EARLY DETECTION OF OIL PALM FUNGAL DISEASE INFESTATION USING A MID-INFRARED SPECTROSCOPY TECHNIQUE

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ABSTRACT

Body of Abstract: Basal stem rot (BSR) caused by \textit{Ganoderma boninense} is known as the most destructive disease of oil palm plantations in Southeast Asia. \textit{Ganoderma} could potentially reduce the market share of palm oil for Malaysia. Currently Malaysia produces about 50\% of the world’s supply of palm oil. Early, accurate, and non-destructive diagnosis of \textit{Ganoderma} fungal infection is critical for management of this disease. Early disease management of \textit{Ganoderma} could also prevent great losses in production and potentially reduce the use of chemicals. In this 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 severe-infected trees were measured using Fourier transform infrared (FTIR) spectrometers system to obtain absorbance data from the range of 2.5-25 µm. Single bounce ATR accessory with dilution with 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 linear discriminant analysis (LDA) as a pattern recognition algorithm. The results indicated that LDA-based algorithm can distinguish between healthy and infected leaves at three stages of infection with high classification accuracies (>90\%). Thus, this study demonstrated that the proposed technique has the potential for early detection of the \textit{Ganoderma} disease.

Keywords: \textit{Ganoderma} disease, Mid-infrared spectroscopy, Linear discriminant analysis

INTRODUCTION

Malaysia with approximately 50\% of palm oil production is counted as the world’s largest producer and exporter of the palm oil (Sumathi et al., 2008). Among various factors, fungal disease (e.g., \textit{Ganoderma}) has been the major reason for great losses in palm oil production and increasing use of chemicals. Basal stem rot (BSR) caused by \textit{Ganoderma boninense} is known as the most destructive disease of oil palm plantations in Southeast Asia for the past 80 year (Flood et al., 2000). \textit{Ganoderma} could reduce the productivity of oil palm
plantations and potentially reduce the market share of palm oil (Sumathi et al., 2008) especially for Malaysia with million hectares under oil palm cultivation (Shuit et al., 2009). Different methods have been used to control *Ganoderma* infection on existing stands and to reduce incidence in replanting but in advanced infections, none of these methods are entirely satisfactory in reducing the disease effects on the yield (Singh, 1990). Currently, the most common way for detection of infected trees is visual inspection for *Ganoderma* specific symptoms that is labor intensive and time consuming. Different studies have shown the capability of spectroscopic techniques for detection of plant diseases in visible and near-infrared bands. Shafri et al. (2009) used visible and near infrared spectroscopy method for detection of *Ganoderma* infestation in the nursery; however, the significant bands could not differentiate between non-infected and mild-infected palms. Shafri and Anuar, (2008) 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. (2010) demonstrated that combination of partial least square regression and linear discriminant analysis can classify oil palm trees into four levels of *Ganoderma* severity with 94% accuracy. Sankaran et al. (2010) 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. Their 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.

**MATHERIALS AND METHOD**

**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. Trees with four levels of healthiness were identified by Sime Darby’s well-trained scouting team members based on specific visual symptoms on the canopy and the stem. Sampled trees were selected and labeled into the four levels of disease infection: 1-healthy or non-infected (G0), 2-slightly infected (G1) 3- moderately infected (G2) 4. Severely infected (G3). Six to ten 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™ Series Fourier transform infrared (FT-IR) spectrometer was used to collect and process mid-infrared spectra in the range of
2.5-25 µm with 0.05 µm resolution (totally 451 spectral bands). Single-reflection ATR (attenuated total reflection) accessory with dilution with potassium bromide (KBr) were used for this purpose. Six to ten pellets prepared for each palm measured with FT-IR spectrometer and acquired spectra were averaged to obtain the mean absorbance for each tree.

**Data pre-processing**

As pre-processing, absorbance spectra collected from four classes of healthiness were baseline corrected and normalized before further analysis. Some representative spectra of G0, G1, G2 and G3 are shown in Fig. 1. Savitzky-Golay (SG) filter was used to calculate smoothed first and second 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.

![Absorbance Spectra](image)

**Fig. 1.** Representative baseline corrected and normalized absorbance spectra (raw data) of leaf samples acquired from FTIR spectroradimeter.

**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 PC scores of PCs were used as input features in linear discriminant analysis (LDA) classification, while they were randomized and
separated into the training and testing datasets with the ratio of 3:1. The LDA-based algorithm was tested five times and the overall and individual class (G0, G1, G2 and G3) classification accuracies were determined.

**RESULTS AND DISCUSSION**

The average classification accuracies calculated from LDA for raw, first derivatives and second derivatives datasets are summarized in Table 1. Comparing the average classification accuracies of the three datasets, as analyzed using LDA-based algorithm, it was found that the pre-processed raw dataset yielded the highest classification accuracies. However, the average overall classification accuracy resulted from first derivatives dataset (90%) is quite close to overall accuracy of raw dataset (92%). Second derivatives dataset with 77% average overall classification accuracy yielded lower overall and individual class classification accuracies than those of other two datasets (Fig. 2). Duncan’s multiple range test through analysis of variance (ANOVA) indicated that all the classification accuracies were different in three datasets, except for the class G3 classification accuracy which was similar in all the three datasets.

**Table 1.** Average overall and individual class classification accuracies of leaflet samples collected from different classes of healthiness classified with LDA.

<table>
<thead>
<tr>
<th>Dataset</th>
<th>PCs</th>
<th>Overall</th>
<th>Class 0</th>
<th>Class 1</th>
<th>Class 2</th>
<th>Class 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear discriminant analysis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raw</td>
<td>53</td>
<td>92.31</td>
<td>83.33</td>
<td>100.00</td>
<td>88.89</td>
<td>100.00</td>
</tr>
<tr>
<td>First derivatives</td>
<td>74</td>
<td>89.74</td>
<td>75.00</td>
<td>88.89</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Second derivatives</td>
<td>88</td>
<td>76.92</td>
<td>66.67</td>
<td>66.67</td>
<td>88.89</td>
<td>88.89</td>
</tr>
</tbody>
</table>

Note: PCs contribute 99.99% variation.
CONCLUSION

In this study the potential of mid-infrared spectroscopy for detection of *Ganoderma* in oil palm leaves was assessed. The results indicated that statistical classifier models such as LDA can distinguish between healthy and infected leaves at three stages of infection with high classification accuracies (>90%). Comparing the average overall and individual classification accuracies of the three datasets acquired from the LDA-based algorithm, the pre-processed raw and first derivatives resulted in higher classification accuracies than pre-processed second derivative dataset. However, pre-processed second derivatives dataset also yielded overall accuracy with acceptable threshold.

This study demonstrates that the amount of carbohydrates in the oil palm leaves changes due to *Ganoderma* fungus activities (Hanif et al., 2005) that could be detected with mid-infrared spectroscopy technique. Unlike Vis and near infrared method, this technique was able to detect the mildly infected trees even before visual symptoms appear. Further work can be done for determination of which kind of carbohydrates changes in the oil palm leaves due to *Ganoderma* attack by extracting the leaves carbohydrates such as starch analysis.

REFERENCES


