A model for the spread of HLB attributed to *D. citri*

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INTRODUCTION

Abstract

A model of the transmission of HLB between the psyllids and trees in a citrus grove is developed to attempt to understand the spread of HLB in Florida. We simulate the spread of HLB in a single grove and focus on the impact of the following factors: long distance migration and local movement of the psyllid vector, vertical and feeding transmission of Las among psyllids, and the difference between the latent period (time between initial infection and the point at which psyllids can acquire the pathogens) and incubation period (time between initial infection and the point at which symptoms appear) of HLB in the trees.

We are particularly concerned with whether the vertical and feeding transmission could be a factor for the rapid rate at which Florida saw the disease spread in its early stages. We also show that if the difference between the latent and incubation period of the disease in the tree is large, then the removal of trees in a grove may not be a reasonable management strategy. One should then consider tradeoffs among combinations of interventions that involve nutrient management of trees, psyllid control, and removal of trees.

Purpose

The purpose of this model is to understand the impact of dual pathways of adult/nymph-to-nymph transmission on the dynamics of the spread of citrus greening. The dual pathway we refer to includes a pathway through transovarial transmission and a pathway due to bacterial release at common feeding sites.

Specific Questions

A. Why can you find positive psyllid nymphs when you cannot find positive plants?

B. With the difference in the latent period and incubation period, can you get ahead of the disease curve by rouging?

C. How did greening spread so quickly in Florida?

Spread in Florida

There is a fairly firm date for the beginning of the Florida HLB epidemic (~January 2000, when *D. citri* first colonized south Miami-Dade County. By 2005, symptomatic HLB was present in all of Monroe County, most of coastal Miami-Dade, Broward, Palm Beach and Martin Counties, the eastern edge of Hendry County groves that border the Everglades, and HLB was relatively easy to find along the east coast of Florida as far north as Fort Pierce in St. Lucie County. There were pockets of Las-positive psyllids in Polk County.

MODEL

Accepted Assumptions

The vast majority of *D. citri* acquire their Las from systemically infected plants.

Most effective transmission of Las to citrus trees is through *D. citri* adults who acquire Las as nymphs feeding on infectious systemically infected citrus trees.

The latent period is at least 3 months and is not the same as the incubation period.

The vast majority of *D. citri* fly 1 km or less in their lifetimes.

	Model I	Model II
Latent & Incubation period	✓	✓
Short distance migration	✓	✓
Long distance migration	✓	✓*
Acquisition of Las through feeding	✓	✓
Vertical Transmission		✓
Adult/Nymph to Nymph		✓

*we are able to account for infections in this manner, whereas previously it was an assumption

Conjectures

Transovarial transmission of 2-6% (Pelz-Stelinksi *et al.* 2010) allows for a growing population of infected psyllids on the infectious tree and nearby healthy trees.

Acquisition of Las by *D. citri* nymphs through feeding at the same site as infectious adults or nymphs on healthy trees**.**

A percentage of adult psyllids migrate over longer distances. ~90 to 124 km (Gottwald *et al.* 2007)

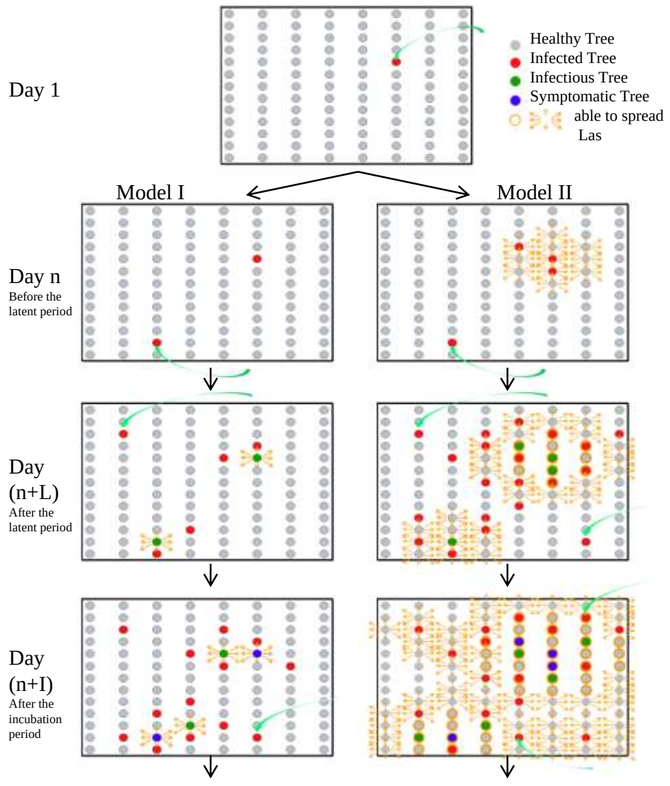
Photo by Michael E. Rogers

Design

• Random appearance of infected psyllids are due to the long distance migration occurs daily at a specified rate.

• Nearby infections occur in two ways: in Model I this only occurs from infectious and symptomatic trees. In Model II this may also occur from healthy and infected trees through the dual pathways mechanism.

Procedure



RESULTS

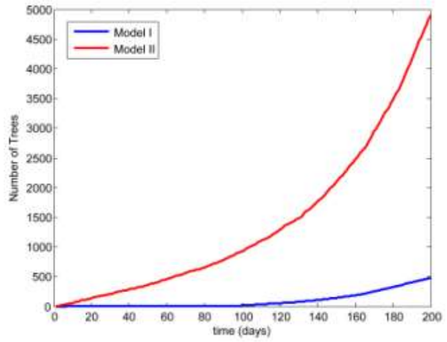


Figure 1: Trees Producing Infected Adults

Figure 1 compares the standard model (blue line) having latent period 90 days with the proposed model (red line) having dual pathways of adult/nymph-to-nymph transmission in a simulated grove with 10,000 trees.

Figure 2 uses the standard model to compare the status of trees in a grove at the end of 240 days. The incubation period of 180 days is kept the same in both simulations while the latent period is taken to be 150 days and 90 days in Figures 2 (a)-(c) and (d)-(f), respectively.

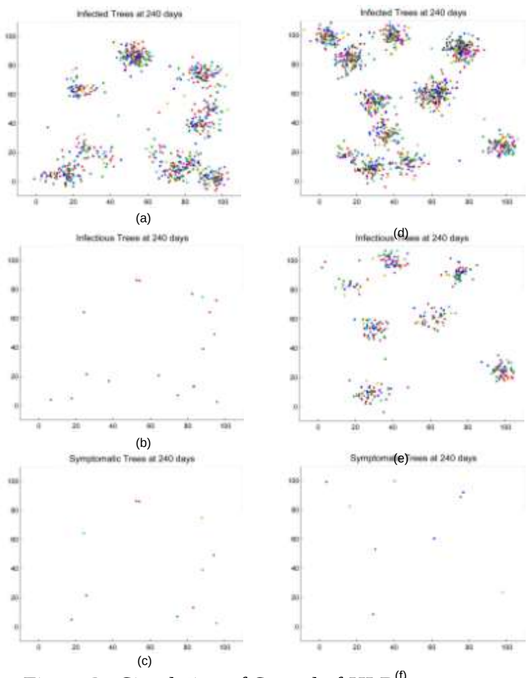


Figure 2 : Simulation of Spread of HLB in a grove

DISCUSSION

Consequences

A. The dual pathway for adult/nymph-to-nymph transmission allows infected psyllids to develop on healthy trees. We hypothesize that the bacterial release at feeding sites is enough to cause transmission among the psyllid population and not necessarily to the tree.

B. The rate of spread of the disease with the dual pathway transmissions does not depend on the latent period of the disease in the tree. The latent period is the period of time between initial infection of a tree and the time when another psyllid can acquire the pathogens from the same tree.

C. Using the standard model with less infected psyllids in a grove, Figure 2 shows that the removal of symptomatic trees is not effective since there would be a large number of infected (a,d) and infectious trees (e) remaining.

D. The rapid increase in the number of infected psyllids within a grove provides a reservoir to facilitate inter-grove spread by a diversity of mechanisms.

Limitations

The transmission rates for the dual pathway are unknown. There is only one source for the presence of transovarial transmission and only speculation for the adult/nymph-to-nymph feeding transmission.

Future Directions

Develop control strategies including psyllid control, clean nursery stock, agronomic management, and new methods that capitalize on the plant's ability to resist disease development.

Supplementary Information

http://www.math.ufl.edu/~joann5/CitrusGreening.html