A model of biological control of plant virus propagation with delays

Mark Jackson, Benito M. Chen-Charpentier

PII: S0377-0427(17)30009-2
DOI: http://dx.doi.org/10.1016/j.cam.2017.01.005
Reference: CAM 10970

To appear in: *Journal of Computational and Applied Mathematics*

Received date: 14 October 2016
Revised date: 28 December 2016

A Model of Biological Control of Plant Virus Propagation with Delays

Mark Jackson[1], Benito M. Chen-Charpentier[1,*]

[a]*Department of Mathematics, University of Texas at Arlington, Arlington, TX 76019-0408.*

Abstract

Plants are a food source for man and many species. They also are sources of medicines, fibers for clothes and are essential for a healthy environment. But plants are subject to diseases. Many of these are caused by viruses. In plants most the virus propagation is done by a vector, usually insects that bite infected plants and the susceptible plants. Chemical insecticides are commonly used to control the insects, but unfortunately these chemicals have toxic effects on humans, animals and the environment in general. An alternative is to introduce a new species, or just increase the number of a naturally present one, to prey on the insects and thus control their number. The different steps in the virus propagation process take take. In this paper we add a predator to a plant-virus propagation model with delays. The model is based on delay differential equations. There are five populations: susceptible and infected plants, susceptible and infected vectors, and predators. The infected vectors have no ill effects from the virus so they do not fight the virus and therefore they do not recover. The predators do not get sick from the virus. The total number of plants is assumed to be constant since for crops the framers will replace the death plants and one of the plant populations can be determined using the total constant plant population. Therefore we have a system of five delay ordinary differential equations in five unknowns. We assume that predators are introduced at the initial time and after their growth rate has a Holling 2 type dependence on the number of vectors. We consider two delays: the time it takes from the moment a plant is bitten by an infected vector to the moment the plant is infected; and a second smaller delay for the time from the moment a vector bites an infected plant to the moment the vector becomes infected. We determine the non-negative steady state solutions of the system of delay differential equations. We analyze their stability by calculating the eigenvalues of the linearized system about each equilibrium point. We do numerical simulations for certain values of the parameters. Finally we search for bifurcation points numerically using the software package biftool. Conditions are presented for which the disease is controlled or even eliminated. From the practical side, the model can be used to determine the amount of introduced predators necessary to eliminate the epidemic under different conditions.

Keywords: delay differential equations, plant virus propagation, mathematical modeling

1. Introduction

Plants play a vital role in almost every ecosystem on the planet. Sometimes plants may become infected with a virus. These infections can be devastating to not only the plants themselves but also the ecosystem that depends on them. Also, plant virus infections can have a negative impact on the crops necessary for human survival. For example, the cassava plant, which is a staple in many underdeveloped African countries, is susceptible to the cassava mosaic virus. This virus has ravaged plants in Kenya, Uganda and Tanzania [6]. Another serious example of plants that have been infected by viruses are tomato plants in India. These viruses cause tomato leaf curling disease (TLCD). This disease causes the leaves of the plants to curl and possibly become sterile [6].

Viruses need a method of transportation to move from one plant to another. Typically an insect vector this is the mode of transportation. In fact, insects are responsible for 70 percent of all plant virus transmissions

*Author for correspondence
Email addresses: mark.jackson@mavs.uta.edu (Mark Jackson), bmchen@uta.edu (Benito M. Chen-Charpentier)