TERAHERTZ SENSING ANALYSIS FOR EARLY DETECTION OF GANODERMA BONINENSE DISEASE USING NEAR INFRARED (NIR) SPECTROMETER

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We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

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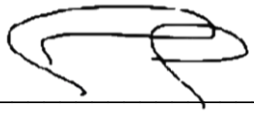

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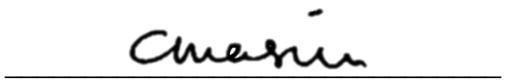

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ABSTRAK

Jangkitan Ganoderma boninense (G. boninense) mengurangkan produktiviti kelapa sawit dan menyebabkan ancaman serius kepada industri minyak sawit. Pengesanan awal G. boninense adalah penting kerana tiada rawatan berkesan untuk menghentikan penyebaran penyakit tersebut. Sistem yang dicadangkan adalah menggunakan spektroskopi inframerah dekat (NIRS) mudah alih untuk pengesanan awal G. boninense pada anak benih kelapa sawit tanpa gejala dan pengelasan data spektrum menggunakan teknik pembelajaran mesin (ML). Perincian tidak invasif, mesra alam (tiada bahan kimia terlibat), mudah alih dan sensitif membolehkan spektroskopi inframerah dekat (NIRS) bersama teknik pembelajaran mesin (ML) dan analitik ramalan sebagai platform penting ke arah pengesanan awal G. boninense pada masa hadapan. Data spektrum dikumpul daripada 6 sampel sampel kelapa sawit berinokulasi dan tidak berinokulasi pada peringkat semaian menggunakan sensor spektroskopi inframerah dekat (NIRS) bersepadu. Kimometrik dilakukan dengan melaksanakan analisis komponen utama (PCA), derivatif dan regresi separa kuasa dua (PLS) untuk mengenalpasti maklumat penting di dalam spektrum. Gelombang inframerah dekat yang ketara adalah pada 1310 nm dan 1450 nm yang masing-masing dapat dikaitkan dengan ergosterol dan kandungan air. Selain itu, puncak spektra derivatif SG berkaitan dengan kumpulan fungsi yang spesifik yang berguna untuk mengesan G. boninense, termasuk rentangan N-H yang ketiga, rentangan C-H yang kedua, dan gabungan rentangan C-H dan rentangan O-H. Analisis kromatografi cecair berprestasi tinggi (HPLC) dilakukan untuk mengenal pasti kandungan ergosterol dalam sampel kelapa sawit. Ergosterol boleh digunakan sebagai biomarker untuk pengesanan G. boninense kerana ia hanya boleh didapati dalam tumbuhan yang diserang kulat. Dalam Teknik pengelasan, empat algoritma teknik pembelajaran mesin (ML) berbeza: K-Nearest Neighbor (kNN), Naïve Bayes (NB), Support Vector Machine (SVM) dan Decision Tree (DT) diuji untuk pengelasan sampel anak benih kelapa sawit yang sihat dan dijangkiti. Algoritma DT pada spektrum daun mencapai prestasi keseluruhan yang memuaskan berbanding dengan pengelas lain dengan ketepatan tinggi sehingga 93.1% dan skor F1 sebanyak 92.6%. Oleh itu, analisis ramalan berasaskan DT pada data daun sebagai rujukan spektrum NIR dibangunkan untuk pengesanan masa nyata bagi jangkitan G. boninense. Prototaip sistem pengesanan G. boninense pintar mudah alih dibangunkan dengan mengimplementasikan Internet of Things (IoT) kepada sistem yang membolehkan gabungan sensor dan server untul melakukan ramalan anak benih kelapa sawit sama ada sihat atau dijangkiti. Prototaip kerja ini menunjukkan bahawa pendekatan yang dicadangkan ini boleh dipercayai dan praktikal untuk pengesanan awal G. boninense pada anak pokok kelapa sawit.

ABSTRACT

Ganoderma boninense (G. boninense) infection reduces the productivity of oil palms and causes a significant impact on the economic viability of oil palm plantations. Early detection is critical for the effective management of this disease since there is no effective treatment that can stop the spread of this disease. The proposed system uses integrated hand-held near-infrared spectroscopy (NIRS) for early detection of G. boninense on asymptomatic oil palm seedlings and classification of spectral data using machine learning (ML) techniques. The non-destructive method using NIRS with ML and predictive analytics has the potential to be a highly sensitive and reliable method for the early detection of G. boninense. Spectral data are collected from 6 samples of inoculated and non-inoculated oil palm samples at nursery stages using an integrated NIRS sensor. Chemometrics is performed by implementing principal component analysis (PCA), derivatives and partial least square (PLS) regression to extract the vital information of the spectra. The significant wavelengths are at 1310 nm and 1450 nm which are attributable to ergosterol and water content, respectively. Furthermore, the SG derivatives spectra peaks corresponded to specific functional groups that could be utilized for the detection of G. boninense. These functional groups encompass the third overtone of N-H stretching, the second overtone of C-H stretching, and a combination band involving both C-H stretching and O-H stretching. High-performance liquid chromatography (HPLC) analysis is performed to identify the ergosterol content in oil palm sample. Ergosterol can be used as a biomarker for the detection of G. boninense since it can only be found in the fungal-infested plant. In classification, four different ML algorithms: K-Nearest Neighbour (kNN), Naïve Bayes (NB), Support Vector Machine (SVM) and Decision Tree (DT) are tested to classify healthy and infected oil palm samples. DT algorithm on leaves spectra achieves a satisfactory overall performance compared to the other classifiers with high accuracy up to 93.1% and an F1-score of 92.6%. Therefore, a DT-based predictive analytic on leaves NIR spectral reference data is developed for real-time detection of G. boninense infection. A portable smart G. boninense detection system prototype is developed by implementing the Internet of Things (IoT) into the system which enables the integration of sensors and server to perform prediction of healthy or infected oil palm seedlings. This working prototype showed that this proposed approach is reliable and practical for the early detection of G. boninense in oil palm seedlings.

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