UNIVERSITI PUTRA MALAYSIA

SPATIAL VARIABILITY OF SOIL AND LEAF NUTRIENT CONTENTS IN BASAL STEM ROT DISEASE INFECTED OIL PALM AREAS

NUR SHUHADA MUHAMAD TAJUDIN

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By

NUR SHUHADA MUHAMAD TAJUDIN

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

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SPATIAL VARIABILITY OF SOIL AND LEAF NUTRIENT CONTENTS IN BASAL STEM ROT DISEASE INFECTED OIL PALM AREAS

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NUR SHUHADA MUHAMAD TAJUDIN

April 2015

Chairman: Mohamed Hanafi Musa, PhD
Institute: Institute of Tropical Agriculture

The basal stem rot (BSR) disease caused by fungi *Ganoderma* had been reported as the most destructive disease of oil palm in Southeast Asia. Adequate contents of nutrient in soil and leaf are necessary to improve the crop yields, plant health and its productivity. This study focus on the applications of geographic information system (GIS) tools to observe the occurrence of the BSR disease, spatial distributions of nutrients in the soil and leaf and to determine their relationship with the disease. The study was conducted in four different blocks, representing two different ages of oil palm. The BSR disease distributions in the study sites were observed from 2009 - 2012 by ground census in combinations with soil and leaf samplings. The BSR disease had increased and spread rapidly in mature oil palm plantation compared to young palm. By 2012, more than 40% of areas in mature oil palm plantations were dominated by high to very high categories of infected area. In the same year, less than 1% of area in young palm blocks was classified into very high category of infected area. For the soil and leaf nutrients determination, soil and leaf were collected based on two level of disease severity in 2009, 2010 and 2011 and by grid sampling in 2012. Content of soil nutrient in T0 and T1 did not show any significant trend between two levels of severity within the three years, while almost all nutrients in the leaf showed a higher value of nutrients in T0 compared to T1, especially in the year of 2010 ($p<0.05$). A significant reduction ($p<0.05$) of nutrients in T1 leaves were observed temporally, as higher content of nutrients recorded in 2009 and the lowest in 2011. From the spatial distributions in 2012, N and P content in soil were classified as high in all of the blocks, ranged from 0.15 to 0.48% and 6.99 to 98.39%, respectively. Potassium was classified as low to moderate level with value ranged from 0.04 to 0.59%. The same trend was also found in Ca and Mg distribution, where the area of young palm blocks was dominated by very low to moderate content. Zinc showed a sufficient content in soil, ranged from low (>0.20 ppm) to moderate (>0.25 ppm), while Cu showed a moderate content (>1.60 ppm) in all of the blocks. Leaf nutrients analysis also showed a higher content of N and P, ranged from 1.99 to 4.38% and 0.11 to 0.56%, respectively. Distributions of K, Ca, Mg and Cu from the leaf collected was considered as deficient in all of the blocks with value lower than optimum level. Correlation analysis between BSR

disease and nutrient content indicated that, N in both soil and leaf showed a significantly positive relationship ($p < 0.01$) with the disease ranged from low to moderate strength of relationship. Nevertheless, Ca showed a significantly negative correlation ($p<0.01$ and <0.05) with only weak relationship. This suggests that, the BSR disease occurrence may be influenced by the unbalanced nutrient factors observed in this study area. The ability of GIS tools for determining spatial and temporal distributions of disease and nutrients is useful in making monitoring studies and management decisions especially in large plantation areas.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

TABURAN KANDUNGAN NUTRIEN DALAM TANAH DAN DAUN DI KAWASAN KELAPA SAWIT YANG DIJANGKITI PENYAKIT REPUT PANGKAL BATANG

Oleh

NUR SHUHADA MUHAMAD TAJUDIN

April 2015

Pengerusi: Mohamed Hanafi Musa, PhD
Institute: Institut Pertanian Tropika

Penyakit reput pangkal batang (BSR) yang disebabkan oleh kulat *Ganoderma* telah banyak menyerang pokok kelapa sawit di Asia Tenggara. Kadar nutrient yang mencukupi dalam tanah dan daun perlu untuk penambahbaikan kesihatan tumbuhan dan pengeluarannya. Kajian ini telah mengaplikasikan teknik GIS dalam menentukan kadar nutrient dalam daun dan tanah dan bagaimana kadar tersebut berhubung dengan penyakit ini. Kajian lapangan telah dijalankan di Ladang Seberang Perak di bawah pengurusan FELCRA Sdn. Bhd. dalam empat blok mewakili dua peringkat umur kelapa sawit. Bamcian penyakit BSR dijalankan dari tahun 2009 - 2012 diikuti persampelan tanah dan daun. Penyakit BSR cenderung untuk merebak cepat di ladang kelapa sawit matang berbanding kelapa sawit muda. Pada tahun 2012, lebih 40% daripada ladang kelapa sawit matang dikategorikan kawasan tinggi penyakit. Di ladang kelapa sawit muda, kurang 1% daripada kawasan diklasifikasikan kepada kategori tinggi penyakit. Sampel daun dan tanah diambil berdasarkan dua teknik dimana teknik pertama diambil berdasarkan tahap kesihatan pokok pada tahun 2009, 2010 dan 2011 dan untuk 2012 sampel diambil berdasarkan grid. Kandungan nutrient tanah pada T0 dan T1 tidak menunjukkan sebarang perubahan yang signifikan selama tiga tahun tersebut tetapi, hampir semua nutrient di dalam daun menunjukkan kadar nutrient yang tinggi didalam sample T0 berbanding T1 pada tahun 2010 ($p<0.05$). Pengurangan kadar nutrient yang signifikan juga dikenalpasti di dalam sampel daun T1 yang mempunyai kadar lebih tiggi pada tahun 2009 dan terendah pada tahun 2011. Taburan spatial pada tahun 2012 menunjukkan kandungan N dan P tanah dikelaskan tinggi dalam semua blok dan bernilai antara 0.15 - 0.48% dan 6.99 - 98.39%. Kalium dalam tanah berada pada tahap rendah hingga sederhana dengan nilai antara 0.04 - 0.59%. Trend yang sama juga dilihat pada taburan Ca dan Mg, di mana blok kelapa sawit muda dikuasai oleh kandungan Ca dan Mg yang sangat rendah hingga sederhana. Zink menunjukkan taburan yang mencukupi di seluruh blok dengan nilai antara sangat rendah (>0.20 ppm) hingga tinggi (15 ppm), manakala taburan Cu berada pada tahap sederhana (1.60 ppm) hingga tinggi (>1.60 ppm) di dalam semua blok. Analisis nutrient dalam daun juga menunjukkan kandungan N dan P lebih tinggi bernilai antara 1.99 - 4.38% dan 0.11 - 0.56%. Kandungan K, Ca,

Mg dan Cu dalam daun berada pada tahap tidak mencukupi dengan nilai lebih rendah daripada tahap optimum. Korelasi antara penyakit BSR dengan N dalam tanah dan daun menunjukkan hubungan positif yang signifikan ($p<0.01$) dengan nilai korelasi rendah hingga sederhana. Bagaimanapun, Ca menunjukkan hubungan yang negatif tetapi signifikan ($p<0.01$ dan <0.05) dengan nilai hubungan yang lemah. Hasil kajian ini mencadangkan ketidakstibilan kadar nutrient akan mempengaruhi penyebaran penyakit di sesuatu kawasan, Selain itu, keupayaan GIS bagi menentukan pengagihan nutrient dan penyakit adalah sangat berguna dalam membuat kajian pemantauan dan keputusan pengurusan terutama di kawasan penanaman yang luas.

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I certify that a Thesis Examination Committee has met on (27th April 2015) to conduct the final examination of Nur Shuhada bt Muhamad Tajudin on her thesis entitled **"Spatial Variability of Soil and Leaf Nutrient Contents in Basal Stem Rot Disease Infected Oil Palm Areas**" 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 Doctor of Philosophy

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Jabatan Kejuruteraan Biologi dan Pertanian
Fakulti Kejuruteraan
Universiti Putra Malaysia
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Jabatan Pengurusan Tanah
Fakulti Pertanian
Universiti Putra Malaysia
(Internal Examiner)

Y. Bhg. Prof. Dr. David J. Mulla, PhD
Dept. of Soil, Water and Climate
University of Minnesota
United States

_____
Prof. Dr. Zulkarnain Zainal, PhD
Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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

Mohamed Hanafi Musa, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Siva Kumar Balasundram, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Idris Abu Seman, PhD
Senior Principle Research Officer
Biological Research Division
GANODROP Unit
Malaysia Palm Oil Board (MPOB)
(Member)

Kamaruzzaman B. Yunus, PhD
Professor
Kulliyyah of Science
International Islamic University Malaysia (IIUM)
(Member)

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Name of Chairman of Supervisory Committee:	Mohamed Hanafi Musa, PhD	Name of Member of Supervisory Committee:	Idris Abu Seman, PhD
Signature:	_____	Signature:	_____
Name of Chairman of Supervisory Committee:	Siva Kumar Balasundram, PhD	Name of Member of Supervisory Committee:	Kamaruzzaman Yunus, PhD

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

GIS	Geographical information system
GPS	Global positioning system
IDW	Inverse distance weight
DOA	Department of agriculture
CEC	Cation exchange capacity
mg kg^{-1}	miligram per kilogram
kg	kilogram
m	meter
ha	hectare
cm	centimetre
YAP	Years after planting
TC	Total carbon
N	Nitrogen
P	Phosphorous
K	Potassium
Ca	Calcium
Mg	Magnesium
P_{av}	Available phosphorous
K_{ex}	Exchangeable potassium
Ca_{ex}	Exchangeable calcium
Mg_{ex}	Exchangeable magnesium
Fe	Iron
Cu	Copper
Zn	Zinc
Mn	Manganese
AA	Auto analyzer
AAS	Atomic absorption spectrophotometer
$\gamma(h)$	Semivariance
h	Lag
n	Number of observation
$C + C_o$	Sill
C_o	Nugget
a	Range
ANN	Average nearest neighbour
MOP	Muriate of potash
RP	Rock phosphate
SOA	Ammonium sulphate
B1M	Block 1 mature
B2M	Block 2 young
B3Y	Block 3 young
B4M	Block 4 mature
MPOB	Malaysia Palm Oil Board

CHAPTER 1

INTRODUCTION

1.1 General introduction

Oil palm (*Elaeis guineensisis*) one of the main crops in several tropical countries that generate the economies. However, one of the common problems faced in these industries is the existence of the basal stem rot (BSR) disease. It is caused by a type of soil borne pathogens named *Ganoderma*. The BSR disease in oil palm has been recorded in Malaysia and Indonesia in South East Asia; Angola, Cameroon, Ghana, Nigeria, Zambia, San Tome, Tanzania, Zimbabwe, and Papua New Guinea (Turner, 1981). It is considered as a destructive disease that causes losses in the field of oil palm industries. This disease generates two kinds of losses which is direct and indirect losses. The direct losses refer to losses in standing oil palm and the indirect loss is weight of oil palm fruits. This disease is difficult to be identified at the early stage due to its slow development and it is only easy to identify when a fruiting body are formed at the base of the oil palm. At this stage, it is too late to be controlled. The disease is characterized by a symptom of decay in the bole of the oil palm with an aerial symptom, such as multiple spears, skirting down leaf and also production of brackets or fruiting body at the base of trunk, and lastly in some cases it ended with the fall of the trees. Most of the severe cases were reported in Malaysia and Indonesia but less in Africa, Papua New Guinea and Thailand (Ariffin *et al.* 2000). This disease is considered as the most prevalent and devastating disease in oil palm cultivation in many parts of Peninsular Malaysia with leading to loss up to 80% of the stand, by the time the oil palm are halfway through out their economic life span (Susanto *et al*., 2002; Turner and Gillbanks, 2003; Susanto 2009).

A number of factors, such as age of oil palm, types of soil, nutrients status and techniques of replanting have been reported to influence BSR disease development in the field. Macro- and micro-nutrient have frequently been recognized to be associated with changes in the level of the disease. An incorrect of nutrient balanced likely plays an important role in introducing BSR disease in oil palm. Nutrients are important for growth development of plants and also microorganisms, but they are also important factors in controlling disease (Agrios, 2005). It is reported that the content of essential nutrient, such as N, P, K, Ca and Mg effects in disease severity incidence (Huber and Graham 1999). An attention should be given on the importance of nutrients balance in disease control by correct managements of nutrients order, such as fertilizing scheme and pest management plan. Generally, nutrients affect the developments of the disease not only by affecting the plant physiology or the pathogen itself but it also can affect both of them and increase the disease incidence. Nutrient content in a particular area would influence the plant growth and therefore it affects the microclimate of the pathogens which will introduce

infection and sporulation of the pathogen (Marschner, 1995). It was found that increased in N level has been shown to increase BSR incidence in nursery condition (Singh 1990; Mohd Tayeb *et al*., 2003). In contrast, fertilizer trials conducted on a recent marine alluvium of a Bernam series with a heavy clay soil showed that K fertilizer had significantly reduced the incidence, whilst N and P only showed slightly increase in the disease incidence (Singh, 1990).

Precision farming defined as a spatial variable management in order to increase efficiency in the management of agricultural practices, productivity, and reduced the environmental impact. Geographical Information system (GIS) is one of a precision tools that had been used extensively nowadays especially in the fields of agriculture practices. It is used to help in term of management of that particular area, such as nutrient management, site specific management, disease management, and also other agricultural purposes, such as site specific management practices. This technology is becoming more efficient nowadays as it is capable to assembling, storing, manipulating and displaying an accurate data referred by the geographical coordinates (Cambardella *et al.*, 1994). Such information is needed for a better view and to fully understand so that we can easily know how to manage that particular area effectively. In term of disease distribution and management, GIS technologies help to understand where the disease is occurring and how dense is the disease in a particular area. The same method also was used in quantifying the spatial variability of soil properties in order to understand the variability of the soil nutrients. Therefore, this study was carried out with objectives to quantify the spatial distribution of selected macro- and micro-nutrients status in leaf and soil and the distributions pattern of the disease in oil palm plantation affected by BSR disease and its correlation to the disease incidence.

Increase of this economical loss has alarmed the industries. One of a better solution in helping the industry is by applying the GIS technologies in order to have an accurate view and understand where the disease is occurring and how its relation to soil nutrients as soil is also one of the factors that influence the tenderness of the disease to be spread.

1.2 Justification of the study

Oil palm is the most important crops in Malaysia. Malaysia is one of the largest exporters of oil palm products and the world's leading oil palm producers. However, the presence of disease caused by species of *Ganoderma*, which caused rotting at the basal of the stem devastate thousands of hectares of oil palm plantings in the area of Southeast Asia especially in Malaysia and Indonesia (Anderson, 1979). Several studies had been conducted in investigating the pattern and source that influence the disease to be spread. However, most of these studies on this disease were conducted at the nursery stage of the plant and focusing on the molecular and genetic studies. Little is known on how spatial and temporal factors affect the disease distribution in term of the disease and nutrient distributions at the field scale. Nutrient in soil and leaves are one of the factors that reported to influence the disease to be

spread over the plantation area. Such information is important to understand the dynamics of the disease and its correlation to nutrient status in regards to spatial and temporal variability. Therefore, by the advancement in computer technology, the task can be simplified to large extent. The application of GIS in plant disease is becoming more important especially when dealing with large area and time. It helps to analyse plant disease in variations of way, such as how the disease outbreak patterns and where the disease is occurring. In this way, preventive actions can be taken at the early stage of the problems. Besides that, GIS applications also were used in quantifying nutrients content in soil and leaf at large scale of area. This study focused on the understanding of how the disease and nutrients can be related with regards to the factors of space and time by using the GIS technology. Besides, this research was an exploratory study to determine nutrients factors that have a potential effect on the BSR disease.

1.3 Objectives of the study

To observe the temporal distribution of BSR disease and its pattern in young and mature oil palm plantation.

1. To determine the soil and leaf nutrient properties in two different severity rate of trees in young and matured oil palm plantation.
2. To determine the spatial variability of soil and leaf nutrient properties in young and mature oil palm plantation.
3. To determine the correlation of soil and leaf nutrient properties with BSR disease in different age oil palm plantation.

1.4 Scope of the study

This study focuses predominantly on the variability of selected soil chemical properties that were reported previously to have a significant correlation on BSR disease in oil palm at field scale. In addition, temporal study on the distributions of the BSR disease was also conducted at two different ages of oil palm in order to understand the dynamic of the disease distribution. Spatial and temporal distributions of the disease and nutrient were developed by using GIS technology as it can deal with large number of area and data.

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