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# A Review of Methods for Detecting Nutrient Stress of Oil Palm in Malaysia

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## ABSTRACT

Oil palm plantation is one of the plantation crops in Malaysia which requires high nutrient input. It is needed to make the crop at the optimum growth and production stage. Nutrient stress is an interference of crop health caused by lack of nutrient elements to support the requirement of crop growth. Generally, it is strongly related to nitrogen status in crop. This article aims to describe advantages, disadvantages and recent advanced techniques to consider a promising method for nutrient stress study in Malaysia. The conventional method of "Kjeldahl Digestion" to determine nitrogen content is known as destructive method, labour-intensive and time consuming. Moreover, transmittance device of SPAD chlorophyll meter is low sensitivity for detecting N stress at early stages and chlorophyll saturation. In addition, multispectral and hyper spectral sensors are very costly and weather dependence but they give more precise and larger areas coverage. As a whole, the study revealed that remote sensing techniques such as, hyper spectral and multispectral sensors have potential for use in detecting nutrient stress of oil palm in near future.
**KEYWORDS:** Nitrogen, nutrient stress, oil palm, remote sensing

## INTRODUCTION

The nutrient status is one of the most important factors in determining oil palm productivity and crop yield. An insufficient of nutrient to meet the requirement of oil palm resulted nutrient stress which contributes to significant drop in oil palm productivity. Nitrogen (N) is one of essential nutrients in plants due to its key roles in chlorophyll production, which is fundamental for the photosynthesis process [1]. Hence, N-content is often used as the benchmark for nutrient stress of oil palm. However, the conventional method for N analysis involves time and labor-consuming, thus restricting the number of analyses that can be done [2].On the other hand, the simpler, less labors and rapid technique such as those optical meters, are expensive, insensitive and atmospheric dependence. In the study is briefly described few methods and techniques for detecting nutrient stress in Malaysia's oil palm estates which later it can be considered for the most promising of these compromise methodologies.

## OVERVIEW OF METHODS, TECHNIQUES AND INSTRUMENTS FOR NUTRIENT STRESS DETECTION

### Kjeldahl method (leaf analysis)

Leaf analysis has been used as a common method to estimate plant N-status of oil palm in Malaysia. It generally uses the 17$^{th}$ frond leaves of oil palm (>2.5 years) to compare actual crop N status of laboratory with plant N status predicted by others instruments or recent developed system. The determination of 17$^{th}$ frond leaves to analyse the N status is caused by the sensitivity of those leaves to indicate nutrient content (N, P and K) in oil palm [3]. Meanwhile, nutrient status in 17$^{th}$ frond leaves has a better correlation to oil palm production compare to others young leaves [4]. This frond is under the 9$^{th}$ frond, which it is somewhat to the left in right-spiral or to the right in leaf-spiral of oil palm. The criteria of sampling technique for leaf analysis should reflect the homogenous unit such as, age of crop, soil type, topography, drainage and technical applied. It is important to avoid false recommendation for fertilization. In history, Kjeldahl method is one of the most used method to determine total N which proposed by Johan Kjeldahl in 1883. It also known as "Kjeldahl Digestion" and it has been widely used

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for N determination on food, beverages, meat, feed, grain, manure, waste water, soils and plant tissue [1]. Generally, a Kjeldahl digestion procedure consisted of three main phases:

1. Digestion—This step aims to break down all of the organic N in the sample to ammonium usingsulphuric acid.
2. Distillation—The digested sample is distilled after addition of a strong alkali, to liberate ammonia which is collected in a known amount of acid.
3. Titration—A back titration is then performed to determine the amount of acid consumed by the ammonia and to calculate the amount of N in the sample.

In order to accelerate the digestion process, Kjeldahl catalyst tablets or Selenium Reaction Mixtureis used as catalyst to reduced digestion time. During digestion process, losses of nitrogen can take place especially when larger amounts of the catalyst are used (> 0.25 g) or when long digestion times are used [5].Although, Kjeldahl method is simple and rapid way in determining total N in plant sample. It also has some disadvantages such as, it cannot measure other nitrogen forms such as, nitrate and nitrite thorough this procedure [1]. In addition, this method is laborious, uses toxic reagents, time-consuming and costly for large areas coverage.

**Soil Plant Analysis Development (SPAD chlorophyll meter)**

The Kjeldahl method has a big lag time between leaf sampling and the results are obtained from laboratories [2]. Hence, in order to reduce acquisition time, a reliable tool with fast data acquisition is needed for determining N status in crop. Currently, SPAD 502 Chlorophyll Meter, Minolta is often used to measure N status in any crop. Meter reading is given in Minolta Company-defined SPAD (Soil Plant Analysis Development) values that indicate relative chlorophyll content [6]. Several studies in Malaysia found thatit has been successfully used to evaluate leaf N status in any crop such as, oil palm by Law et al. [2], corn by Rostami et al. [7], paddy by Gholizadeh et al.[6] and others. Those studies discuss on nutrient stress of the crop and its relationship to the increment of chlorophyll and leaf N status. The linear relationship between N and SPAD values has led to the adaptation of the SPAD meter to assess crop N status and to meet the requirement of crop for additional N fertilizer [8-10].The chlorophyll meter or SPAD device is chosen for the most of oil palm estates in Malaysia due to its simplicity and portable diagnostic tool relative chlorophyll content of leaves. It also provided instantaneous in-situ reading for leaf greenness status. However, there are some disadvantages of this device. SPAD chlorophyll readings are better when they are taken around the midpoint of a leaf, not the midrib [11]. It also depends to weather condition, the data acquisition cannot be taken in rain day and sunlight exposure should be taken into consideration due to it directly affects leaf N content readings. Furthermore, Rafael et al. [1] concluded the disadvantages of SPAD meter such as, it is unable to detect over fertilized crops due to the chlorophyll saturation and low sensitivity for detecting N stress at early stages.

**Field spec Spectro-Radiometer Sensor (Ground-Based)**

Field Spec Pro portable Spectro radiometer is a passive crop canopy reflectance sensor applied to estimate crop N status. It is available in five different models: FieldSpec Pro UV/VNIR (350 - 1050 nm), FieldSpec Pro NIR (1000 - 2500 nm), FieldSpec Pro FR (350 - 2500 nm), FieldSpec Pro UV/VNIR/CCD (350 - 1030 nm) and FieldSpec Pro Dual UV/VNIR (350 - 1050 nm). It required a calibration procedure by measuring reflectance of a dark and a white reference panel before it could be used. A Study by Selvaraja et al. [12] has also reported that reflectance measurements obtained by using spectroradiometer can identify and discriminate between OS disease and K deficiency symptoms in oil palm. This study found that Photosynthetic Active Radiation (PAR) region (400-700 nm) is suitable to be used for the discrimination between symptomatic OS-infected and K-deficient leaves. Furthermore, Mazlan et al. [13] used spectroradiometer instrument to detect oil palm growth variability. The study indicated that oil palm crop performance can be explained by analyzing the shape of spectral reflectance. The recent studies showed that analysis of spectral or vegetation indices (i.e.NDVI, OSAVI, MCARI and TCARI) from bandwidths of spectroradiometer can determine nutrient stress thorough linear relationship spectral indices and N status in crop. The disadvantages of this instrument are calibration required, expensive instrument, complex system and sunlight dependence. The battery life is low when the instrument used to measure many samples. Additionally, it needs a specific expertise to operate and how to process the data especially, in post-processing works.

**Multispectral imagery (satellite-platform)**

The satellite images can deliver the information for N management over a large region [14]. This technique collaborates with GIS to offer some advantages such as, rapid data processing system, flexible, high data storage and large area coverage compare to any conventional methods [15].Previous studies reported that remote sensing data could be used to detect phosphorus and nitrogen in wheat, nitrogen in oil palm and nitrogen in corn [16-18]. Recently, satellite sensors have developed high spatial resolution to detect and give more accuracy for nutrient stress in crop. The use of high spatial resolution (10 metres or lower) is able to identify kind of crop stress and how serious it is. When chlorophyll starts to break down in stressed crops, it will affect the cellular structure of the leaves. Then, the condition will affect crop reflectance in the near infrared region, even before the changes of chlorophyll loss are reflected in the visible region. With remote sensing technique the changes in the near infrared region which are invisible to human eyes can be identified before the chlorotic symptoms appear. Hence, the analyst can determine that the crops are at the level of stress or not. Common satellite sensors used to detect nutrient stress in oil palm such as, Quick Bird, Ikonos, Geo-Eye, Landsat and SPOT. Some of oil palm estates in Malaysia, like Sime Darby and MPOB have used these satellite images for nutrient mapping, tree counting, crop growth monitoring and yield forecasting.

In addition, new satellite sensors, such as Rapid Eye and World View offer a new channel (red edge) which is a spectral region for chlorophyll estimation and vegetation classification. The presence of a red edge band is a unique feature that distinguishes these satellites from most other multispectral satellites. Since, nutrient stress strongly depends on an adequate supply of nitrogen (N). Therefore, the use of red edge band for chlorophyll estimation according to spectral indices will give more accurate information about N-status. It caused by the red edge band is one of the areas where chlorophyll strongly absorbs light and NIR is where the leaf cell structure produces a strong reflection. Through this band is able to provide additional specific information in order to identify N-status and health status of plant. Furthermore, Pinar and Curran [19] noted that the red edge region is sensitive to chlorophyll content and N-status. It can see when chlorophyll concentration increases, the typical slope in the red edge spectral region shifts towards the near-infrared (NIR).However, the study about detecting nutrient stress in oil palm using these satellite sensors has not been widely used in Malaysia's oil palm estates.

Despite, there are some weakness of this technique such as, expensive imagery, geo-location accuracy, cloud cover and delay of image acquisition time. Meanwhile, new satellite sensor such as, Rapid Eye and World View, both are not able to identified Red Edge Inflection Point (REIP) wavelength which is used as chlorophyll indicator for this shift. Several studies revealed that the detection of this inflection point and the assessment of the shift were not possible for broad spectral band. Recently, new studies have found that a broad red edge band, as used in the Rapid Eye sensor, is appropriate for obtaining information about chlorophyll and N-content of crops [20]. The study applied the combination of vegetation index (i.e. NDVI/NDRE, TCARI/OSAVI and MCARI/MTVI2) to create linear relationship with chlorophyll concentration by in-situ measurement. For example, Schelling [21] has obtained a coefficient of determination of $R^2$=0.77 by using the combination of Normalized Difference Vegetation Index (NDVI) and Normalized Difference Red Edge Index (NDRE) to predict chlorophyll concentration in wheat. In addition, Eitel et al. [20] revealed that the new index MCARI/MTVI2 derived from Rapid Eye data might be a suitable alternative to indices computed from narrow band data for predicting SPAD values or leaf N concentration in dryland wheat.

**Hyperspectral imagery (airborne-platform)**

The multispectral sensors have some weakness such as, restricted spectral range, coarse spatial resolution, slow turn-around and inadequate repeat coverage. Hence, the use of hyperspectral sensors allows the acquisition of higher spectral and spatial resolution data with fast turn-around time and more repeat coverage [22]. Moreover, the narrow band of hyperspectral sensors is very useful to detect red edge inflection point and assess the shift [23]. More accurate N deficiency detection could be reached in near future because of the current development of hyperspectral sensors [24]. In addition, previous study by Rodriguez et al.[25] has found that several spectral indices using narrow bands, both from ground-based spectroradiometers or airborne sensors have been successfully applied to determine green biomass, water content, chlorophyll content and N-status. The use of hyperspectral sensor for oil palm estates in Malaysia has not been widely used. It may be caused by very costly to use it. Several types of hyperspectral sensor are generally used for land mapping such as, AISA, AVIRIS, EnMap, HERO, Hymap and others. In Malaysia, A study by Helmiet al. [26] has been successfully used Advanced Imaging Spectrometer for Applications (AISA) airborne to detect Ganoderma Disease in oil palm which is located in Serdang, Selangor. The study concluded that red edge based techniques are more effective than vegetation indices in detecting Ganoderma-infected oil palm trees.The type of airplane or helicopter used for platform must consider some factors; range, human pilot, sensor payload, passenger room, safety and reliability. Thus, lighter-than-air craft used to carry the sensor, the new system is Unmanned Aerial Vehicle (UAV). The autonomous aircraft is unmanned, thus no one on board controls the aircraft, maintains the sensor and adjusts the direction of the sensor. All of tasks conducted on the ground by human controller in real time. These characteristics make UAV an attractive alternative to other platforms. It also gave reasonably precise coverage with low altitude aircraft (0.5 m spatial resolution). However, the aircraft has an obstacle with fuel source (i.e. battery or petrol) for larger area coverage. Thus, it is very suitable for small estates area that needs a precise mapping. Recently, UAV system has not been widely used in Malaysia's oil palm estates yet. Some drawbacks of hyperspectral sensors; high hourly cost, aircraft operating cost, analyst cost, trained team and weather interferences (i.e. rain day and haze).

## DISCUSSIONS

After reviewing some methods and techniques for detecting nutrient stress in oil palm, we found that Kjeldahl digestion has been employed as reference methods in Malaysia to determine total N contents in leaf plant. It has been used to analyze N-content from variant of crop in this region such as, oil palm, paddy, corn and others. Even though, this method is highly destructive, hazardous and time consuming. Moreover, the dominant portion of studies obtain that there is a strong relationship between chlorophyll and N-status [2, 6]. Hence, this major finding is strongly suggested the use of SPAD chlorophyll meter reading that is portable and reliable tool to determine N-status in plant. This is certainly good for the small estate that is able to get the in-situ chlorophyll readings by using SPAD instrument. However, this conventional method will be laborious to be applied at the large scale of estate. Therefore, recently the use of global positioning system (GPS), remote sensing (RS) and geographic information system (GIS) have been applied widely to assess oil palm foliar nutrient content at large scale area. Generally, stressed crops can be detected from the reflection of various wavelengths of light that are different from those reflected by healthy crops. Furthermore, it gives more works needs to be carried out to make it more accurate, reliable and sensitive to the small changes in the foliar N content. Thus, this study recommended a Fieldspec Spectro-Radiometer instrument for ground-based study. The narrow spectral bands from this instrument will be very useful for vegetation indices analyses to determine N-status. Moreover, the use of hyperspectral data will also give further enhance for the development of this technique. The narrow band of this sensor is very useful to detect red edge inflection point and assess the shift.

## CONCLUSION

Thisstudyrevealed that remote sensing techniques such as, hyperspectral and multispectral sensors with red edge band could be a promising method in near future for detecting nutrient stress in oil palm. Although, the data is expensive but it is very suitable for large scale of area. Otherwise, multispectral data are more economical compare to hyperspectral data. However, the use of hyperspectral sensors such as, UAV in small estates is still recommended for the best result demand. Indeed, the situation depends on the estates management how they allocate their budget for this purpose. In addition, the combination between remote sensing techniques and in-situ measurement by SPAD chlorophyll meter and spectro radiometer instruments is helpful to estimate the accuracy of nutrient stress detection in oil palm.

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