



Study of Prey–Predator System with Additional Food and Effective Pest Control Techniques in Agriculture

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Abstract

The protection of crops from pests eventually contributes to increase crop yields. In this study, we build a mathematical model for prey–predator and describe an ecosystem that includes crops, susceptible pests, infected pests, and natural enemies of the pest. Further, the dynamic behavior of the framework, the description of steady-state equilibrium behavior, and pest control are discussed. The basic reproduction number and sensitivity analysis are addressed to determine the most influential parameters. Furthermore, a comprehensive analysis of the optimal control strategy is performed. The study discusses the strategic planning of pests, which provides optimal control of pests in contexts of operating costs and ecological harm. Pontryagin's maximum principle is used to develop an optimal strategy for pest control. Finally, numerical simulations are carried out to support the analytical results and explain the various dynamic systems that are used in the model.

Keywords Prey–predator · Crop · Pest · Optimal control · Pontryagin's maximum principle

1 Introduction

Food wastage caused by pests and crop disease has become one of the massive food issues, especially in developing nations. The United Nations has stated that the global population was recorded at 7.2 billion in 2014, an approximate annual growth rate of 82 million, with a quarter of that in low-income nations (United Nations Concise Report on the World Population Situation 2014). This enormous number of people worldwide poses serious problems for food producers and policy experts, particularly in terms of decreasing yield losses caused by pests and crop diseases, estimated to be as large as 40% of global output. All kinds of vegetables and crops are our primary source of livelihood, but land resources are limited.

However, several tiny insects, weeds, and living organisms contribute to the loss of these essential crops. There are so many bacteria, fungi, viruses, etc., that cause damage by infecting crops. Managing these is one of the world's biggest challenges (Peshin and Dhawan 2009). Table 1 demonstrates the overall worldwide output of grain from 2010–11 to 2016–17 and the prediction for the 2017–18 and 2018–19 [<https://www.statista.com/statistics/271943/total-world-grain-production-since-2008-2009/>] (Table 1).

Here, an overview is presented on various kinds of crop damage. For the duration 2001–03, among crops, the total worldwide massive loss due to pests varied from nearly 50% in wheat to more than 80% in cotton yield. Actions are recorded as falls off 26–29% for soybean, wheat, and cotton, and 31, 37, and 40% for maize, potatoes, and rice, respectively. Overall, seeds recorded the largest potential damage (34%), with animal pests and pathogens being less significant (losses of 18 and 16%) (OERKE 2005). As per a study by US Agriculture and Natural Resources scientists and other representatives of the International Society for Plant Pathology, organizations recognize that they are losing agricultural productivity for five major food crops by 10–40% due to pests. The factors that work against growers include viruses, bacteria, fungi, oomycetes,

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