ABSTRACT

To better understand disease dynamics within plant ecosystems and develop effective management measures, **Chapter 3** discusses the foundational elements and contributions of plant eco-epidemiological models. The mathematical model of disease dynamics is highlighted as a tool for understanding the complex relationships between ecological factors and disease dissemination. The eco-epidemic model incorporates all relevant plant populations, pesticide rate variables, and disease dynamics, making it easy to study epidemic development and disease management. The plant formulation model is based on the assumptions that plant populations are either susceptible or infected, that pesticide and pesticide quantities respond linearly, and that system solutions have positivity and boundedness. The study uses mathematical and computer simulations to explain in detail the effectiveness of disease transmission and intervention approaches for decreasing plant rates. The findings demonstrate the need for mathematical models, along with ecological and epidemiological research, to develop disease management techniques that are effective in agricultural environments. The study contains information about eco-epidemiological processes, as well as agricultural and ecosystem management.

In **Chapter 4**, a model of a pesticide-plant epidemic using nonlinear ordinary differential equations (ODEs) and the Holling type II functional response is utilised to analyse the disease spread dynamics within infected and susceptible plant populations. The basic reproduction number (R_0) and equilibrium points, such as disease-free and disease-endemic equilibria, are calculated using the model to determine system stability. Disease stability analysis says $R_0 < 1$ signifies no diseases in equilibrium, and $R_0 > 1$ denotes endemic diseases. Transfer rates, repair rates, and pesticide effectiveness were used as examples of crucial factors in pesticide analysis to understand how diseases spread and how to prevent them. The high sensitivity to transfer rates, which demonstrates the effectiveness of interventions aimed at curbing disease transmission, highlights the need for improving pesticide usage. Disease sensitivity to host population factors stresses ecological factors in disease dynamics. Numerical simulations support analytical results. To better manage diseases, the study examines focused interventions tailored to ecological circumstances. A sensitivity analysis-led approach to disease decision-making

may assist researchers in making better choices to increase the effectiveness of efforts to manage diseases and sustain healthy farmland and ecological balance.

Using ordinary differential equations (ODEs), **Chapter 5** describes and looks at a compartmental SIR (Susceptible-Infected-Recovered) model of a plant-pesticide ecosystem. The eco-epidemic model divides plant populations into susceptible, infected, and recovered. Pesticide application is a control method. Ecosystem-plant dynamics are employed in the model to demonstrate how pesticide usage affects disease transmission in groups of plants. The study reveals that the model is biologically valid, with extensive mathematical analysis. The emphasis is on model positivity, boundedness, existence, solution uniqueness, and equilibrium states. The basic reproduction number (R_0) influences whether a disease disappears or persists. Control measures are the lowest at this number. Numerical simulations using MATLAB R2015a show how the dynamics of the model alter with different starting circumstances and parameter choices. The results reveal that pesticide intervention affects the delicate balance between infected and susceptible populations, which converges to an endemic equilibrium. Studying the infective-induced rate of pesticides (θ) and contact rates (d_1 and d_2) in further detail might help identify crucial limitations that result in a supercritical Hopf bifurcation. Population dynamics in this scenario have altered from stable to wavelike. These findings demonstrate the intricate relationship between disease dynamics and pesticide application, emphasising the need for accurate pesticide measures. This study advances the subject of eco-epidemiology, especially with reference to sustainable agricultural methods and efficient disease management in plant populations.

In order to examine the dynamics of plant populations and herbivores, **Chapter 6** presents a deterministic mathematical model for studying the dynamics of plant populations and herbivores, integrating the application of pesticides as a control strategy. The model encompasses susceptible and infected plants, along with a single herbivore population, with the objective of investigating their interactions and dynamics. Pesticides are utilised to target both susceptible and infected plants, aiming to curtail the spread of infections within plant populations. The analysis of the model includes considerations such as positivity, boundedness, uniqueness, and the existence of solutions, as well as system permanence, ensuring its biological validity. The basic reproduction number (R_0) of the infection is determined, indicating stability conditions for the disease-free equilibrium state. Additionally, a necessary condition for the existence of optimal controls is derived using Pontryagin's Minimum Principle. Numerical simulations are conducted to validate analytical findings, ultimately contributing novel insights to the field of theoretical ecology.

Chapter 7 examines the existence and uniqueness of solutions to the model equations developed in **Chapter 4**, with a particular emphasis on plant population dynamics under pesticide application. Mathematical analysis accomplishes this by identifying the conditions that ensure the existence of these solutions and their uniqueness. In addition to this, the chapter explores optimal control strategies for regulating the dynamics of plant populations. The objective is to strike a balance between the advantages of pesticide use and the concerns of the environment and the economy. These findings not only add to a more in-depth understanding of plant population control in agricultural systems, but they also provide crucial insights into the methods of pesticide administration that are environmentally responsible.