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Spectral features selection and classification of oil palm leaves infected by Basal stem rot (BSR) disease using dielectric spectroscopy

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ABSTRACT

Basal stem rot (BSR) is a prominent plant disease caused by *Ganoderma boninense* fungus, which infects oil palm plantations leading to large economic losses in palm oil production. There is need for novel disease detection techniques that can be used to reduce the oil palm losses due to BSR. Thus, this paper investigated the feasibility of utilizing electrical properties such as impedance, capacitance, dielectric constant, and dissipation factor in early detection of BSR disease in oil palm tree. Leaf samples from different oil palm trees (healthy, mild, moderate, and severely-infected) were collected and measured using a solid test fixture (16451B, Keysight Technologies, Japan) connected to an impedance analyzer (4294A, Agilent Technologies, Japan) at a frequency range of 100 kHz–30 MHz with 300 spectral interval. Genetic algorithm (GA), random forest (RF), and support vector machine-feature selection (SVM-FS) were used to analyze the electrical properties of the dataset and the most significant frequencies were selected. Following the selection of significant frequencies, the features were evaluated using two classifiers, support vector machine (SVM) and artificial neural networks (ANN) to determine the overall and individual class classification accuracies. The selection model comparative feature analysis demonstrated that the best statistical indicators with overall accuracy (88.64%), kappa (0.8480) and low mean absolute error (0.1652) were obtained using significant frequencies produced by SVM-FS model. The results indicated that the SVM classifier shows better performance as compared to ANN classifier. The results also showed that the classes, features selection models, and the electrical properties were found to be significantly different ($p < .1$). The impedance values were highly classified by *Ganoderma* disease at different levels of severity with overall accuracies of more than 80%. Impedance can be considered as the best electrical properties that can be used to estimate the severity of BSR disease in oil palm using spectroscopy technique. As such, this study demonstrates the potentials of utilizing electrical properties for detection of *Ganoderma* diseases in oil palm.

1. Introduction

Oil Palm is one of the most important economic crop in Southeast Asia, particularly in Malaysia and Indonesia. For example, Malaysia has the second largest oil palm plantation in the world with an estimated over four million hectares of land have been used for oil palm cultivation. Annually, approximately 18 million tons of palm oil are produced (Liaghat et al., 2014a). Palm oil is considered the world's most widely consumed vegetable oil with approximately 12% and 27% of the world's total productions and exports of oils and fats, respectively (Madihah et al., 2014; Bivi et al., 2010). However, this crop is susceptible to Basal stem rot (BSR) disease especially in Malaysia and Indonesia and is been considered the main threat to sustainable oil palm production (Wong et al., 2012; Nusaibah et al., 2016). BSR caused by *Ganoderma boninense* fungus, is a fatal disease which infects oil palm plantations leading to decline productivity and hence large economic losses in palm oil (Nurnadiah et al., 2014; Markom et al., 2009).

About 15 species of *Ganoderma* have been reported from various parts of the world, and 7 of them were from peninsular Malaysia, including most destructive is *Ganoderma boninense* (Ho and Nawawi, 1985; Khairudin, 1990; Flood et al., 2000).

To better understand *Ganoderma* disease and its effects on oil palm crops, Paterson (2007) stated that, *Ganoderma* degrades lignin in cell walls of stem tissues into carbon dioxide (CO_2) and water. As the fungal activities continue, due to the degradation of lignin, the vascular circulation of plant is affected, thereby restricting the nutrient and water

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Fig. 1. Ganoderma specific symptoms on oil palm trees in Perak, Malaysia: (a) healthy tree (b) infected tree with retarded growth (c) fungus fruiting bodies on the infected trunk.

consumption, consequently reducing the oil palm production (Horbach et al., 2011). Meanwhile, this disease can significantly decrease the leaf stomatal conductance, intercellular CO_2 concentration and chlorophyll content thus affect the photosynthesis (Haniff et al., 2005). Eventually, it will lead to basal tissues in plants damage (Meor et al., 2009). Once infected, oil palm trees developed typical symptoms such as yellowing leaves, unopened fronds (spears), small canopy, and an existence of *Ganoderma* fruiting bodies (Fig. 1). Progression of the disease leads to tree decline, dieback of fronds, and finally, tree death.

Recently, researchers have shown an increased interest in the use of advanced techniques to detect BSR disease in oil palm trees. These includes terrestrial laser scanning (Khairunniza-Bejo and Vong, 2014), image processing (Kulkarni and Ashwin, 2012), electronic nose (Markom et al., 2009), gas chromatography-mass (GC-M) (Akmar and Pauzi, 2011), sonic tomography (Ishaq et al., 2014), microfocus X-ray fluorescence (uXRF) (Meor et al., 2009), infrared spectroscopy (Liaghat et al., 2014a), and GanoSken technology (Nurnadiah et al., 2014). Most of these advanced techniques have limitations that include cumbersome process, long setup process, high-cost, and very sensitive to the changes of the environmental condition requirement (Fang and Ramasamy, 2015).

Among the recent BSR disease detection techniques, spectroscopy technique has shown to be the most advantageous (Khaled et al., 2017). The advantages of this technique over others include simplicity, rapidity and affordability (Wu et al., 2008; Abu-Khalaf, 2015). Field spectroscopy have been used for determinnation and classification of plant diseases. Liaghat et al. (2014b) investigated the application of mid-infrared (MIR) spectroscopy to detect the BSR disease in oil palm leaves, in which the authors uses fourier transform infrared (FT-IR) spectroscopic technique in order to establish a statistical model for the discrimination at different levels of disease severity. The MIR spectra of the oil palm samples were measured in the wavelength region of 1000–2500 nm at different levels of disease severity and the leaf samples were collected from trees which were labeled into four classes namely: healthy, mild, moderate and severely infected, based on visual symptoms and polymerase chain reaction (PCR) analysis. Principle component analysis (PCA) was used to reduce the dimensionality of data. They found that the overall accuracy was higher than 80%. Similarly, Izzuddin et al. (2013) reported an investigation into the applicability of near-infrared spectroscopy to classify *Ganoderma* disease