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Mid-infrared spectroscopy for early detection of basal stem rot disease in oil palm

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ABSTRACT

Basal stem rot (BSR), caused by *Ganoderma boninense* is known as the most destructive disease in oil palm plantations in Southeast Asia. *Ganoderma* could reduce the productivity of oil palm plantations and potentially reduce the market value of palm oil in Malaysia. Early disease management of *Ganoderma* could prevent production losses and reduce the use of chemicals. This study focuses on the development of a statistical model for the discrimination of *Ganoderma* infestation on oil palm trees at different stages using a Fourier transform infrared (FT-IR) spectroscopic technique. Leaf samples of healthy, mild, moderately, and severely-infected trees were measured using FT-IR spectrometers to obtain absorbance data from the range of 2.55–25.05 μm s (3921–399 cm^{-1}). The samples were analyzed with and without dilution with KBr. After pre-processing (baseline correction and normalization), the Savitzky–Golay method was used to calculate first and second derivatives. Then, for the preprocessed raw, first derivatives and second derivatives datasets, principal component analysis was performed to reduce the dimensionality of the data. The selected principal component scores were used in classification using linear discriminant analysis (LDA), quadratic discriminant analysis (QDA), k-nearest neighbor (kNN) and Naive-Bayes (NB) multivariate classification algorithms. The algorithms were tested to classify the leaf samples into four levels of disease severity. The results demonstrated that when samples were prepared with KBr, the LDA-based model resulted in the highest average overall classification accuracy of 92%, with individual classification accuracies greater than about 90% using the pre-processed raw dataset. This verifies the potential of mid-infrared spectroscopy for *Ganoderma* detection in early symptomless stages of infection in oil palm.

1. Introduction

Malaysia, with more than four million hectares of land under oil palm cultivation, produces up to 18 million tons of palm oil each year. Palm oil is the world's most widely used vegetable oil. About 12% and 27% of the world's total productions and exports of oils and fats is provided through Malaysian palm oil industry. Malaysia is the world's second largest producer and exporter of the palm oil. Recently there is an increasing interest in producing bio-diesel from palm oil as a source of renewable energy (Sumathi et al., 2008; Shuit et al., 2009). Among various factors, fungal diseases such as *Ganoderma* cause great losses in palm oil production and increasing use of chemicals. Basal stem rot (BSR) caused by *Ganoderma boninense* Pat. is known as the most destructive disease of oil palm plantations in Southeast Asia, especially in Malaysia and North Sumatra (Flood et al., 2000).

Ganoderma degrades lignin (e.g. lignocelluloses in which cellulose and hemicellulose are well-associated with lignin) into carbon dioxide (CO_2) and water (Paterson et al., 2000). Lignin is a water impermeable seal across cell walls, and acts as a wall against microbial attack. Lignin strengthens the xylem tissues of plants (Paterson, 2007). As the fungal activity affects the vascular circulation, it restricts the nutrient and water consumption, thus reducing the oil palm production. Meanwhile, this disease can significantly reduce the leaf stomatal conductance, transpiration rate, intercellular CO_2 concentration and chlorophyll content that effects photosynthesis (Haniff et al., 2005). *Ganoderma* has great economic impact on palm oil industries (Sumathi et al., 2008) especially in Malaysia, with millions of hectares of oil palm cultivation (Shuit et al., 2009). This disease can infect oil palm trees in all growth stages, although the incidence of this disease increases with the

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tree age and usually does not affect young trees (Ariffin et al., 2000).

Different methods have been used to control *Ganoderma* infection such as fungicide treatment (George et al., 1996), biological control (Zaiton et al., 2006), removal of infected palms and soil mounding, or combination of these methods (Ariffin and Idris, 2002). Unfortunately, in advanced infections, none of these methods are entirely satisfactory in reducing the disease effects on the yield (Singh et al., 1990). A commonly used method, is the detection of infected trees by visually identifying the *Ganoderma* specific foliar symptoms and fungus fruiting bodies (Basidiomycota mushroom) on the infected trunks or primary roots near soil level by the scouting crew (Fig. 1). Following the identification, the infected trunk samples are extracted by drilling for the isolation, growth and identification of the fungus in the laboratory (Lim and Fong, 2005) and polymerase chain reaction (PCR) analysis is performed to confirm the presence of fungus. Such diagnostics process is often difficult and expensive (Lelong et al., 2010; As'wad et al., 2011).

Infrared (IR) spectroscopy is used for identifying molecular structures and properties (Kacurakova and Wilson, 2001; Bunaciu et al., 2011). One such study was done by Sankaran et al. (2010) where Huanglongbing (HLB)-infected citrus leaves were classified from healthy ones using a mid-infrared spectrometer (5.15–10.72 μm). The results indicated that the accumulation of starch in HLB-infected leaves could contribute to good classification accuracies. Hawkins et al. (2010) used a similar approach for detecting Huanglongbing (greening) in citrus leaves. In addition, Cardinali et al. (2012) used attenuated total reflection (ATR) Fourier transform infrared (FT-IR) spectroscopy for detecting Huanglongbing (HLB) and citrus variegated chlorosis (CVC) diseases in leaves of sweet orange trees in Brazil. They applied induced classifier via partial least squares regression to differentiate the IR spectral of healthy, CVC symptomatic, HLB-symptomatic and HLB-asymptomatic leaves. This method could identify these different leaf types with about 93% accuracy. A comparative study of mid-infrared diffuse reflection and attenuated total reflection (ATR) spectroscopy for the detection of fungal infection on RWA2-corn was done by Kos et al. (2004). In this study, corn samples could be classified from a single genotype (RWA2, blanks and contaminated with *Fusarium graminearum*) with classification efficiency of 100% when principal component analysis (PCA) and cluster analysis were implemented on MIR data.

It was anticipated since *Ganoderma* affects water and nutrient uptake in trees, IR spectra can provide a unique fingerprint related to the biochemical constituents that may change upon infection. One of the major challenges in identifying foliar symptoms is that the symptoms appear only in the advanced stages of the infection. Thus, there is a need for an efficient sensing technique for early detection of *Ganoderma* in oil palm plantations. Early and accurate detection of *Ganoderma* is critical for management of this disease. In this paper, we propose the use of a mid-infrared (MIR) spectroscopic technique for detection of infected oil palm at three different stages of *Ganoderma* infection from the leaves.

2. Materials and methods

2.1. Sample collection

Samples were collected from Sime Darby oil palm plantations located in Banting, Selangor, Malaysia (2° 50′ 32″ N 101° 29′ 19″

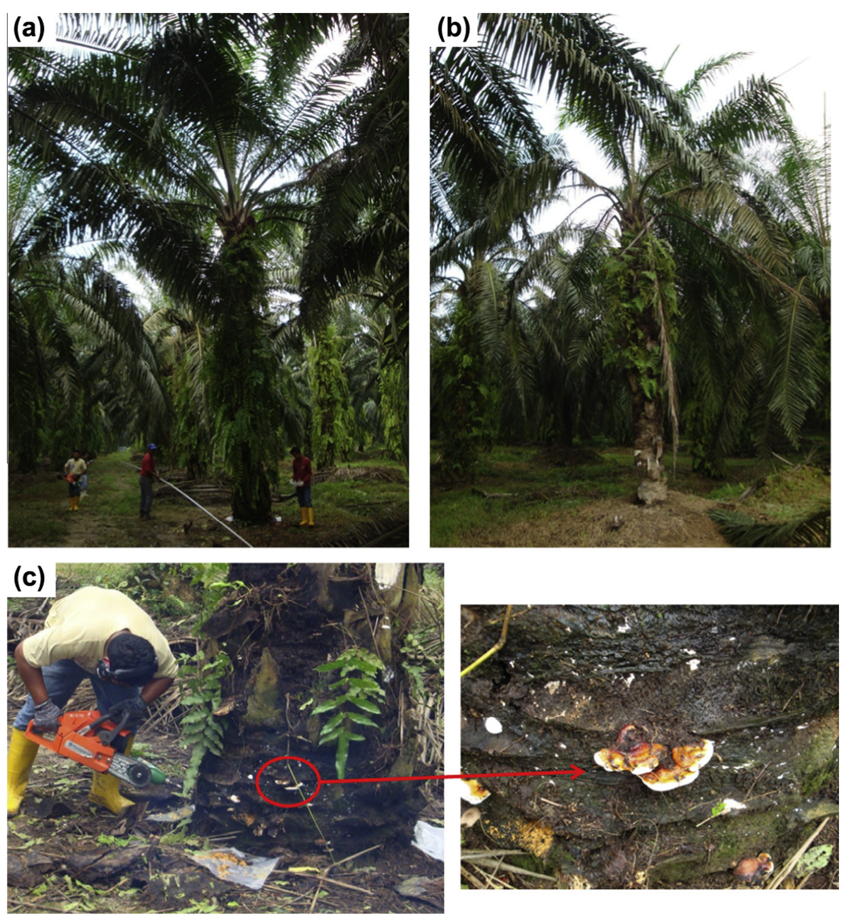

Fig. 1. *Ganoderma* specific symptoms on oil palm trees in Banting, Selangor, Malaysia: (a) healthy tree, (b) infected tree, and (c) fungus fruiting bodies (Basidiomycota mushroom) on the infected trunk.