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Identifying the Early Visible Symptoms of the *Ganoderma*-Infected Oil Palms: A Case Study on the Infected Palms Which Collapsed Within Twelve Months after Disease Census

Assis Kamu[1*] , Ho Chong Mun[1], Chong Khim Phin[1] and Idris Abu Seman[2]

[1]*Faculty of Science and Natural Resources, Universiti Malaysia Sabah, UMS Road, 88400 Kota Kinabalu, Sabah*

[2]*Ganoderma and Diseases Research for Oil Palm Unit, Malaysian Palm Oil Board (MPOB)*

In the region of Southeast Asia especially in Malaysia and Indonesia, *Ganoderma* Basal Stem Rot (BSR) disease is considered as the most devastating disease in oil palm industry. The objective of this study is to identify the important early visible symptoms which can give early signal that the palms infected by *Ganoderma* BSR disease will collapse within 12 months after the disease census conducted. The visible external symptoms of the disease considered were presence of bunch, presence of rotting trunk, presence of more than three unopened spears, and the number of active fruiting bodies *Ganoderma* species. A binary logistic regression was employed with the parameters of the model were estimated using maximum likelihood method. This study found that the infected palms which have more than five active fruiting body of *Ganoderma* species and did not produce any fruit bunch during the census most probably will collapse within 12 months after the census. This result suggests that the priority for curative action should be given to the infected palms which show these two visible symptoms during the census.

Keywords: visible symptoms, oil palm, Ganoderma, logistic regression

I. INTRODUCTION

Ganoderma Basal Stem Rot (BSR) disease is caused by the white rot fungus *Ganoderma* (Flood *et al.*, 2000) *Ganoderma* boninense was identified as the main species that causes the disease (Ho & Nawawi, 1985; Siang *et al.*, 2013; Wong *et al.*, 2012). The disease is the most widely studied and knowledge available oil palm disease in Malaysia (Idris, 2012). In the region of Southeast Asia especially in Malaysia and Indonesia, this disease is considered as the most devastating disease. But in some countries in Africa (i.e. Angola, Cameroon, Ghana, Nigeria, Zambia, San Tome, Principe, Tanzania, Zimbabwe, and Republic of Congo), Central America (i.e. Honduras), and in Oceania (i.e. Papua New Guinea), some oil palm fields were reported to be infected by *Ganoderma* BSR disease (Ariffin *et al.*, 2000). The disease can reduce the yield of the infected palms either from total yield loss by killing the infected palms (or also called as direct loss) or by reducing the weight or the number of fresh fruit bunch (FFB) of the infected palms but still living palms (or

*Corresponding author's e-mail: assis@ums.edu.my

indirect loss) (Roslan & Idris, 2012; Assis *et al.*, 2016).

The presence of *Ganoderma* BSR disease can be detected through visual and non-visual method. Visual assessment can be conducted based on foliar symptoms, rotted root, stem/ trunk, and the presence of fruiting body of *Ganoderma* species at the base of the trunk (Idris, 2012). The advantages of visual assessment are immediate result and low cost. Usually the early infection cannot be detected by just conducting visual assessment. The infected palms appear to be symptomless during the early stage of the infection and the symptoms are only visible by naked eyes when the infection is already at the late stage where usually the palms are severely infected and usually unable to be cured (Soepena *et al.*, 2000). Once young palms show symptoms of the disease they usually die within 1 or 2 years, while mature trees can survive for only another 3 or so years (Corley & Tinker, 2016). By early detection of the disease, the management may still have an opportunity to treat the infected palm from being seriously infected and too late to be saved. The objective of this study is to identify the important early visible symptoms which can give early signal that the palms infected by *Ganoderma* BSR disease will collapse within 12 months after the disease census conducted.

II. LITERATURE REVIEW

The starting point of the disease is the pathogen that will firstly kill the roots and the basal stem of the infected palm. That means the infection started from roots and followed by the base of the hole. By killing these parts, the transportation of water and also nutrients to the upper parts of the infected palm will be reduced or restricted causing chlorosis. The reduction of water and nutrients can be detected by visual symptoms of frond wilting and malnutrition. The symptoms also include unopened new fronds (spears), wilting of green fronds hanging downward like a ‘skirt’, yellowing fronds due to nutrient deficiency, and small canopy due to production of smaller fronds (Chung, 2011).

To be specific, the infection of young palm can be detected by the failure of young leaves to open, while for old palm, it can be detected by collapsing the lower leaves, hanging vertically downward from the point of attachment to the trunk (Corley & Tinker, 2016). Another very important symptom and commonly used is the presence of fruiting body (i.e. basidiomata) of *Ganoderma* on the palm trunk base (Ariffin *et al.*, 2000). Usually, the stem has already severely been infected when the symptom is visible, but there is no fixed pattern or progression of the foliar symptoms due to *Ganoderma* BSR disease.

III. MATERIALS AND METHODS

A single-plant method was used in this study. Each plant was considered as a single datum point for regression analysis (Gaunt, 1990). This means that the sampling unit was the individual palm. The study was conducted at one of the commercial areas of oil palm cultivation in

Tawau district, Sabah with the total area is 10.75 hectares. The location of the area is latitude 4°19'24.96"N and longitude 118°05'26.88"E. The palms in this area were planted in 2002. All the infected palms in the studied sites were sampled and monitored for the duration of 12 months starting from the disease census. The disease census was conducted using a visual method. This visual method was conducted by following the standard procedures used by Malaysian Palm Oil Board (MPOB) in conducting *Ganoderma* BSR disease census (Idris *et al.*, 2016).

The dependent variable in this study was the status (i.e. not dead or dead) of the infected palms 12 months after the disease census. The internal value of the dependent variable is as shown in Table 1. The independent variables are the visible external symptoms of the disease, which are presence of bunch, presence of rotting trunk, presence of more than three unopened spears, and the number of active fruiting bodies *Ganoderma* species. All of the independent variables are categorical. Thus, a dummy transformation was performed and the codings of the dummy are as shown in Table 2.

Table 1. Dependent variable encoding

Original Value	Internal Value
Not dead	0
Dead	1

Table 2. Categorical variables codings

		Parameter coding
Presence of bunch (Bunch)	No	0
	Yes	1
Presence of rotting trunk (Rotting)	No	0
	Yes	1
Presence of unopened spear (> 3) (Unopened)	No	0
	Yes	1
Number of active fruiting bodies (Fruiting)	≤ 5	0
	> 5	1

A binary logistic regression was employed in order to determine the important early visible symptoms of the dead oil palms due to *Ganoderma* BSR disease. In logistic regression, the parameters of the model are estimated using the maximum likelihood method. That is, the coefficients that make the observed results most likely are selected. For each possible value a parameter might have, a software computes the probability that the observed value would have occurred if it were the true value of the parameter. Then, for the estimate, it picks the parameter for which the probability of the actual observation is greatest. Let π denote the probability of the infected palm will collapse or dead, then the following equation can be used to describe the relationship between π and X (i.e. the independent variable) with a curvilinear rather than a linear function.

$$\log\left(\frac{\pi}{1-\pi}\right)=\alpha+\beta X \quad (1)$$

The ratio π/(1- π) equals the odds. This equation uses the natural log of the odds, and is called the logistic transformation, or logit for short. Thus, as π increases from 0 to 1, the odds increases from 0 to +∞, and the logit increases from -∞ to +∞. Table 3 shows the ranges of probability, odds, and log odds.

Table 3: Ranges of probability, odds, and log odds

		Lowest level	Mid point	Highest level
Probability	π	0	0.5	1
Odds	π/(1-π)	0	1	+∞
Log Odds	Log (π/1-π) or logit (π)	-∞	0	+∞

IV. RESULTS AND DISCUSSIONS

Table 4 shows that there were 94 infected palms censused and monitored during the study. Twelve months after the disease census conducted, a total of 44 infected palms or 46.8% were dead or collapse. There were four visible external symptoms have been recorded during the disease census, namely the presence of bunch, presence of rotting trunk, presence of more than three unopened spears, and the number of active fruiting bodies *Ganoderma* species. The results of the census are as shown in Table 4.

Table 4: The descriptive statistics

Variable	Category	N	Percentage
Disease infection status after 1 year	Not dead	50	53.2%
	Dead	44	46.8%
Presence of bunch (Bunch)	No	24	25.5%
	Yes	70	74.5%
Presence of rotting trunk (Rotting)	No	48	51.1%
	Yes	46	48.9%
Presence of unopened spear (> 3) (Unopened)	No	29	30.9%
	Yes	65	69.1%
Number of active fruiting bodies (Fruiting)	≤ 5	64	68.1%
	> 5	30	31.9%

Table 5 is the binary regression model summary where the -2 log likelihood statistic is 109.042. This statistic measures how poorly the model predicts the decisions. The smaller the statistic the better the model. The Cox & Snell R^2 can be interpreted like R^2 in a multiple regression, but cannot reach a maximum value of 1. The Nagelkerke R^2 can reach a maximum of 1.

Table 5: Model summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	109.042[a]	.199	.266

[a] Estimation terminated at iteration number 4 because parameter estimates changed by less than .001.

The output as shown in Table 6 shows that the additive form of the logistic regression equation is

$$\text{Log}(Odds) = 0.917 + 1.172Fruitting + 0.584Rotting - 0.21Unopened - 2.054Bunch \quad (2)$$

Table 6: Variables in the equation

Variable	B	S.E.	Wald (B/S.E.)	df	Sig.	Exp(B)
Fruiting	1.172	.511	5.256	1	.022*	3.230
Rotting	.584	.492	1.412	1	.235	1.794
Unopened	-.210	.558	.142	1	.706	.810
Bunch	-2.054	.618	11.059	1	.001*	.128
Constant	.917	.717	1.632	1	.201	2.501

*significant at 5% level of significance

The Bs in Table 6 refer to the log-odds of being dead or collapse. This implies that the presence of fruiting body and rotting increases the log odds of dead, while the presence of more than three unopened spears and bunch decreases the log odds of dead. The output also gives the Exp(B). This is better known as the odds ratio predicted by the model. This odds ratio was computed by raising the base of the natural log to the b^{th} power, where b is the slope from the logistic regression equation. Values of Exp(B) greater than 1 indicate that the variable increases the odds of the dependent 'event' occurring and values less than 1 (i.e. between 0 and 1) indicate a decrease in the odds. For this model, $e^{1.172} = 3.230$ for number of active fruiting bodies. That means that the model predicts that the odds of the infected oil palms with the number of active fruiting bodies more than five to collapse are 3.230 times higher than the infected oil palms with the number of active fruiting bodies five or less (assuming other factors constant). Another significant variable at 5% level of significance (i.e. sig. value < 0.05) is presence of bunch where the $e^{-2.054} = 0.128$. This means that the model predicts that the odds of the infected oil palms which have at least one fruit bunch to collapse are 0.128 times lower than the infected oil palms with no fruit bunch (assuming other factors constant).

Table 7: Classification table

Observed		Predicted: Disease infection status after 1 year – Not dead	Predicted: Disease infection status after 1 year – Dead	Predicted: Percentage Correct
Disease infection status after 1 year	Not dead	40	10	80.0
	Dead	16	28	63.6
Overall Percentage				72.3

The results of this logistic regression can be used to classify the infected oil palms with respect to the collapse status. But before this model can be used to classify the infected oil palms, one needs to have a decision rule. The decision rule is if the probability of the event is greater than or equal to some threshold, it shall predict that the event will take place. By default, the cut value of the threshold is 0.5. Table 7 shows that this rule allows us to correctly classify 28 / 44 = 63.6% of the infected oil palms where the predicted event (dead) was observed. This is known as the sensitivity of prediction, the P (correct | event did occur), that is, the percentage of occurrences correctly predicted.

We also see that this rule allows us to correctly classify 40 / 50 = 80% of the infected oil palms where the predicted event was not observed. This is known as the specificity of prediction, the P(correct | event did not occur), that is, the percentage of non-occurrences correctly predicted. Overall the predictions were correct 68 out of 94 times, for an overall success rate of 72.3%.

This result proves that once young palms show symptoms of the disease they usually die within 1 or 2 years, while mature trees can survive for only another 3 or so years (Corley & Tinker, 2016). This result suggests that the priority for curative action should be given to the infected palms which show these two visible symptoms during the census. One of the curative controls that can be applied on the infected palm to delay the collapse is soil mounding around the base of mature infected palms (Ho & Khairuddin, 1997). Soil from adjacent areas is collected for heaping at the palm trunk up to a height of 75 cm and 1 m radius wide at the ground. Soil mounding helps to prolong the economic life of yielding palms affected by the disease (Chung, 2011).

V. SUMMARY

Ganoderma BSR disease is the most devastating disease ever faced by oil palm industry in the region of Southeast Asia. However, the total economic loss due to the collapse of the palms infected by the disease can still be minimized if early action is taken. But to cure all the infected palms will be costly. Therefore, the curative action on the infected palms should be selective. The selection of the infected palms can be based on the visible symptoms of the disease. This study found that the infected palms which have more than five active fruiting body of *Ganoderma* species and did not produce any fruit bunch during the census most probably will collapse within 12 months after the census. This result suggests that the priority for curative action should be given to the infected palms which show these two visible symptoms during the census.

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