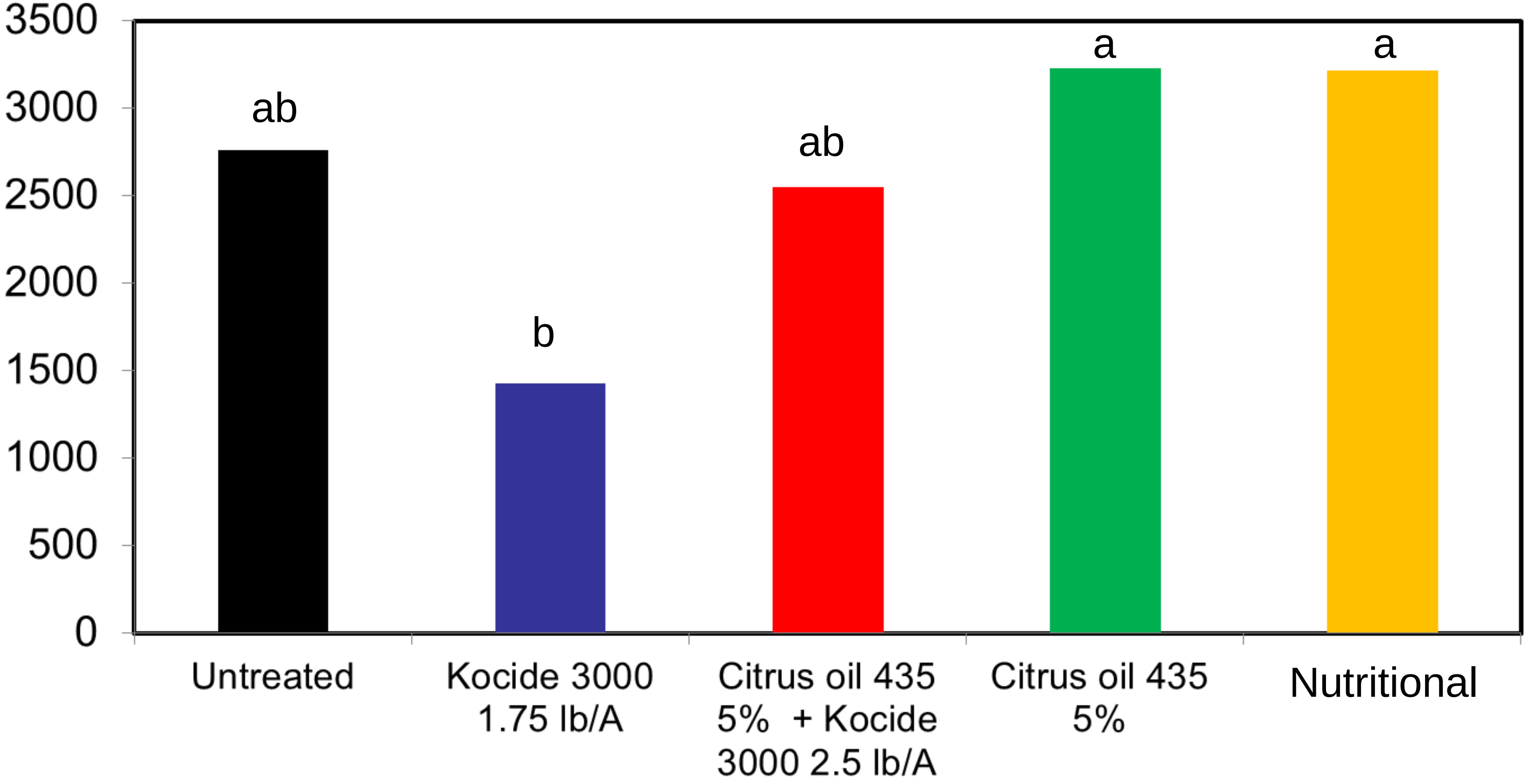
Tornato



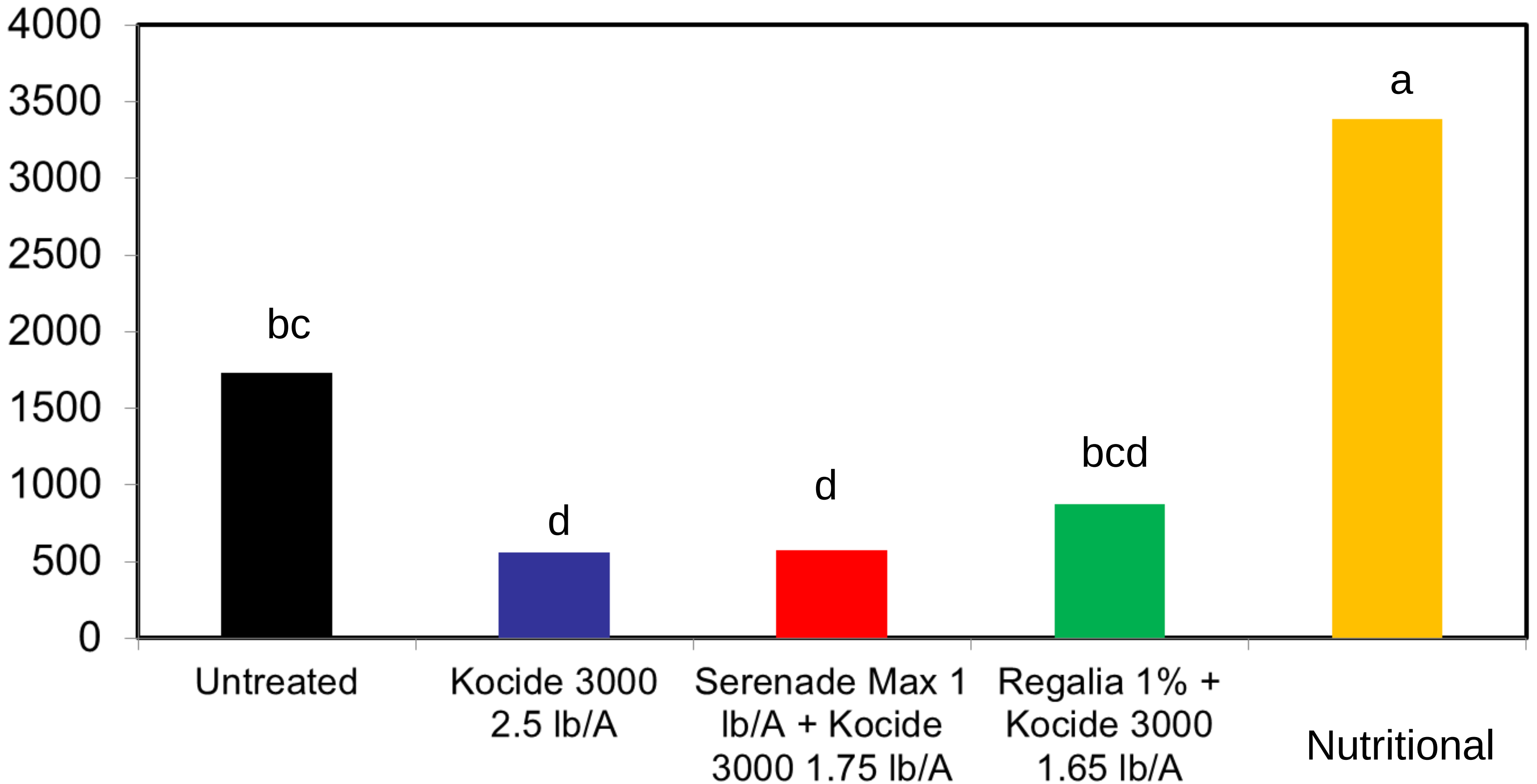
Untreated
Area under the disease progress curve
20
18
16
14
12
10
8
6
4
2
0
June
July
Sept
Oct

Fungicide	Rate (lb or oz per acre)	% Metallic Equivalent	kg AI/ha	oz AI/A
Kocide 3000	2.5 lb	30	0.841	12.0
Kocide 3000	1.25 lb	30	0.420	6.0
Kocide 3000	0.625 lb	30	0.210	3.0
Magna Bon	64 oz (100 gal prep, 250 ppm)	5	0.234	3.2
Magna Bon	51.2 oz (100 gal prep, 200 ppm)	5	0.187	2.6
Magna Bon	25.6 oz (100 gal prep, 100 ppm)	5	0.094	1.3
Copper Count N	2 lb	8	0.179	2.6
Cueva	256 oz	1.8	0.337	4.6
Badge X2	2.68 lb	28	0.841	12.0

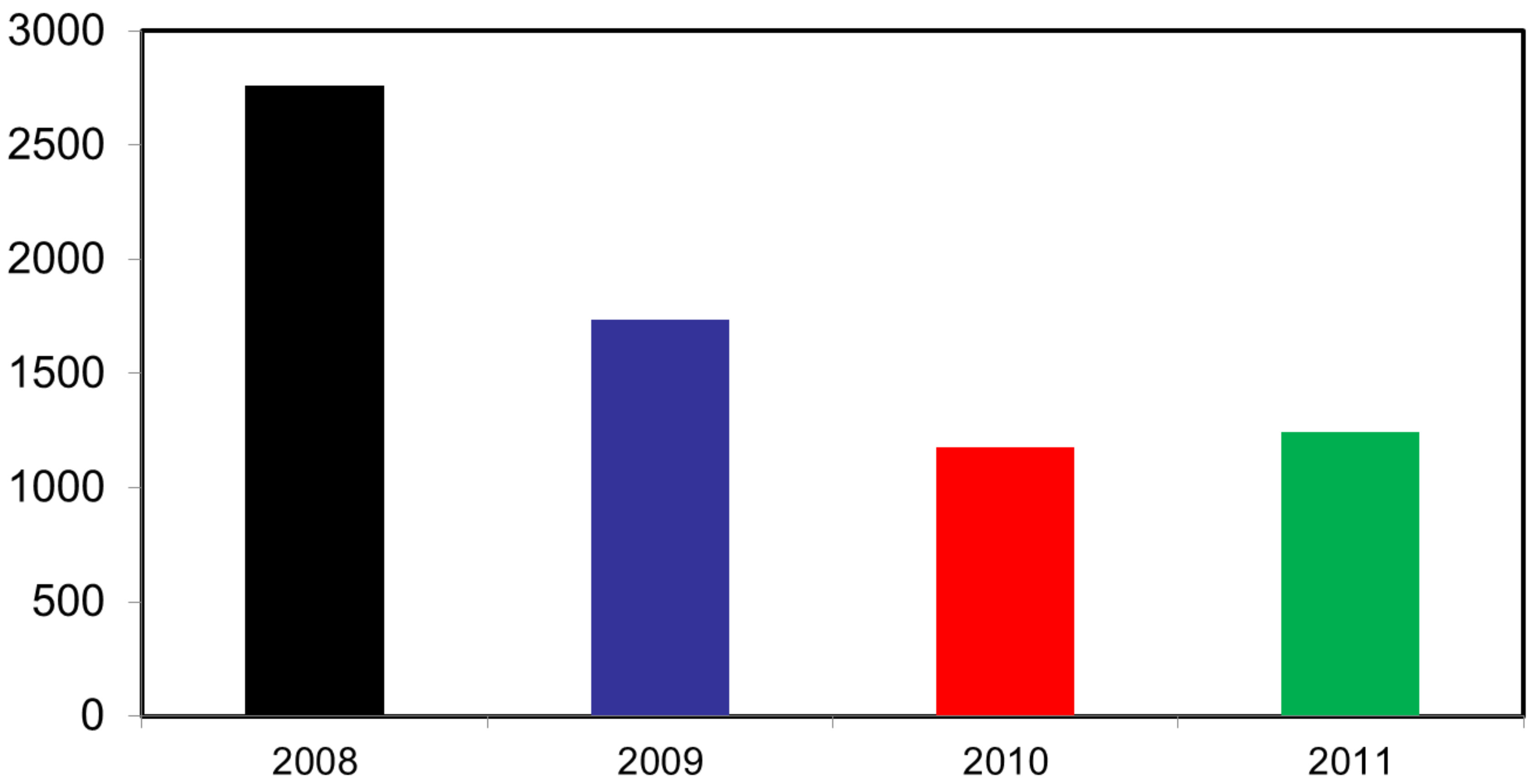
Area Under the Disease Progress Curve
Commercial Site, Valencia, 2008



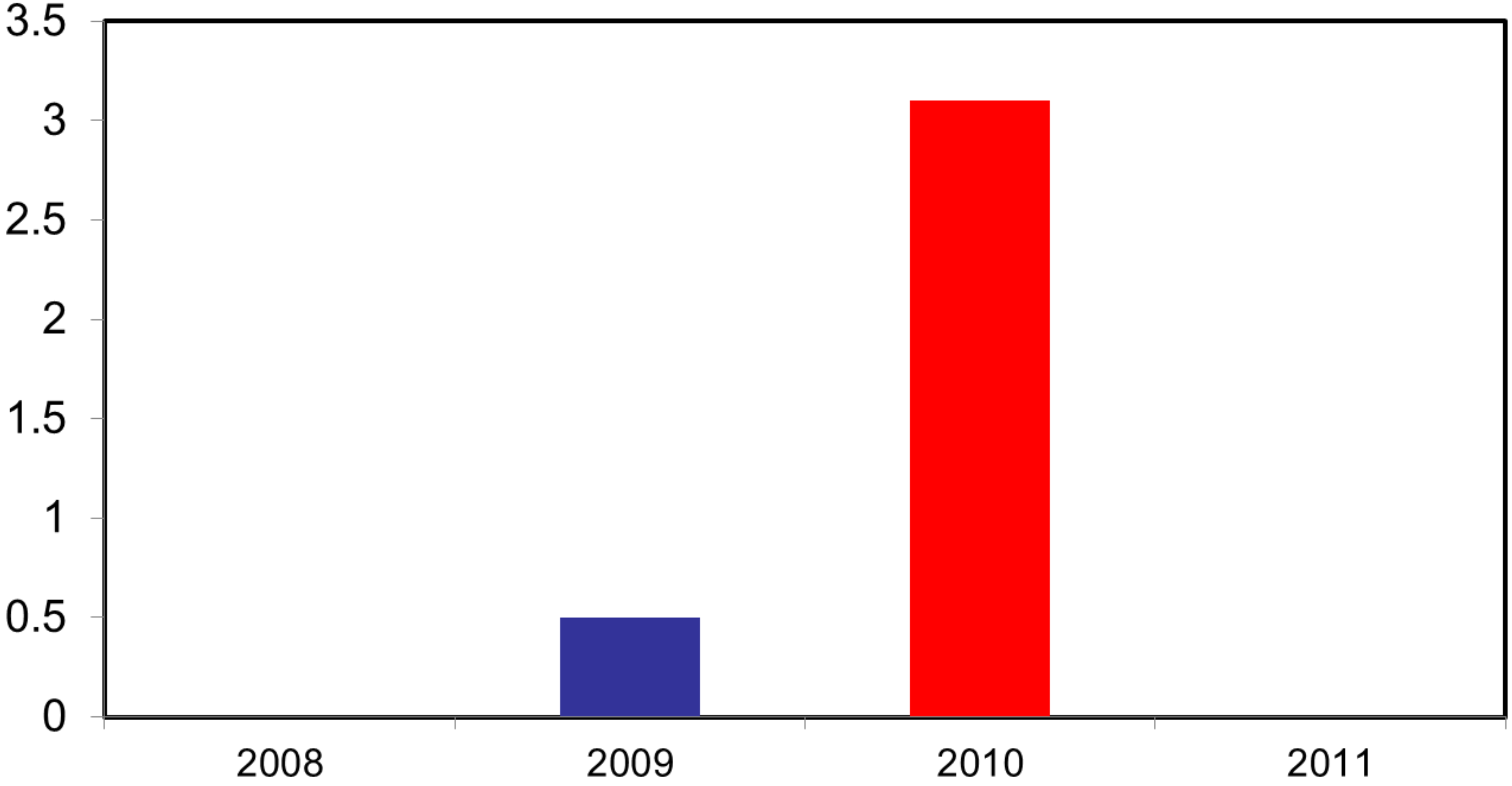
Area Under the Disease Progress Curve
Commercial site, Valencia, 2009



Area Under the Disease Progress Curve for Untreated Valencia Trees 2008-2011

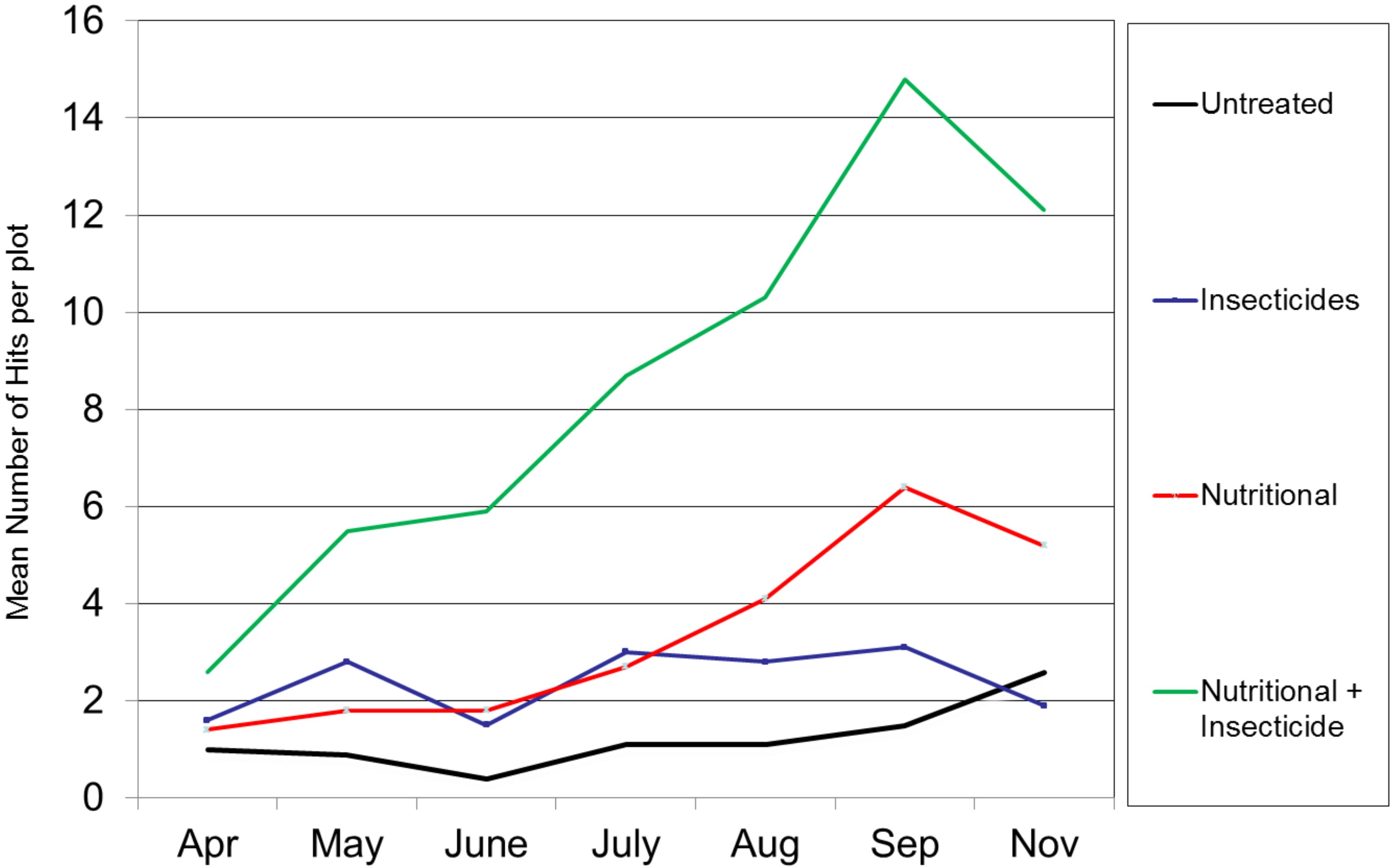


Greening rating on a scale of 0-9 in untreated plots of canker trial



Greening was interfering with canker development

Citrus Canker Disease Progress, Valencia 2011



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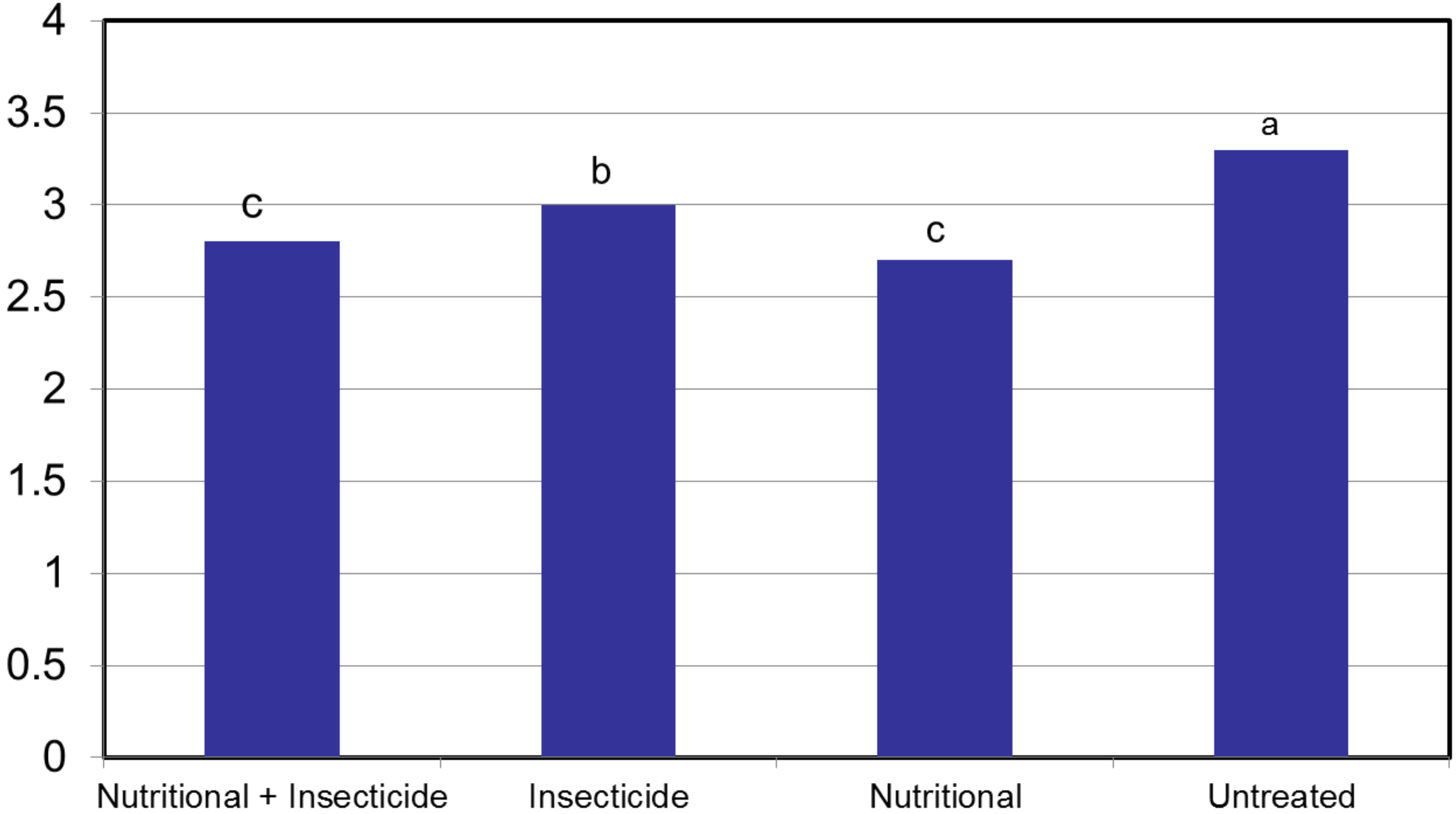
Greening Severity Ratings
0= no symptoms;9= tree dead



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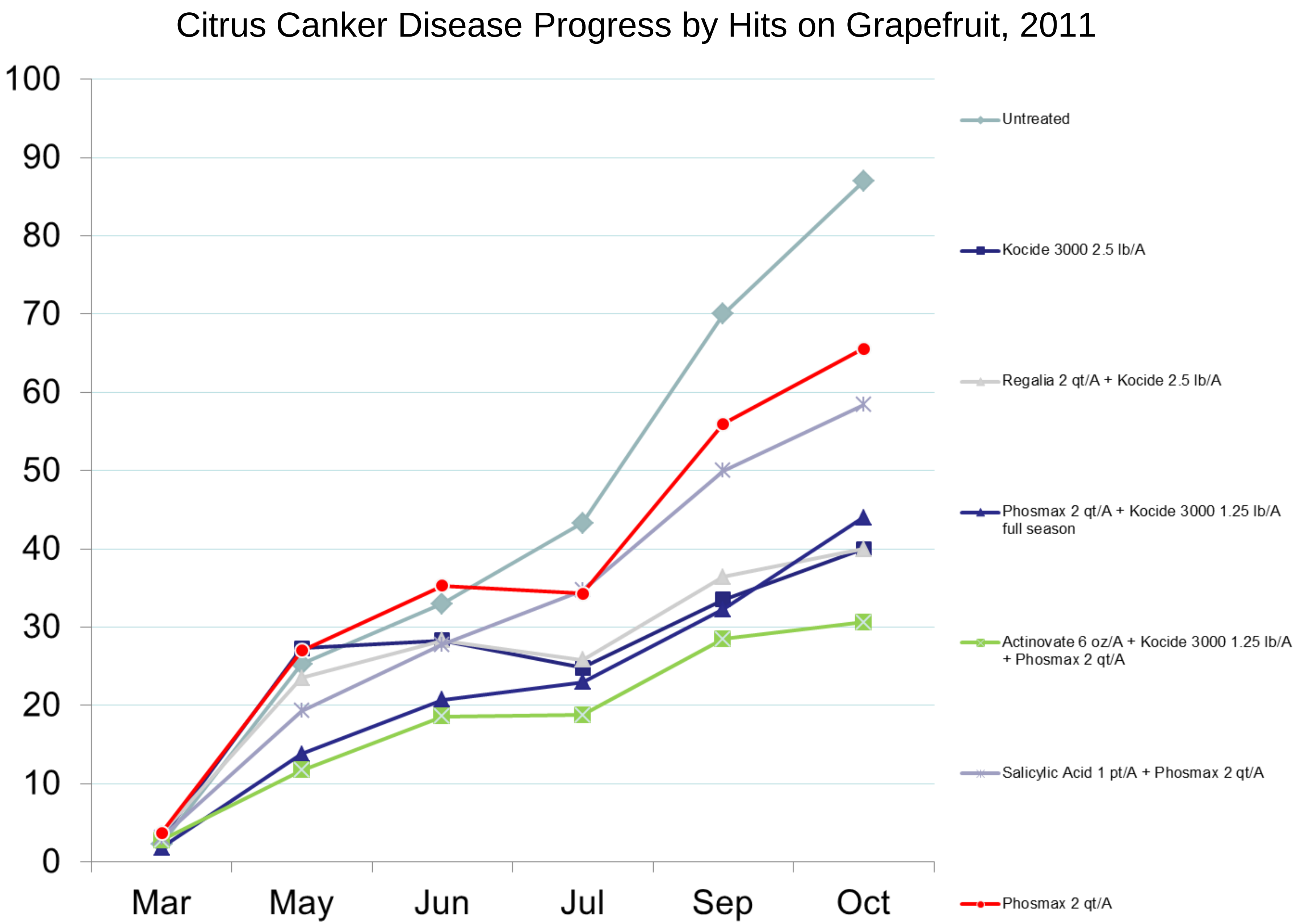
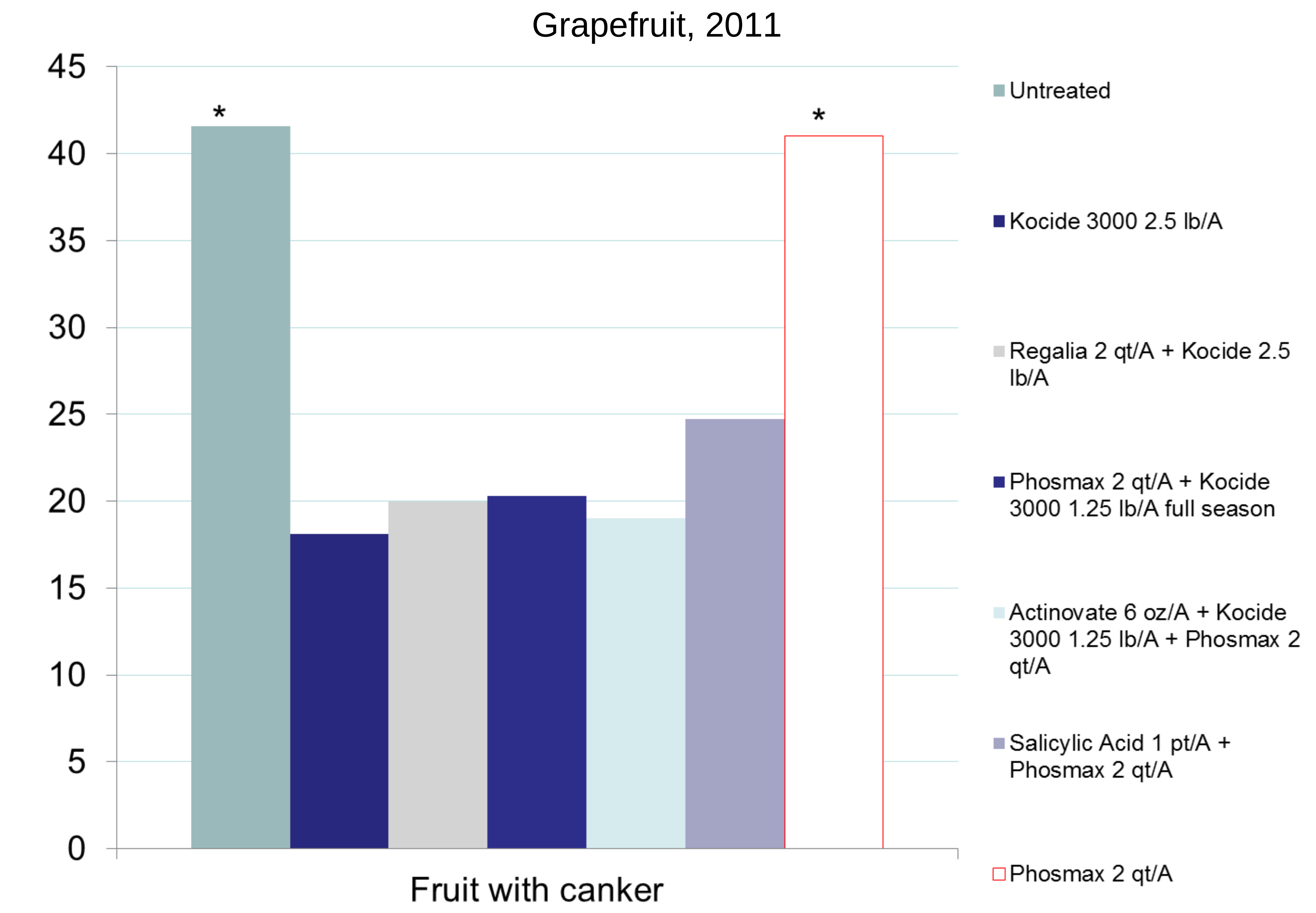

Citrus Canker Disease Progress by Hits on Grapefruit, 2011
100
90
80
70
60
50
40
30
20
10
0
Mar
May
Jun
Jul
Sep
Oct
Untreated
Kocide 3000 2.5 lb/A
Regalia 2 qt/A + Kocide 2.5 lb/A
Phosmax 2 qt/A + Kocide 3000 1.25 lb/A full season
Actinovate 6 oz/A + Kocide 3000 1.25 lb/A + Phosmax 2 qt/A
Salicylic Acid 1 pt/A + Phosmax 2 qt/A
Phosmax 2 qt/A


Grapefruit, 2011
45
40
35
30
25
20
15
10
5
0
*
*
Fruit with canker
Untreated
Kocide 3000 2.5 lb/A
Regalia 2 qt/A + Kocide 2.5 lb/A
Phosmax 2 qt/A + Kocide 3000 1.25 lb/A full season
Actinovate 6 oz/A + Kocide 3000 1.25 lb/A + Phosmax 2 qt/A
Salicylic Acid 1 pt/A + Phosmax 2 qt/A
Phosmax 2 qt/A

My reason for doing these trials to evaluate Products and Programs that are being applied to citrus to control canker or mitigate HLB

Regalia

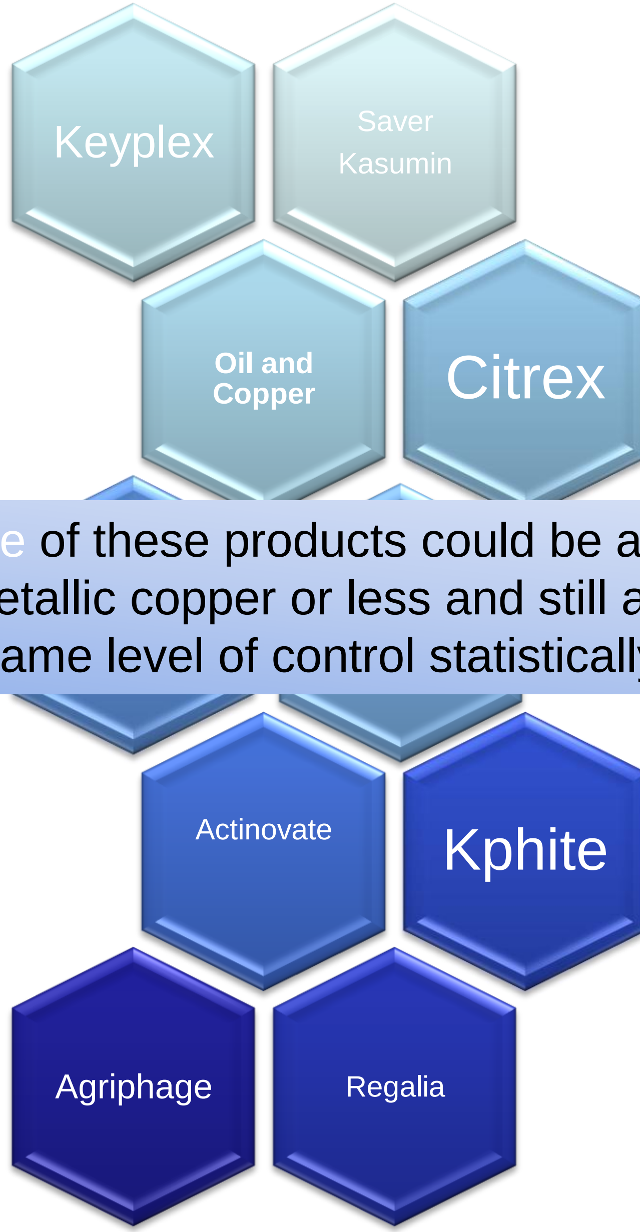
Serenade Max

Actinovate AG

Phosphorus acid

Sulphur

Zinc Oxide



In repeated testing, some of these products could be alternated or combined with 0.6 lb metallic copper or less and still achieve the same level of control statistically at

Summary

- I think that we all know that canker development is tied very closely to the environment
- However, changes in management programs for HLB will also impact citrus canker control
- Copper compounds are currently the most efficacious for canker but many other products are being used
- http://swfrec.ifas.ufl.edu/plant_path/publications/

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