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[F] PhD Extended Abstract Form *(Please select the Calibri 10 typeface)*

FULL PhD THESIS TITLE

Simulation of Interactive Heat and Disease Affected Tree Inside Mobile Heat Treatment Canopy Cover; HLB Affected Citrus Tree in Florida as Case Study

by *[Name Surname]*
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Extended Abstract

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The insect-spread bacterial infection known as Huanglongbing (HLB) or citrus greening is a very destructive citrus disease. HLB has caused massive losses in Florida's citrus industry since 2005. Research has shown that heat treatment slows down the progress of this disease and increases the production life of HLB-affected trees. However, applying this method in the field, especially in orchards, can be difficult due to technical complications with regards to total coverage of large trees.

The long term objective of this research was to develop a mobile heat treatment system to heat treat individual HLB-affected citrus trees under field conditions. Based on previous studies, the system was designed to produce heat inside a canopy cover that covered a whole citrus tree, raising the internal temperature to 54°C and treating the tree for 90 s. The system was able to increase the heat inside the canopy cover using different heat sources by either releasing steam or a combination of steam and hot water. A series of experiments were conducted to assess the uniformity of heat distribution within the tree canopy and the time to reach an appropriate temperature utilising two treatment types: Steam Treatment (ST) and Hot Water & Steam Treatment (HWST). Results indicated that the uniformity of heat is similar with both treatment types, while the average time for the entire treating process was 63% shorter when using HWST compared to ST. Furthermore, HWST reduced energy consumption by 52% compared to ST.

In addition, we illustrated the ability of Computational Fluid Dynamics (CFD) as an engineering design tool to predict the indoor air flow and heat distribution in a canopy cover. Utilizing the model can significantly reduce costly experimental time to evaluate the aforementioned device. Although the simulation results had consonance with the experimental data, there were many simplifications in that simulation and further research is necessary to improve the design of the system while eliminating those simplifications.

Since, HLB is caused by an insect-transmitted bacterial pathogen, Candidatus Liberibacter asiaticus (CLas), which is a fastidious and non-cultivable organism, survival rates of surrogate bacterium, Klebsiella oxytoca were measured in order to evaluate the effectiveness of a mobile thermotherapy delivery system developed for in-field treatment of HLB-affected trees. K. oxytoca is a Gram-negative, rod-shaped bacterium that was originally isolated from soil and has been used in the development of industrial applications related to ethanol fuel production. It served as a biologically-based sensor of temperature stress (biosensor) in this study. Thermocouples and packets containing the K. oxytoca were attached to an HLB-affected citrus tree and their canopy locations mapped. The survival rate of the applied biosensors was found maximally 5% with a maximum temperature of 54°C applied for approximately 250 s for the whole treatment process.

Although, the survival rate is low, measuring of heat penetration gradient inside the tree plays an important role in evaluating the thermotherapy system as the bacteria live in the phloem, under the bark. This gradient depends on the age of the tree, the thickness of bark and tree heat resistance. To measure the temperature in the phloem, holes were drilled in tree branches, with different diameters, and in tree trunks. K-type thermocouples were installed inside and outside of the holes. Initial experiments showed that the temperature in the phloem was 10-40% lower than the temperature on the

bark (near branch's surface). When the temperature reached the maximum treatment value of 54°C outside of the bark, the temperature in the phloem, where the bacteria live, did not achive the desired value to kill the bacteria.

Finally, a thermodynamic model was developed to simulate the heat distribution inside the phloem based on the outside treatment temperatures. The heat transfer model was developed by a comparative analysis of the experimental data; ANSYS software was used to simulate the heat transfer in the phloem. The simulation results were consistent with the experimental results, with an average relative error of less than 5%.

1. Chapter 1

INTRODUCTION

Heat Treatment

Computer Simulation in Agriculture

Computational Fluid Dynamics (CFD) in Agriculture

Citrus Industry in Florida

Citrus Huanglongbing Disease

Objectives

2. Chapter 2

LITERATURE REVIEW

Heat Treatment

Hot Water

Spraying Hot Water

Soaking in Hot Water

Steam

Hot Air, Dry Heat and Heat Shock

Microwave

Computational Fluid Dynamics

Principles of CFD

Governing Equations

Numerical Analysis

3. Chapter 3

DESIGN MODIFICATION AND FABRICATION OF A MOBILE HEAT TREATMENT SYSTEM

Materials and Methods

Materials

Heating System

Temperature Acquisition System

Methodology and Experimental Design

In-Field Experimental Results

Experiment 1: Steam Treatment (ST)

Experiment 2: Hot Water and Steam Treatment (HWST)

Experimental Results Comparison (ST vs. HWST)

Applied Fluid Flow Rate

The Effect of Fluid Flow Rate on Treatment Time

In-Field Experimental Results

Energy Requirement

Discussion

4. Chapter 4

EVALUATION OF MOBILE HEAT TREATMENT SYSTEM BY ANALYZING BIOSENSOR SURVIVAL RATE

Biosensors

Preliminary Experiments

Biosensors Survival Rate after Heat Treatment

Discussion

5. Chapter 5

COMPUTER SIMULATION OF MOBILE HEAT TREATMENT SYSTEM AND TREE TRUNK CROSS SECTION

Background

Assumptions

Materials and Methods

Experimental Procedure

Simulation

Numerical Method

Results

Discussion

6. Chapter 6

CFD SIMULATION OF HEAT DISTRIBUTION THROUGHOUT CANOPY COVER IN MOBILE HEAT TREATMENT SYSTEM

Background

Assumptions

Materials and Methods

Experimental Procedure

Simulation

Development of CFD Model

Governing Equations and Models

Numerical Simulation

Geometry of the Computational Model

Boundary Conditions

Results

Experimental Results

Simulation Results

Discussion

7. Chapter7

SUMMARY AND CONCLUSION

Final remarks concerning the competition benchmarks and strength points

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A novel in-field heat treatment machine was developed and evaluated for treating the diseased affected citrus trees in Florida, USA. The efficacy of the machine to kill similar bacteria was analysed by measuring the survivability rate of the biosensors. The survival rates of the bacterial cultures were less than 5% after treatment. Then, the performance of the developed system was modelled mathematically and simulation results were consistent with the experimental data by 1-4% error.