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An Introduction to Citrus Greening and a Host-Vector Model with Roguing

Huanglongbing (HLB), commonly known as citrus greening disease, is a vector-transmitted bacterial disease that is significantly impacting the citrus industry in Florida and poses a great risk to the remaining citrus-producing regions of the United States. This is a very important issue because Florida is the nation's largest citrus producer and the second largest producer of orange juice in the world. A recent study by the University of Florida's Institute of Food and Agricultural Sciences estimates that from 2006 to 2011 citrus greening has caused $3.63 billion in lost revenue and over 6,000 lost jobs in the state. The five-year production level for orange juice is estimated to be 1.7 billion gallons less than projected. In addition to Florida, the presence of HLB has also been detected in other southeastern states as well as in Texas and California.

An insect known as the Asian citrus psyllid, Diaphorina citri, carries the organism that causes citrus greening, Candidatus Liberibacter asiaticus (Las). An infected psyllid carries the bacteria in its saliva and infects a healthy tree when it feeds. Similarly, a healthy psyllid can get the bacteria from a diseased tree. Observations suggest that once a tree becomes infected, it may remain asymptomatic for six months to six years, contributing to the difficulty in controlling the disease. While an adult psyllid can usually only fly a mile, citrus greening has been able to spread throughout almost the entire state of Florida due to the transportation of infected citrus stock by discount stores. Recent findings also support the idea that the disease is transmitted transovarially and sexually amongst the psyllid population. This would help to explain why the disease has spread so rapidly.

Multiple control strategies have been used, such as applying insecticides to groves and administering antibiotics to affected trees. However, in addition to being very costly, none of these techniques have been completely effective so far. Another method is to rogue (or remove) an infected tree and replant a healthy tree in its place. We have developed a mathematical model for the host and vector populations within a single grove of trees which uniquely incorporates roguing as a control strategy. Our model includes four stages for the trees (susceptible, infected but asymptomatic, infected and symptomatic, and dead) and two vector stages (susceptible and infected). Roguing is incorporated in both the symptomatic and dead states, and then the replanted trees can enter either the healthy or asymptomatic states.

Our analysis of the model includes finding the equilibria and calculating a condition for existence of positive endemic equilibria. We also calculate the basic reproduction number R_0 using the next-generation matrix method. Since there are many different definitions of R_0, we show the equivalence of our mathematical basic reproduction number to one with a biological interpretation. Finally, we look at a variation on the term that represents transmission of the disease between trees and vectors. If either the psyllids or trees are considered as a limiting factor, the new transmission term yields only slight changes in our R_0 value.