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FT-IR ABSORBANCE DATA FOR EARLY DETECTION OF OIL PALM FUNGAL DISEASE INFESTATION

Shohreh Liaghat [1], Shattri B. Mansor [1, 2], Helmi Zulhaidi Mohd Shaffri [2], Sariah Meon [3], Reza Ehsani [4] and Siti Hajar Md Nor Azam [5]

[1] Spatial and Numerical Modeling Laboratory (SNML), Institute of Advanced Technology (ITMA), University Putra Malaysia (UPM), 43400 Serdang, Selangor, Malaysia
[2] Department of Civil Engineering, Faculty of Engineering, University Putra Malaysia (UPM), 43400 Serdang, Selangor, Malaysia
[3] Department of Plant Protection, Faculty of Agriculture, University Putra Malaysia (UPM), 43400 Serdang, Selangor, Malaysia
[4] Citrus Research and Education Center (CREC), IFAS, University of Florida, 700 Experiment Station Road, Lake Alfred, FL 33850, USA
[5] R&D Plantation, Plant Protection, Sime Darby Research Sdn Bhd, 42700 Banting, Selangor, Malaysia
Email: sliaghat.upm@gmail.com

ABSTRACT

Basal stem rot (BSR) is a serious fungal disease in oil palm plantations which potentially could reduce the market share of palm oil for Malaysia. Due to the preventing great losses in production and reducing the use of chemicals, early detection of *Ganoderma* fungal infection is critical for management of this disease. At present study, we propose to apply a mid-infrared spectroscopy technique for detection of infected oil palm trees at three stages of infection. Leaf samples of healthy, mild, moderate and sever-infected trees were measured using Fourier transform infrared (FTIR) spectrometers system to obtain absorbance data from the range of 2.55-25.05 µm. Single bounce ATR accessory with and without dilution with potassium bromide (KBr) were used in this study. Savitsky-Golay method was used for smoothing. The selected principal component (PC) scores were used as input features in quadratic discriminant analysis (QDA) as a pattern recognition algorithm. The results indicated that QDA-based algorithm can distinguish between healthy and infected leaves at three stages of infection with high classification accuracies (˃80%) when leav
demonstrated that the proposed technique has the potential for early detection of the *Ganoderma* disease.

Keywords: *Mid-infrared spectroscopy, Quadratic discriminant analysis, Basal stem rot; Oil palm*

INTRODUCTION

Malaysia with more than four million hectares of land under oil palm cultivation is counted as the world's largest producer and exporter of the palm oil [1]. Basal stem rot (BSR) caused by *Ganoderma boninense* is known as the most destructive disease of oil palm plantations that is the major reason for great losses in palm oil production in Southeast Asia for the past 80 year [2]. This disease could reduce the market share of palm oil for Malaysia [1]. *Ganoderma* fungus gains energy by degrading lignin component to carbon dioxide and water [3]. Lignin biodegradation as secondary metabolic process uses more energy than can be obtained from utilization. Lignin can play the main role to provide the strength of the xylem tissue of plants [4]. Meanwhile, disorder in vascular circulation due to the fungus activity causes some problem in nutriments and water drawing up by the vessels and consequently reduces the oil palm production. Thus, *Ganoderma* has great economic impact on palm oil industries. The spores that grow in non-living tissues such as oil palm residues [5] probably spread root to root [6] or by wind. Airborne spores can enter trees through wounds caused by shedding of branches, etc. [3]. Different methods such as chemical and biological controls are not entirely satisfactory in reducing the disease effects on the yield in advanced BSR infection [7]. Visually finding the *Ganoderma* specific symptoms such as foliar symptoms (yellowing and necrosis leaves, unopened spears, small canopy and skirt-like shape of crown) and fungus fruiting body on the infected trunks that is currently the most common way for detection of infected trees is labour intensive and time consuming. Different studies have shown the capability of spectroscopic techniques for detection of plant diseases. Shafri et al. [8] used visible and near infrared spectroscopy method for detection of *Ganoderma* infestation in the nursery; however, the significant

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bands could not differentiate between non-infected and mild-infected palms. Similarly, Shafri and Anuar [9] selected significant bands from derivative spectra that were not able to discriminate between two levels of *Ganoderma* infection in nursery with high accuracy. Lelong et al. [10] could only classify BSR in high levels of severity with acceptable accuracy using hyperspectral reflectance data. Sankaran et al. [11] used a mid-infrared spectroscopy method to classify healthy trees from Huanglongbing (HLB)-infected trees in citrus orchards. They used multivariate classification algorithms in their study. The results confirmed the capability of mid-infrared spectroscopy in detection of HLB in citrus. Currently, there is a need for an efficient field-based sensing technique for early detection *of Ganoderma*. The goal of this study was to evaluate the possibility of using a mid-infrared (MIR) spectroscopy technique for detection of infected oil palm trees at three different stages of *Ganoderma* infection.

MATERIALS AND METHODS

Samples collection

Field measurements were carried out in Sime Darby oil palm plantations located in Banting, Selangor, Malaysia (2˚ 50′ 32″ N 101˚ 29′ 19″ E) with *Ganoderma* infected trees at different range of severity. Samples were selected from 15-year old mature oil palm trees. Samples/ trees with four levels of healthiness were pre-marked using spot imagery and confirmed by well-trained scouting team members of Sime Darby based on specific visual symptoms on the canopy and the stem. Sampled trees were selected and labelled into the four levels of disease infection based on specific standard symptoms on the canopy and the stem including unopened spears, yellowing and necrosis leaves, small canopy and *Ganoderma* fruiting bodies on the trunk or primary roots near soil level [12]: 1. healthy or non-infected (G0), 2. mild-infected (G1), 3. moderate-infected (G2) and 4. severe-infected (G3). Three to six leaflets from 49 healthy (G0), 37 mild-infected (G1), 36 moderate-infected (G2) and 37 severe-infected (G3) oil palm trees (totally 159 trees) were selected for the measurement. Leaflets were collected randomly from frond number 17 of each tree.

Spectral measurement

A Thermo Scientific's Nicolet^{TM} Series Fourier transform infrared (FT-IR) spectrometer was used to collect and process mid-infrared spectra in the range of 2.55-25.05 µm with 0.05 µm resolution (totally 451 spectral bands). Single-reflection ATR (attenuated total reflection) accessory with and without dilution with potassium bromide (KBr) were used for this purpose, termed method A and method B respectively. Three to six leaflets from each tree were measured directly with FT-IR spectrometer in method A, while in method B, three to six pellets prepared with KBr from the same leaflets in method A and measured with spectrometer. Acquired spectra (three to six absorbance data) were averaged in both methods to obtain the mean absorbance for each tree.

Data pre-processing

As pre-processing, absorbance spectra collected from four classes of healthiness in both method A and method B were baseline corrected and normalized before further analysis. Some representative spectra of G0, G1, G2 and G3 acquired from method B are shown in Fig. 1. Savitzky-Golay (SG) filter was used to calculate smoothed first (D1) and second (D2) derivatives from the pre-processed data, using MATLAB® 7.8 software. The derivatives were calculated using a second order of polynomial (quadratic) and a window size of seven. Three datasets were generated from each method including pre-processed raw dataset, first derivatives dataset and second derivatives dataset.

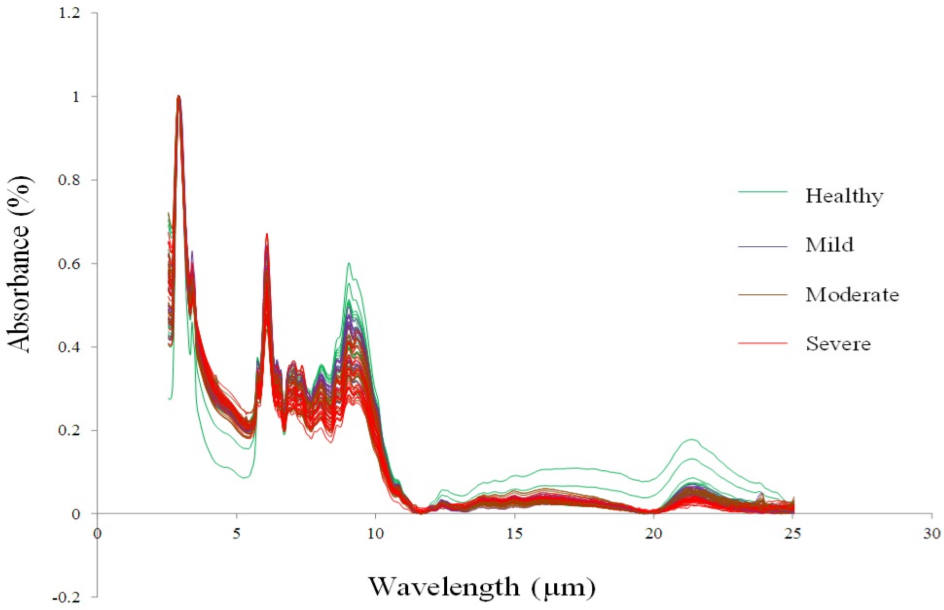

Fig. 1: Representative baseline corrected and normalized absorbance spectra (raw data) of leaf samples acquired from FTIR spectroradimete in method B.

Pattern recognition

Due to the large data sets, principal component analysis (PCA), a multivariate statistical technique, was performed for dimensionality reduction of each dataset. The selected PCs were used as input features in quadratic discriminant analysis (QDA) classification, while they were randomized and separated into the training and testing datasets with the ratio of 3:1. In both Method A and method B, the QDA-based algorithm was tested five times and the overall and individual class classification accuracies were determined from confusion matrix. In this study, the desired results were obtained when the false negative (*Ganoderma* infected samples found as healthy) and false positive (healthy samples classified as *Ganoderma* infected) errors were low (especially low false negative).

RESULTS AND DISCUSSIONS

The average classification accuracies calculated from QDA model for raw, first derivatives and second derivatives datasets are summarized in Table 1. In this model, due to the large number of PCs a negative covariance matrix was generated that cannot be classified with QDA. Thus, PCs were accounted for 99% variability within the data. As it is hard to visually distinguish between healthy trees and mild *Ganoderma* infected (symptomless stage) trees in the field, it is important to diagnose class G0 (Healthy) from G1 (mild-infected) for the purpose of BSR early detection. Thus, in this study, it is ideal that class G0 could be separated from class G1 with high accuracies using QDA model.

Table 1: Average overall and individual class classification accuracies of leave samples collected from different classes of healthiness classified with QDA-based model.

	Method A						Method B					
	PCs	Overall	G0	G1	G2	G3	PCs	Overall	G0	G1	G2	G3
QDA												
Raw	29	65.0	88.1	41.8	64.7	55.5	7	60.5	45.0	54.4	71.1	77.8
D1	43	43.9	99.1	13.8	15.2	15.4	13	88.7	94.6	79.2	84.4	95.6
D2	59	61.9	87.6	37.1	66.2	46.1	21	76.9	96.7	75.6	53.3	75.6

Comparing the average overall and individual class (G0, G1, G2 and G3) classification accuracies of the three datasets (raw, first derivatives and second derivatives) derived from method A, as analysed using the QDA-based algorithm, it was observed that the pre-processed raw dataset yielded higher average overall classification accuracy than that of other two datasets. In method B, comparing the different types of datasets, pre-processed first derivatives dataset with average overall accuracy of 89% (low false negative and low coefficient of variation) and individual class classification accuracies of more than about 80% presented the highest performance (Fig. 2). Although, the average overall classification accuracies of method A were relatively lower (except with raw dataset) than those of method B, the average individual class classification accuracies of class healthy (G0) obtained from raw and first derivatives datasets were higher than accuracies of method B.

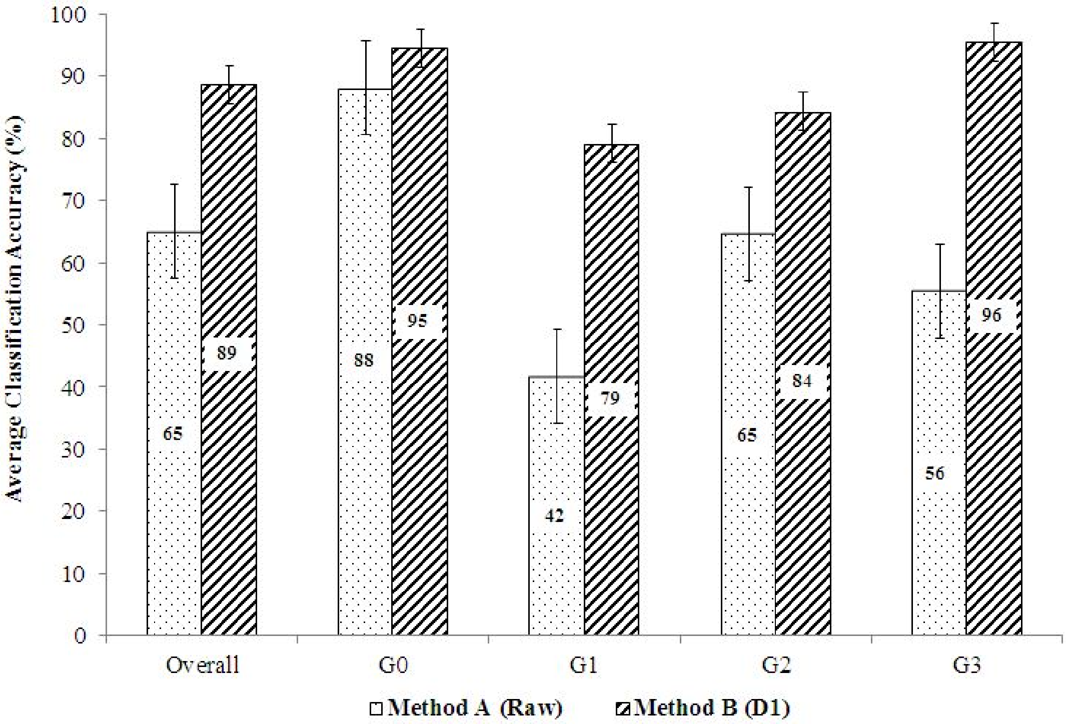

Fig. 2: The average classification accuracies yielded from pre-processed raw dataset in method A and first derivatives dataset in method B as the best performances among different type of datasets using QDA-based model.

The results indicated that KBr plays an important role to improve the spectra as well as improving the classification accuracies. Forato et al. [13] demonstrated that spectral distortions can be completely eliminated using dried sample preparation such as KBr pellets.

CONCLUSIONS

In this study the potential of mid-infrared spectroscopy for detection of *Ganoderma* in oil palm leaves was assessed. The results indicated that pattern recognition algorithms such as QDA can distinguish between healthy and infected leaves at three stages of infection with high classification accuracies ($\geq$80%). Among three types of datasets, the pre-processed first derivatives dataset resulted in a higher overall classification accuracy with desirable individual class G0 and Class G1 accuracies when samples diluted with KBr.

Unlike previous works, this technique was able to detect *Ganoderma* infection even before visual symptoms appear (i.e. slight infection) which provides alternative detection methods that can be used in ground-based sensors.

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