Effects of Basal Stem Rot on Oil Palm Inter-frond Angles for Different Severity Levels

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***Abstract*—Basal Stem Rot (BSR) is the most destructive disease of oil palm in Malaysia. White-rot fungus *Ganoderma* is the causal pathogen of BSR disease leading to significant economic loss to the oil palm industry. Early disease detection is crucial to control the disease and to reduce the disease effects on the yield. Terrestrial Laser Scanning (TLS) is an active imaging method which is contact-free, precise, cost-effective and user-friendly. It provides accurate information on tree dimensions and morphology, which relates to plant development and health. This study proposed an image processing technique using the point clouds, ground input data taken from the terrestrial laser scanner that has capability to get a top view image of the tree. The objective of this study was to analyze the oil palm inter-frond angles (measured in degrees) using top view image of oil palm tree at four different severity levels of infection. From the results, mean degree of frond angle in each level showed significant relationship with severity level of BSR with high correlation, R^2 values of 0.96. Results from Analysis of Variance (ANOVA) for frond angles exhibited significant differences between all levels of infection with p-value less than 0.0001.**

***Index Terms*—Lidar, point cloud, image processing, frond angle, terrestrial laser scanner**

I. Introduction

Basal Stem Rot (BSR) is the most destructive disease of oil palm in South-East Asia especially in Malaysia and Indonesia, and Malaysia has recorded yearly losses up to RM 1.5 billion (around 400 million USD) due to the BSR [1]. From the study, it was found that *Ganoderma* attack could lead to fresh fruit bunches (FFB) yield reduction up to 4 tonnes per hectare and was estimated a total of 400 000 hectares could be affected in the year 2020.

White-rot fungus *Ganoderma* is the causal pathogen of BSR disease, which infects oil palm primarily through the roots and degrades the lignin component of wood, causing dry rotting of root bole and the stem base [2].

The disease can infect all stages of oil palm plants [3]. In the early stages of infection, plants usually appear symptomless and the symptoms appeared only when the plant is severely infected. Thus, plants with severe symptoms were unable to be saved. The main visible symptoms could be discovered at the external part of infected oil palms, especially at the bottom of the trees and the leaves parts (foliar symptoms). Foliar symptoms of infected oil palms are wilted green fronds, crown hanging downward like a skirt, several unopened new fronds and fronds becoming yellowish [4]. These types of visual inspection for the infected trees are labour intensive and time consuming.

Recent studies have shown the use of LiDAR (Light Detection and Ranging) to monitor the plant growth and physiology of plant canopy is promising [5]. These 3D profiling systems have features that could provide accurate information on tree dimensions and morphology. It relates to plant development and health, such as high degree of accuracy and precision (up to mm) [6]. The data collected from the scanner was comparably fast (highly detailed documentary data in minimal amounts of time), automated and the data acquisition is easy and rapid (can reach up to 1 million points per second) allowing very high resolutions [7]. Some of the applications using TLS method for complete and precise tree architectures were demonstrated by [8]-[11]. Several features were extracted from the TLS data i.e. tree height, crown based height, crown diameter, crown volume and plant area index. The results showed that point clouds data from TLS could be used for extraction of various tree parameters with high correlation. Until now, there was no critical investigation on the characteristics of the canopy architecture related to the diseases and implemented it for early detection. The aim of this study was to analyze the oil palm inter-frond angles (measured in degrees) using the top view image of oil palm trees at four different severity levels of infection using TLS data and computer software.

II. Materials and Methods

A. Terrestrial Laser Scanner

In this study, physical characteristics of oil palm tree were analyzed using Faro Laser Scanner Focus 3D data (FARO Technologies, Inc., Florida, USA). FARO laser

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scanner uses a high-speed laser technology to acquire millions of three-dimensional (3D) laser points for detail measurement and documentation in significantly shorter time. Since the field of view of Faro Laser Scanner Focus 3D is 360 ° × 305 °, therefore, ground scanning has the capability to scan top view of the tree. After all data were collected, pre-processing and post-processing steps were conducted using SCENE software (version 6.2, FARO Technologies, Inc., USA).

B. Data Collection

The study area is located at oil palm plantation in Seberang Perak, Malaysia. The ages of oil palm trees were ranging between 8 to 10 years while the heights of the trees were ranging between 10 to 11 meters where the production is at the peak. The oil palm trees were categorized into four healthiness levels as defined in Table I. A total of 40 oil palm trees had been selected with 10 trees for each healthiness level randomly taken from several different locations.

TABLE I. CLASSIFICATION AND TREE DESCRIPTIONS [12], [13].

Classification	Tree observations
T0	Healthy tree.
T1	Looks healthy but presence of fungal fruiting bodies on the stem bark. Yellowing or drying at some leaves.
T2	Visibility of fungal fruiting bodies and unopened spears. Collapse of lower leaves. Sometimes there is rot at bark stem.
T3	"Skirt-like" crown shape. Well-developed fungal fruiting bodies,

The data collection was done in early July 2017. Fig. 1 shows an example of the data collection set up in the plantation site. Five to eight reference spheres were placed around the tree and the scanner was placed at a distance of 1 to 2 m from the tree. A total of four scanning points were run for each tree. The spheres were used as reference points in case there was a problem in synchronizing the scanned data. Setting of the laser scanner was adopted with the scanning parameters such as scan profile, resolution, quality and scan duration as shown in Table II.

Figure 1. Example of the data collection setup in the plantation site.

TABLE II. LASER SCANNING PARAMETERS

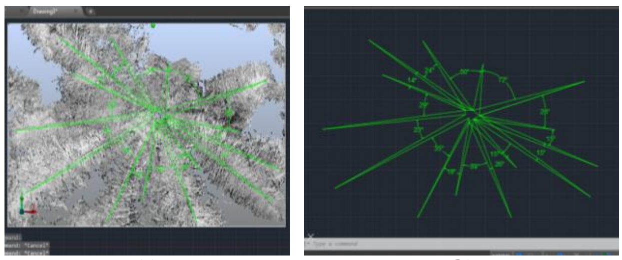
Scan Profile	Parameters
Resolution	1/5
Quality	4x
Scan Duration (min:s)	6:31
Full Scan Duration (min:s)	8:50

C. Scanned Data Analysis

All scans data were analyzed and processed using SCENE software. After that, an automatic registration was chosen with the method of top view combined with cloud to cloud. Based on the recorded scan points and its location, confirmation of the clustered scan points could be verified. Multiple pairs of scan images were matched and synched to create a cluster of point clouds. Lastly, a cluster of scan points was created and the point clouds could be viewed in 3D view.

D. Frond Section

Frond analysis was started by creating a clipping box at the center of the canopy (crown). Blue circle at the center of clipping box was placed on the hollow center (trunk) of the canopy. Then, the cursor of the clipping box was moved up until the uppermost part of the canopy tree and was moved down to the bottom limit (before the ground), so that the whole tree image could be seen. The size of the clipping box was set differently according to the size of the frond area. Next, the clipping box was viewed in top view and 'Save Screenshot' operation was performed to save the image of the frond from top view. After that, the image was analyzed using AutoCAD software. The image was first being attached to the AutoCAD software. Then, 'Layers' tool was selected to create a new layer for the image. The new layer was set as the current layer. The 'Draw' tool was then selected and 'Polyline' was used to edit the image. The process of image profiling began with the polyline followed the shape of the frond on the image. Next, 'Dimension' tool was selected to determine the inter-frond angle (measured in degrees). Finally, the angle between the fronds for every tree was recorded. Fig. 2 illustrates the process of creating shapes of fronds and dimensioning the angles.



(a) (b)

Figure 2. Frond processing. (a) Polyline drawing of the fronds (b) dimensioning angle between fronds

III. RESULTS AND DISCUSSION

Fig. 3 shows the pattern of healthiness oil palm tree conditions, where the degree of angle between fronds is increasing from healthy (T0) to unhealthy (T3). The linear relationship was clearly shown through the result of linear regression analysis (1) with value of $R^2 = 0.96$ meaning that the degree of angle between fronds increased concurrently with the level of infection.

$$y = 7.7415x + 7.7615 \quad (1)$$

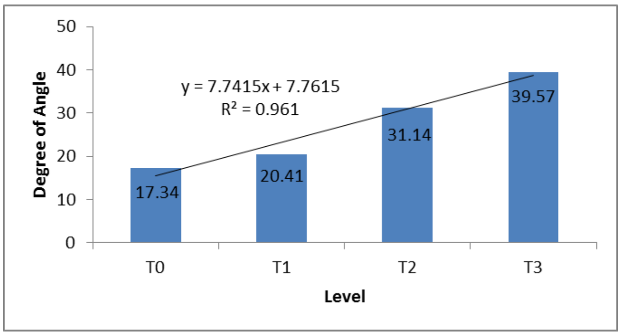


Figure 3. Graph of mean angle between fronds at different levels of healthiness.

Results from Analysis of Variance (ANOVA) for degree of frond angle showed significant differences between all levels of infection with p-value less than 0.0001 (Table III). Newman-Keuls (SNK) and Tukey's HSD post-hoc tests showed the same results where all levels were significantly separated with p-value less than 5%, only T1 and T0 were not significantly separated (Table IV). Even though there was a difference between mean degree of frond angle for T0 and T1 (3.1°), it was not enough for post-hoc tests to separate them. The mean degree of frond angle for healthy (T0) and mildly infected (T1) trees could not be differentiated using post-hoc tests. This could be due to the fact that the symptoms at early stage of infection were not very obvious. The difference of mean degree of frond angle beween T1 and T0 was the lowest compared to T3 and T2 (8.4°) and T2 and T1 (10.7°).

TABLE III. ANOVA FOR FROND ANGLE

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob> F
Level	3	3114.44	1038.15	41.28	<.0001*
Error	36	905.25	25.15		
C. Total	39	4019.7			

*significant at 5% level

TABLE IV. SNK AND TUKEY'S HSD MEAN COMPARISON OF FROND ANGLE

Healthiness Level	Mean
T3	39.57 [A]
T2	31.14 [B]
T1	20.41 [C]
T0	17.34 [C]

*Levels not connected by same letter are significantly different

Table V shows the descriptive statistics of the degree of angle between fronds for each healthiness level. For the maximum degree of angle between fronds, T0 had the lowest value with 20.4° followed by T1 with 24.9°, T2 with 37° and T3 with 52.6°. The mean degree of angle between fronds for T3 was the highest (39.6°) compared to T2 (31.1°), T1 (20.4°) and T0 (17.3°). The minimum degree of angle between fronds for different healthiness level also showed some differences from level T0 to level T3. Leaves are normally produced in spiral, and in healthy tree, the increasing growth of fronds around the trunk will reduce the angle between fronds if viewed from the top. In infected trees, growths of new leaves were affected. Some fronds collapsed resulting in increase of angle between fronds if viewed from the top. In overall, the increasing pattern of lines from T0 to T3 is illustrated in Fig. 4.

TABLE V. DESCRIPTIVE STATISTICS OF DEGREE OF ANGLE FROND FOR EACH HEALTHINESS LEVEL

Statistics	Healthiness level			
	T0	T1	T2	T3
Mean	17.34	20.41	31.14	39.57
Standard Error	0.65	0.70	1.31	2.73
Median	17.48	20.05	32.27	39.98
Standard Deviation	2.04	2.21	4.13	8.62
Sample Variance	4.18	4.87	17.07	74.28
Kurtosis	-0.38	0.92	-1.24	-1.22
Skewness	-0.16	1.15	-0.40	-0.06
Range	6.26	7.22	11.87	25.64
Minimum	14.12	17.71	25.13	26.93
Maximum	20.38	24.93	37.00	52.57
Sum	173.42	204.06	311.44	395.68
Count	10	10	10	10
Coeff. of Variance	0.118	0.108	0.133	0.218

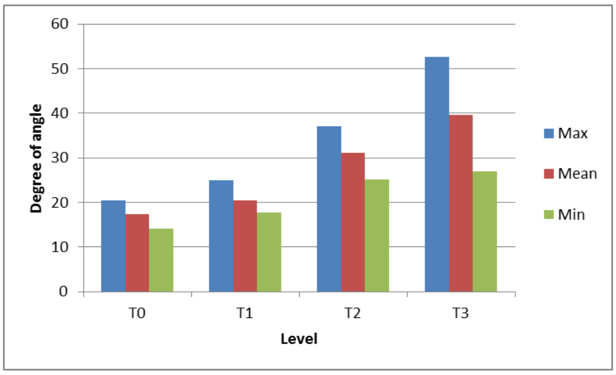


Figure 4. Graph of minimum, mean and maximum values of angle between fronds at different levels of healthiness.

Fig. 5 shows the frequency of angle for all measured oil palm trees grouped by their healthiness level. From the frequency graph, the number of angles with smaller value (less than 30°) was more than the number of angles with larger values (more than 30°) for T0 and T1 healthiness level of oil palm trees. This contradicted with T2 and T3 healthiness levels where larger number of angles (more than 30°) was greater than smaller value of angle between fronds (less than 30°).

Foliar symptoms of the tree caused by *Ganoderma* infection reduced the chlorophyll pigments used in the photosynthesis process. When the fungus destroyed the palm wood internally, it would affect the xylem (water and solutes transport tissues). Reduced chlorophyll pigments and water deficiencies reduced the photosynthesis process. This could lead to declining numbers of frond in oil palm tree infected by *Ganoderma* disease. When the frond counts declined and the older fronds retained their position, this would lead to increase of inter-frond angles (from top view) concomitant with the level of BSR infection.

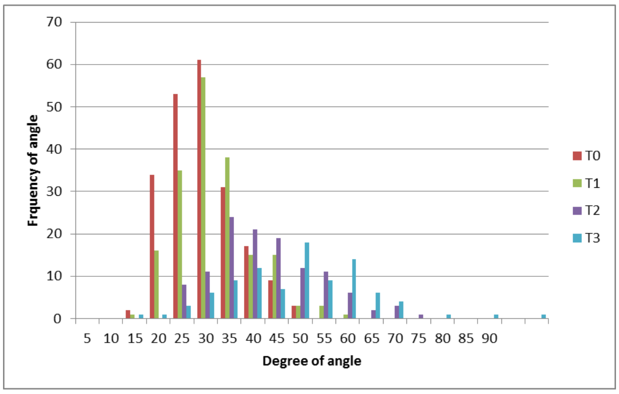


Figure 5. Frequency of angle at different levels of healthiness.

IV. Conclusions

Based on the results, it can be concluded that the comprehensive laser point data from terrestrial laser scanner could be used to obtain the physical characteristics of the oil palm tree. The top view image of oil palm tree extracted from the laser point data could be utilized for the oil palm frond analysis. Inter-frond angles measured from the tree's top view image could be used as a parameter to differentiate non-infected and infected oil palm trees at different severity levels. From the statistical analysis, all levels of healthiness were significantly separated with p-value less than 0.0001 using Analysis of Variance (ANOVA). Degree of frond angle had shown a significant relationship with the severity level of BSR with high correlation, R-squared value of 0.96. The more severe the trees infected by BSR, the smaller the frond angle values. Post-hoc tests showed that only T1 and T0 levels were not significantly separated. Level T0 was not significantly different with T1 because in the early stage of the infection the symptoms were not apparent. Using this method, the earliest detection of BSR disease could be done as early as T2 level. In summary, TLS data showed the potential in distinguishing non-infected and infected BSR at different severity levels using inter-frond angles. Additional oil palm parameters or tree's architecture could be examined to get better understanding of the physical attributes of the BSR disease symptoms and use it for early detection and severity classification.

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