Identification of Healthy and BSR-Infected Oil Palm Trees Using Color Indices

Siti Khairunniza-Bejo, Yusnida Yusoff, Nik Salwani Nik Yusoff, Idris Abu Seman, Mohamad Izzuddin Anuar

Abstract**—**Most of the oil palm plantations have been threatened by Basal Stem Rot (BSR) disease which causes serious economic impact. This study was conducted to identify the healthy and BSR-infected oil palm tree using thirteen color indices. Multispectral and thermal camera was used to capture 216 images of the leaves taken from frond number 1, 9 and 17. Indices of normalized difference vegetation index (NDVI), red (R), green (G), blue (B), near infrared (NIR), green – blue (GB), green/blue (G/B), green – red (GR), green/red (G/R), hue (H), saturation (S), intensity (I) and thermal index (T) were used. From this study, it can be concluded that G index taken from frond number 9 is the best index to differentiate between the healthy and BSR-infected oil palm trees. It not only gave high value of correlation coefficient (R=-0.962), but also high value of separation between healthy and BSR-infected oil palm tree. Furthermore, power and S model developed using G index gave the highest R^2 value which is 0.985.

Keywords**—**Oil palm, image processing, disease, leaves.

I. Introduction

MALAYSIA is one of the world's largest palm oil exporters and currently accounts for 39% of world palm oil production and 44% of world exports. Oil palm plantations in Malaysia make up 77% of agricultural land or about 15% of total land area. However, oil palm plantations in Malaysia are facing problem associated with Basal Stem Rot (BSR) disease that causes huge economic losses to the plantations [1].

The BSR disease caused by *Ganoderma boninense* is a root disease which includes the infection on the basal stem. This disease can be identified based on the following symptoms; the failure of young leaves to open, which indicates that the stem is already extensively damaged and water uptake is restricted [2], leaves turn yellow, the fruiting body of *Ganoderma* sp. appears, and the base of the stem rots and blackens. In severe infections the whole crown of the palm may fall off or the trunk may collapse [3], [4].

S. Khairunniza-Bejo is with the Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor Darul Ehsan, Malaysia (corresponding author to provide phone: +603-89464332; fax: +603-89466425; e-mail: skbejo@upm.edu.my).

Y. Yusoff is with the Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor Darul Ehsan, Malaysia(e-mail: yusnidamyusoff88@gmail.com).

N. S. N. Yusoff was with the Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor Darul Ehsan, Malaysia(e-mail: nsalwaninyusoff@gmail.com).

I. A. Seman and M. I. Anuar are with the Malaysian Palm Oil Board (MPOB), No. 6, Persiaran Institusi, Bandar BaruBangi, 43000 Kajang, Selangor Darul Ehsan, Malaysia (e-mail: idris@mpob.gov.my, mohamad.izzuddin@mpob.gov.my).

Many measures have been used to detect BSR disease in oil palm such as manual observation based on the disease symptoms, Ganoderma Selective Medium (GSM) [5], Enzymn-Linked Immunosorbent Assay (ELISA) [6] and GanoSken Tomography [7]. Enzyme Linked Immunosorbent Assay (ELISA) polyclonal antibody which is an immunoassay protein-based gives accurate results [6]. The study was done to test the reactivity and specificity of BSR using indirect ELISA with fresh and dry leaf samples [8]. Another potential method is by using GanoSken Tomography Technology. The tomography is a non-invasive tool designed for assessing tree's decay and degradation. The equipment consists of a sound sensor and tomography software called GanoSken Tomography [7]. Sound sensors are installed around a circumference of oil palm stem. This technique can identify the internal structure of an object such as dimensions, shape, internal defects, and density and measured the size of the decay. However, this method is quite time-consuming since it needs to be done for every tree.

Since oil palm plantation is cultivated in extensively wide areas, it needs very easy and cheap detection tool. Remote sensing technology serves the right answer. High resolution of QuickBird satellite imagery has been used for detecting and mapping the oil palms infected by BSR disease. The method has been developed by using two image processing technique which are image segmentation and vegetation indices. Image segmentation was used to delineate areas where the palms had died because of BSR infection. This resulted in a map showing the spatial pattern of the disease. Six vegetation indices which are ARVI, GNDVI, GBNDVI, NDVI, SAVI, and SR were investigated for their ability to detect infected living palms that were infected by the disease [9]. From his research, the result has been identified that ARVI and GBNDVI are the most accurate to detect the infected oil palms with accuracy of 85%. However, using high resolution imagery of remote sensing need greater cost, which is impossible to be applied in small farms. This study explores the use of multispectral and thermal camera in discriminating healthy and BSR infected oil palm trees by extracting the leaf color indices.

II. Methodology

A. Sample Collection

The sample was collected from oil palm plantation in Kluang, Johor. The age of oil palm tree is 25 years old. A total of 12 oil palm trees which consist of three healthy and nine BSR infected trees were used. These samples were categorised according to its severity level, which are T1, T2, T3 and T4 by the expert from Malaysian Palm Oil Board (MPOB), as tabulated in Table I where T1 is defined as a healthy tree with healthy frond, no white fungus and no rotted roots. Meanwhile, T2 is defined as infected tree with healthy frond, appearance of white fungus but without any rotted roots. T3 is defined as infected tree with fallen frond, appearance of white fungus but without rotted roots. Finally, T4 is defined as infected tree with fallen frond, appearance of white fungus and occurrence of rotted roots.

TABLE I
TREES CATEGORIES

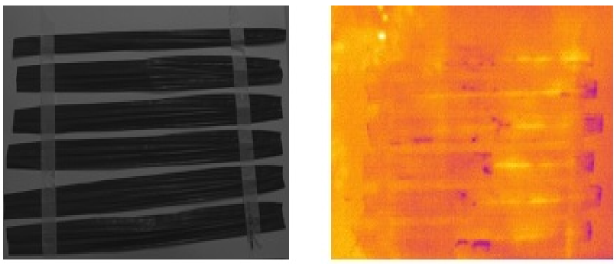
Camera	Category	Description
Multispectral	T1	Healthy frond, no white fungus, no rotted roots
	T2	Healthy frond, white fungus appear, no rotted roots
	T3	Fallen frond, white fungus appear, no rotted roots
Thermal	T4	Fallen frond, white fungus appear, rotted roots

TABLE II
CAMERA SPECIFICATIONS

Camera	Resolution (pixel)	Wavelength
Multispectral	1360 x 1024	400 – 1000 nm
Thermal	320 x 240	700 – 1400 nm

TABLE III
MULTISPECTRAL BANDS AND WAVELENGTHS

Camera	Wavelength
Red	590 – 670 nm
Green	500 – 590 nm
Blue	400 – 500 nm
NIR1	670 – 830 nm
NIR2	830 – 1000 nm



(a) G band image (b) Thermal image

Fig. 1 Sample of oil palm leaves captured by multispectral and thermal camera

For each tree, three fronds which are frond number 1 (F1), 9 (F9), and 17 (F17) were identified and cut down by experienced workers of MPOB. In total, 36 fronds were used in this study. For each frond, six pieces of leaves were cut off taken from both left and right side at about quarter end of the frond for analysis. Fig. 1 shows the sample of image captured by multispectral and thermal camera.

B. Data Acquisition

The images of six leaves from each frond (F1, F9, F17) were acquired using multispectral camera (Condor5 VNN-285, Quest Innovation, Netherland) and E-60 FLIR thermal camera (FLIR Systems, Inc., King Hills, West Malling, Kent, United Kingdom). Further details of the camera specification are given in Table II. Multispectral camera consist of 5 bands namely Red, Green, Blue, NIR1 and NIR2 and the respective wavelengths are shown in Table III.

C. Data Extraction and Analysis

Thirteen color indices namely normalized difference vegetation index (NDVI), red (R), green (G), blue (B), near infrared (NIR), green – blue (GB), green/blue (G/B), green – red (GR), green/red (G/R), hue (H), saturation (S), intensity (I) and thermal index (T) were used in this study to analyze healthiness level of oil palm tree using 216 sample of leaves. The mean intensity for each color index were then used to identify healthy and BSR infected tree. SPSS software was used to perform correlation analysis between color indices and BSR severity level.

III. RESULTS AND DISCUSSION

Table IV shows the resulting correlation matrix between BSR severity level of oil palm trees and color indices for frond number 1, 9 and 17. Frond number 1 located at the innermost part of the canopy while frond number 17 located outermost. These locations of the frond influence the maturity of the leaves. Frond number 1 defined as young leaves compared to frond 17 which is considered as mature leaves. Meanwhile, frond 9 defined as medium leaves. Based on the table, only indices of G, B, GB, rGB, and GR from frond number 9 give significant correlation to the BSR severity level of oil palm trees. The correlation coefficient for each indices were -0.962 for G, -0.961 for B, -0.954 for GB, -0.961 for rGB and -0.963 for GR with significant level at 0.05.

TABLE IV
CORRELATION MATRIX BETWEEN BSR SEVERITY LEVEL OF OIL PALM TREE AND COLOR INDICES (N=4).

Frond No.			NDVI	R	G	B	NIR	GB	rGB	GR	rGR	H	S	I	THERMAL
		Pearson Correlation	.784	-.265	-.015	-.265	.573	.082	.307	.128	-.011	.059	.096	-.131	-.832
1	Level	Sig. (2-tailed)	.216	.735	.985	.735	.427	.918	.693	.872	.989	.941	.904	.869	.168
		N	4	4	4	4	4	4	4	4	4	4	4	4	4
		Pearson Correlation	.781	-.853	-.962*	-.961*	.719	-.954*	-.961*	-.963*	-.910	-.694	-.922	-.949	.385
9	Level	Sig. (2-tailed)	.219	.147	.038	.039	.281	.046	.039	.037	.090	.306	.078	.051	.615
		N	4	4	4	4	4	4	4	4	4	4	4	4	4
		Pearson Correlation	.778	-.256	-.681	-.644	.738	-.594	-.057	-.737	-.803	-.929	-.432	-.639	.817
17	Level	Sig. (2-tailed)	.222	.744	.319	.356	.262	.406	.943	.263	.197	.071	.568	.361	.183
		N	4	4	4	4	4	4	4	4	4	4	4	4	4

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

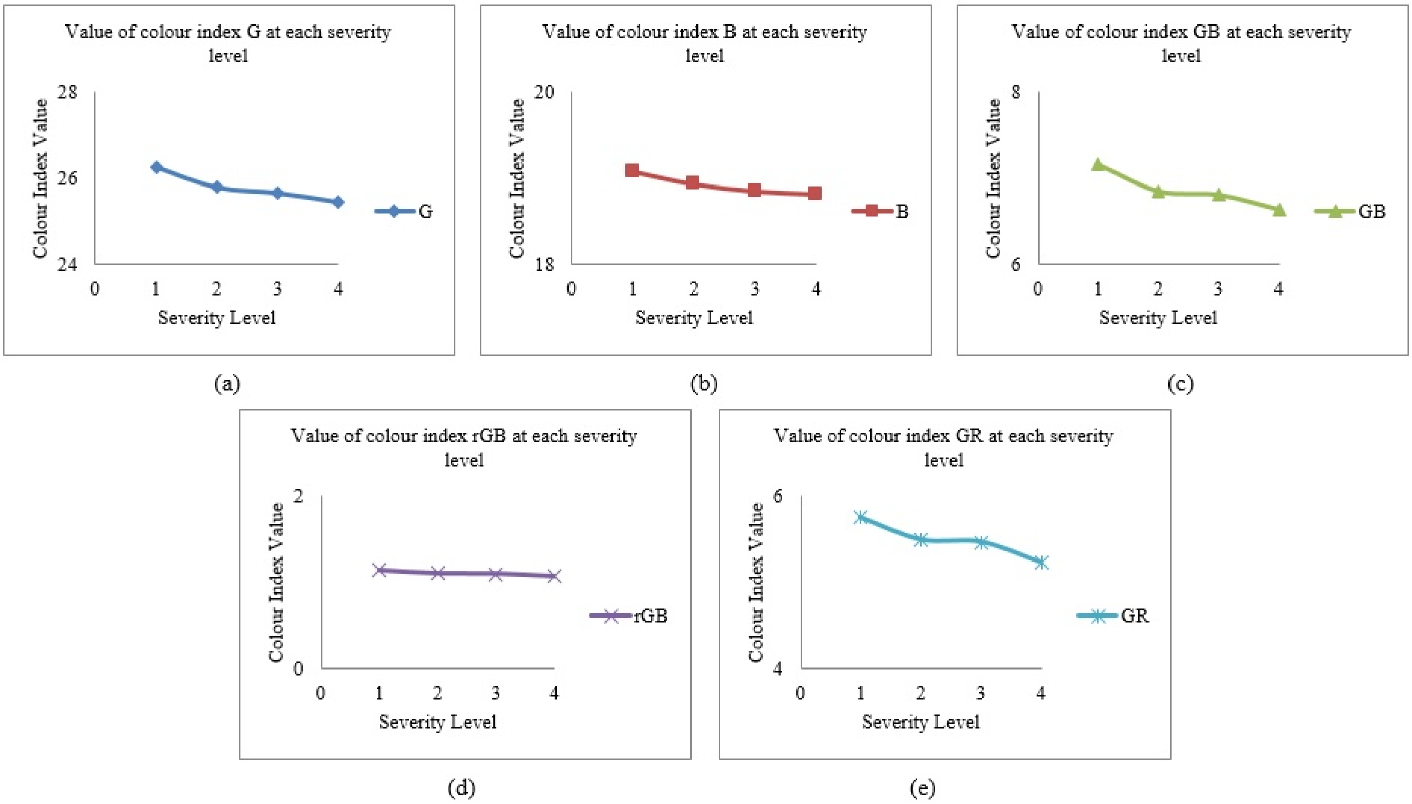


Fig. 2 Relationship between G, B, GB, rGB, GR indices and BSR severity level

The relationship between G, B, GB, rGB, GR indices and BSR severity level from frond number 9 are presented in Fig. 2. The values of color indices are decreasing with the increment level of BSR severity. Value of G index is higher as compared to B index in all severity levels as shown in Figs. 2 (a) and (b). It is confirmed with its difference values between both indices indicated by the GB index with positive difference amounting around 7 value of pixel intensity in all severity levels as shown in Fig. 2 (c). Fig. 2 also showed that among significant indices, although all indices gave decrement trends; however, the rGB index at T1, T2, T3 and T4 gave small value of difference. Further analysis has been done in order to determine the best color index to classify healthy and BSR-infected oil palm trees. Table V shows the results of average intensity difference at G, B, GB, rGB and GR indices for healthy and infected oil palm trees. It can be seen from the table that healthy oil palm trees have higher index compared to the infected oil palm trees. G is the best color index to classify healthy and BSR-infected oil palm trees due to the large different between healthy and infected which is 0.606.

G band has highest average value compared to R and B band because chlorophyll pigment absorbs most energy at about 650nm (R) and 450nm (B). Other pigments absorb more visible wavelengths, but the most absorption occurs in the R and B portions of the spectrum. This absorption removes these colors from the amount of light that is transmitted and reflected; causing visible color reaches human eyes as green. This is the reason healthy vegetation appears as a dark green. Unhealthy vegetation, on the other hand, will have less chlorophyll and thus will appear brighter (visibly) since less is absorbed and more is reflected to human eyes. This increase in red reflectance along with the green causes a yellowish in colour. The darker the leaves, the more photosynthesis can be done which can indicate the tree is healthy and vice versa.

Table VI shows a model summary and parameter estimates for severity level using G index. Based on this table, the power and S model shows highest significant value ($p<0.01$) with R-squared equals to 0.985.

TABLE V
VALUE OF G, B, GB, RGB, GR INDICES FOR HEALTHY AND INFECTED OIL PALM TREES

Color Index	Color Index Value		Different between healthy and infected tree
	Healthy	Infected	
G	26.240	25.633	0.606
B	19.080	18.868	0.212
GB	7.159	6.765	0.394
rGB	1.138	1.087	0.051
GR	5.746	5.391	0.356

TABLE VI
MODEL SUMMARY AND PARAMETER ESTIMATES FOR SEVERITY LEVEL USING G INDEX

Equation	Model Summary					Parameter Estimates	
	R-Squared	F	df1	df2	Sig.	Constant	b1
Linear	.926	25.067	1	2	.038	9.91E+01	-3.745
Logarithmic	.928	25.846	1	2	.037	3.18E+02	-96.985
Inverse	.930	26.659	1	2	.036	-9.49E+01	2511.410
Quadratic	.926	25.067	1	2	.038	9.91E+01	-3.745
Cubic	.926	25.067	1	2	.038	9.91E+01	-3.745
Compound	.984	125.195	1	2	.008	3.00E+20	.166
Power	.985	128.373	1	2	.008	9.88E+65	-46.516
S	.985	131.356	1	2	.008	-4.59E+01	1203.417
Growth	.984	125.195	1	2	.008	4.72E+01	-1.798
Exponential	.984	125.195	1	2	.008	3.00E+20	-1.798
Logistic	.984	125.195	1	2	.008	3.33E-21	6.036

IV. CONCLUSION

Based on the result, it can be concluded that medium maturity of leaves which was taken from frond number 9 gave significant correlation with healthiness level of oil palm tree. Among all color indices being tested, the study has concluded that G, B, GB, rGB and GR indices have correlation with BSR severity level. Healthy oil palm tree has higher G, B, GB, rGB, GR indices compared to infected oil palm tree and the value of these color indices decreasing with severity level of BSR. Results in this study has shown that G is the best color index to differentiate the healthy and BSR infected trees since it gave higher value of difference between healthy and infected oil palm trees which was 0.606. Furthermore, power and S model developed using G index gave the highest R^2 value which is 0.985.

ACKNOWLEDGMENT

The authors would like to acknowledge the Universiti Putra Malaysia (UPM) for sponsoring this research under IPB Grant, research number GP-IPB/2013/9415601.

REFERENCES

[1] A. Roslan, and A.S. Idris,“Economic impact of Ganoderma incidence on Malaysian oil palm plantation – a case study in Johor,” in *Oil Palm Industry Economic Journal*, vol. 12, no. 1, pp. 24-30, 2012.

[2] R.H.V. Corley, and P.B. Tinker, *The oil palm (Elaeisguineensis Jacq)*. Oxford: Wiley-Blackwell, 2004, 4th edition.

[3] R.H.Y. Corley, J.J. Hardon, and B.J. Wood, *Oil palm research*. Amsterdam: Elsevier, 1976.

[4] P.D. Turner, *Oil Palm Diseases and Disorders*. Oxford: Oxford University Press, 1981.

[5] D. Ariffin, A.S. Idris, and H. Khairuddin, “Confirmation of Ganoderma infected palm by drilling technique,” in *Proc of the PORIM International Palm Oil Congress: Update and Vision (Agriculture)*, Bangi, 1993, pp. 735-738.

[6] A.S. Idris, and R. Rafidah, “Enzyme linked immune sorbent assay-polyclonal antibody (ELISA-PAb),” *MPOB Information Series*, no. 430, pp. 4, 2008.

[7] A.S. Idris, M.S. Mazliham, P. Loonis, and M.B. Wahid,“Gano Sken for early detection of Ganoderma,”*MPOB Information Series*, no. 499, pp. 4, 2010.

[8] T.W. Darmono, and Suharyanto, “Detection of basal stem rot disease of oil palm using polyclonal antibody”,*Menara Perkebunan*, 67(1), pp. 32-39, 1999.

[9] H. Santoso, T. Gunawan, R. Jatmiko, W. Darmosarko, and B. Minasny, “Mapping and identifying basal stem rot disease in oil palms in North Sumatra with Quickbird Imagery,” *Precision Agriculture*, 12(2), pp. 233-248, 2011.

Siti Khairunniza-Bejo is an Associate Professor at Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang, Selangor, Malaysia. She obtained her Bachelor of Engineering degree in Computer Systems and Communication from Universiti Putra Malaysia and her Ph.D degree in Image Processing from the University of Surrey, UK. Her fields of specialization are in Imaging Technology and Precision Agriculture. She was the Guest Editorial Board Member for the Pertanika Journal of Science & Technology. She is the Executive Committee of Institute of Electrical and Electronics Engineers (IEEE) Young Professionals and a member of IEEE, The Institution of Engineers Malaysia (IEM), Malaysian Remote Sensing Society (MRSS) and Malaysian Society of Agricultural Engineers (MSAE).

Yusnida Yusoff is a Master student at UniversitiPutra Malaysia, Serdang, Malaysia. She obtained her Bachelor of Engineering (Agricultural and Biosystem) in 2011 from the same university. Previously, she worked as a Research Assistant at the same university in the field of remote sensing, image processing and precision agriculture.

Nik Salwani Yusoff obtained her Bachelor of Engineering (Agricultural and Biosystem) from UniversitiPutra Malaysia in 2014. She is currently working at Sandakan Politechnic, Malaysia.

Idris Abu Seman is the Head of Unit for Ganoderma and Diseases Research for Oil Palm (GanoDROP), Biological Research Department, Malaysian Palm Oil Board (MPOB) Malaysia. He obtained his Dip. Agric. in 1984, and BSc. Agric. in 1987 from Universiti Putra Malaysia. He obtained his PhD (Plant Pathology) from Wye College, university of London, United Kingdom in 1999. He has been working with PORIM/MPOB since 1987 and had 27 years' experience in R&D on Ganoderma disease in oil palm.

Mohamad Izzuddin Anuar is a Research Officer of Ganoderma and Diseases Research for Oil Palm (GanoDROP), Biological Research Department, Malaysian Palm Oil Board (MPOB) Malaysia. He obtained his BSc. Remote Sensing in 2007 from UniversitiTeknologi Malaysia .He obtained his MSc (GIS and Geomatic Engineering) from Institute of Advance Technology (ITMA), Universiti Putra Malaysia in 2010. He has been working with MPOB since 2012 and had 8 years' experience in R&D on Ganoderma disease in oil palm.