GanoSken FOR EARLY DETECTION OF *Ganoderma* INFECTION IN OIL PALM

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Diagnosis of *Ganoderma* infection in oil palm is based on the presence of basidiomata of the pathogen on the stem base or frond bases or roots (Idris and Ariffin, 2004). To conduct various studies on *Ganoderma* in oil palm, a *Ganoderma* selective medium (GSM) was developed (Ariffin and Idris, 1991). The medium was used to isolate the pathogen from any part of the infected tissues directly from the field, with or without surface sterilization. The GSM enables identification of the presence of *Ganoderma* infection in plants even when external symptoms are not revealed (Ariffin *et al*., 1993). Studies elsewhere indicate that 5%-16% of healthy-looking oil palms are actually infected (Ariffin *et al*., 1996). The method used in these studies is time-consuming and the accuracy is not very high. Other technologies for the early detection of *Ganoderma* have been developed through the enzyme-linked immunosorbent assay-polyclonal antibody (ELISA-PAb) (Idris and Rafidah, 2008) and the molecular polymerase chain reaction-DNA (PCR-DNA) techniques (Idris *et al*., 2003). These techniques offer several advantages in providing specificity and sensitivity in the detection of *Ganoderma* in oil palm. Another new technology, GanoSken, for the early detection of *Ganoderma* infection in oil palm is described here.

DEVELOPMENT OF GanoSken TECHNOLOGY

GanoSken refers to the cross-sectional imaging of an object from either transmission or reflection data collected by exposing the object under study to a source wave coming from many directions. A sound sensor is used in this work, which consists of a set of sensors connected by using nails around the oil palm stem (*Figure 1*). Sound waves generated from a nail (emitter) and travelling to the other nails (receptors) through the oil palm stem is called a sound line. The sound velocities are calculated based on the time of flight of the sound waves, and the distance between the emitter and the receptor. The sound velocity (V) in wood (the stem) is governed by its elasticity (E) and density (D) as given in the following equation (Mazliham, 2008):

Figure 1. Installation of sound sensors on the oil palm stem for the detection of Ganoderma *infection.*

$$V = \sqrt{\frac{E}{D}}$$

where V = velocity, E = elasticity and D = density.

The sound lines are segmented into five colours, which indicate different conditions: white or blue or green (decayed wood, slow velocities); violet (degraded wood), and brown or dark brown (solid wood, high velocities) (*Figure 2*). However, sound line visualization only provides partial sound propagation mapping in the oil palm stem. Complete mapping is obtained using an interpolation function that interpolates the known data to obtain other unknown data. Values of the intersection of the sound lines are used to generate the interpolation calculations based on the Inverse Distance Method (Mazliham, 2008). Sound velocities across an infected and an uninfected section of the oil palm stem are included in the interpolation calculations to enhance the reliability of the resultant tomography image. *Figure 2* is

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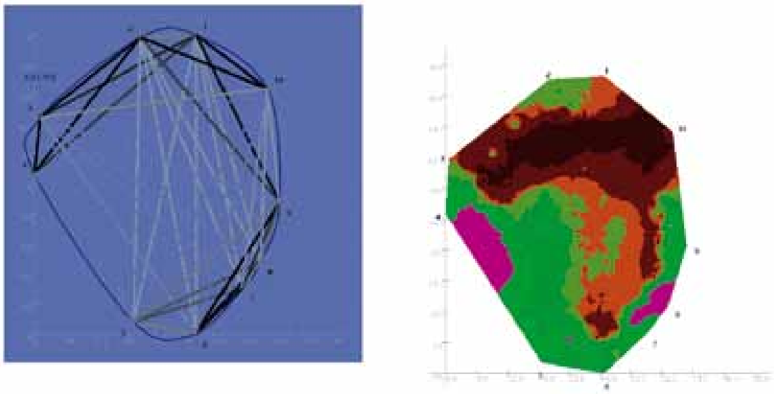
an example of the lines and the tomography calculated based on the values of the intersection of these lines.

GanoSken is an experimental platform which allows the implementation of the calculations of sound image tomography for the oil palm stem. The ability of this software to visualize oil palm data is made possible as prior information on the sound wave propagation in the oil palm stem is taken into consideration in the calculations. The software allows the programme to return to the previous stage if the current results are unsatisfactory. The acquired data provide a visual of the sound line intersection points, and the quality of the acquisition will then be decided (*Figure 3*). The analysed data will generate a visual that gives the first indication of the condition of the oil palm stem. Applying the Inverse Distance Method for interpolation and Fuzzy C Means for classification, GanoSken produces a full tomography image (*Figure 4*).

FIELD TESTING OF GanoSken FOR EARLY DETECTION OF *Ganoderma* INFECTION

For the field evaluation, cross-sections of 30 oil palm stems were classified into two groups: healthy-looking palms (H) and diseased (infected) palms (I) as shown in *Figures 5*, *6* and *7*. GanoSken tomography images were produced and confirmed the size and site (location) of *Ganoderma* infection in oil palm stems. The images of real cross-sections were correlated with the tomography images. Dark brown areas indicated intact and healthy stems, while violet and greenish areas indicated *Ganoderma* infection. These inspections of the oil palm stems were confirmed using the *Ganoderma* selective medium (Ariffin and Idris, 1999). The results show that GanoSken is capable



2a 2b

Figure 2. Sound lines (2a) and sound tomography (2b) of GanoSken.

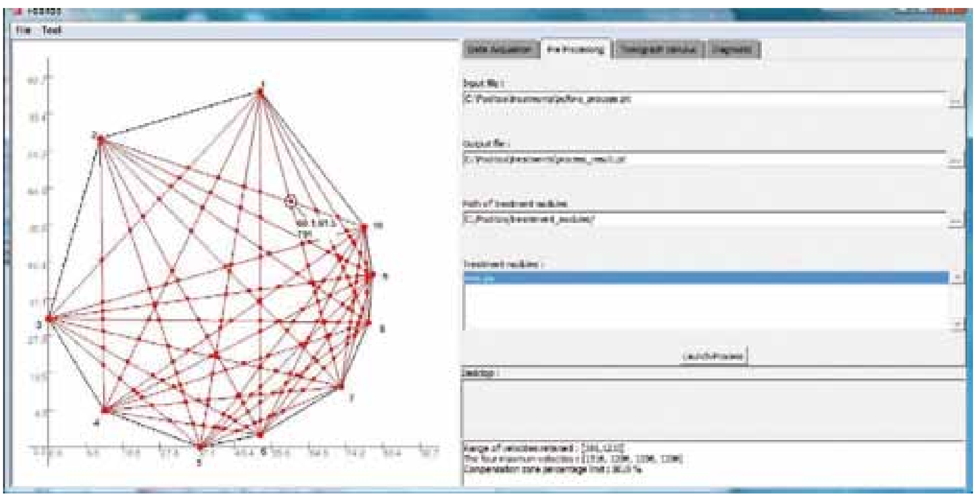


Figure 3. Visualization of the intersection points using GanoSken.

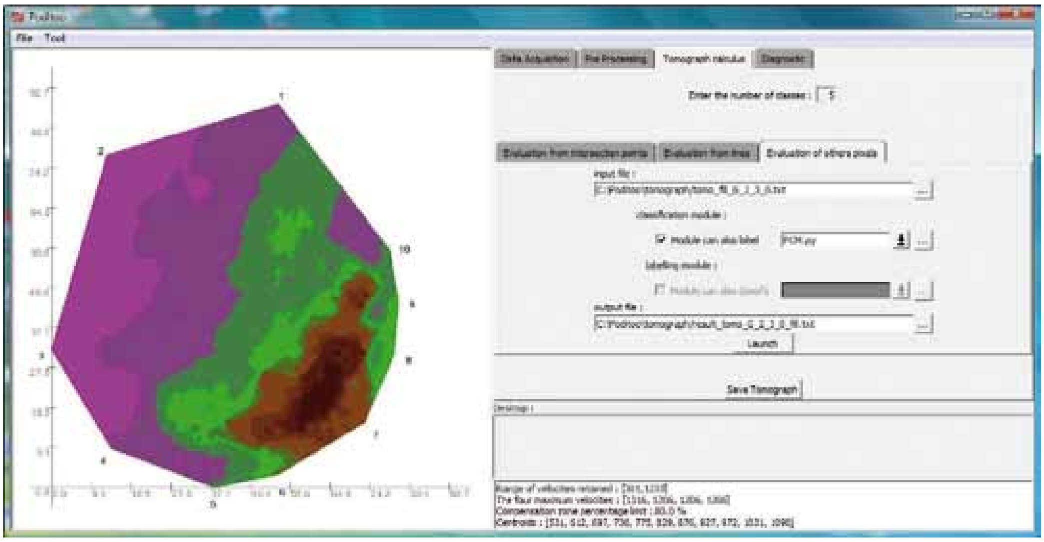
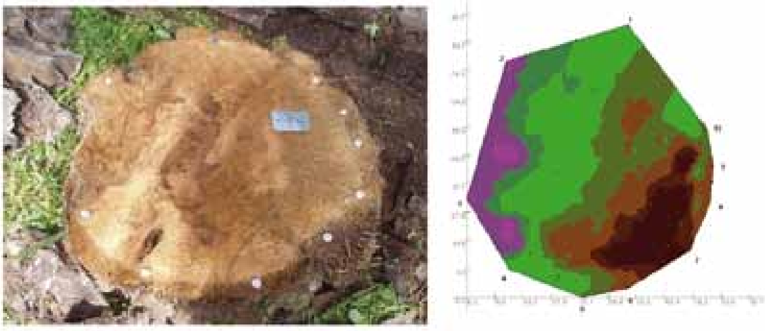
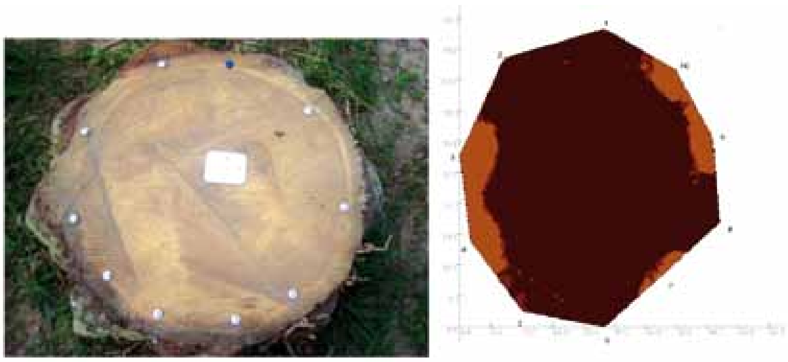


Figure 4. Complete tomography image using GanoSken.



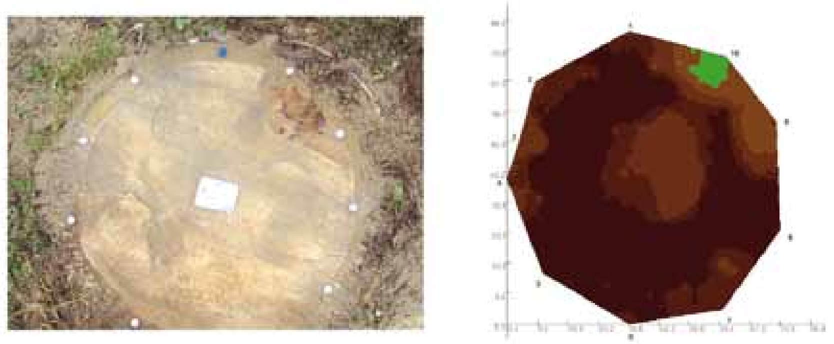
5a **5b**

Figure 5. Cross-section (5a) and GanoSken tomography image (5b) of a diseased standing palm with basal stem rot (BSR) foliar symptoms and stem decay due to Ganoderma *infection.* Ganoderma *infection in stem tissues is indicated in green.*



6a **6b**

Figure 6. Cross-section (6a) and GanoSken tomography image (6b) of a healthy-looking palm without external basal stem rot (BSR) foliar symptoms or fruiting body of Ganoderma. *No* Ganoderma *infection is detected in the stem tissues.*



7a 7b

Figure 7. Cross-section (7a) and GanoSken tomography image (7b) of a healthy-looking palm with Ganoderma *infection in the stem tissues (green area) without external basal stem rot (BSR) foliar symptoms or fruiting body. This is proof of early detection of* Ganoderma *infection.*

of performing an early detection of *Ganoderma* infection in oil palm stems.

CONCLUSION

GanoSken is capable of detecting and identifying *Ganoderma* infection in healthy-looking oil palms. The technology utilizes a tomography image, the mathematical interpolation function and information on the physical proprieties of *Ganoderma* infection. Decay and degradation caused by *Ganoderma* are detected using sound wave propagation characteristics. Infected and uninfected areas of the stem are distinguishable in the tomography image. This will help with the responsible use of fungicides to control *Ganoderma* in oil palm.

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