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Detection of Basal Stem Rot (BSR) Infected Oil Palm Tree Using Laser Scanning Data

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Abstract

Basal Stem Rot (BSR) is a well-known disease that affecting the production of oil palm. Early disease detection is vital to manage the disease effectively. This study examined the potential use of Terrestrial Laser Scanning (TLS) data to analyse the properties of oil palm tree at canopy and trunk section for non-infected and infected BSR at different severity level of infection. In summary, area and perimeter at trunk section 150cm; and size of canopy shows significant relationship with the severity level of BSR with the Pearson correlation value of -0.571, -0.530 and -0.806, respectively.

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*Keywords:*Basal Stem Rot; Terrestrial Lase Scanner; trunk; canopy

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1. Introduction

Oil palm is one of the important crops in Malaysia. On an area basis, it is considered being the most efficient oilseed crop in the world (Sime Darby, 2013). The two different types of oils produced by oil palm are palm oil and palm kernel oil. Palm oil is mainly used in food products such as cooking oils and margarine while palm kernel oil is for the non-food products including soaps, detergents and cosmetics. According to Malaysia Palm Oil Board (MPOB), oil palm production and exportation are increasing from year 2012 to 2013. The planted area of oil palm plantation has increased by 152, 810 ha from year 2012 to year 2013 and the total exports including palm oil, palm

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kernel oil and cake, oleochemicals, biodiesel, finished products and other palm products has increased by 1, 111, 682 tonnes from year 2012 to year 2013. Hence, the well management of oil palm plantation is vital to ensure the continuous production and exportation of oil palm.

One of the vital problem that threatening the production of oil palm is Basal Stem Rot (BSR), a root disease infects the basal stem which the roots and affected basal stem are killed by the fungal pathogen (Chung, 2011).According to Wong et al. (2012), the BSR disease was diagnosed in Malaysia's oil palm plantation since 1928 which affected the oil palms with age of 30 years and above. Then, it had attacked the younger oil palms of 10-15 years old after 1957 and the disease had spread in nursery stage's oil palms too. The symptoms of infected oil palms are few unopened new fronds, green fronds wilts and hanging downward like a skirt, fronds become yellowish, small canopy due to smaller fronds production and existence of basidiomata of the pathogen on the trunks.These types of visual inspection for the infected trees need much labour force and spending much time.

Researches had been carried out to develop techniques to detect BSR disease in oil palm including laboratory base method which used polyclonal antibodies (PAbs) in the pathogen using enzyme-linked immunosorbent assay (ELISA) (Suharyanto and Darmono, 1999). Meanwhile, Yusoff et al. (2009) used microfocus XRF to determine BSR disease in local oil palm. The analysis illustrated that all of the inspected elements are lower in the infected leaf than in the normal leaf except of Si. An investigation had also been done using GanoSken technology (Idris et al., 2010). The results indicated that GanoSken which acts as the experimental platform to implement the calculations of sound image tomography of the oil palm stem is capable to detect BSR infection in oil palm stems. In addition, other methods such as testing the samples obtained from the drilling of diseased material in the tree using colorimetric method has been done. However, these methods were not very accurate and time-consuming (Hushiarian et al., 2013; Liaghat et al., 2012). According to Liaghat et al. (2012), the use of visible and near infrared spectroscopy method to identify BSR disease for oil palm in nursery in some studies could not differentiate its severity level of infection. Another techniques investigated by Izzuddin et al. (2013) has shown that spectroscopy is capable to differentiate between healthy and infected palms but not the level of severity infection. Naher et al. (2013) examined the detection and ecological impact of BSR disease in oil palm plantation.

Terrestrial Laser Scanning (TLS) has been noted to be able to determine some biophysical parameters and it is a new technique in precision farming (Riczu et al., 2011). Many researches had justified the capability of TLS to extract individual tree parameters such as Breast Height Diameter (DBH), tree height, stem and crown shape and focused on area like forest inventory plot (Brolly and Kiraly, 2009; Bienert et al., 2006; Wezyk, 2012). However, the study on the use of TLS to detect BSR disease in oil palm by relating the palm parameters with the healthy and different stages of severity infection is limited. Hence, this study examined the potential use of TLS to detect BSR disease in oil palm by relating the palm parameters with the healthy and different stages of severity infection.

2. Materials and methods

In this study,physical characteristics of oil palm tree were analysed using Faro Laser Scanner Focus 3D data. The process was firstly start with data acquisition, followed by data pre-processing and analysis. The analysis was divided into two sections which are trunk and canopy. For the trunk analysis, the accuracy of the scanned data was first calculated by comparing the value of DBH gathered from the scanner and its ground truth data. Later, the 3D image of oil palm tree constructed using the scanned data were sliced horizontally to identify at which level of trunk height the DBH of tree give significant difference between healthy and infected tree. Canopy analysis has been done using the size of canopy and number of unopened new fronds. Since the field of view of Faro Laser Scanner Focus 3Dis 360° × 305°, therefore, ground scanning has the capability to scan top view of the tree.

2.1. Data collection

The study has been done at the oil palm plantation located in Kluang, Johor. The oil palm trees were categorized into four healthiness levels i.e. T1: Tree without BSR infection, T2: Tree with slightly infected BSR, T3: Tree with moderately infected BSR and T4: Tree with severely infected BSR. Sixteen samples were taken from a 25 years old mature oil palm tree.

2.2. Faro Laser Scanner Focus 3D

The working principle of Faro Laser Scanner Focus 3D is by sending an infrared laser beam into the centre of its rotating mirror which deflects the laser beam on a vertical rotation around the scanned environment. Then, scattered light from surrounding objects will be reflected back into the scanner. It utilizes phase shift technology (constant waves of infrared light of varying length are projected outward from the scanner) to measure distance of object from the scanner. An angle encoders is used to measure the mirror rotation and the horizontal rotation of the Focus 3D. Hence, distance, vertical and horizontal angle measured will form a polar coordinate which then transformed to a Cartesian coordinate (x, y, z). In this study, the setting of the laser scanner was adopted with the scanning parameters as shown in Table 1 which was kept consistent for each scan. A total of 24 scans had been made.

Table 1.Laser scanning parameters being adopted.

Scan Profile	Outdoor 20m
Resolution	¼
Quality	4x
Full Scan Duration (min:s)	9:06

2.3. Scanned data analysis

2.3.1. Register scans

All of the collected scans images had been analysed using SCENE 5.2 software. Firstly, the scans images were inserted into SCENE in a new scan project. All of the scans were viewed in a ‘Quick View’ and undergone a ‘Find Objects’ operation which is to find the reference spheres to register all the scans. Next, a ‘Registration’ operation was carried out to register the scans. The accuracy of the registration process is indicated by a colour of spheres. Therefore, to indicate the accuracy of the registration process, the number of reference spheres must be detected as ‘green’ colour. The ‘green’ colour illustrates the reference sphere’s object fit which represent all the individual quality criteria of the fit are met. ‘Amber’ colour shows that there is at least one quality criterion is compromised while ‘red’ colour illustrates that at least one individual criterion of the fit is seriously compromised.

2.3.2. Trunk section

First of all, specific Region of Interest (ROI) to be analysed was selected using a clipping box. Therefore, a new clipping box was created for one of the tree samples. The clipping box was set to a height of 1.3 m to indicate Diameter at Breast Height (DBH) of the tree. Then, the upper section of clipping box with the height of 0.05m was exported into ‘DXF’ file and ‘PTS’ file for further analysis. For the other trunk section analysis, 10 horizontal slices, for every 0.3 m height starting from the ground were selected. The same procedure has been done to extract the area and perimeter of the trunk.

The ‘DXF’ file of trunk section was analysed using ArcGIS software. The ‘DXF’ files of trunk sections were added into ArcGIS. Then, shape file with ‘Polygon’ feature type was created for each trunk section. The spatial reference of the shape file was edited to select ‘Kertau (RSO) RSO Malaya (Meters). After that, the ‘Editor’ tool was utilized to start editing the shape file. The attribute table of the shape file was opened to add field of ‘Area’ and ‘Perimeter’. Subsequently, the area and perimeter of the trunk sections were determined by the operation ‘Calculate Geometry’ and shown in the attribute table.

2.3.3. Canopy

2.3.3.1. Canopy top view

Another clipping box was created so that the whole tree sample could be seen in the clipping box from different views (left, right, front and back view). The clipping box would then be viewed in top view and ‘Save 3D View Screenshot’ operation was performed to save the image of the canopy top view. After that, the image was analysed using Matlab software version 2012b. The image was first being transformed from RGB to gray and followed by selecting the ROI which is defined as the desired canopy top view image. The area which was the number of pixels of the image was then calculated.

2.3.3.2. Number of unopened new frond

Clipping box was created in the upper section canopy of each tree sample to observe the existence of unopened new frond. The clipping box was viewed in right, left, front and back view and image for each view was saved using 'Save 3D View Screenshot' operation. The number of unopened new frond in the trees will be identified.

2.4. Statistical analysis

2.4.1. Pearson correlation coefficient

The linear correlation between oil palm tree properties and its healthiness level will be analysed using a Pearson correlation coefficient. Pearson correlation coefficient is a standard method for determining correlation. This method assumes a linear correlation between x and y, giving a value between +1 and −1 inclusive, where 1 is total positive correlation, 0 is no correlation, and −1 is total negative correlation. The correlation between two variables is statistically significant if the value of significance level (Sig) is less than or equal to 0.05. That means, increases or decreases in one variable do significantly relate to increases or decreases in the second variable. In certain cases, the data is very well correlated, however the relationship is not linear which resulting underestimation of the degree of correlation.

2.4.2. Linear regression

Linear regression will be performed for modelling the relationship between oil palm tree properties and its healthiness level. Linear regression fit the line through the set of data points in such a way that makes the sum of the squares of the residuals of the model as small as possible. The terms 'linear' in linear regression means that the regression function is linear in the scaling coefficient and it is not required that the dependent variable appear as linear terms in the regression function. Therefore, the regression function could also be in the form of non-linear function such as exponential, power, cubic, quadratic, etc. The R^2 value indicates how much of the dependent variable, can be explained by the independent variable. The best model will be identified by the highest value of R^2.

3. Results and discussion

3.1. Trunk Section

3.1.1. Diameter at Breast Height (DBH)

The Faro DBH calculated using area and perimeter are significantly correlated to the DBH taken from ground ($P < 0.01$) as tabulated in Table 2 with the Pearson correlation value of 0.939 and 0.855, respectively. Hence, the Faro DBH calculated using area provides better estimation of the DBH taken from ground than Faro DBH calculated using perimeter. These significant linear relationship are clearly shown through the results of Linear Regression Analysis (Fig. 1) where the line fits well linearly (Eqs. (1) and (2)) through the set of data points in such a way that makes the sum of the squares of the residuals of the model as small as possible with the value of $R^2 = 0.8814$ for DBH using area and $R^2 = 0.7312$ for DBH using perimeter.

Calculated DBH using Faro (Area):

$$y = 0.8319x + 11.17 \quad (1)$$

Calculated DBH using Faro (Perimeter):

$$y = 0.5043x + 25.242 \quad (2)$$

where x is value of DBH calculated using Faro as follows:

$$DBH_{area} = \sqrt{\left(\frac{4A}{\pi}\right)} \quad (3)$$

$$DBH_{perimeter} = \frac{P}{\pi} \quad (4)$$

where A = area, P = perimeter

Table 2.Pearson correlation of DBH for trunk section analysis.

		Healthiness level	DBH taken from Ground	DBH calculated using Area	DBH calculated using Perimeter
DBH taken from Ground	Pearson Correlation	-.402	1	.939**	.855**
	Sig. (2-tailed)	.123		.000	.000
	N	16	16	16	16

** Correlation is significant at the 0.01 level (2-tailed).

Results on the average DBH for each healthiness level has shown that the value of DBH is slightly reduced from T1 to T4. The lowest value of DBH can be seen at T4, while the highest is at T1. T2 and T3 have almost similar value of DBH.

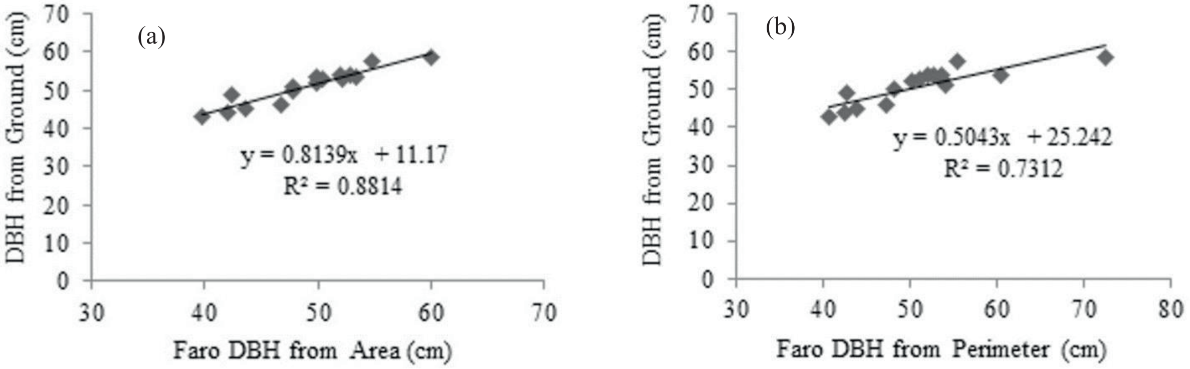

Fig. 1. Relationship between DBH taken from ground and Faro DBH calculated using (a) area and (b) perimeter.

3.1.2. Area of trunk section

The average area of each level of healthiness decreases with increasing trunk section as indicated in Fig. 2. All of the healthiness level also fits well using power equation with R^2 value nearly 1.0 for T1, T2 and T3; and nearly 0.9 for T4. However, in general, there is no clear trend to distinguish between different severities levels of BSR. Based on the result of Pearson correlation (Table 3), the relationship between area of trunk section and healthiness level is only significant at trunk section 150cm ($P < 0.05$) with the correlation value of -0.571.This indicates that the higher the severity level, the lowers its area at trunk section 150cm. The trunk size is larger in non-BSR tree as compared to the BSR tree. This condition happen might be due to the restriction of water and nutrient transport caused by BSR infection. As a result, only non-BSR tree got complete nutrient and water application. Water plays important role in plant growth. It is primary component of photosynthesis and transpiration. The tree uses sugar to grow all of its parts such as leaf, wood, root, bark, etc. Tree trunks grow thicker as new cells are added beneath the bark. These cells carry water and nutrients throughout the tree. Water also act as a solvent to move minerals from the soil up to the plant. Therefore, water shortage not only reduced growth and vigor of the tree, but also causing nutrient deficiencies. Furthermore, water also acts as a solvent to move products of photosynthesis throughout the tree, source of pressure to move roots through the soil and medium for biochemical reactions. Therefore, restriction of water will also reduce growth and health of roots which leads to reduction of water and nutrients absorption from the soil and finally reduced the health of tree.

Averaging replication data from all locations giving us highly significant correlation which fits well using quadratic equation (Eq. (5)) with $R^2 = 0.998$.

$$y = -21.908 + 430.451x - 1117.490x^2 \tag{5}$$

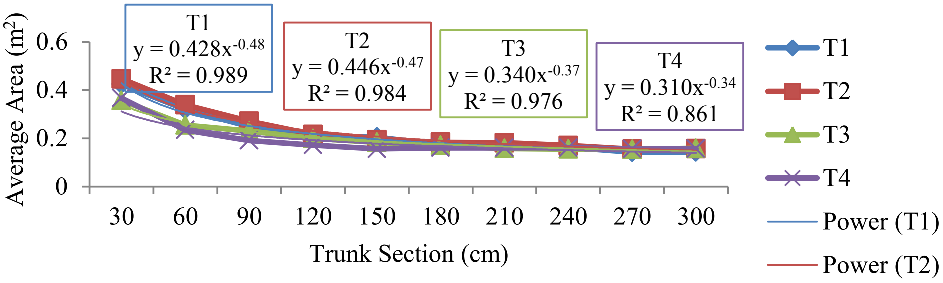

Fig. 2. Scatterplot of average area of trunk section for each healthiness level.

Table 3.Pearson correlation between healthiness level and area of trunk section.

		Healthiness	60 cm	90 cm	120 cm	150 cm	180 cm	210 cm	240 cm	270 cm
Healthiness	Pearson Correlation	1	-.465	-.409	-.385	-.571*	-.261	-.201	-.145	.297
	Sig. (2-tailed)		.069	.116	.140	.021	.328	.473	.606	.302
	N	16	16	16	16	16	16	15	15	14

3.1.3. *Perimeter of trunk section*

The average perimeter of each healthiness level decreases with increasing trunk section as indicated in Fig. 3. All the healthiness level also fits well using power equation with R^2 value more than 0.9 for T1, T2 and T3; and 0.8 for T4. However, in general, there is no clear trend to distinguish between different severities levels of BSR. Based on the result of Pearson correlation (Table 4), the relationship between perimeter of trunk section and level of healthiness is only significant at trunk section 150cm ($P < 0.05$) with the correlation value of -0.530. This indicates that the perimeter decreases with the increasing healthiness level. As discussed in the previous section, this condition might be happened due to the effect of BSR in slowing down the plant growth operation. Based on the Regression Analysis, inverse equation as defined in Eq. (6) fits the data well with $R^2 = 0.302$. However, averaging replication data from all locations did not give significant correlation.

$$y = \frac{-2.315}{7.537x} \tag{6}$$

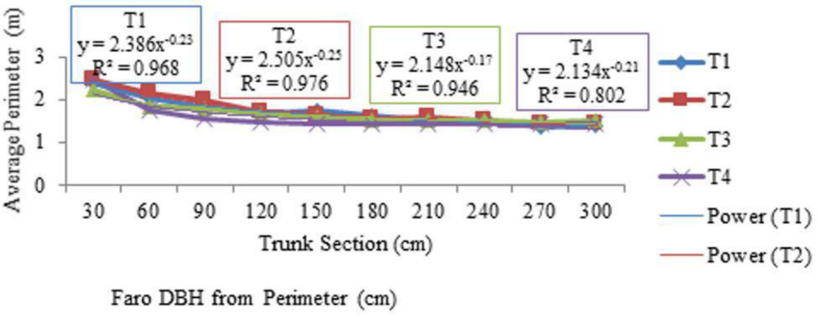

Fig. 3.Average perimeter of trunk section for each treatment.

Table 4. Correlation between healthiness level and perimeter of trunk section.

		Healthiness	60cm	90cm	120cm	150cm	180cm	210cm	240cm	270cm
Healthiness	Pearson Correlation	1	-.448	-.362	-.376	-.530*	-.467	-.280	-.200	.234
	Sig. (2-tailed)		.082	.168	.151	.035	.068	.313	.474	.421
	N	16	16	16	16	16	16	15	15	14

3.2. Canopy section

3.2.1. Canopy top view

Fig. 4 represents example of canopy top view for each healthiness level. Based on this figure, it is clearly shown that the highly severe infected BSR tree (T4) give the smallest canopy cover as compared to the others. The largest size of canopy can be gathered from the healthy tree (T1). Meanwhile, the slightly infected BSR (T2) and moderately infected BSR (T3) gave slightly similar size of canopy cover. Table 5 shows results of Pearson correlation between canopy cover and level of healthiness. Based on this results, it is clearly shown that both parameters give high significant relationship with the value of Pearson correlation of -0.806. This indicates that the higher the severity level, the smaller its canopy cover. Smaller canopy is due to production of smaller frond. Furthermore, most of the fronds at higher severity levels were hanging downward like a skirt. Averaging replication data from all locations give high significant relationship. The size of canopy decreases in increasing level of healthiness (T1 – T4). T1 has average area of 150000 pixels followed by T2 with 140000 pixels, T3 with 132000 pixels and T4 with 70000 pixels. The quadratic model (Eq. (7)) fits well in determining BSR severity level with R^2 = 1. As discussed earlier, the reduction of canopy cover might be due to the effect of BSR to the growth of trees.

$$y = 0.612 + 8.601 \times 10^{-5}x - 5.432 \times 10^{-10}x^2 \tag{7}$$

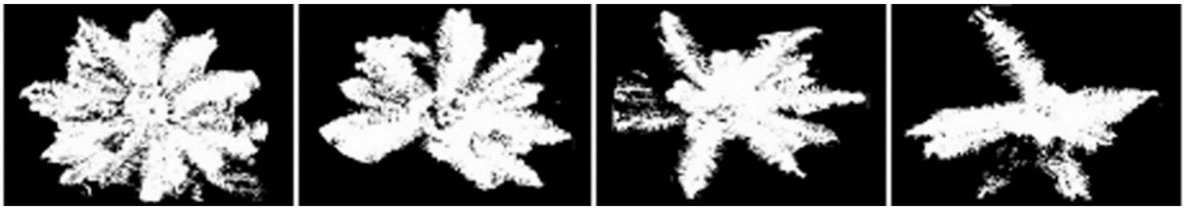
T1 T2 T3 T4

Fig. 4.Canopy top view images for each treatment.

Table 5.Correlation between healthiness level and area of canopy top view image.

		Healthiness level	Area of canopy
Healthiness level	Pearson Correlation	1	-.806**
	Sig. (2-tailed)		.000
	N	16	16

** Correlation is significant at the 0.01 level (2-tailed).

3.2.2. *Number of unopened new frond*

Table 6. Summary of number of unopened new frond for each healthiness level of tree.

Healthiness level	T1	T2	T3	T4
Percentage number of unopened new frond (%)	0	25	25	75

Table 6 indicate the summary for percentage number of unopened new frond appeared in each healthiness level of tree. For T1, there are no trees with unopened new frond. There is only 25% of the sample with unopened new frond for T2 and T3, while 75% for T4. Hence, it is easier to differentiate between T1 and T4 with regard to the visibility of unopened new frond than between T1 and T2 or T3.

4. Conclusions

In this study, the potential application of TLS in detecting different non-BSR and BSR infected tree in different severity level based on its trunk and canopy has been investigated. The results has shown that the DBH of tree can be determined using Faro DBH calculated from area and perimeter using linear function with R^2 = 0.8814 and 0.7312, respectively. The area and perimeter of trunk section decreases with increasing level of trunk section. This relationship fits well using power equation with R^2 value near to 1 for T1, T2 and T3; and above 0.8 for T4. The area and perimeter at trunk section 150cm is significantly correlates with the healthiness level of tree with the value of Pearson correlation of -0.571 and -0.530, respectively. Consequently, it can be concluded that area and perimeter of trunk section at 150 cm could be utilized to distinguish non-infected and infected oil palm at different severity levels. Area gave superior results compared to perimeter since it gave R^2=0.998 when using average replication data from all locations to identify BSR at different severity level. For canopy section, the canopy top view is significantly correlates with the healthiness level of tree with the value of Pearson correlation of -0.806. The more severe the trees from BSR, the smaller its size of canopy cover. In terms on number of unopened new frond, it can be used to indicate the BSR and non-BSR but having limitation in classifying its severity level. In summary, TLS data showed the potential in distinguishing non-infected and infected BSR at different severity levels especially using area and size of canopy cover. Better model of BSR prediction might be gathered by combining all of these significant parameters.

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