MATHEMATICAL MODELING OF OPTIMAL BIOLOGICAL PEST CONTROL STRATEGIES FOR EFICIENT AND SUSTAINABLE SUGARCANE PRODUCTION

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Ethanol is a good choice as a fuel and additive because it is produced from renewable resources; promises cleaner combustion leading to a cleaner environment; produces relatively low levels of green-house gas emissions over its lifecycle; can be seamlessly integrated into the existing transportation system; provides a new outlet for agricultural products; reduces the global dependence on depleting reserves of crude oil; and has a potential to have a large-scale impact. The increase in world demand for ethanol will bring an increase of the sugarcane planted in Brazil. One of challenges of the improvements in the farming and harvesting of cane is the biological pest control. In spite of the biological control of *Diatraea saccharalis* by *Cotesia flavipes* is considered successful in Brazil , there are some areas where *Cotesia flavipes* has not the good control. The using of the parasitoid *Trichogramma galloi* is considered an interesting option in this case. In other hand, the dynamics of pest – parasitoid populations become complex, making the prediction of outbreaks difficult. Understanding the processes of these interactions can lead to a mathematical modeling playing a decisive role in controlling pest populations and contributing to the stability of natural systems.

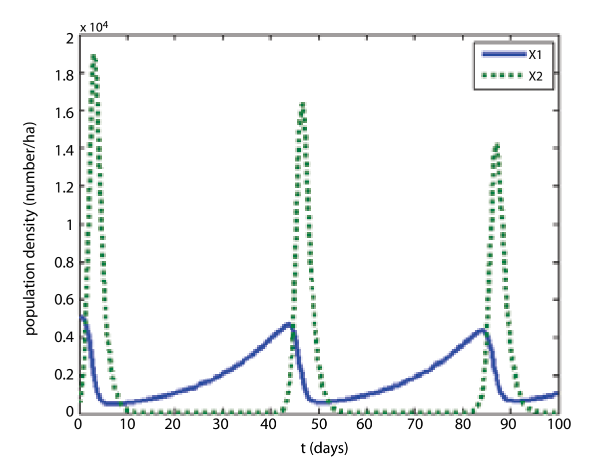

Figure 1. Evolution of sugarcane borer and parasitoid populations without control according to the mathematical model (Rafikov, Angeleli, 2009)

The main aim of this project is to apply methods from optimal control theory and from the theory of dynamic systems to the mathematical modeling of biological pest control strategies.

The specific aims of this project are: modify existing and/or develop new mathematical models adequate to represent interactions between the sugarcane pests and its enemy populations; identify coefficient and parameters of proposed mathematical models and determine the equilibrium level of sugarcane ecosystems from mathematical models; formulate and solve the biological pest control in sugarcane as optimal control problem that determine algorithms of the optimal strategy, minimizing cost functional; elaborate the computational tools based on above mentioned algorithms; undergo numerical simulations for different possible scenarios of biological pest control in sugarcane based on the mathematical models.

SUMMARY OF RESULTS TO DATE AND PERSPECTIVES

The main objective of the biological pest control is to maintain the pest population in an equilibrium state below the economic injury level. Thus, parasitoids and predators are commonly reared in laboratories and periodically liberated in high-density populations (inundative biological control) when the pest population reaches a control level.

For the modeling of first possible scenario, the ecosystem sugarcane borer – its parasitoid was described by two differential equations. For numerical simulations of interactions between the sugarcane borer (*Diatraea saccharalis*) and its parasitoid (*Cotesia flavipes*) were identified the values of model coefficients based on data from literature. *Figure 1* presents the population oscillations without control according to the mathematical model.

The numerical simulations show that the inundative control, applied in initial moment by introduction 20000 parasitoids/ha, maintain the pest population below the economic injury level (2500 pests/ha) only 35 days. After this period, it is necessary to apply the control again.

In order to determine algorithms of the optimal strategy of introduction of the natural enemy species, the biological pest control in sugarcane was formulated and solved as optimal control problem. The linear feedback control is designed to drive the ecosystem sugarcane borer – its parasitoid to the equilibrium state below the economic injury level, as shown in *Figure 2*. Numerical simulations showed that the great amount of parasitoid have to be introduced in initial instance. This fact suggests that the proposed feedback control strategy can be integrated into existing biological control technologies, applying the feedback control after the traditional inundative pest control. This control strategy directs the ecosystem to the stable equilibrium point. It is not necessary to apply the periodic releases or a seasonal introduction of a small population of natural enemies after this control application.

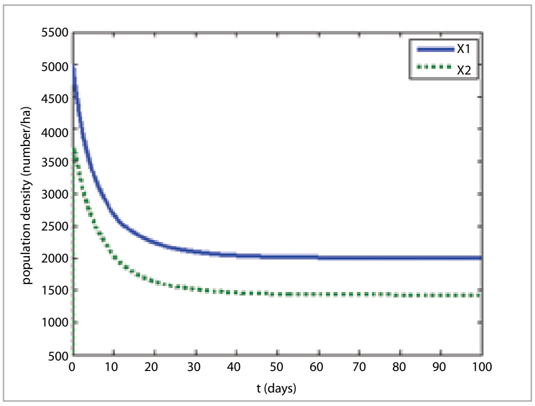

Figure 2. Evolution of sugarcane borer and parasitoid populations with optimal control (Rafikov, Angeleli, 2009)

The next steps of this project will study scenarios which consider age structures of populations and interactions between the sugarcane borer and two parasitoid species.

MAIN PUBLICATIONS

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