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Stability Analysis and Optimal Control of Plant Fungal Epidemic: An Explicit Model with Curative Factor

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Abstract. Many plants could not escape from diseases caused by fungi. The use of fungicide can help to reduce the spread of the fungi but if it used continuously with the same dosage, the fungi would be invulnerable to fungicide eventually. Hence, it is critical to know the appropriate level of fungicide application and its impact on the dynamics of the plants. In this paper we use an explicit model of fungal outbreaks of plant by taking into account a curative factor including the dynamic of fungicides itself. Granting of fungicide on crops is useful to control the infected plants as well as protecting the vulnerable plants. Optimal control is used to find out how many doses of the appropriate fungicide should be used to cure infected plants. Optimal control is obtained by applying Pontryagin's Minimum Principle. We found that the presence of appropriate level of fungicide speeds up the reduction of infected plants as well as accelerates the growth of healthy plants.

Keywords: Fungus, plant growth dynamic, fungicide, stability analysis, optimal control, Pontryagin minimum principle.
PACS: 02.30.Hq, 02.30.Yy.

INTRODUCTION

Fungal plant disease is commonly found in agriculture. An example of the disease is anthracnose disease, which often attacks the chilli pepper (*Capsicum annuum*). Anthracnose disease is caused by the fungus *Colleotrichum gloeosporiodes* and *Colleotrichum capsici*. The disease causes a failure for the plants to germinate, dieback, stem and leaf dry rot, and also causes dark brown spot in the fruit of the plants and soft rot. There are many ways known to control the disease such as the selection of the seed before planting, maintaining sanitation around the plants, spraying the plants with fungicides, perform post-harvest processing [1].

Of the various ways of prevention of this disease, farmers often use a fungicide to accelerate the reduction in fungus-infected plants. But farmers do not know how much fungicide should be used effectively and efficiently. This practice often results in an unwanted situationthat over time the fungus can become resistant to fungicides used by farmers. With the cost of fungicide application is not small, it can be detrimental to the farmers themselves.

Many disciplines are trying to tackle this problem, not least the mathematical sciences. The role of mathematics is usually in modeling and simulating the problem. It is common in mathematical modeling to study the spread of the disease via an SIR epidemic model, which assumes that the plants population is divided into three compartments, namely *susceptible, infected,* and *recover*. Since usually farmers prevent the spread of the fungus by giving fungicide before visible signs of fungus-infected plants, so that some plants become protected, then the SIR epidemic model is often modified into an SIP epidemic model, where P stands for *protected*. The SIP model is a model which not only considers the cure of the plants from the disease but also considers the protectionof the plants from the fungal attack [2].

The study of plant epidemic models which involve fungicide often discusses the dynamics of protectant (fungicide) by the simple expedient of changing some of the parameters of the existing epidemic models [3], the effect of the use of different assumptions in plant populations and the dynamics of plant diseases [4]. The authors in

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