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RELATIONSHIP BETWEEN CHLOROPHYLL CONTENTS AND SPECTRAL PROPERTIES OF FROND 9 AND 17 OF MATURE OIL PALM

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Abstract: Presently non-invasive light-based chlorophyll determination has become the standard for a quick overview of general plant health and yield estimation. For oil palm which is a perennial crop, however, the determination should be done by considering effects of oil palm age and frond number. In this study, spectral reflectance obtained from (a) spectroradiometer and (b) SPAD were used to investigate variations in chlorophyll a, b, and total. It was found that SPAD values were inadequate to predict leaf chlorophyll content in young and mature oil palm for both frond 9 and 17 (r^2 = 0.0001 – 0.40 and r^2 = 0.019 – 0.16, respectively). Correlation analysis showed that spectroradiometer reflectance at 700 - 1350nm wavelength has relationship with chlorophyll content as high as r=0.4. There was also other peaks at 400nm, 1600nm, and 1900nm which could be of interest in future studies.

Keywords: oil palm, chlorophyll, SPAD, spectroradiometer

INTRODUCTION

Presently non-invasive light-based chlorophyll determination has become the standard for a quick overview of general plant health and yield estimation. The theory is that plant greenness can be correlated to plant health and yield. The greenness is resulted from the chlorophyll pigmentation that can be measured through the reflectance or absorbance at a certain wavelength. Currently for oil palm (*Elaeis guneensis*), ground based or satellite based sensor were usually used to predict nitrogen (N) level but not chlorophyll. In order to estimate nitrogen content, understanding the effects of chlorophyll is rather essential since these two are related. The current popular device used to approximate chlorophyll content is Konica Minolta SPAD-520 meter which uses the ratio of red and near infrared to give a relative value (SPAD number) of chlorophyll. A current research by Amiruddin et al. (2014) and Salim (2014) alluded that SPAD data was only correlated to immature oil palm, while mature oil palm demonstrated a poor correlation value. The other device that can be utilised to approximate chlorophyll content is the spectroradiometer. This device allows the measurement of leaf reflectance data up to1nm resolution from 350 - 2500nm. Yoder & Pettigrew-Crosby (1995), through the use of spectroradiometer, have shown that leaf chlorophyll could be predicted with high accuracy by transforming the reflectance from the near infrared region. Gitelson et al. (2003) further refined the relationship between spectral reflectance and chlorophyll by illustrating the usefulness of region 520 - 550nm and 695 - 705nm. Nevertheless, due to the physiology of oil palm, it is expected that the reflectance will be correlated to chlorophyll content according to its age and frond number. This is due to the leaf thickness and the variation in the intercellular air spaces as demonstrated by Slaton et al. (2001). Finding the most representative wavelengths that correspond to the chlorophyll count according to oil palm growth stages is the first step in using light based analysis for oil palm health, nitrogen, and yield prediction.

METHOD

The experiment was conducted by using the Random Complete Block Design – split plot design with the site treatment as the main plot and frond number and N treatments as the subplot. There were two sites representing two ages. The site of 12 years old (AGE12) is located at 2.377779°N, 102.265658°E, with a density of 148 stands per hectare. The site of 15 years old (AGE15) is located at 2.380374°N, 102.238012°E, with a density of 147 stands per hectare. Each site has 3 N treatments; 0 kg, 1 kg, and 2 kg of N per plants with 3 replications per treatment. There were 16 plants in each experimental unit, whereby 8 plants were sampled for frond 9 (F9) and 17 (F17).

The Minolta SPAD meter was used to measure chlorophyll content from 3 leaflets from each left and right leaf blades, close to the frond thorn. Spectral reflectance from the same leaflets was measured afterwards by using a Fieldspec 4 Std-Res spectrometer (ASD Inc.). The spectral range is from 350 - 2500nm with 10nm resolution. The instrument was firstly optimised for the site environmental conditions. Reflectance data was collected by placing the leaflets in the sample holder with the back of the leaf blade towards the dark background and the upper side of the leaf blade towards the light source. Chlorophyll a, b, and total was then extracted for $1cm^2$ area punched from each leaflet by leaching the samples in acetone. Their absorbance was measured by using a table top spectrometer (Shimadzu uv-3101 spectrometer at 647nm and 664nm with 1cm pathlength). These readings were averaged according to the replications prior to statistical analysis.

The data was analysed by using PROC GLIMMIX procedure (SAS 9.3). Association and linear relationship between chlorophyll a, b, and total with SPAD and each of the wavelength between 400 - 2500nm was conducted by using PROC REG and PROC CORR procedure, respectively (SAS 9.3).

RESULTS AND DISCUSSION

For AGE12, SPAD reading and spectroradiometer reflectance for both frond numbers showed weak linear relationships with chlorophyll a, b, and total. Of the two fronds for both ages, F9 had slightly stronger linear relationship than F17, with the highest one was observed between SPAD values and chlorophyll b of F9 ($r^2 = 0.39$) (Figure 1).

SPAD and spectroradiometer reflectance of AGE15 also depicted weak relationships for both F9 and F17 (Figure 2). The values were extremely poor for F9, almost having no linear relationship at all (r^2=0.0001), possibly due to the saturation of the SPAD device or the presence of leaf thickness effect (Slaton et al., 2001). On the other hand, F17 had slightly better linear relationships ($r^2 = 0.019 – 0.16$). Generally, AGE12 had higher r^2 values compared to AGE15 except for the chlorophyll a for F17. This finding is similar to Amirruddin et al., (2014) who found that younger oil palms had higher relationship between SPAD and N content compared to mature palms.

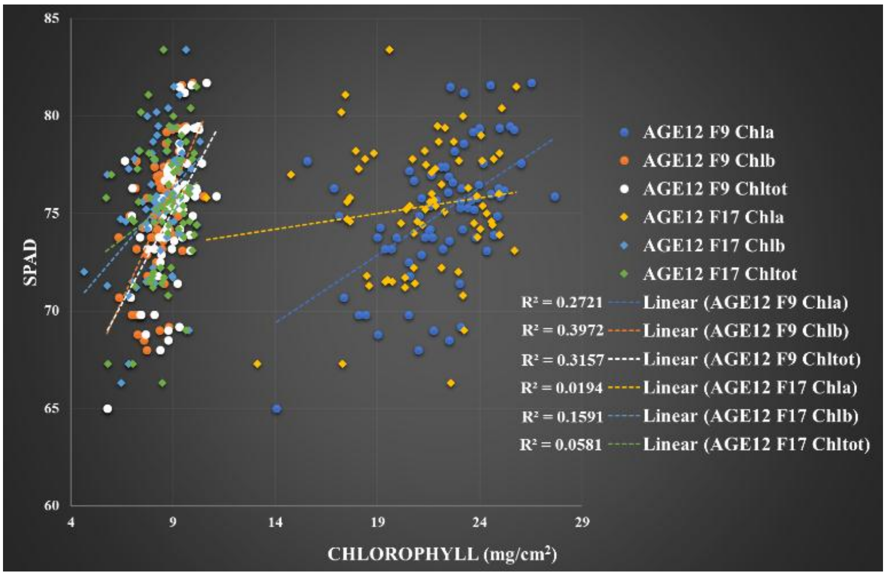

Figure 1: AGE12 SPAD vs chlorophyll.

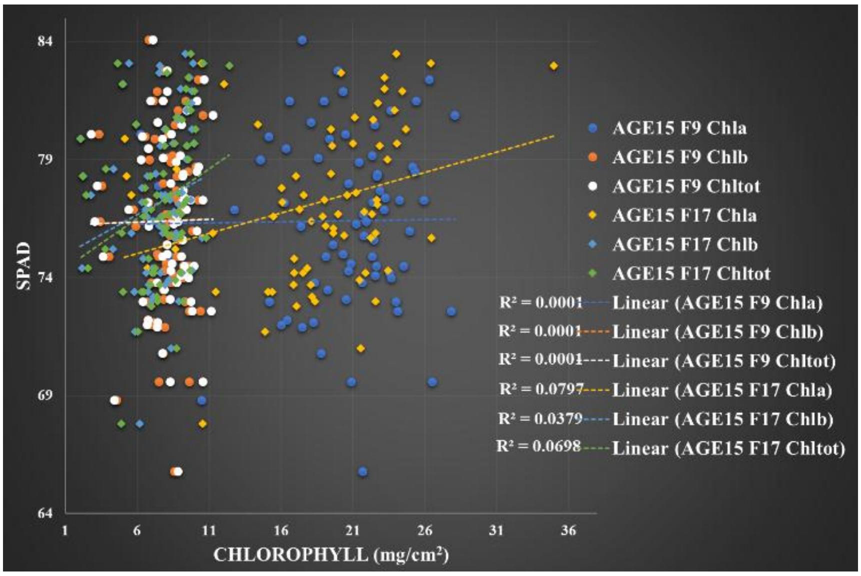

Figure 2: AGE15 SPAD vs Chlorophyll.

Generally, the shape of the graph for the correlation values between the chlorophylls and the spectroradiometer reflectance resembled the vegetation spectral signature. The correlation between all chlorophyll variables and the spectral reflectance illustrate that the relationships were weak (maximum of r = -0.1 - 0.4 for AGE12) and (r=-0.4 – 0.1 for AGE15). The difference between r values of F9 and F17 was smaller in AGE12 compared to AGE15, suggesting that in AGE12, frond number did not affect the relationship between spectral reflectance and chlorophyll much. For both ages, F9 had more positive correlations than F17. Generally, higher correlations were obtained for 700 - 1350nm region, with additional peaks observable at 400nm, 1600nm and 1900nm. This finding was in contrast with Gitelson et al., (2003) who found that 520 – 550nm and 695 – 705nm illustrated the highest correlation to chlorophyll derivatives and used NIR reflectance to adjust for leaf cell structure. On the other hand, 1600nm and 1900nm had been correlated with plant water stress status (Carter, 1993).

Nevertheless, our finding had similarities with Amiruddin et al., (2017) who utilize wavelengths from 835 – 1085nm to predict N sufficiency level.

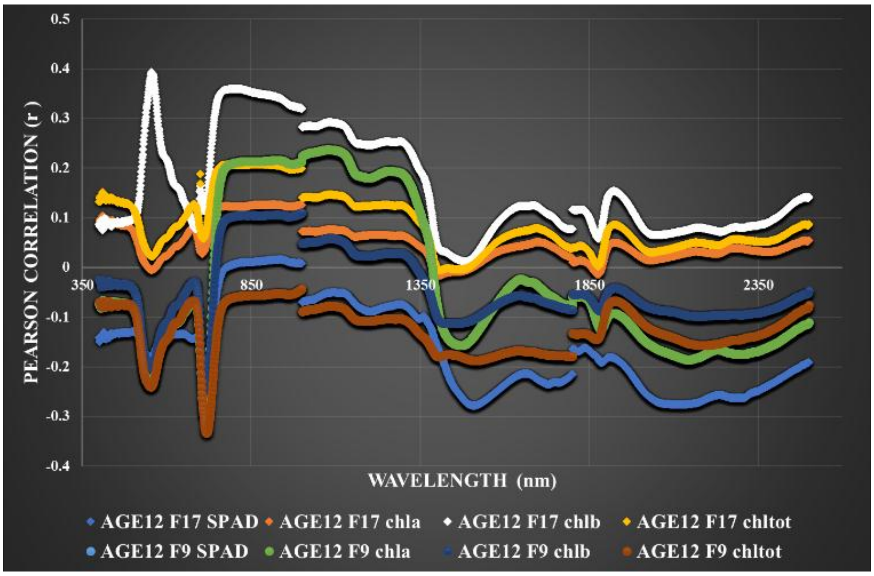

Figure 3: Pearson correlation between chlorophylls and SPAD for AGE12.

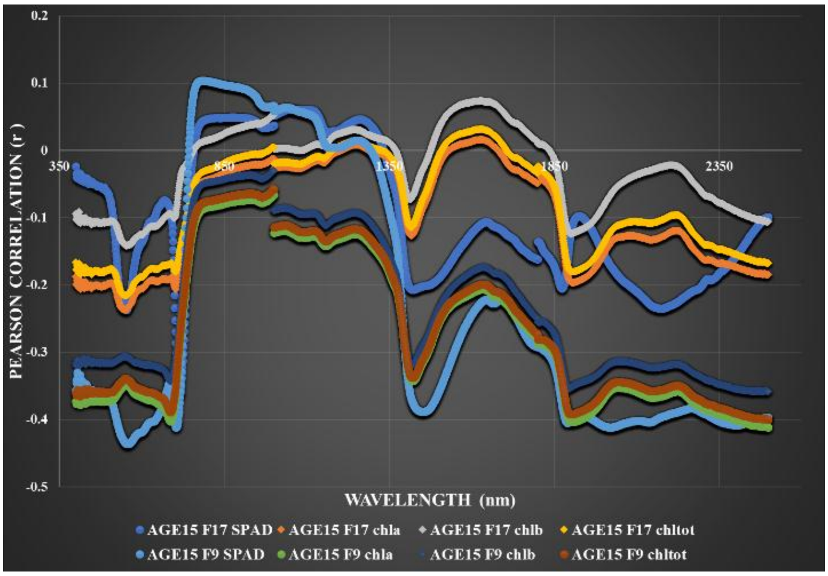

Figure 4: Pearson correlation between chlorophylls and SPAD for AGE15.

CONCLUSION

Reflectance at 700 - 1350nm illustrated higher correlation values with chlorophyll variables, suggesting its usefulness in in predicting chlorophyll content. The correlation values for AGE12 were in the range of 0.1 – 0.4 while AGE15 were in the range -0.4 – 0.1. F9 was found to depict more positive correlations to chlorophylls than F1, as such a good candidate for the chlorophyll estimation.

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