UNIVERSITI PUTRA MALAYSIA

***ASSESSMENT OF ORANGE SPOTTING SEVERITY IN OIL PALM USING MULTI SPECTRAL REFLECTANCE APPROACH***

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# ASSESSMENT OF ORANGE SPOTTING SEVERITY IN OIL PALM USING MULTI SPECTRAL REFLECTANCE APPROACH

By

**SUDHARSAN SELVARAJA**



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

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Abstract of Thesis Presented to the Senate of Universiti Putra Malaysia in the Fulfillment of the Requirement for the Degree of Master of Science

**ASSESSMENT OF ORANGE SPOTTING SEVERITY IN OIL PALM USING MULTI SPECTRAL REFLECTANCE APPROACH**

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**SUDHARSAN SELVARAJA**

**September 2014**

**Chairman: Siva K. Balasundram, PhD**
**Faculty: Agriculture**

Orange Spotting (OS) caused by a variant of Cadang-Cadang Coconut Viroid (CCCVd) is an emerging problem in oil palm plantations of Malaysia. This work was an effort to study epidemiology of OS in an oil palm plantation using Precision Agriculture (PA) tools. A 4.2 ha plot were established in a commercial plantation situated at Sungai Buloh, Selangor. A total of 587 geo-referenced mature trees were visually observed to identify OS-infected oil palm trees based on symptoms. OS incidence and severity data were acquired from all 587 observed oil palm trees and the data subjected to a series of spatial variability analysis. Forty symptomatic oil palm trees were systematically selected based on OS severity for leaflets sampling. Leaflets from another 10 nonsymptomatic oil palm trees were also sampled. The sampled leaflets were subjected to spectral reflectance acquisition followed by Dot-Blot analysis. A second study plot was established in a mature oil palm stand (approximately 10 km away from the first study site) which was selected based on presence of potassium deficiency and absence of OS. The sampled leaflets were subjected to spectral reflectance acquisition followed by leaf Potassium (K) analysis.

The incidence of OS incidence in the study area was 74.3%. OS severity ranged from 0-92.3%. The spatial structure of OS severity was described by an exponential model with an effective range of 29.1 m. Orange spotting severity exhibited a strong spatial dependence with a nugget to sill ratio of 0.15. The spatial variability map of OS severity revealed spatial clustering of kriged values, where 73% of the study area showed low severity (1-30%), 25% showed moderate severity (30-60%) and approximately 2% showed high severity (>60%). This study demonstrates the utility of geo-spatial information in understanding the OS severity scale which could assist in site-specific disease monitoring and intervention.

Dot-blot assay showed CCCVd presence in 40% of the samples obtained from nonsymptomatic oil palm trees. Symptomatic leaf samples showed a significant correlation ($r$=-0.70) between leaf chlorophyll reflectance and OS severity. Spectral reflectance of symptomatic leaves was significantly lower than that of nonsymptomatic leaves at the 465-711 nm wavelength regions. Spectral reflectance of healthy and asymptomatic leaves, however, did not exhibit significant differences

across all wavelengths investigated. In symptomatic leaves, spectral reflectance showed a decreasing trend with an increase in OS severity of up to 60% at the 555 nm and 780-1000 nm wavelengths. Among the vegetation indices tested, MCARI1 and $mSR_{705}$ performed best in predicting OS severity with a goodness of fit (measured vs. predicted) of 66% and 56%, respectively.

Reflectance between OS-infected and K-deficient leaves showed significant separability ($p < 0.05$) at 400-538 nm and 667-688 nm wavelengths. Reflectance of K-deficient leaves was significantly different than that of OS-infected leaves from OS severity classes (1-20%, 21-40%, 41-60% and 61-80%). All oil palm leaflets exhibited green peak at 555 nm wavelength, with average reflectance value of 0.15.

Abstrak Tesis yang Dikemukakan kepada Senat Universiti Putra Malaysia
Sebagai Memenuhi Keperluan untuk Ijazah Master Sains

**PENILAIAN PENYAKIT ORANGE SPOTTING DI TANAMAN KELAPA SAWIT MELALUI PENDEKATAN PANTULAN MULTI SPEKTRUM**

Oleh

**SUDHARSAN SELVARAJA**

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Penyakit "Orange Spotting" (OS) disebabkan oleh "Cadang-Cadang Coconut Viroid" (CCCVd) kini telah mula menular ladang-ladang kelapa sawit di Malaysia. Penyelidikan ini adalah satu usaha untuk mengkaji epidemiologi penyakit OS di dalam sebuah ladang kelapa sawit dengan menggunakan peralatan "Precision Agriculture" (PA). Plot kajian seluas 4.2 ha telah disediakan di ladang komersial yang terletak di Sungai Buloh, Selangor. Sebanyak 587 pokok matang yang digeo-rujuk telah dikaji berdasarkan pemerhatian visual untuk mengenal pasti pokok-pokok kelapa sawit OS dijangkiti. Insiden penyakit OS dan data tahap diperolehi daripada semua 587 pokok kelapa sawit diperhatikan dan data tertakluk kepada satu siri analisis kebolehubahan spatial. Empat puluh gejala pokok kelapa sawit telah dipilih secara sistematik berdasarkan keparahan penyakit OS yang simtomatik bagi tujuan persampelan daun. 10 pokok kelapa sawit yang tiada simtom juga telah disampel. Sampel daun tersebut tertakluk kepada pengambilalihan pantulan spektrum diikuti oleh analisis Dot-Blot. Plot kajian kedua ditubuhkan di sebuah kawasan kelapa sawit matang (kira-kira 10 km dari tapak kajian pertama) yang dipilih berdasarkan kepada kehadiran kekurangan kalium dan ketiadaan penyakit OS. Sampel daun tertakluk kepada pengambilalihan pantulan spektrum diikuti dengan daun Kalium (K) analisis.

Insiden penyakit OS di kawasan kajian ini adalah 74.3%. Tahap penyakit OS adalah diantara 0-92.3%. Struktur ruang tahap penyakit OS digambarkan oleh model eksponen dengan jarak berkesan sejauh 29.1 m. Tahap penyakit OS telah menunjukkan pergantungan spatial yang kukuh dengan nugget kepada nisbah 0.15. Peta spatial kebolehubahan tahap penyakit OS mendedahkan kelompok jangkitan, di mana 73% daripada kawasan kajian menunjukkan tahap rendah (1-30%), 25% menunjukkan tahap sederhana (30-60%) dan kira-kira 2% lagi menunjukkan tahap tinggi (> 60%). Kajian ini menunjukkan utiliti maklumat geo- spatial dalam memahami tahap penyakit OS yang boleh membantu dalam khusus tapak pemantauan penyakit.

Analisis Dol-Blot menunjukkan kehadiran CCCVd sebanyak 40% dalam sampel yang diperolehi daripada pokok kelapa sawit yang tiada simtom. Sampel daun

menunjukkan perkaitan yang signifikan (r = -0.70) antara pantulan klorofil daun dan tahap penyakit OS. Pantulan spektrum daun adalah jauh lebih rendah daripada itu daun yang tiada simtom dalam rantau jarak gelombang sebanyak 465-711 nm. Pantulan spektrum daun yang sihat dan asimptomatik tidak menunjukkan perbezaan yang ketara di semua panjang gelombang disiasat. Dalam daun simptomatik, pantulan spektrum menunjukkan trend yang semakin mengecil dengan peningkatan dalam tahap penyakit OS sehingga 60% pada jarak gelombang di 555 nm dan 780-1000 nm. Antara indeks tumbuh-tumbuhan yang diuji, MCARI1 dan mSR705 dilakukan terbaik dalam meramalkan penyakit OS keterukan dengan keserasian sebanyak 66% dan 56% secara masing-masing.

Pantulan antara daun dijangkiti OS dan kekurangan K menunjukkan yang ia boleh dipisahkan secara signifikan ($p < 0.05$) pada panjang gelombang di 400-538 nm dan 667-688 nm. Pantulan daun kekurangan K adalah jauh berbeza daripada yang daun dijangkiti OS dengan tahap penyakit OS(1-20%, 21-40%, 41-60% dan 61-80%). Semua sampel daun kelapa sawit telah mempamerkan puncak hijau di panjang gelombang 555 nm, dengan purata nilai pantulan sebanyak 0.15.

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I certify that a Thesis Examination Committee has met on 23 September 2014 to conduct final examination on Sudharsan Selvaraja on his thesis entitled "Assessment of Orange Spotting Severity in Oil Palm Using Multi Spectral Reflectance Approach" in accordance with the Universities and University College 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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| | |
|---|---|
| CCCVd | Coconut Cadang-Cadang Viroid |
| et al. | et alia |
| GIS | Geographical Information System |
| GM | Gitelson and Merzlak Index |
| GPS | Global Positioning System |
| MCARI | Modified Chlorophyll Absorption in Reflectance Index |
| mND | Modified Normalized Difference |
| MPOB | Malaysian Palm Oil Board |
| MS | Mean Square |
| MSE | Mean Square Error |
| mSR | Modified Spectral Ratio |
| NDCI | Normalized Difference Cloud Index |
| NDI | Chlorophyll Normalized Difference Index |
| NDRE | Normalized Difference Red Edge |
| NDVI | Normalized Difference Vegetation Index |
| NPCI | Normalized Pigment Chlorophyll Index |
| OS | Orange Spotting |
| PSSR | Pigment Specific Simple Ratio |
| RI | Response Index |
| SIPI | Structural Independent Pigment Index |
| SPAD | Soil Plant Analysis Development |
| SRPI | Simple Ratio Pigment Index |
| VI | Vegetation Index |
| ZM | Zarco-Tejada and Miller Index |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

The oil palm, *Elaeis guineensis*, originates from Africa. Palm oil is mainly processed and refined as edible oil. Palm oil is also extensively used to make soap, detergent and margarine in an industrial scale. Crude palm oil is the most exported commodity in Malaysia with a constantly increasing demand. Total oil palm planted area in Malaysia increased by 4.5% to 4.69 million hectares in 2009. Among the regions, Sarawak registered the largest increase in planted area at 12.8%, followed 3.3% and 2.1% in Peninsular Malaysia and Sabah, respectively. Sabah still stands as the state with the largest oil palm acreage, accounting for 1.36 million hectares or 29% of the total planted area in Malaysia (MPOB, 2012). Currently, Malaysia produces 17.73 million tonnes of palm oil and 2.13 tonnes of palm kernel oil. Malaysia is one the largest producers and exporters of palm oil in the world, accounting for 11% of the world's oils & fats production and 27% of export trade of oils & fats (USDA, 2013). The industry provides employment to more than half a million people and livelihood to an estimated one million people.

However, oil palm trees are prone to diseases which may significantly affect oil palm yields (Corley, 2008). Kamarudin and Arshad (2006) had reported oil palm yield affecting pests and diseases such as foliar damage caused by *Metisa plana* (bagworms) and fruit bunch damage caused by *Oryctes rhinoceros* (Asiatic rhinoceros beetle). This study revealed that 50% of defoliation damage in an oil palm plantation results in loss of 4 tonne per hectare of fresh fruit bunches. Another well-known disease of oil palm such as basal stem rot disease caused by *Ganoderma sp*. also affects oil palm yield significantly (Naher et al., 2013). These damages had been well documented and its' epidemiology are known, thus, control methods could be conducted timely and efficiently by removing the infected palm. Recently, OS disease incidence had been reported in several oil palm plantations situated along the west coast of Malaysia. Even though, presence of OS in Malaysian oil palm plantations known, epidemiology of OS in oil palm is not documented. Thus, lack of understanding in epidemiology of OS disrupts plantation managements in taking timely control actions.

Orange Spotting (OS) is becoming a significant problem in oil palm plantations in Malaysia based on the symptom exhibited in several oil palm plantations. Vadamalai (2009) had associated OS disease with several variants of Coconut Cadang-Cadang Viroid (CCCVd) in oil palms in Malaysia. OS disease epidemiology in an oil palm plantation is still unclear since there are no publications available to date. Therefore, this study was focused on understanding the epidemiology of OS via plant disease assessment. Potential of contemporary techniques in plant disease assessment had been evaluated in an effort to accurately quantify and understand the distribution of OS. This study may serve as a stepping stone towards understanding epidemiology of OS in oil palm.

## 1.2 Problem Statement

In Malaysia, studies on epidemiology of OS disease in oil palms have not been documented. Unknown epidemiology, mainly distribution and phytopathometry, of OS in Malaysian oil palm plantations would affect disease control actions in case of an outbreak of the disease.

Symptoms of OS are exhibited on oil palm leaves (Hanold and Randles, 1998). Conventional plant disease assessment via visual assessment could yield erroneous result due to high canopy position in matured oil palm trees. Plant disease assessment requires an accurate and robust method for quick and effective disease control actions (Nutter et al., 2006).

OS of oil palm could be asymptomatic (Turner, 1981). Asymptomatic oil palm trees do not exhibit OS symptoms while acting as CCCVd host. Asymptomatic oil palm trees could act as a loci or a source point of OS transmission which may not be detected by visual assessment.

Symptoms of OS and Potassium (K) deficiency are similar via visual assessment. Trained skilled workers required for the discrimination of OS and potassium deficiency in oil palm. Hence, disease assessment may vary between raters causing unreliable disease assessment results (Nutter *et al*., 2006).

Plant disease assessment of OS in oil palms of Malaysia had not been conducted.

## 1.3 Significance of Study

Firstly, the distribution of OS in an oil palm plantation was evaluated using spatial variability technique. A geostatistical analysis has been adopted in this spatial variability OS study to accurately estimate the distribution of OS. Spatial variability study of OS severity may reveal if the disease is random or aggregated in an oil palm plantation.

Secondly, there was a need to accurately quantify OS severity (Nutter *et al*., 2006). Potential of spectral reflectance to quantify OS severity had been evaluated this study. Use of spectral reflectance in quantifying OS may replace the need of erroneous visual assessment in OS assessment.

Thirdly, spectral reflectance is used to discriminate OS and K deficiency in oil palm trees. This may serve as an alternative method in discriminating these disorders.

## 1.4 Research Objectives

1. To assess the incidence and severity of OS in an oil palm plantation using spatial variability technique.
2. To quantify and discriminate OS severity into significant clusters using multispectral reflectance and several published vegetation indices.
3. To evaluate and analyze the performance of multispectral reflectance in discriminating OS and K deficiency symptoms in oil palm trees.

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