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A Review of Application of Computed Tomography on Early Detection of Basal Stem Rot Disease

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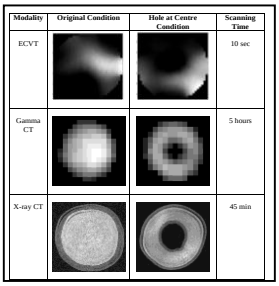
Graphical abstract



Abstract

To the best of our knowledge in agriculture, basal stem rot disease causes a major loss in palm oil industry as it affects the production of the edible oil as well as for biofuel industry. The disease attacks the root of the tree which is cause by fungal of Ganoderma Boninense. Meanwhile, there is no sensor commercially available to detect any disease or stress in the tree without the risk of damage from physical intrusion. Hence, early detection technique on the infected tree is crucial to avoid more damage to the tree. Development of tomography application on detecting the disease in plant plays important role to enhance the quality in research and development on managing a better and healthier plantation management. In recent years, several tomography systems such as X-Ray microtomography and GammaScorpion are used to analyse wood microstructure and for early detection of basal stem rot respectively. Electrical Capacitance Volume Tomography or ECVT is a promising non-invasive imaging technique that provides 3D and real time imaging of object. In this paper, we compared the images between the healthy and unhealthy palm oil trunk using these three tomography imaging techniques which is X-Ray, Gamma Ray and ECVT in terms of clarity, time taken and portability of the devices. The result indicates the potential of ECVT as the most suitable device to be used to detect the disease due to its fastest time taken, safety and easy to be used.

Keywords: Tomography; basal stem rot; palm oil; *ganoderma boninense*

1.0 INTRODUCTION

Many benefits and advantages offer by palm oil cultivation lead the developers, stakeholders and also researchers to involve in this industry without hesitate. This energy crop provides direct and indirect employment to 860,000 people excluding other multi- plying effects and spin-offs activities [1]. This profitable oil crop is the most demand among other vegetable oils surpasses the soybean, rapeseed, sunflower and coconut in year 2005. Approximately 80% of the production of palm oil is used in food industry as cooking oil and additive in food. In Sabah and Sarawak, the drastic increase in the 1990s can be attributed to the government policy in the intensification of palm oil industries in East Malaysia [2].

Ganoderma attacks palm trees early as 10 to 15 years old trees since 1957 and recently it was claimed that the spread of the disease occurs in younger palm trees. This shows that the fungi has adapted to its surrounding and act as parasite specifically to the root of the tree.

In present paper, several species had been reported to be responsible for BSR disease of oil palm in Malaysia, namely, *G. boninense*, *Ganoderma zonatum* and *Ganoderma miniatotinctum* respectively, while *Ganoderma tornatum* is non-pathogenic, infecting only dead trunks of oil palms [3]. However, in this review, we will only focus on Ganoderma boninense as it is the most aggressive pathogen.

Furthermore, species of Ganoderma are the causal agents of rots of numerous other plantation crops including coconut, rubber, betel nut, tea, cocoa, guarana, and grapevines. Forest trees such as Acacia, Populus and Macadamia are also affected [4]. Besides, through various plant disease detection techniques, some precaution steps can be taken to stop or overcome the damage on the plant. For example, the using of pesticides and fertilizers might be the solution for the infected plant to recover and grow healthier if we can detect the disease in early stage simultaneously cut off excessive amount of money to spent on the new tree that have to be replanted.

2.0 ELECTRICAL CAPACITANCE VOLUME TOMOGRAPHY AS A POTENTIAL CT IN DETECTING BSR

Electrical Capacitance Volume Tomography (ECVT) is a technique considered has a potential to measure soil water content by utilizing the significant difference in permittivity

values between air, soil and water. Because of its ability to measure objects in three dimensions, then the measurement of soil water content using this tool allows the circumstances to be able to image distribution of water in the soil. ECVT technique gives several advantages, such as: non-destructive, non-invasive, and can visualize the distribution of water in three dimension image in real time.

The low profile and flexibility of capacitance sensors, increased number of imaging frames per second, and relatively low cost of the ECVT system are characteristics that have moved the technology to the top of the list of industrial imaging tools [5]. The principle of ECVT is the reconstruction of 3D image based on signal from capacitance sensor whereas any changes in phase distribution will result in nonlinearity in electric field distribution. Basically, there are a lot types of shape of ECVT like t-shape vessel, half -cylindrical vessel, and smooth right-angle bend.

When ECVT is operating, the image appear on the screen really depends on the permittivity of the object. The permittivity is an ability of an object to affect electric field set up in it where the higher the value of permittivity, the lower the electric field that is presented. Therefore, different value of permittivity will visualize uneven distribution of the object tested for example the infected trunk of palm oil, the damage area of infected part (usually will become hollow) will have different permittivity rather than the healthy part.

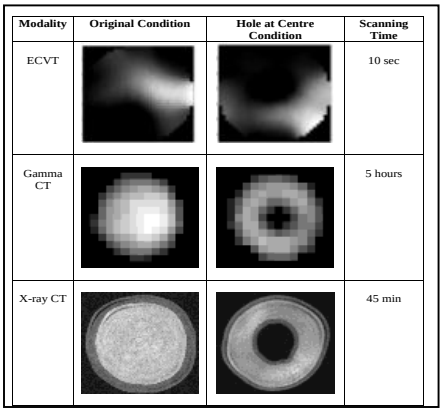


Figure 1 Comparison of CT system to image stem of palm oil between original stem and artificially hole at the centre of stem

Based on Figure 1, the images of palm oil stem have been captured using three different CT systems: ECVT, Gamma CT and X-Ray CT. Two types of stems are prepared to compare between healthy stems and artificially hollow made to mimic the diseased stem. Fastest result shows that ECVT can reconstruct the image within 10 seconds while CT using X-Ray took about 45 minutes to generate the image. On the other hand, the time of scanning for one oil palm trunk using GammaScorpion at a certain level of cross section took about five to six hours complete scanned. Therefore, ECVT gives optimum result in the shortest period and a lot of time can be saved for imaging hundreds of trees in the plantation.

■3.0 GAMMASCORPION

Present status for early detection of BSR is by 'GammaScorpion', apparatus using gamma ray application where utilize some amount of sealed radioactive source. Realizing that a fast and reliable method is needed for field inspection, a transportable computed tomography (CT) system, GammaScorpion has been designed. This scanner is able to noninvasively detect BSR, and precisely determine the magnitude and location of BSR damage without the need to cut the tree [6].

Gamma rays are a form of electromagnetic radiation or light emission of frequencies produced by sub-atomic particle interactions, such as electron–positron annihilation or radioactive decay [7]. The gamma-ray transmission data are collected by radiation detectors at many different angles within the image plane, and these data are then used to reconstruct a meaningful cross-sectional image that is essentially a map of the density distribution.

The results are presented in the form of cross-sectional image of density profile of ionizing radiation when traversing through the oil palm trunk. The system consists of the scanner hardware and system software. The hardware section contains four separate mechanical parts, i.e. a radioactive source holder, a radiation detector holder, a pair of linear translation arms and a circular motion rig (C-frame).This, make a system heavily and hard to handle (mobility and portability) during the field condition.

Figure 2 GammaScorpion is being used to scan the trunk of palm oil [6]

However, there are several factors and constrain need to consider for in-situ inspection such as the weight of the system, mobility and portability, canning time taken and radiological safety. Though it is portable, the ability of this massive 150 kg machine to detect all possible diseased trees in wide plantation is still questionable. Apart from the size, the effect of the radiation to user is undeniable.

■4.0 HIGH RESOLUTION X-RAY COMPUTED TOMOGRAPHY (HRXCT)

X-ray computed tomography (CT) is a minimally-invasive structural imaging method that allows three-dimensional (3-D) reconstruction of scanned objects. Today CT is commonly utilized in animal sciences, mainly in cancer research, bone architecture study, angiogenesis, and in vivo imaging of small animals [8].

The important features of wood micro- and nano-structure include the presence and distribution of different wood cell types (including tracheids, fibres, longitudinal parenchyma cells, ray parenchyma cells and vessels) that constitute the structure and, on a smaller scale, the orientation of the cell wall cellulose

microfibrils which give the wood its tensile strength and stiffness [9].

Progress improvement of computed tomography in plant's research and development has introduced micro-CT specifically in imaging of the morphological of the root. Due to innovation of technology, micro-CT achieved a new level where the scanning resolution rises up to sub-micron level, and this is when it is called high-resolution X-ray computed tomography. HRXCT produces a 3D reconstruction with a consistent resolution in all 3 axial directions and enables digital sectioning in any desired orientation without physical damage to the sample [7]. The availability of laboratory X-ray sources with sources sizes from a few microns down to the submicron scale have opened up the possibility of laboratory-based microtomography of wood capable of revealing intra-cellular scale features [9].

Time taken for 3D image reconstruction is based on the resolution, size of the object and noise. Apart from limitation on longer time of scanning for larger object, the magnification depends on the size of sample too. When placing a rather huge sample, X-ray detector has to be placed farther away, hence reduce the quality of the image.

Another impracticality of using this ionizing based tomography is the damage on human tissue cells when exposed to the radiation. Standard medical practice restricts x-ray exposures of pregnant women because of the accepted increased risks of childhood cancer from *in utero* exposure to x-rays. The biological impacts of x-rays are considered to be essentially the same as gamma rays [10].

5.0 CONCLUSION

There are no commercial methods yet available which are able to give the result of the test directly on the site with count in factors of un-expensive system, safety related, light and easy system for mobility and the most importantly is time factor, time to produce the result immediately. All the above-mentioned techniques are normally applied to oil palms trees when the symptom of BSR disease can be observed by naked eyes. Typically, the primary symptom that may be observed is a wilting, mild to serve, of all leaves but the spear leaf. GammaScorpion and HRXCT serve the need for imaging of the trunk but unfortunately they are dangerous to human and also have a long time taken as well as huge hardware to be used in the plantation. Therefore, physical inspection methods and apparatus for early detection and inspection of BSR damage are urgently required. The practicality of ECVT serves most potential CT to be applied in early detection of BSR in the future for its fast time taken, easy to use, safe and within the budget.

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