UNIVERSITI PUTRA MALAYSIA

APPLICATION OF SONIC TOMOGRAPH FOR BASAL STEM ROT DETECTION IN OIL PALM

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By

ISHAQ BIN IBRAHIM

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

September 2016

DEDICATION

Specially dedicated to:

My loving mother Rozana Ahmad (Mother), my most respectful father Ibrahim Ismail (Father), my dear little sister Siti Aisyah Ibrahim (Sister), my passionate little brother Ilyas Ibrahim (Brother), my dear little sister Siti Fatimah Ibrahim (Sister), and my lovely wife Noor ‘Izzati Rahmat.

For their love and support throughout my work and study

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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ISHAQ BIN IBRAHIM

September 2016

Chairman : Alias Mohd Sood, PhD
Faculty : Forestry

Basal stem rot (BSR) has been known as a silent killer to the oil palm industries especially in Malaysia as the disease symptoms can only be observed once the infected tree is highly damaged from the inside. Losses have reached up to millions of ringgit per year due to high reduction of fresh fruit bunch production. The main objective of this study was to improve the BSR disease detection technique by sonic tomography (SoT) assisted by *Ganoderma* selective medium (GSM). Hence, a sonic tomography was used to measure and to reveal the internal condition of 51 selected oil palm trees, as well as to classify the percentage of damage detected in each selected trees at a measuring level between 0 and 100 cm near the ground level. Eight trees were selected as the focal tree by using purposive sampling, while 43 neighboring trees were selected nearby the focal trees via adaptive sampling. Four sensors were mounted around the circumference of the tree trunk. Then, the measuring points were nailed into the trunk. Next, each measuring points was tapped by an electronic hammer to generate sound waves. Subsequently, the sonic waves were captured by the sensors and were measured to produce tomogram. The tomogram contain information on the percentage of damage and the general location of the decayed area within the scanned tree. The percentage of damages from each selected trees was classified into 0%, 1 to 20%, 21 to 40%, 41 to 60%, and 61 to 100% damage. Afterwards, trunk samples were extracted by using an increment borer from the 51 scanned trees (excluding the three control trees) at the same elevation from four directions of north, south, east, and west by referring to tomogram images. Then, each sample was cut into five portions of 2 mm size each, isolated onto the GSM, and stored inside a closed box under room temperature for five days. Subsequently, the occurrence of *Ganoderma* mycelium inside the Petri dishes was counted and the percentage of the occurrence was determined and classified into 0%, 1 to 20%, 21 to 40%, 41 to 60%, and 61 to 100% occurrence. Lastly, the tomogram were corroborated with the occurrence of *Ganoderma* mycelium to determine if the damages found in the trees were caused by *Ganoderma*, and at the same time, to determine the

accuracy of SoT to locate *Ganoderma* inside the tree trunk. As a result, tomographic images revealed that among the 51 selected trees, two trees had 0% damage, nine trees had between 1 and 20%, 19 trees had between 21 and 40%, 15 trees had between 41 and 60%, and six trees had between 61 and 100%. Other than that, the occurrence of *Ganoderma* mycelium in the Petri dish had been discovered in 3 trees with 1-20%, 19 trees with 21-40%, 14 trees with 41-60%, and 6 trees with 61-100%. This study concluded that the SoT was able to detect damages caused by *Ganoderma* at a total percentage of 82%.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENGGUNAAN SONIC TOMOGRAFI UNTUK PENGESANAN REPUT PANGKAL BATANG DI DALAM KELAPA SAWIT

Oleh

ISHAQ BIN IBRAHIM

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Pengerusi : Alias Mohd Sood, PhD
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Reput Pangkal Batang (RPB) dianggap sebagai pembunuh senyap bagi industri minyak sawit terutamanya di Malaysia di mana gejala penyakit ini hanya dapat dilihat apabila pokok yang dijangkiti itu telah mengalami kerosakan yang teruk di bahagian dalamnya. Kerugian telah mencapai sehingga jutaan ringgit setiap tahun disebabkan oleh pengurangan yang tinggi terhadap pengeluaran tandan buah segar. Objektif utama kajian ini adalah untuk menambahbaik teknik pengesanan penyakit RPB menggunakan sonic tomography (SoT) dibantu oleh *Ganoderma* selective medium (GSM). Oleh itu, satu alat sonic tomography telah digunakan untuk mengukur dan mendedahkan keadaan dalaman 51 pokok sawit terpilih yang masih hidup, serta untuk mengklasifikasikan peratusan kerosakan yang dikesan dalam setiap pokok yang terpilih pada paras pengukuran antara 0 dan 100 sm berhampiran permukaan tanah. Lapan pokok telah dipilih sebagai pokok fokus dengan menggunakan persampelan bertujuan, manakala 43 pokok jiran telah dipilih berdekatan pokok fokus melalui persampelan adaptif. Empat sensor dipasang di sekeliling lilitan batang pokok. Kemudian, titik pengukur dipaku kedalam batang. Seterusnya, setiap titik pengukur telah diketuk menggunakan tukul elektronik untuk menjana gelombang bunyi. Selepas itu, gelombang bunyi yang terhasil dibaca dan diukur oleh sensor untuk menghasilkan tomogram. Tomogram mengandungi maklumat mengenai peratusan kerosakan dan lokasi umum kawasan reput dalam pokok yang diimbas. Peratusan kerosakan daripada setiap pokok yang diimbas telah dikelaskan kepada 0%, 1 hingga 20%, 21 hingga 40%, 41 hingga 60%, dan 61 hingga 100% kerosakan. Selepas itu, sampel batang telah diekstrak daripada 51 pokok yang telah diimbas pada ketinggian yang sama dari empat arah iaitu utara, selatan, timur, dan barat dengan menggunakan increment borer. Kemudian, setiap sampel

dipotong kepada lima bahagian dengan masing – masing bersaiz 2 mm sebelum diasingkan ke GSM, dan disimpan di dalam kotak tertutup di dalam suhu bilik selama lima hari. Selepas itu, kejadian pertumbuhan hifa *Ganoderma* dalam piring petri dikira dan peratusan kejadian telah ditentukan dan dikelaskan kepada 0%, 1 hingga 20%, 21 hingga 40%, 41 hingga 60%, dan 61 hingga 100% kejadian. Akhir sekali, tomogram telah dibandingkan dengan kejadian hifa *Ganoderma* untuk menentukan sama ada kerosakan di dalam pokok adalah disebabkan oleh *Ganoderma*, dan pada masa yang sama, untuk menentukan ketepatan SoT untuk mencari *Ganoderma* dalam batang pokok. Selain itu, klasifikasi peratusan kerosakan dari imej-imej tomografi membuktikan bahawa di antara 51 pokok yang dipilih, dua pokok mempunyai 0% kerosakan, sembilan pokok mempunyai antara 1 dan 20%, 19 pokok mempunyai antara 21 dan 40%, 15 pokok mempunyai antara 41 dan 60%, dan enam pokok mempunyai antara 61 dan 100%. Selain daripada itu, kejadian hifa *Ganoderma* dalam piring petri telah ditemui pada 3 pokok dengan 1-20%, 19 pokok dengan 21-40%, 14 pokok dengan 41-60%, dan 6 pokok dengan 61-100%. Oleh itu, kajian ini mendapati bahawa Sot dapat mengesan kerosakan yang disebabkan oleh *Ganoderma* pada jumlah peratusan 82%.

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I certify that a Thesis Examination Committee has met on 20 September 2016 to conduct the final examination of Ishaq bin Ibrahim on his thesis entitled "Application of Sonic Tomograph for Basal Stem Rot Detection in Oil Palm" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BSR	Basal Stem Rot
C	Carbon
CSR	Common Spear Rot
DBH	Diameter at Breast Height
DNA	Deoxyribonucleic Acid
DSI	Disease Severity Index
ELISA	Enzyme-Linked Immunosorbent Assay
FAO	Food and Agriculture Organization
FCM	Flow Cytometry
FELCRA	Federal Land Consolidation and Rehabilitation Authority
FELDA	Federal Land Development Authority
FISH	Fluorescence *in-situ* Hybridization
GSM	Ganoderma Selective Medium
Ha	Hectare
IF	Immunofluorescence
LED	Light-Emitting Diode
MP	Measuring Point
NDT	Non-Destructive Testing
PCR	Polymerase Chain Reaction
PDB	Potato Dextrose Broth
PEH	PiCUS Electronic Hammer
PUNDIT	Portable Ultrasonic Nondestructive Digital Indicating Tester
RISDA	Rubber Industry Smallholders Development Authority
RPB	Reput Pangkal Batang
RRD	Red Ring Disease
SoT	Sonic Tomography
VTA	Visual Tree Assessment

CHAPTER 1

INTRODUCTION

1.1 Research Background

Malaysia is one of the leading countries in terms of palm oil production. At the end of 2014, Malaysian Palm Oil Board (2014) stated that the total area covered with oil palm trees in Malaysia was approximately 5,392,235 ha, which shows an increase of 3% or 162,496 ha from the previous year. The total area was mostly contributed by the private estates (62%) followed by independent smallholders (15%), Federal Land Development Authority (FELDA) (13%), state schemes and government agencies (6%), Rubber Industry Smallholders Development Authority (RISDA) (1%), and Federal Land Consolidation and Rehabilitation Authority (FELCRA) (3%).

Plant health is crucial in obtaining maximum production since the occurrence of plant disease could cause major production and economic losses in agriculture and forestry (Sankaran et al., 2010). In Malaysia, oil palm plantation is fortunate to be greatly disease free, suffering from only one major disease known as basal stem rot (BSR). Mazliham et al. (2007) and Wong et al. (2012) suggested that the cause of the disease is a pathogen called *Ganoderma boninense* from a group of wood decaying fungus. The disease is considered as the greatest threat to sustainable palm oil production in Malaysia and some estates in South East Asia (Idris et al., 2000a, Idris et al., 2000b; Susanto, 2009) in which the losses can reach up to 80% of the planted palm oil trees after replanting. Controlling the disease is an important aspect of maintaining and subsequently increase the palm oil production.

The primary foliar symptoms of the disease significantly suggest that over half of the lower internal stem tissue (trunk) have been killed by the fungus (Najihah et al., 2015). This includes mild to severe wilt, reduced growth, overall off-colour foliage, and older fronds that are chlorotic or necrotic that eventually drop (Elliott et al., 2004). The challenge is that the disease is hidden from human eyes as it spreads inside the tree trunk (Durand-Gasselin et al., 2005). The arborists are having a hard time finding the infected tree at its early stage as the BSR disease is categorized as an internal structural defect (Wang and Allison, 2008) which is symptomless at the early stage of infection (Laila et al., 2011).

Hence, early BSR disease detection methods are needed to prevent such losses and further inhibit the spread of the disease (Sankaran et al., 2010) especially for the planters in Malaysia and Indonesia to deal with the disease effectively (Wong et al., 2012) while ensuring that the methods would value these factors; non-invasive, cost-effective, early detection, and highly accurate. In addition, the location of damage or infection on the oil palm trunk is the most reliable information for planters to prevent further decay of the damaged tree. Some techniques that have been proven to be reliable in detecting an internal defect are introduced in detecting the BSR disease and one of the techniques is sonic tomography.

Sonic tomography (SoT) was used in this study as the main instrument. The SoT was highly capable of detecting any unusual condition inside a tree trunk (Brazee et al., 2011) and it can determine the general location of the defect (Wang and Allison, 2008) while minimizing any additional damage to the diagnosed tree. A *Ganoderma* selective medium (GSM) was used as the supportive tool to justify either the damaged to the oil palm trunk is caused by *Ganoderma* or not. Wong et al. (2012) have stated that GSM was capable of allowing *Ganoderma* species to grow on its medium while inhibiting the growth of bacteria and other saprophytic fungi.

1.2 Problem Statement

The BSR disease has been presumed as an unimportant and an unthreatening disease because the infection can only be found in oil palm trees over 25 years old. Merely, it was soon reported that the spreading of BSR had increased in many plantations and younger palm trees at the age of 5 years old were also affected (Ho and Nawawi, 1985). It was once observed that the internal tissues were already 50 % decayed (Naher et al., 2013) and this was considered severely damaged. Basal stem rot disease of palm oil trees has been recognized as the most serious and deadly disease since the year 1928 (Wong et al., 2012). The fresh fruit bunch production was highly affected by the disease which have caused a major loss to the oil palm industry where the loss had reached up to millions of Malaysian Ringgit (RISDA, n.d.).

Studies on how to prevent the disease from spreading have been done many years ago. One of the problems that have been discussed among researchers was the nature of the disease that attacks an oil palm tree without showing any external symptoms at its early invasion (Mazliham et al., 2007) which was labelled as a silent killer. Hence, a technique to detect an affected oil palm tree which shows no external symptoms or signs of the disease is highly necessary in order to prevent the tree from dying and also to prevent the disease from spreading to other neighbouring trees. The technique must be able to be operated with a maximum of two persons and it must be able to determine the affected trees in the field. It should also have the capability of determining the level of damage in order to classify the damage percentage which could be very helpful in dealing with the disease at different stages with specific actions.

Even so, the knowledge of the damage percentage alone cannot determine what type of prevention or actions should be done. The knowledge of the disease causal should solve the problem. Hence, the tool must be capable of detecting the cause of the damage whether it is by *Ganoderma* or not. Some techniques are highly capable of detecting the damaged area but it still requires other tools as the supporting tools to justify the cause.

Another criteria of the technique required for detecting the BSR disease is it should be able to reveal the location of the decayed area inside the tree trunk. High accuracy disease location detection technique is very important to oil palm planters especially in preventing the disease from becoming more severe; i.e. applying injections that can stop the spreading of the disease or cut down the tree and dig out the tree stump along with the root.

1.3 Research Objectives

This study aimed to improve the detection method of BSR disease on oil palm trees by combining a powerful tool in detecting the internal damage of a tree trunk and a recommended selective medium in isolating the *Ganoderma*. The specific objectives were:

1) To detect and quantify BSR-induced damage on the oil palm trunk using sonic tomography.
2) To determine presence of BSR causal agent, *Ganoderma,* in the damaged tree using a selective medium.

1.4 Research Scope

As a tree assessment tool, sonic tomography is capable of detecting the damage, decay or cavity inside a tree trunk. Yet, it cannot define whether the damage is caused by *Ganoderma* or else. This study only covers oil palm trees.

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