REMOTE SENSING MEASUREMENT FOR DETECTION OF BAGWORM INFESTATION IN OIL PALM PLANTATION

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Bagworms (Lepidoptera: Psychidae) are leaf eating caterpillars characterised by the possession of bag, built from pieces of dried plant materials such as leaves and small twigs (Barlow, 1982). Their outbreaks are common in several states in Malaysia and have a significant economic impact on oil palm yield. According to Wood *et al*. (1973), 43% of yield decline over the next two years is caused by 50% of canopy damage. Hence, early detection of bagworm infestation becomes a critical part of reducing crop loss in oil palm plantations.

Remote sensing provides a possible solution to the intensive sampling required for site-specific pest management. In the broad sense, remote sensing is the acquisition of information using a device not in physical contact with an object or area under study for further analysis and interpretation (Lillesand and Kiefer, 2000). Spectral resolution varies depending on the device used to acquire the image, but typical multispectral imagery includes wavelengths in the visible region which comprises of blue (400-500 nm), green (500-600 nm), red (600-700 nm) and near infrared region (700-1100 nm).

Ground base spectrometer provides high spectral resolution of small areas and can be used to help validate and calibrate other kinds of imagery. The use of remote sensing for site-specific management is based on the knowledge that crop plants are subjected to environmental and anthropogenic influences that can induce stress responses in plants (Lichtenthaler and Rinderle, 1988).

Scattering and absorption characteristics of the leaf internal structure and biochemical constituents like pigment, water, nitrogen, cellulose, lignin (Asner, 1998; Coops *et al*., 2002), chlorophyll, cell structure and cell water content (Jensen, 1983) determine the spectral characteristics of the foliar. Pigments influence spectral responses in the visible wavelengths (Gaussman, 1977). Photosynthetic capacity and productivity rely mainly on chlorophyll pigment contents (Gaussman, 1977; Curran *et al*., 1992). Cellular structure and water content resolve the spectral response in near and mid-infrared wavelength as shown in *Figure 1*.

METHODOLOGY

The study was carried out at MPOB Teluk Intan Research Station (*Figure 2*) at geographic location (upper left: 101˚ 4′ 36.74″E, 3˚ 50′ 3.15″N, lower right: 101˚ 6′ 48.04″ E, 3˚48′ 12.49″ N). Sampling points were carried out on immature and mature palms and marked using Trimble Juno SB Differential Global Positioning System (DGPS) equipment with 2-5 m accuracy after post-processed. The area was infested by bagworm and a total of 97 sampling points were collected during the survey. Each Global Positioning System (GPS) collected data and sampling measurements were transferred in Geographic Information System (GIS) database for further data recording.

Damage Rating

As precisely estimating the percentage of oil palm foliar affected by bagworm damage was difficult, bagworm damage ratings were assigned based estimation of damage severity, corresponding to the ratings suggested by Pickel *et al*. (2006). However, in this study, each foliar was given a damage rating ranging from 0 (no damage) to 3 (severe damage). The criteria used to assign the damage ratings is listed in *Table 1*.

Foliar Spectral Reflectance Measurement

GER 1500 field spectrometer (*Figure 3*) with 512 spectral bands at sampling intervals of 1.5 nm was used to characterise the foliar reflectance. It covered ultraviolet (UV), visible (blue, green and

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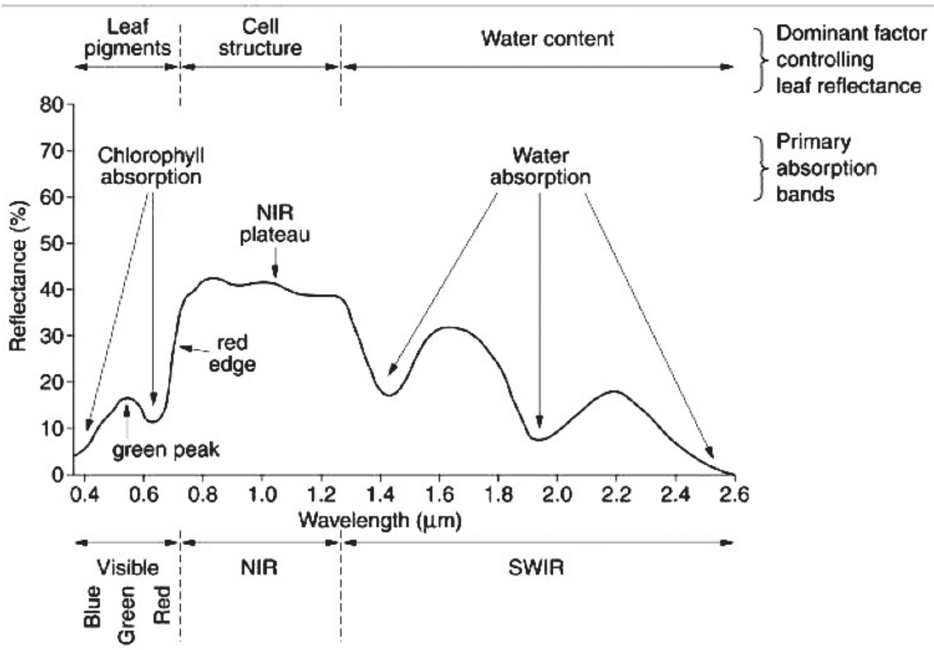


Source: adapted from Gaussman (1977).

Figure 1. Typical reflectance sensitivities as controlled by leaf pigments, cell structure and water content.

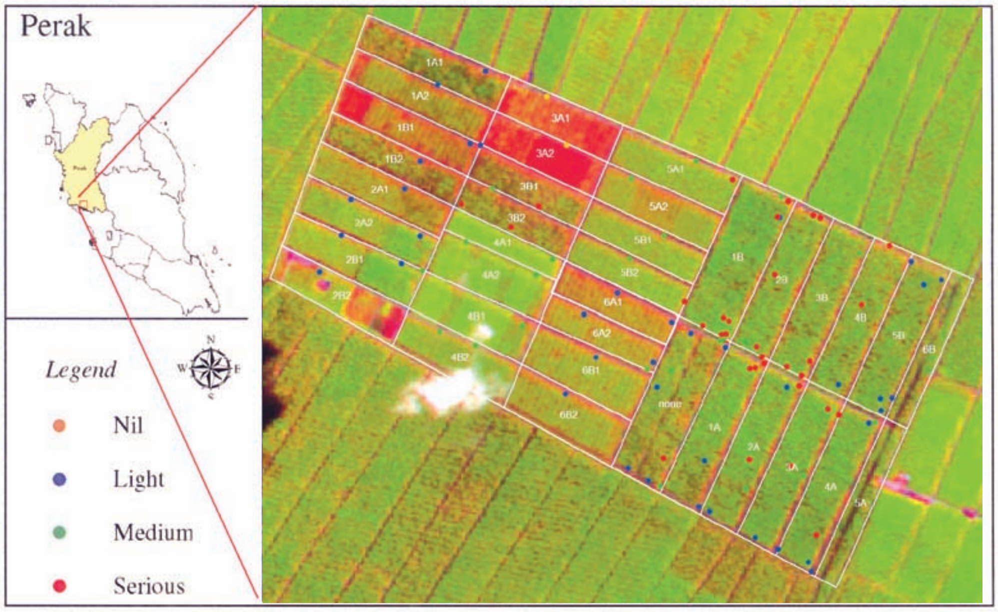


Figure 2. Distribution of sampling points overlayed in SPOT 5 satellite image of MPOB Research Station, Teluk Intan, Perak.

TABLE 1. DESCRIPTION OF DAMAGE RATING CLASS

Damage rating	Class Name	Description
0	Nil	No visible bagworm damage.
1	Light	Very few bagworm larvae and pupae on leaflets.
2	Medium	Most leaflets with bagworm larvae and pupae. Many holes on leaflets with slight necrosis.
3	Serious	Lots of bagworm larvae and pupae on almost all leaflets. Lots of holes and necrosis. Leaflets turning brown and dessicated.

Figure 3. GER 1500 field spectrometer.

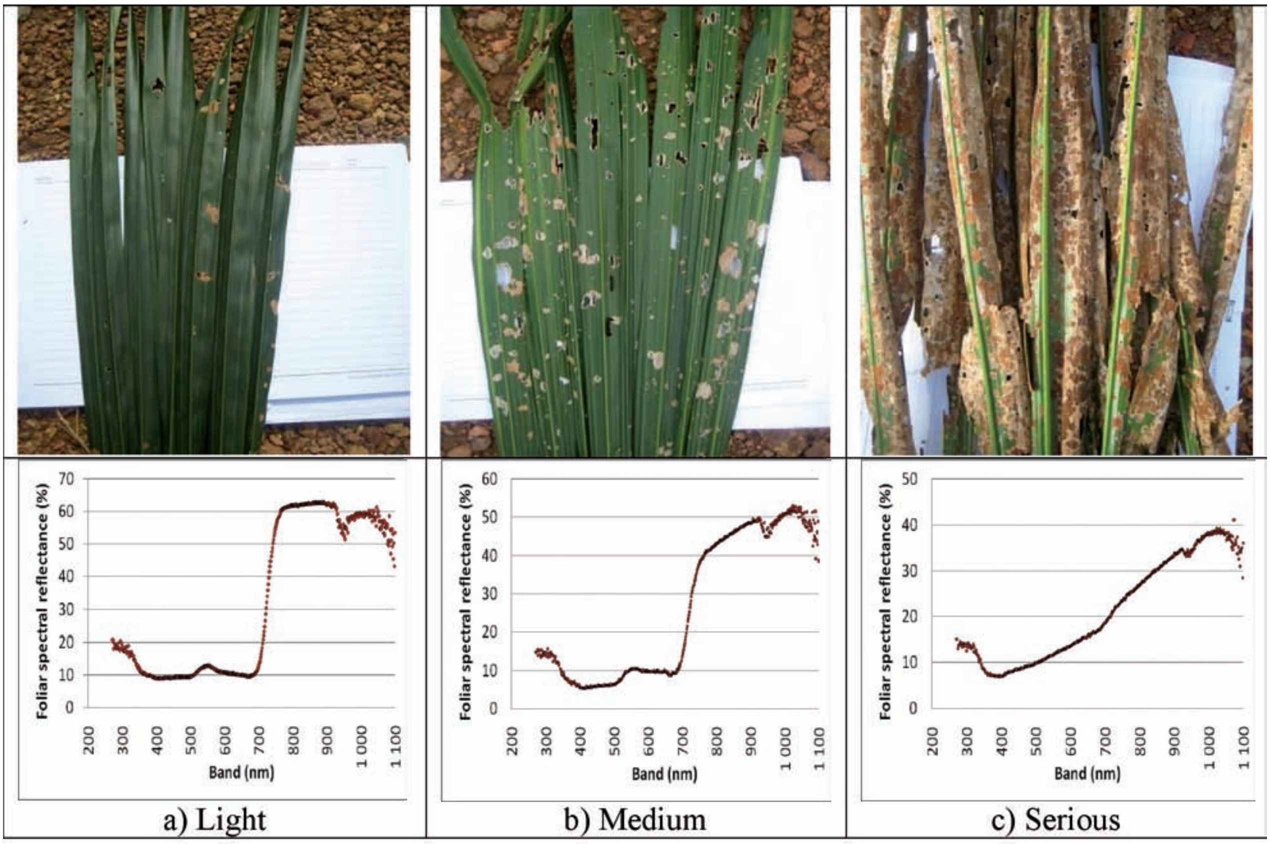
red bands) and near infrared (NIR) wavelengths from 350 nm to 1050 nm. Diffraction grating with a silicon diode array activated laser sighting through a 4° standard fibre optic cable was used as the light source to illuminate the leaves. Each reflectance measurement was referenced to white standard panel coated with $BaSO_4$ measured and illuminated under the same conditions. Leaves were arranged into a 10 cm × 10 cm stack, two to three layers thick. In order to stimulate the canopy reflectance, leaf stacks were used rather than single leaf layer. For each sample, five reflectance measurements were taken then averaged to obtain a mean reflectance spectrum.

RESULTS AND DISCUSSION

Figure 4 shows three types of foliar damage and its respective spectral measurements. It comprised of light, medium and serious damage.

Identification of Significant Wavelengths

Reflectance data from the 512 bands of the spectrometer were analysed statistically using partial least squares (PLS) regression. Several researchers have shown that PLS regression (Wold, 1995; Wold *et al.*, 1998) is a powerful tool to identify significant signals in such datasets (Frank and Friedman, 1993; Ourcival *et al*., 1999; Kooistra *et al.*, 2003; Wilson *et al.*, 2004; Delalieux *et al.*, 2007). From the analysis, band centred at 570 nm, 680 nm, 734 nm, 787 nm, 996 nm and 1047 nm were identified as most sensitive wavelengths to bagworm infestation in both immature and mature palms (*Figures 5* and *6*, repectively). *Tables 3* and *4* show the spectral reflectance for each damage rating at different sensitive wavelength in immature and mature palms.



a) Light b) Medium c) Serious

Figure 4. Spectral reflectance characteristics on each level of foliar damaged.

TABLE 2. DESCRIPTIVE STATISTICS OF SPECTRAL REFLECTANCE FOR EACH LEVEL OF FOLIAR DAMAGE

Descriptive statistics	**Class of foliar damage**		
	Light damage	**Medium damage**	**Serious damage**
No. of observations	512	512	512
Minimum	8.9	5.4	6.9
Maximum	62.7	53.0	41.1
Mean	34.1	27.1	21.7
Standard deviation	23.6	18.7	11.0
Variance	557.0	351.4	121.0
Coefficient of variation (%)	69.3	69.2	50.6

TABLE 3. SPECTRAL REFLECTANCE IN IMMATURE PALMS

Damage rating	**Sensitive wavelength (nm)**						**Statistical analysis**				
	570	**680**	**734**	**787**	**996**	**1 047**	**Mean**	**Std. dev**	**Variance**	r^2	**$P < 0.05$**
1	11.9	9.8	43.1	61.5	58.6	58.6	40.6	23.9	573.0	0.648	0.05
2	10.4	9.3	32.5	42.0	50.6	52.4	32.9	19.2	368.1	0.821	0.01
3	12.5	16.9	22.2	25.9	38.0	38.1	25.6	10.7	113.8	0.985	0.00008

TABLE 4. SPECTRAL REFLECTANCE IN MATURE PALMS

Damage rating	**Sensitive wavelength (nm)**						**Statistical analysis**				
	570	**680**	**734**	**787**	**996**	**1 047**	**Mean**	**Std. dev**	**Variance**	r^2	**$P < 0.05$**
1	12.2	10.0	43.4	58.1	57.2	52.2	38.8	22.1	489.8	0.606	0.07
2	6.9	6.0	26.5	34.9	39.7	38.6	25.4	15.4	237.2	0.760	0.02
3	7.7	10.8	18.4	22.5	30.8	31.1	20.2	9.8	96.8	0.948	0.001

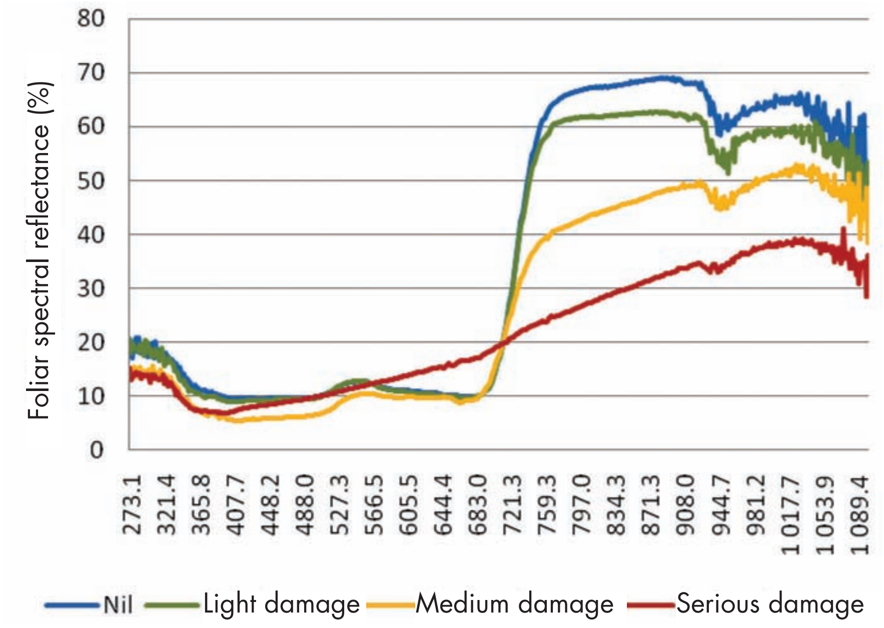


Figure 5. Discrimination of foliar damage (immature palms).

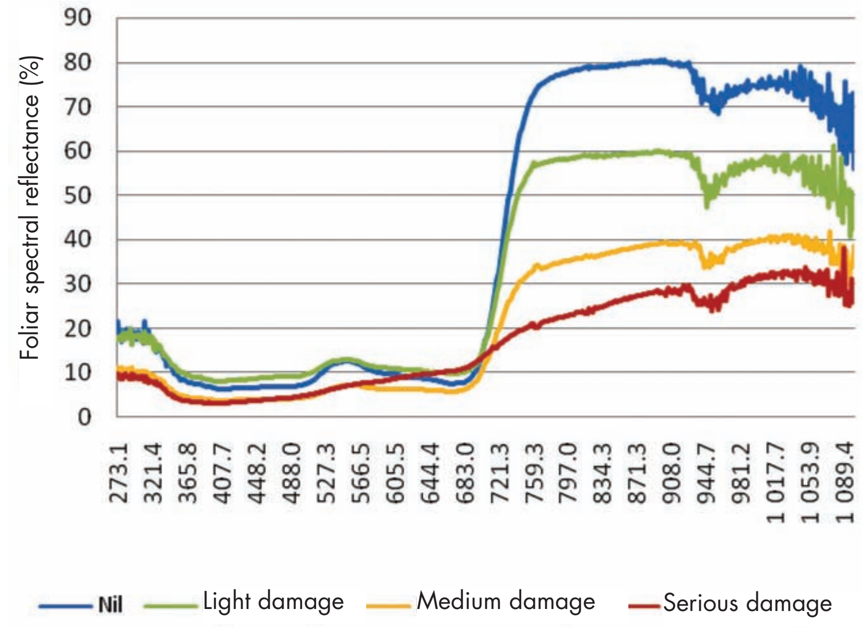


Figure 6. Discrimination of foliar damage (mature palms).

Linear regression between spectral reflectance for each class of damage rating had high r^2 ($0.648 \leq r^2 \leq 0.985$ and $0.606 \leq r^2 \leq 0.948$) in immature and mature palm respectively (*Figure 7*). Based on *P* value, spectral reflectance in both immature and mature palms were statistically significant to discriminate the damage rating of classes 2 and 3. However, for damage rating of class 1, the spectral reflectance was not significant to characterise the physical damage of the foliar. Yet, the results suggested that sensitive bands from field remote sensing measurement can be used as a non-destructive prediction method to determine and monitor the foliar damage due to bagworm infestation.

CONCLUSION AND RECOMMENDATION

Results showed that it was possible to detect bagworm damage on oil palm foliage using a spectral reflectance measured from field specrometer. It provides a realistic basis for the realisation of remote sensing application for pest infestation. The outcome from this study is important for theoretical remote sensing of plant stress for further investigation using ground-based, airborne and spaceborne sensors. It is a cost-effective technology where it is able to display spatial pattern at variable scales. It includes the use of field spectrometer measurement and satellite imagery in filling spatial or temporal gaps in other data collection methods, and as a result, is

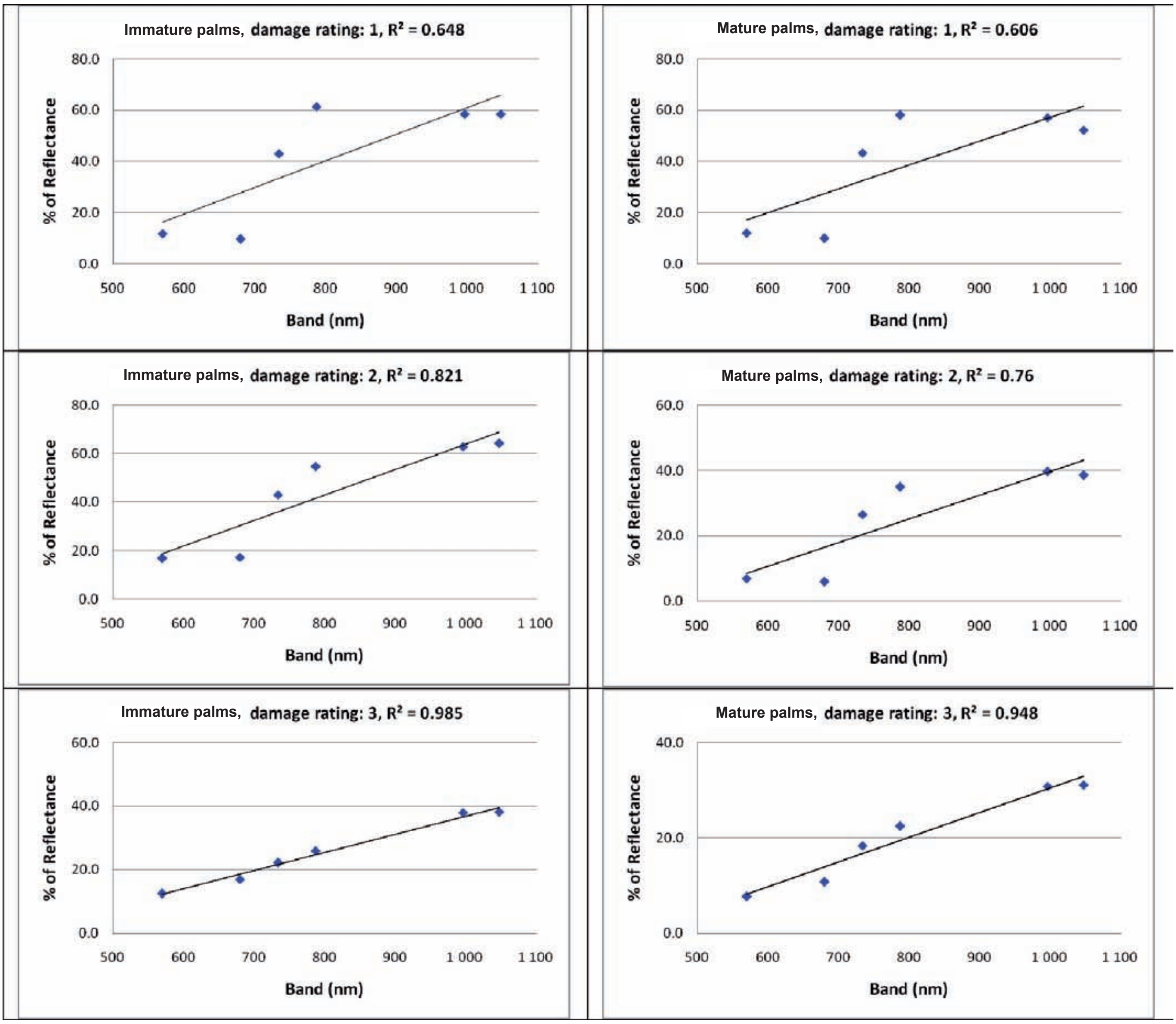


Figure 7. Relationship of spectral reflectance for each damage rating in both immature and mature palms.

complementary to existing methods of bagworm detection. Reflectance measurement can be used as an assessment method when non-invasive and non-destructive assessments are desired. It can also be used as an additional method to ease visual assessments.

Furthermore, it expands the bagworm detection survey options available to plantation managers, and should therefore be considered as a viable data source for detecting and monitoring bagworm damage.

REFERENCES

ASNER, G P (1998). Biophysical and biochemical sources of variability in canopy reflectance. *Remote Sens. Environ., 64*: 234-253.

BARLOW, H S (1982). *An Introduction to the Moths of South East Asia*. Art Printing Work Sdn Bhd. Kuala Lumpur. p. 305.

COOPS, N; DURY, S; SMITH, M L; MARTIN, M and OLLINGER, S (2002). Comparison of green leaf eucalypt spectra using spectral decomposition. *Aust. J. Bot., 50*: 567-576.

CURRAN, P J; DUNGAN, J L; MACLER, B A and PLUMMER, S E (1992). The effect of a red leaf pigment on the relationship between red-edge and chlorophyll concentration. *Remote Sens. Environ., 35*: 69-75.

DELALIEUX, S; VAN AARDT, J; KEULEMANS, W; SCHREVENS, E and COPPIN, P (2007). Detection of biotic stress (Venturia inaequalis) in apple trees using hyperspectral data: non-parametric statistical approaches and physiological implications. *Eur. J. Agron., 27*: 130-143.

FRANK, I E and FRIEDMAN, J H (1993). A statistical view of some chemometrics regression tools. *Technometrics, 35*: 109-135.

GAUSSMAN, H W (1977). Reflectance of leaf components. *Remote Sens. Environ., 6*: 1-9.

JENSEN, J R (1983). Biophysical remote sensing. *Annals of the Association of American Geographers, Volume 73, Issue 1*: 111-132.

KOOISTRA, L; LEUVEN, R; WEHRENS, R; NIENHUIS, P H and BUYDENS, L M C (2003). A comparison of methods to relate grass reflectance to soil metal contamination. *Int. J. Remote Sensing., 24*: 4995-5010.

LICHTENTHALER, H K and RINDERLE, U (1988). The role of chlorophyll fluorescence in the detection of stress conditions in plants. *Crit. Rev. Anal.Chem., 19*: S29-S85.

LILLESAND, T M and KIEFER, R W (2000). *Remote Sensing and Image Interpretation*, 4th edition. Wiley & Sons.

OURCIVAL, J M; JOFFRE, R and RAMBAL, S (1999). Exploring the relationships between reflectance and anatomical and biochemical properties in Quercus ilex leaves. *New Phytol., 143*: 351-364.

PICKEL, C; BENTLEY, W J; HASEY, J K; DAY, K R; GUBLER, W D; ADASKAVEG, J E; WESTERDAHL, B B; MCKENRY, M V; SHRESHTA, A; LANINI, W T and HEMBREE, K J (2006). *UC IPM Pest Management Guidelines Peach*. UC Statewide Integrated Pest Management Program, University of California, Oakland, CA, USA.

WILSON, M D; USTIN, S L and ROCKE, D M (2004). Classification of contamination in salt marsh plants using hyperspectral reflectance. *IEEE Trans. Geosci. Remote Sensing, 42*: 1088-1095.

WOLD, S (1995). PLS for multivariate linear modeling. *Chemometric Methods in Molecular Design: Methods and Principles in Medicinal Chemistry* (van der Waterbeemd, H ed.). Verlag-Chemie, Weinheim, Germany. p. 195-218.

WOLD, S; ANTTI, H; LINDGREN, F and OHMAN, J (1998). Orthogonal signal correction of near-infrared spectra. *Chemometr. Intell. Lab, 44*: 175–185.

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