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IMAGE-BASED LEAF ANALYSIS FOR DETECTION OF NITROGEN STATUS IN SWEET CORN PRODUCTION

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APPROVAL SHEET

This project report here entitled **"Image-Based Leaf Analysis for Detection of Nitrogen Status in Sweet Corn Production"** prepared and submitted by **Aimi Amira Binti Ab Halim** in partial fulfilment of the requirement for the Bachelor of Agricultural and Biological Engineering is hereby accepted.

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ABSTRACT

Accurate timing and rate of nitrogen (N) fertilizer application plays a significant part in the yield and quality of crops. For the effective use of nitrogen fertilizers, prediction of N demands is essential. Nitrogen is one of the most limiting factors for sweet corn production. Over-fertilization of nitrogen to the crop can decrease crop yield. The Dark Green Colour Index (DGCI) is a quantitative measure of greenness which is closely related to leaf N concentration. So, in this study, a field experiment was carried out to explore the feasibility of image processing technique in sweet corn nitrogen non-destructive diagnosis using the DGCI value from the image processing. Based on the image processing technology of visible light, this study investigated the relationship between the nutrients status and the greenness of sweet corn leaves, which are captured by smartphone camera. Data of moisture content, EC and included photos were taken daily. The processing of the colour plant image was done in MATLAB. DGCI and EC shows a correlation with R^2 was 0.7142. The predicted values of nitrogen status were correlated with R^2 value (0.7767), this showed that the plant nitrogen content can be estimated by its colour image feature. Future research should improve the relationship between the camera- and the app-methods in predicting DGCI values. The proposed method is fast, non-destructive and easy to apply as it does not require any laboratory work to be done.

ABSTRAK

Masa tepat dan kadar penggunaan baja nitrogen (N) memainkan peranan utama untuk hasil dan kualiti tanaman. Ramalan keperluan N diperlukan untuk penggunaan baja nitrogen yang cekap. Nitrogen adalah salah satu faktor yang boleh mengehadkan pengeluaran jagung manis. Pembajaan nitrogen yang berlebihan kepada tumbuhan boleh mengurangkan hasil tanaman. Indeks Warna Hijau Gelap (DGCI) adalah ukuran kuantitatif yang berkait rapat dengan kepekatan daun N. Oleh itu, dalam kajian ini, satu ekperimen lapangan dijalankan untuk mempelajari tentang kemudahan teknik pemprosesan imej dalam diagnosis nitrogen jagung manis mengikut cara yang tidak merosakkan tumbuhan dengan menggunakan nilai DGCI hasil daripada pemprosesan imej. Berdasarkan teknologi pemprosesan imej cahaya yang kelihatan, kajian ini bertujuan untuk menyelidik hubung kait antara status nutrien dan kehijauan warna daun jagung manis, yang ditangkap oleh kamera telefon pintar. Data kandungan kelembapan, EC dan gambar direkod setiap hari. Pemprosesan imej tumbuhan warna dilakukan menggunakan MATLAB. DGCI dan EC menunjukkan korelasi dengan R^2 ialah 0.7142. Nilai ramalan status nitrogen yang diramal berkorelasi dengan nilai R^2 (0.7767), ini menunjukkan bahawa kandungan nitrogen tumbuhan boleh dianggarkan dengan ciri imej berwarna. Kajian masa depan perlu meningkatkan hubungan antara kamera dan kaedah aplikasi dalam meramalkan nilai DGCI. Kaedah yang dicadangkan adalah pantas, tidak merosakkan dan mudah digunakan kerana kaedah ini tidak memerlukan kerja-kerja di dalam makmal.

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LIST OF ABBREVIATIONS

DGCI	Dark Green Colour Index
N	Nitrogen
P	Phosphorus
K	Potassium
EC	Electrical Conductivity
NO3	Nitrate
NH4	Ammonium
NDVI	Normalised Difference Vegetation Index
H	Hue
S	Saturation
I	Intensity

CHAPTER 1

INTRODUCTION

1.1 Background

Fertilizer is one of the basic needs for all plants and crops. In order to achieve high yields, fertilization plays a critical factor. The primary nutrient that consists in the fertilizer are nitrogen (N), phosphorus (P) and potassium (K). Nitrogen is the nutrient that are going to be analysed by using the image-based leaf analysed for the detection of fertilizer status in sweet corn production because it is considered essential in plant mineral nutrition. Nitrogen fertilization is the important factor to improve the crop yields. The detection of the amount of fertilizer in soil are very crucial as to make sure that the optimum amount of fertilizer is supplied to the sweet corn. Excessive supply of fertilizer or over-fertilization of N to the crop would only cause other problem to arise such as reduce crop profitability by wasting the fertilizer, fertilizer burn, disease infection and cause pollution to the environment as the result of the fertilizer being washed away into the river and ocean. The sweet corn will also have difficulty in absorbing the water from the soil as soil have higher concentration of solute compared to water if excessive fertilizer is applied. This shows the importance of knowing the fertilizer status in plants. In Bangladesh, about 70% of farmers have practised the traditional fertilizer broadcasting which has caused a significant environmental degradation. Traditional fertilizer broadcasting, in which fertilizers are cast across the surface of crop fields by hand, a method that cannot control the rate of nutrient frequency, triggers inefficient fertilization which also associated with high levels of residual nitrate in the soil, which potentially contribute to groundwater and atmospheric pollution as a result of leaching.

There are few methods and devices that have been developed to detect the amount of fertilizer or more specifically the nitrogen (N) status in soil. These methods can be classified into two which is destructive and non-destructive. The destructive methods are the Kjeldahl-digestion and Dumas-combustion. This method is known as destructive because it is based on the tissue analysis. Both of these methods are high cost and consume more time for the sampling of tissue and the subsequent laboratory analysis. For the non-destructive, it is more on the usage of tools such as SPAD-502, Dualex and chlorophyll fluorescence. These tools measure the leaf pigment (chlorophyll) as the indicator for the nitrogen (N) status estimation. Many studies also has been carried out in determining the nitrogen content by using the image analysis and image processing as the nitrogen status is closely related with the colour of the leaves such as estimation or determination of nitrogen status in barley (Pagula et. al., 2009); (Hu et. al., 2010), tomato seedlings (Mercado-Luna et. al., 2010), potato (Yudav, Ibaraki & Gupta, 2010), paddy crop (Tewari et. al., 2013); (Bachik, Hashim, Wayayok, Che Man & Saipin, 2017). This method is considered as a low cost and non-destructive among of the other method.

1.2 Problem statement

Nitrogen is the essential element required in the sweet corn production. Excessive application of nitrogen fertilizer to the sweet corn plant will result not only economic loss but also the environmental problem. The leaf image-based analysis is required to help in detecting the nutrient status in soil as the existing method is time consuming, tedious, hardworking, expensive and longer time taken for the data analysis and decision. This statement is supported by (Lichtenthaler and Wellburn, 1983) which claims that the chlorophyll content that was measured by the spectroscopic and chromatographic methods are time consuming, destructive and too laborious.

1.3 Aim and Objectives

The main aim of this study is to develop a non-destructive and quick technique to determine the nutrient status in the soil by using the image analysis of leaf and experimental field data of nutrient availability. The specific objectives are:

1. To determine the Dark Green Colour Index (DGCI) value by leaf image analysis using MATLAB.
2. To derive the relationship between the DGCI and the soil electrical conductivity (EC).
3. To estimate the nutrient status in soil using the DGCI value.

1.4 Scope and Limitation

The scope of study is limited to the detection of nutrient status in sweet corn production where the study area is located at Division of Agricultural Engineering. The sweet corn stage is starting from the 47 days after planting until harvesting time. The images were taken using the smartphone camera of 8-megapixel and software used for the image processing is by using the MATLAB.

CHAPTER 2

LITERATURE REVIEW

2.1 Importance of nitrogen nutrition in plant

Accurate timing and optimum supply of nitrogen play an important role for growth and quality of crop. To make sure that efficient usage of nitrogen fertilizer, a prediction of nitrogen is required. Tewari et. al. (2013) also emphasized in their research that the most important element for the growth and development of crop is nitrogen. The normal amount of nitrogen by weight of a crop is between 1-5% (Lee et. al., 1999; Arregui et. al., 2006). By improving the efficiency of nitrogen fertilizer utilization, it can reduce the amount of nitrogen that can potentially contaminate soil and water resources. Nitrogen stimulates root development and other nutrient uptake as well. Generally, nitrogen is taken up by the plant in the form of nitrate (NO3) and ammonium (NH4).

The plant's concentration of N is strongly related to its development, and deficiencies of N may change or inhibit plant growth. If the concentration of any nutrient in the tissue is below the critical concentration, the plant cannot reach its highest development. Excess nitrogen contributes to a luxury consumption phenomenon. The excess of N does not add to the output because it is not metabolized by the plant into functional or structural compounds (Barker and Bryson, 2007). Nitrogen absorption in plant differs across locations, based on the texture and structure of the soil, the sort of genotypes adopted and the management of soil-N.

2.2 Soil electrical conductivity as nutrient availability indication

Soil electrical conductivity (EC) is a measure of the quantity of salts in soil. It is a significant soil health indicator. It impacts crop yields, plant nutrient accessibility, and soil microorganism activity. All major and minor nutrients important for plant growth are taken in the form of either cations (positively charged ions) or anions (negative charged ions). These ions, which are dissolved in soil water, carry electrical charge and therefore determine the soil's EC amount and how many nutrients are accessible for the plants to bring in. Electrical Conductivity is a very fast, easy and cheap technique that farmers and home gardeners can use to verify the health of their soils. While nitrogen is a useful measure of the equilibrium of nutrients available in the soil, electrical conductivity can almost be seen as the amount of nutrients available in the soil (Mirzakhaninafchi, Mani Mishra, & Mirzakhani Nafchi, 2017).

2.2.1 Relationship between soil electrical conductivity and soil nitrogen

Mirzakhaninafchi, Mani Mishra, & Mirzakhani Nafchi (2017) conclude that the relationship between soil electrical conductivity and nitrogen concentrations was discovered to be important in their research. The requirement of plants for nitrogen varies within a field and in distinct crop seasons depending on many variables such as soil type, recover climate, crop needs, and crop rotation scheme. Mirzakhaninafchi, Mani Mishra, & Mirzakhani Nafchi (2017) further point out that there was an important correlation between EC and distinct concentrations of nitrogen as well as varying concentrations of moisture. Both the amount of moisture and nitrogen showed an elevated amount of correlation as anticipated. The EC of three distinct soil types ranging from sandy loam to clay loam showed a growing trend with gradually higher nitrogen levels.

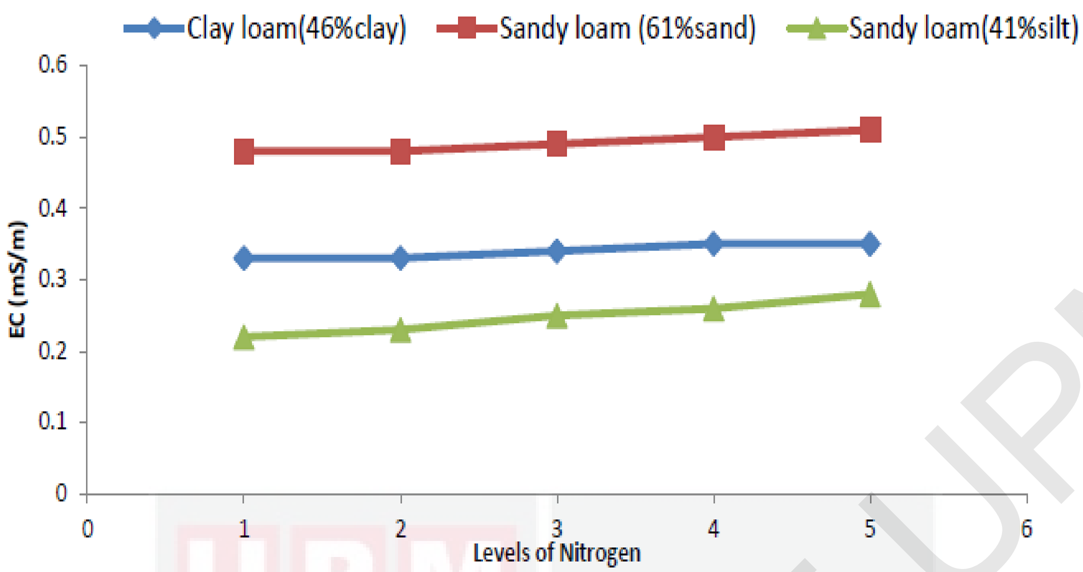


Figure 2.1: The relationship between levels of nitrogen in various types of soil and EC. (Source: Mirzakhaninafchi, Mani Mishra, & Mirzakhani Nafchi, 2017)

2.3 Types of method for analysing the nitrogen content in plant

Many methods have been introduced to detect the nitrogen availability in soil of sweet corn plant. These methods can be classified into two classes. The two classes of techniques for foliar analysis of nitrogen content are the destructive method and non-destructive method.

2.3.1 Destructive method

Yuan et al. (2016) explained that the destructive method for detecting the nutrient status in plant is a time consuming and have a complex procedure that need to be done as it requires to make the leaf sampling and undergo further chemical analysis in laboratory. Hu et al. (2013) stated that the colour of the leaves is determined by the chlorophyll, carotenoid and other pigments status, so the conventional analysis methods of pigments used are relatively high cost and also time consuming. The destructive method are the Kjeldahl-digestion and Dumas-combustion.

2.3.2 Non-destructive method

Non-destructive methods for nitrogen status detection commonly based on the analyses leaf blade colour and absorbed or reflected light. By analysing the colour of the leaf, it can be a best indicator to detect the plant health and also the nutrient availability in the plant. Usually, the greenness colour of the leaf is related to the chlorophyll content which is also correlated with the nitrogen status in the plant (Wolfe et. al., 1988). There are many non-destructive and indirect methods that can be used to determine the nitrogen availability which is vary in complexity such as the use of leaf colour chart (Furuya, 1987). The leaf colour chart is the easiest way as it is just the comparison of leaf colour with the chart references. Zhang et al, (2009) suggested a few of portable leaf greenness meters that can be used such as SPAD-502, CCM200 and Dualex 4. Yuan et al (2016) also has suggested the same tool which is widely used for the nutrient detection in plant which is the SPAD-502 chlorophyll meter. This tool help in determining the crop chlorophyll content and also crop nitrogen diagnosis.

2.4 Existing method for analysing nitrogen content in soil

There are a few types of methods that have been introduced to determine the value of nitrogen status in soil. Some of the methods are very easy and quick but not very accurate. Some of the methods will consume too much time because it involve the laboratory work. The examples of the methods are digitalimage analysis, SPAD meter, Kjedahl method, NDVI, Dualex sensor and leaf colour chart.

2.4.1 Digital image analysis using MATLAB

The intensity of green colour from digital images of leaves is another technology that can provide a suitable way to evaluate plant N status. The process for digital image processing involve started with capturing the image of plant in the field. Pagola et.al. (2008) suggested that the leaf image of the crop should be taken at a distance of 20 cm and covered with a piece of black board to make sure the process for image processing become more easier as it not affected by other colour and also to reduce the reflection. After the image has been captured, it will be processed in a software called MATLAB 7.0 platform. Pre-processing of image is needed to enhance the visual quality before the images are being transformed to the colour image (RGB) into normalized red, green and blue chromaticity coordinate. The composite colour images were decomposed into red(R), green (G) and blue (B) spectrum image (Tewari et al., 2013). Ahmad et al. (1999) further explained that the value obtained in the red, green and blue spectrum can be used to calculate the hue, saturation and also the intensity. Colour information can only be extracted when the entire image features segmented from its background. The segmentation can be done by using the automatic segmentation technique based on modification of Otsu's algorithm (Otsu, 1979). Figure 1 shows the flow charts of extracting colour image features. Yadav, Ibaraki & Dutta Gupta (2009) concluded that in their study that estimation of chlorophyll content in plant tissue culture system demonstrates a rapid and non-invasive method.

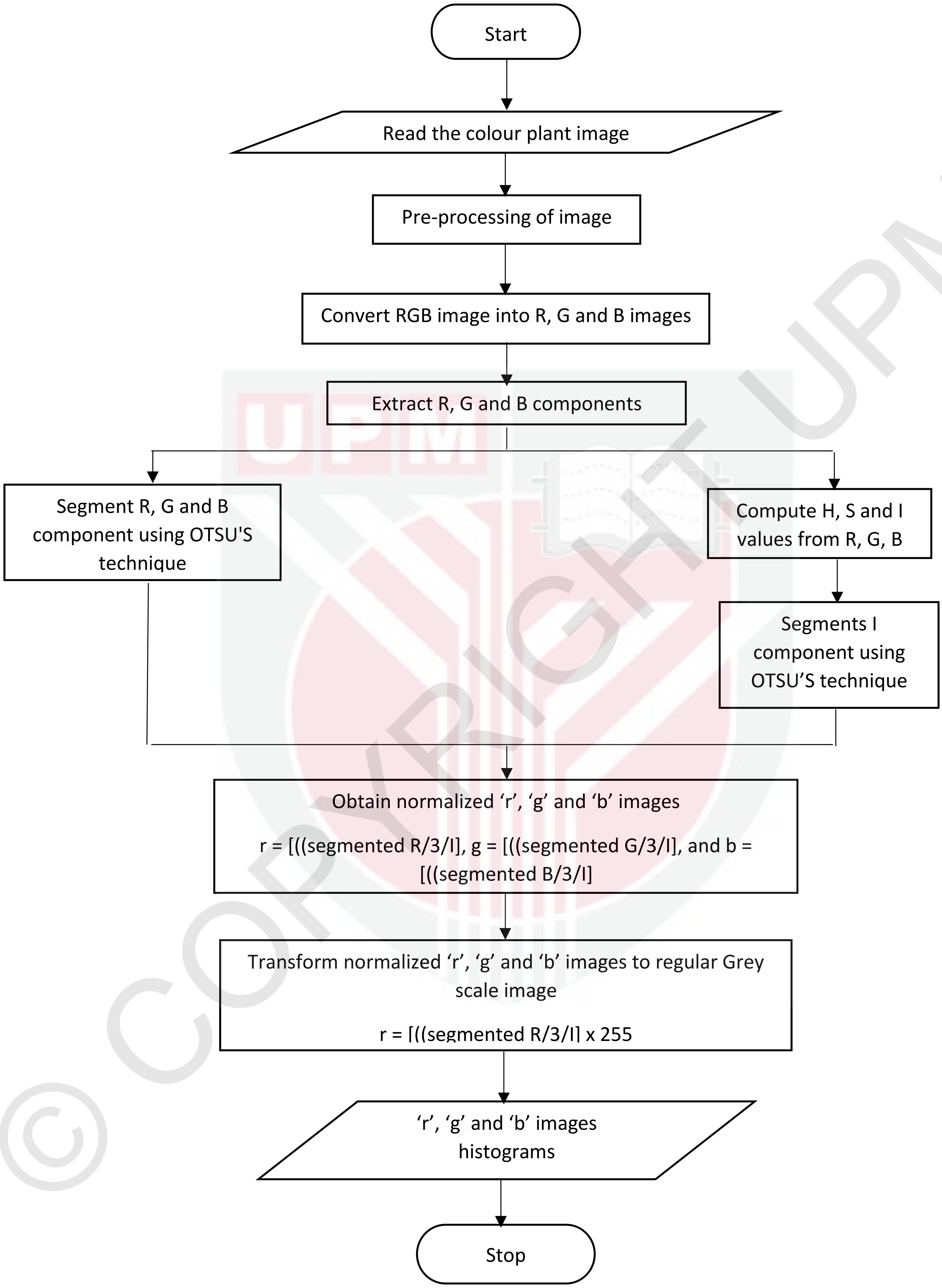


Figure 2.2 The flowchart for image processing.

(Source: Agric Eng Int, 2013)

2.4.2 Soil Plant Analyses Development (SPAD-502)

The SPAD-502 is a portable tool that enables quick, easy measurement of the chlorophyll content of plant leaves without damaging the leaf. Chlorophyll content is one indicator of plant health, and can be used to optimize the timing and quantity of applying additional fertilizer to supply crop yields of higher quality with lower environmental load. Hu et al. (2010) explained about the proper method on how to use the SPAD-502 instrument where the SPAD-502 must be placed in the youngest of fully developed leaf to record the reading. At least 10 measurement of each leaf were taken and get an average value. The instrument calculate and record the reading based on the red light transmission which is at 650 nm where chlorophyll absorb light and also based on the infrared light transmission at 940 nm where no absorption occurs. Unfortunately, the chlorophyll meter has some constraints because it is costly and has only a tiny sampling region of 6 mm^2 (Zhang et al., 2008).

Figure 2.3 The SPAD-502 instrument which to detect the chlorophyll content.

Beegle, Piekielek, Lingenfelter, & Fox (2008) have provided a proper guide on how to determine which leaf part that need to be considered for taking the measurement using the SPAD meter such as the reading should not be taken if plant is below the six-leaf stage as the plant may be affected by starter N and also the stress from the environment. The recommended time that the reading should be taken is at seven-eight stage leaf. The leaves must be the youngest fully developed and by referring the Figure 3, the best leaf that can be chosen to record the reading is the leaf number 6.

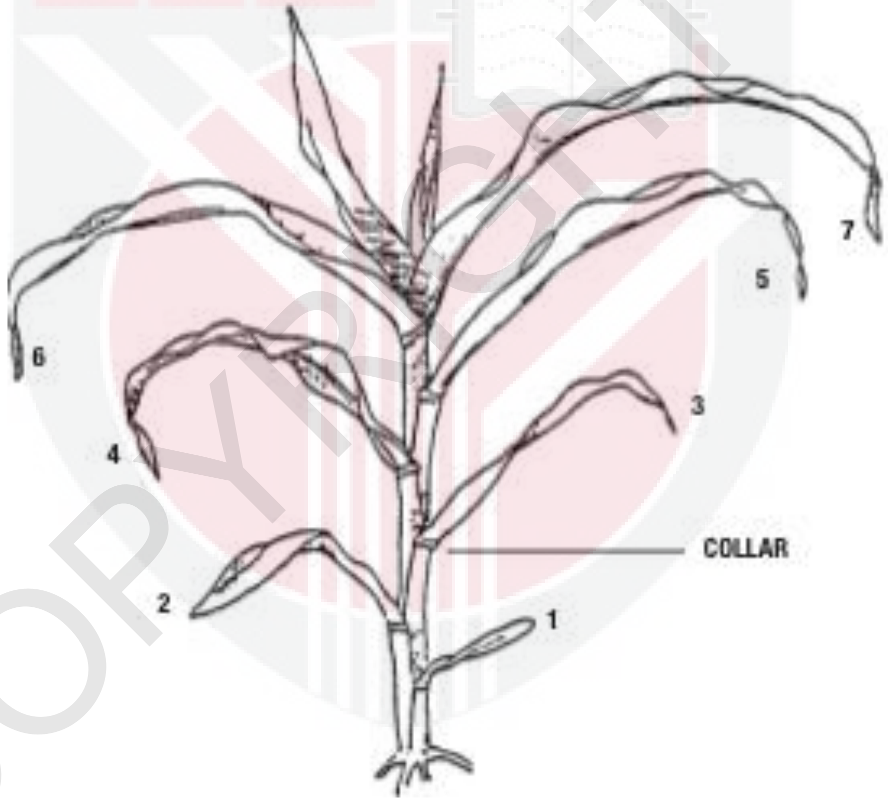


Figure 2.4 The leaf part (number 6) measured by SPAD-502 meter.

2.4.3 Kjeldahl Method

Johan Kjeldahl who was a Danish chemist in 1883 introduced the Kjeldahl method and this method is a quantitative determination of nitrogen. It is the most accurate method but time consuming. This method may take up to one week to analyse 72 samples. This method is not preferable to be used to determine the nitrogen in a big area.

2.4.4 Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is also a measurement that has been used extensively to assess N status in maize and other crops (Mullen et al., 2003). NDVI values are strongly correlated with N concentration in the canopy (Schlemmer et al., 2013). This method is a numerical indicator that using the visible and near infrared bands of electromagnetic spectrum. Nitrogen is measured based on the light that being absorbed by the plant. NDVI is a high cost method and suitable for large area as it is obtained from satellite image.

There are two kinds of NDVI tools: passive instruments and active sensors. To calculate NDVI, passive sensor tools depend on natural energy that is reflected or emitted from the observed scene, and internal sunlight is the most prevalent internal radiation source used by passive NDVI devices. Although most hyper-spectral sensors are passive, passive NDVI sensors are not hyper-spectral. NDVI tools with active sensors, on the other side, are fitted with light-emitting parts which provide energy to illuminate the object they observe. Active sensors can be used separately of solar radiation, but can only handle particular wavelengths by light sensor type (Hatfield et al., 2008).

$$NDVI = \frac{NIR - red}{NIR + red}$$

2.4.5 Dualex sensor

The Dualex sensor is also used to evaluate the plant's N status by calculating the quantity of leaf-related polyphenolics in the leaf. Sensors using near-infrarot radiance were able to estimate optimum maize N rates at tasseling but not early crop development (Sripada et al., 2005).

2.4.6 Leaf colour chart

Leaf colour chart contains many shade of leaf colour starting from light green to dark green. This is the easiest method as in only require to compare the sample leaf with the colour in the chart. Although it is the easiest method but, it is also the most inaccurate. It is suitable for medium area.

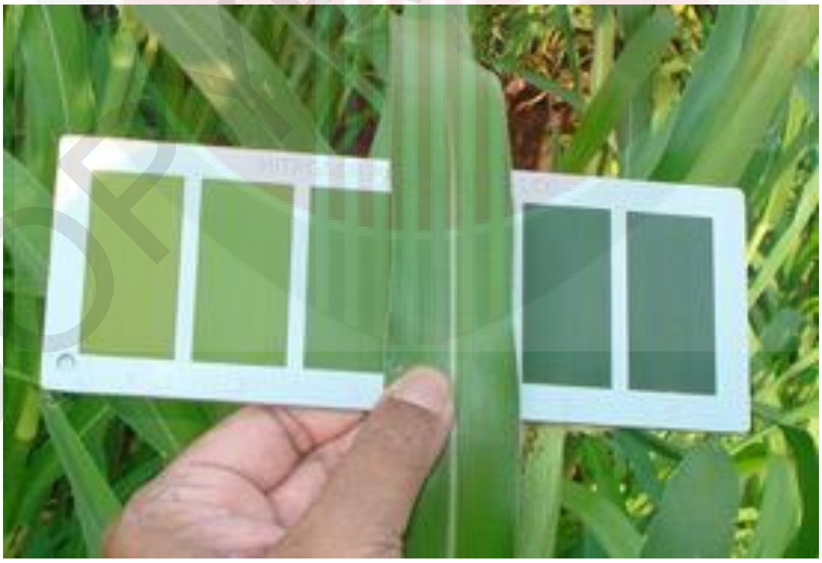


Figure 2.5 The leaf colour chart for maize plant.

2.5 Colour Analysis

The colour of an object is determined by the wavelength of light reflected from its surface. Sun et al. (2018) stated that the most commonly used space displaying and saving the colour image is the RGB colour space and it is display by three primary colour which is red (R), green (G) and blue (B). Yuan et al. (2018) further explains that this colour space is affected by the light changes and other environment factors. RGB image utilizes 8-bit monochrome standard and has 24 bits/pixel where 8 bits for every colour (red, green and blue) (Padmavathi & Thangadurai, 2016).

2.5.1 Colour features parameter for leaf images analysis

The colour feature parameters were calculated using the gray average value of all pixels. The parameter that were normally calculated are R, G, B, normalized redness intensity (NRI), normalized greenness intensity (NGI), normalized blueness intensity (NBI), Hue (H), Value (V), Saturation (S) and Dark Green Colour Index (DGCI).

2.5.1.1 Hue, Saturation and Intensity

Hue is an attribute associated with the dominant wavelength in a mixture of light waves. Hue represent dominant colour as perceived by an observer. Meanwhile, saturation refers to the relatives purity or the amount of white light mixed with a hue. Intensity is the darkness or lightness of a colour. RGB model is suitable for describing colour in terms that are practical for human interpretation. Moreover, HIS model is an ideal tool for developing algorithms based on colour descriptions that are natural and intuitive to humans.

2.5.1.2 Dark Green Colour Index (DGCI)

DGCI is a quantitative measure of greenness that relate with the concentration of nitrogen. Prabowo (2015) further explained that the value for the DGCI may be affected due to difference in lighting conditions, the quality and setting of the camera. The resulting DGCI value is on a scale from 0 (very yellow) to 1 (dark green).

The nitrogen content status by the method of image processing is determined based on the spectral information of visible bands which is one of the low cost method but has a high resolution of image (Prabowo, 2015). The result from the image processing will give the value for red, green and blue intensity based on the input image. So, to determine the value for the DGCI which is equivalent to dark green colour, there will need a calculation to be made first to determine the value for hue and saturation. Below are the formula for these parameter:

$$r = \frac{R}{R+G+B} \qquad (1)$$

$$g = \frac{G}{R+G+B} \qquad (2)$$

$$b = \frac{B}{R+G+B}$$

(3)

The colour in the HIS model are defined with respect to normalized red, green, and blue values. These normalized value are used for calculating the HIS.

$$I = \frac{1}{3}(R + G + B)$$

(4)

$$S = 1 - \frac{3}{R+G+B}[\min(R, G, B)] \quad (5)$$

$$H = \cos^{-1}\{\frac{\frac{1}{2}[(R-G)+(R-B)]}{[(R-G)^2+(R-B)(G-B)]^{\frac{1}{2}}}\}$$

(6)

DGCI values were more accurate measure compared to the individual RGB values. DGCI was calculated as:

$$DGCI = [(H - 60)/60 + (1 - S) + (1 - I)]/3$$

(7)

CHAPTER 3

MATERIALS AND METHODS

3.1 Study area

The field experiments are conducted to evaluate the nitrogen status where the sweet corn plants are cultivated in the field. The experimental field for the sweet corn is located at the Division of Agricultural Engineering, MARDI, Serdang, Selangor. The sweet corn has been cultivated continuously from one season to another season. The soil type of this experimental field is dark and clay soil. The area of this field is about 812 m^2. The total land is divided into two sub plot of 22m x 37m.

Figure 3.1: The sweet corn field at Department of Agricultural Engineering, MARDI.

3.2 Determination of EC and moisture content in soil of sweet corn in the field

3.2.1 Data Collection

In this experimental field, two types of instrument that have been used to collect the data for electrical conductivity (EC) and also the moisture content in the soil. The reading for EC in the soil were taken by using the direct soil portable EC meter. For EC meter reading, there were 3 different marks on the probe. The reading were taken for the first mark and the third mark of the probe because the root zone depth of sweet corn was in between these depth. Next, the average value for these two reading were calculated. While the reading for the moisture content were recorded using the Fieldscout TDR 350 Soil Moisture meter. Both reading which is EC and moisture content were taken daily.

Table 3.1: Specification for EC meter

Readout	LCD digital display
EC Range	0.00 – 19.99 mS/cm
Temperature range	0 - 55°C (32 - 122°F)
Probe length	7.7 in (19.5 cm)
Probe Diameter	0.30 in (0.8 cm)

Figure 3.2: Type EC meter used to record EC value.

Figure 3.3: The EC meter used for collecting data in the field.

Table 3.2: Specification for TDR 350 Soil Moisture Meter

Display	Backlit, high-contrast, graphic LCD
Weight	1.9 kg
Probe height dimension	2.4” x 1.4” (6cm x 3.5cm)
Shaft dimension	Extended Length: 38” (96.5cm) Collapsed Length: 23” (58.4cm) Width: 1.4” (3.5cm)

Figure 3.4 The TDR used to record the moisture content.

Figure 3.5: The reading of moisture content was taken using TDR.

3.3 Determination of DGCI of leaf part of sweet corn in the field

3.3.1 Image acquisition

Before the leaf image can be analysed, the leaf images were captured by using the cell phone camera of 8.0 mega-pixels. It is more convenient to focus only one crop out of the total crops in the field. Only one leaf that need to be captured with the distance of 20 cm from the object. During the image analysis, the image was crop out so that only the green part of leaf was focused. The preferable time to capture the leaf image is between 11 a.m to 2 p.m. The leaf images also were taken daily.

Figure 3.6: The image of sweet corn leaf was taken using the smartphone camera.

3.3.2 Algorithm development

The leaf images were analysed by using the MATLAB. A suitable algorithm was developed to get the value of DGCI. The algorithm was built based on some formulas involved before the value of the DGCI can be determined such as normalized red, normalized green, normalized blue, hue, saturation and intensity.

$$DGCI = [(H - 60)/60 + (1 - S) + (1 - I)]/3$$

3.3.3 Image processing

This process was done after the leaf image of sweet corn was taken. The leaf image of the sweet corn that has been captured was uploaded and became the input source for the image analysis process. This images were stored in MATLAB in the form of PNG format. The process of image processing was run after the algorithm had been written. So, a correct algorithm need to be prepared for the image processing method.

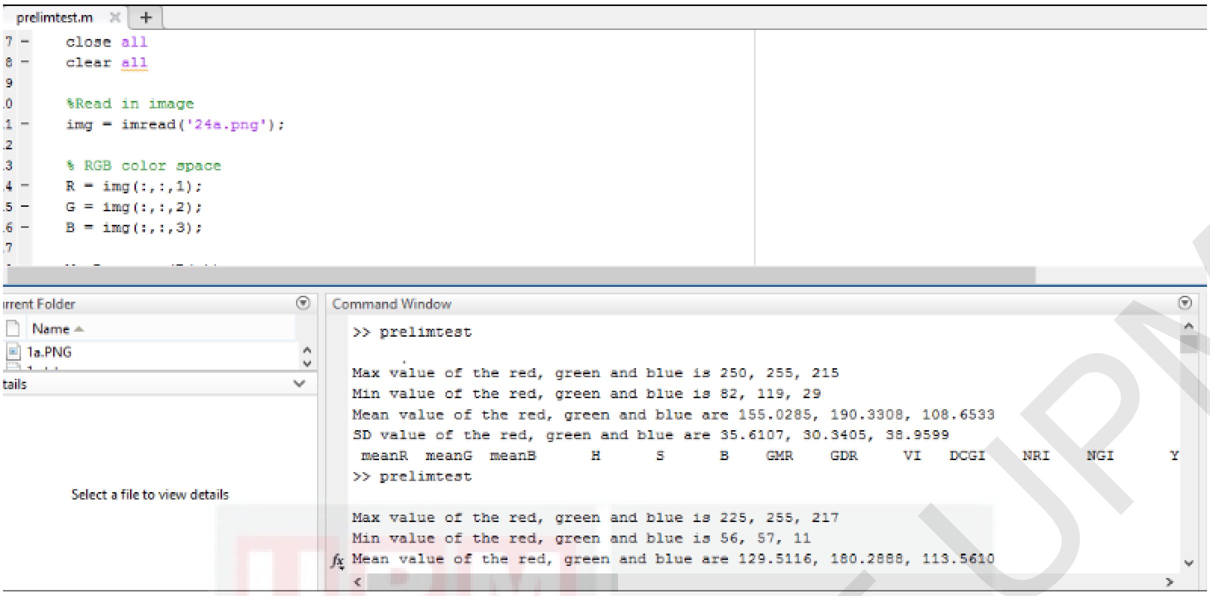


Figure 3.7: The coding for the image analysis using MATLAB.

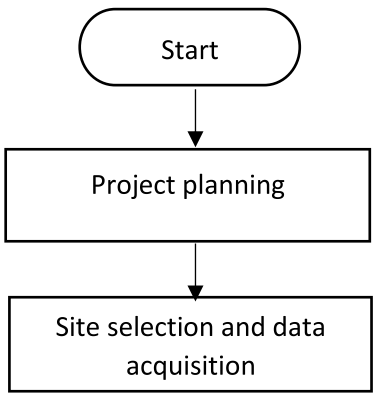
3.4 Development of the relationship between DGCI and EC

The relationship between DGCI and EC were developed by plotting a graph in Microsoft Excel. The graph was plotted according to the measured value of EC in the sweetcorn field and also the value of DGCI data obtained from the image analysis using the MATLAB. By plotting the graph, we can know the pattern and also the relation between both variables. The graph can prove whether these two variable were correlated with each other.

3.5 Estimation of the nutrient status

The nutrient status was estimated by plotting the graphs of DGCI against all the nutrient values obtained from the lab analysis that had been done by the PhD student that I had worked together while the research was conducted. These graph were used to estimate the value of each nutrient parameter for the corresponding EC values that was measured in the field. The nutrient parameters that were involved were the total nitrogen (TN), ammonia (NH_3), ammonium (NH_4), potassium (K), total kjedahl nitrogen (TKN) and phosphorus (P).

The graph plotted of DGCI against the nutrient value can be used to estimate the nitrogen status in soil.



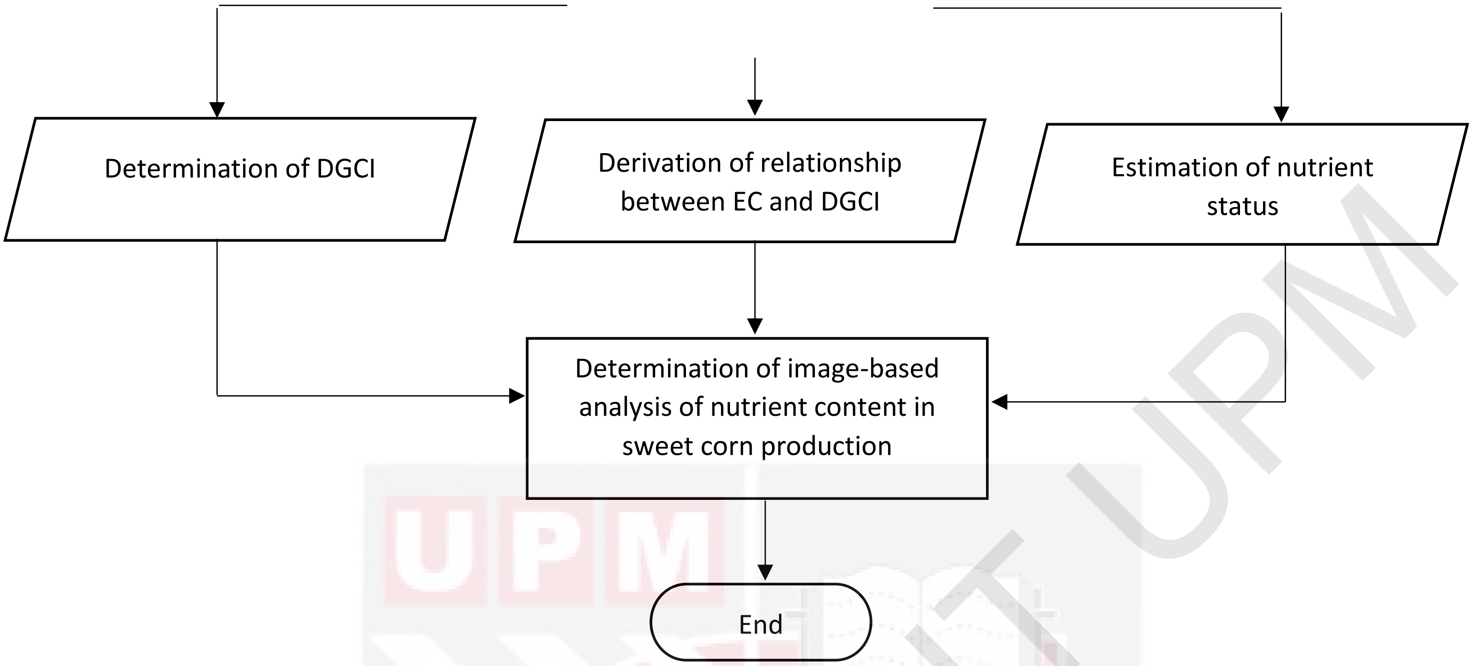


Figure 3.8: The flow chart for the methods involve in completing the project.

CHAPTER 4

RESULTS AND DISCUSSION

In this chapter, the result was divided into 3 parts which is the first part was about the value DGCI value obtained from the image analysis. The second part was about the derivation of relationship between DGCI value and the recorded soil electrical conductivity measured in the sweetcorn field. Third was about the estimation of nutrient status in soil by using the DGCI value.

4.1 DGCI value from the image analysis

In this part, we will be discussed about the image data analysis that had been collected and analysed using the MATLAB. The MATLAB software was used to run the coding for the leaf image analysis. A complete and correct coding was written in the MATLAB to get the value for Dark Green Colour Index (DGCI). This DGCI is actually a quantitative measurement of greenness that is closely related with the concentration of nitrogen. Since nitrogen has highly correlated with green colour of the leaves that was the reason the DGCI was used to estimate the nitrogen status. DGCI value range from 0 (very yellow) to 1 (dark green). So, by referring to the graph in Figure 4.1 and also Table 4.1, it portrayed that on certain day the value of DGCI is very low and on other day was quite high. The lowest value of DGCI was 0.3024 while the highest was 0.8202. From here, we can know that there was some variations for the value of DGCI. The DGCI were not constant throughout all days. This means that the nutrient status in soil was vary everyday.

DGCI is not the only index that we can when it is involving with image analysis. There are other index that can be used such as Normalized Difference Vegetation Index (NDVI). NDVI quantifies vegetation by measuring the near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). The range for NDVI is starting from the -1 to +1. Usually the negative values indicate that it is water while if the value close to +1, there is high possibility that it is green leaves. But when NDVI is close to zero, there is no green leaves part is detected and it could even be an urbanized area. NDVI usually is used for precision farming, measure biomass, quantify forest supply and also the leaf area index.

Table 4.1: The value of DGCI at different days.

Days after planting	**DGCI**
47	0.4189
48	0.5613
49	0.3922
50	0.3479
51	0.382
52	0.3295
53	0.3024
54	0.5245
55	0.5524
56	0.6098
57	0.6337
58	0.6487
59	0.6791
60	0.6832
61	0.5945
62	0.4738
63	0.4487
64	0.5522
65	0.5824
67	0.8202
68	0.6722
69	0.5373
70	0.4866
71	0.5983
72	0.4638
73	0.5278

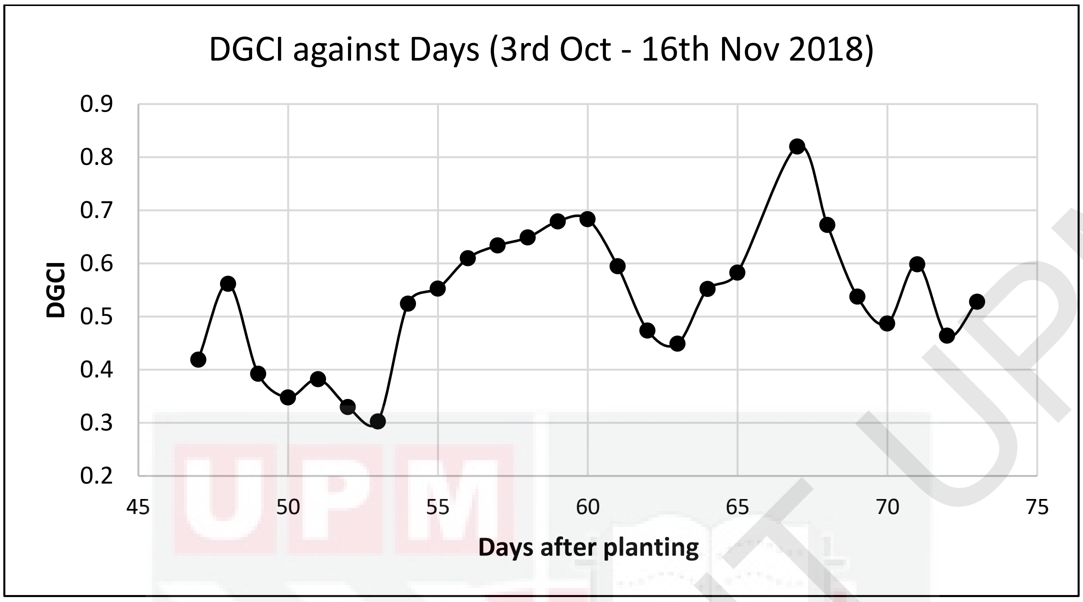


Figure 4.1: The graph above shows the DGCI values does not constant for each day.

Moreover, NDVI is a good indicator of drought. It will has lower relative NDVI and density of vegetation when the water limits the vegetation growth. But in this project, NDVI cannot be used because certain parameter cannot be determined by the image analysis to complete the calculation for NDVI.

NIR is one of the important parameter that need to be determined for the NDVI calculation to be done. In my project, the value for the NIR could not be determined because the leaf was taken and captured by using the smartphone. The information for that spectral band is not there. Red light is captured around 550-700 nm while the near-infrared (NIR) is more than 700 nm wavelength. Most of camera manufacturers put an infrared filter in front of the sensor which is used specifically to block and filter out the infrared light from causing a problem. The infrared light may affects the camera's ability to record the visible light correctly.

4.2 Relationship between DGCI with EC and moisture content.

By referring to Figure 4.2, it shows the graph plotted of DGCI against the moisture content. The moisture content values were obtained by using an instrument called the Time-domain Reflectometer (TDR 350). This instrument will record the measurement for the soil moisture in Hi clay and also the standard. Hi clay is the data that has relation with the moisture content (MC) sensor while the standard means the data was same if the soil sample was carried out in lab. The reading for the moisture content were taken daily.

Date	**Hi clay MC (%)**	**Standard MC (%)**	**Soil Electrical Conductivity EC (mS/cm)**
3/10/2019	38.03	49.43	244.0
10/10/2019	31	46.8	207.3
17/10/2018	25.6	34.3	180.3
24/10/2018	30.1	40.8	179.7
31/10/2018	33.03	44.17	183.0
7/11/2018	38.7	50.3	163.7
14/11/2018	32.03	42.83	127.6

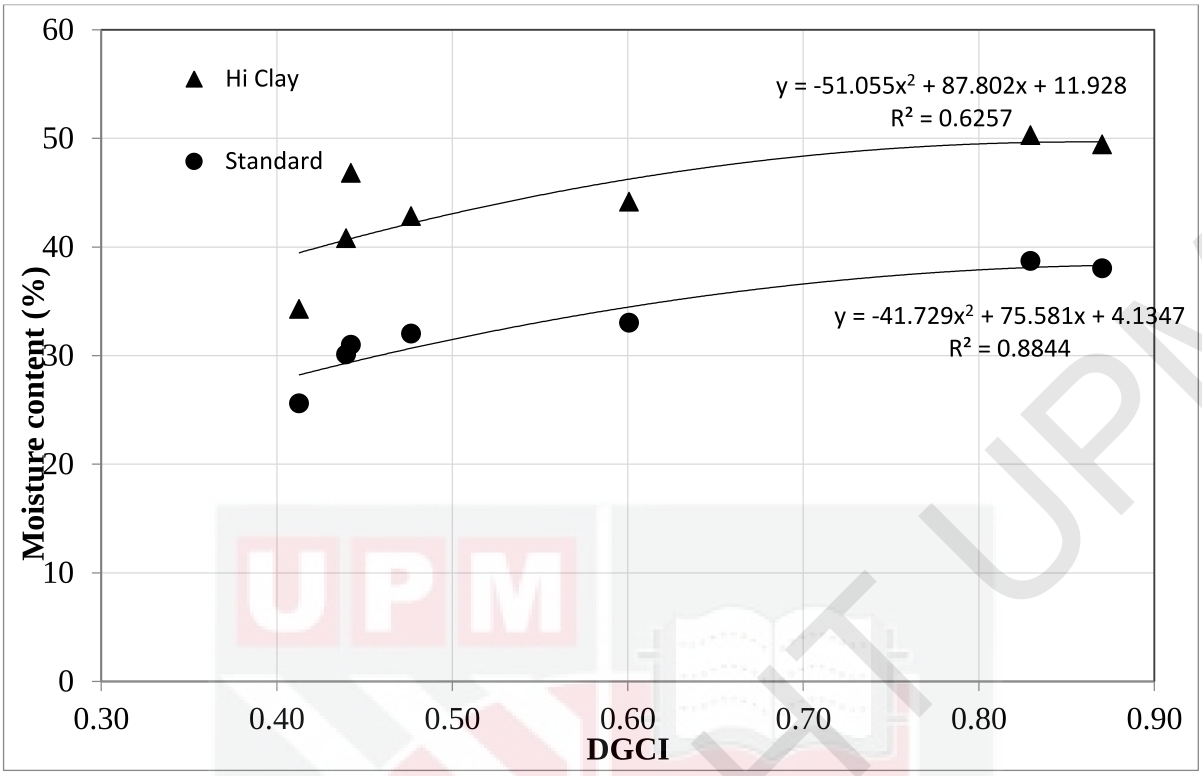


Figure 4.2: The graph plotted of DGCI against Moisture Content (%).

But for this graph in Figure 4.2, only the same date that the nutrient samples were taken was chosen. This is to make sure that the analysis of the data of DGCI, nutrient values, and moisture content were compared with same date. So, from here we can know that how does the values differ from day to day. From this graph, we know that when the value of DGCI increases, the value for moisture content also increases. The correlation between both variables also quite high with R^2 of 0.8844 for the standard data while 0.6257 for Hi clay.

In figure 4.3, the graph shows the relationship between DGCI and EC. Soil electrical conductance (EC) is a measure of the amount of salts in soil. Excess salts in the soil can affect the soil-water balance which hinder the plant growth. Although EC does not provide a direct measurement of specific ions or salt compounds, it has been correlated to concentrations of nitrates, potassium, sodium, chloride, sulphate, and ammonia. By referring to graph in Figure 4.3, the correlation between these two values is high which the value for R^2 is 0.7142. The value of EC increases when the value of DGCI increases. This shows that EC is proportional to DGCI. The equation obtained for the graph is y = -3.55.15x² + 611.01x – 40.209. So, by using this equation, we can estimate the EC content in the soil if we have the value of x which referring to DGCI value. For this graph, there were only seven data of EC and DGCI that has been plotted even though the data for EC and DGCI were taken daily. These seven data were chosen because we want to make sure that the value obtained can be compared with the nutrient status data in the soil. This is because the value for the nutrients status that I have obtained from the PhD student were only on certain date.

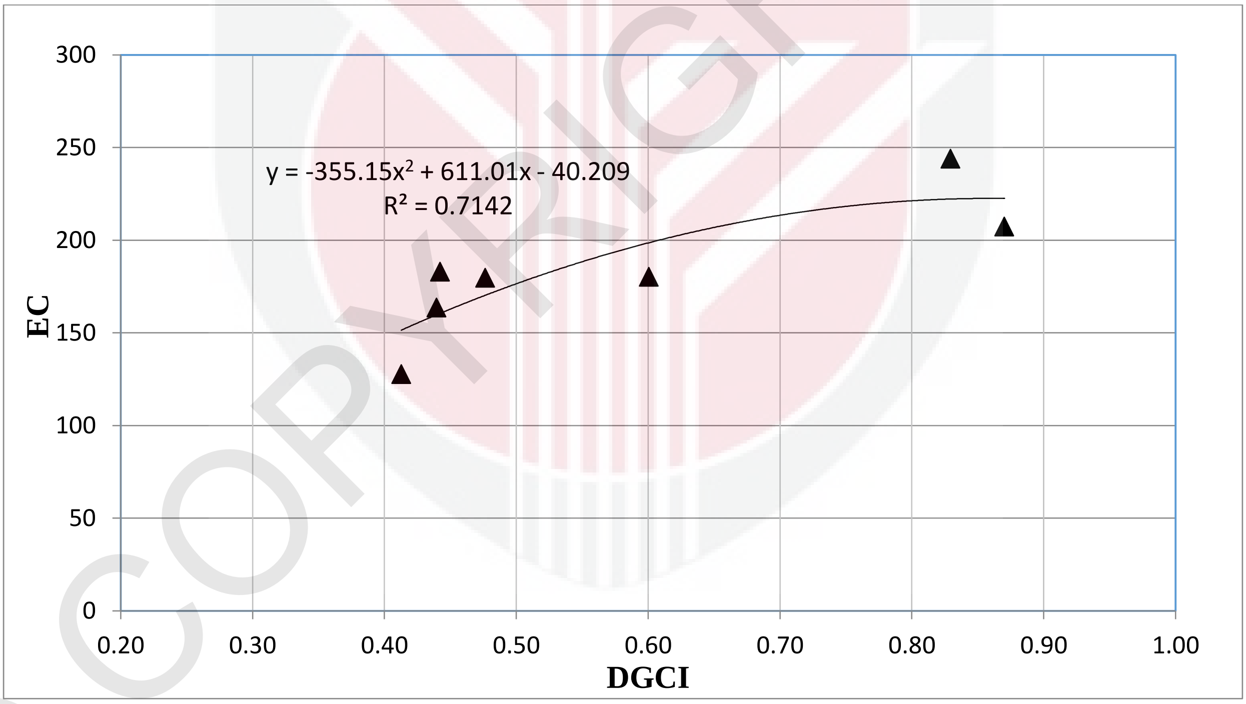


Figure 4.3: A graph plotted of DGCI against EC.

4.3 Estimation of nutrients in soil

In this part, the value of DGCI obtained from the image analysis using MATLAB was used to plot the graph and estimate the nutrients status in the soil.

4.3.1 Nutrient value from the lab analysis

Table 1 below shows all of the nutrients data were obtained from the lab analysis. The soil samples from the sweet corn field were taken to the laboratory for further analysis to be done. The soil sample was taken once a week for the analysis. Actually, the nutrient data obtained was not carried out by myself. I have cooperated with the PhD student to see how our work can apply. The PhD student study on determination on runoff of fertilizer. These nutrients data were used to compare with the value of the DGCI that was obtained from the MATLAB. The parameter that have been determined were total kjeldahl nitrogen (TKN), ammonium (NH4), nitrate (NO3), total nitrogen (TN), phosphorus (P) and potassium (K).

Table 4.2: The data of nutrients obtained from the lab analysis.

Date	TKN	NH4	NO3	TN (mg/l)	P (mgl/l)	K (mg/l)
3/10/2019	13.07	2.88	11.20	23.30	0.09	7.73
10/10/2019	14.47	9.33	14.93	28.93	0.06	7.90
17/10/2019	10.73	1.87	9.33	21.47	0.11	7.67
24/10/2019	12.10	1.40	8.87	21.00	0.05	6.40
31/10/2019	12.13	1.40	8.40	20.07	0.03	6.40
7/11/2019	9.27	1.33	7.00	19.60	0.02	11.47
14/11/2019	14.00	0.00	5.13	16.27	0.05	6.40

4.3.2 Graph plotted of DGCI against each of nutrient parameter value

The graph in Figure 4.4 below shows a positive non-linearly relationship between both variables which is the DGCI value and also the total nitrogen (TN). By referring to the graph, the lowest value of nitrogen was 16.0 mg/L when the value for DGCI was 0.42. Both variables shows a correlation with R^2 of 0.7767. So, from this relationship, we can conclude that when the value of DGCI increases, it indicate a high content of nitrogen status. So, from the smartphone based DGCI, it was able to predict the value for the nitrogen status.

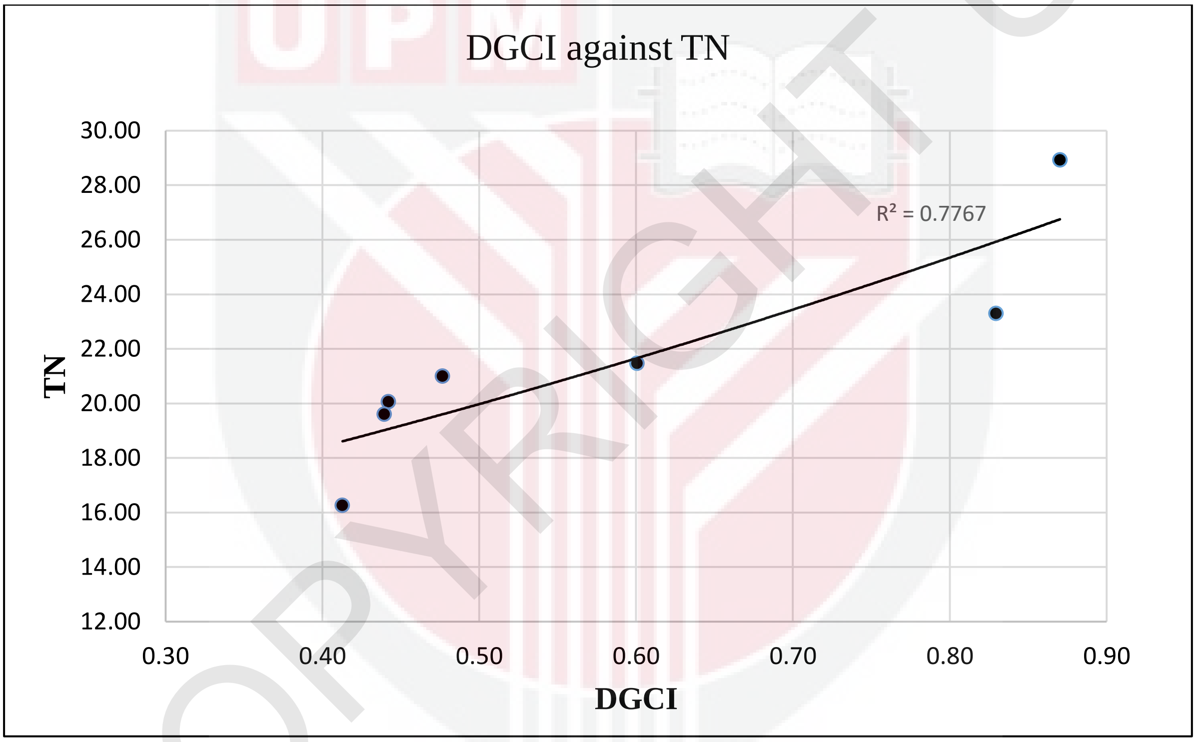


Figure 4.4: The graph of DGCI against the total nitrogen (TN).

Instead of total nitrogen value, the other nutrient obtained from the soil sample lab was the ammonium. The ammonium content also being compared because the plants absorb nitrogen from the soil in the form of nitrate (NO3−) and ammonium (NH4+). Since, the greenness of the plant is related with the nitrogen content that was why the DGCI was compared with both variables. The graph of DGCI versus ammonium also shown a positive non-linear relationship with R^2 of 0.7243. While for the graph of DGCI against NO3 in Figure 4.4 shows a linear relationship with R^2 of 0.8227. High value of R^2 prove that the DGCI index has a strong relationship with the nutrient content in the soil. From the both graph in Figure 4.5 and Figure 4.6, we can conclude that as DGCI increases, the ammonium and nitrate value also increases. So, here means that DGCI has a strong relationship with nitrogen status.

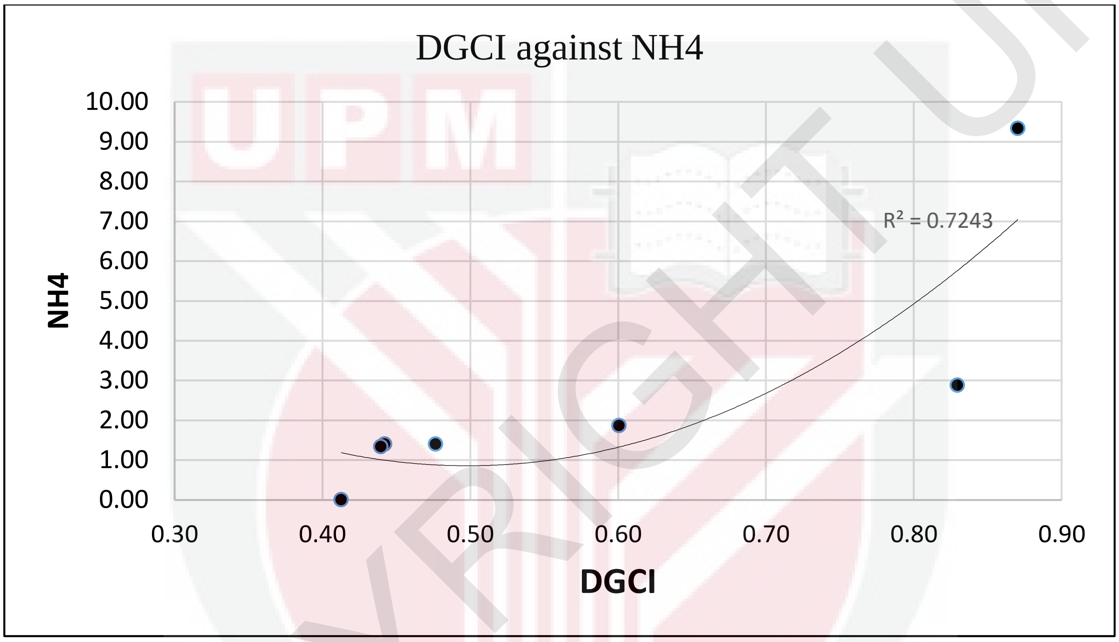


Figure 4.5: The graph of DGCI against the ammonium (NH4).

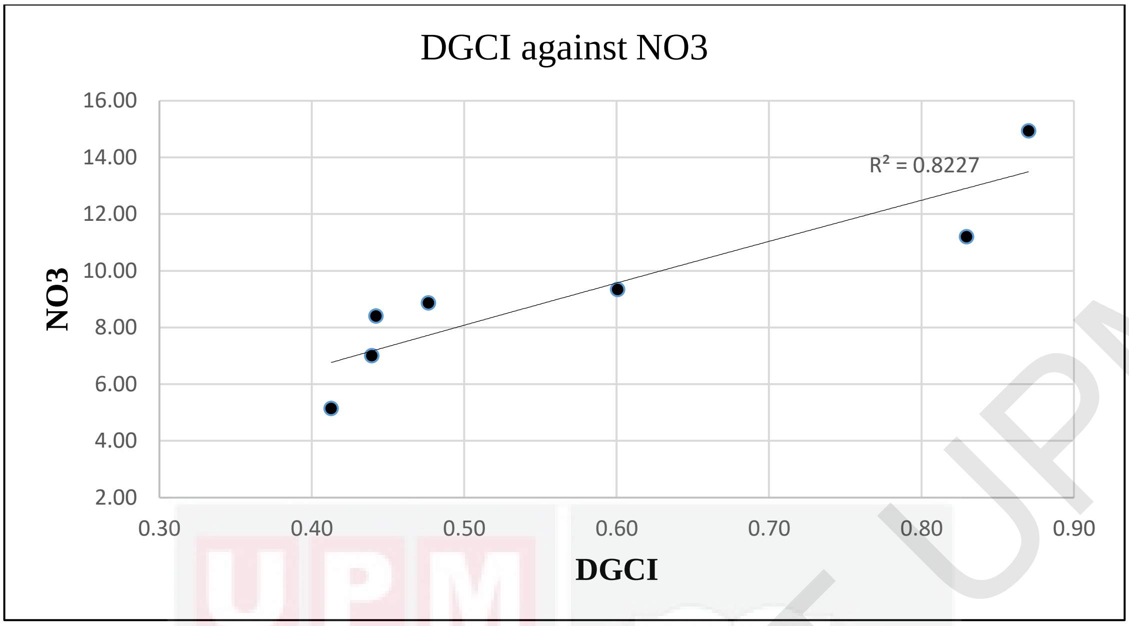


Figure 4.6: The graph of DGCI against the ammonia (NO3).

By referring to Figure 4.5 and Figure 4.6, the equations can be developed based on the behaviour of the graph. Once we have the equation, the amount of the nutrient status in the soil can be predicted and estimated using the value of DGCI.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Nitrogen and chlorophyll contents are closely related to greenness of the leaf. The greenness of the leaf can be effectively used for nitrogen estimation using image processing technique. The proposed technique of estimating nitrogen by image processing method can be cost effective as well as faster. This is because this method was only using the smartphone to estimate the nutrient status which everyone would have it. This can be a valuable and suitable tool for farmers faster for fertilizer applications. In this project, the determination of smartphone based DGCI can be determined and completed. Other than that, the derivation of relationship between DGCI and EC also can be determined. Last but not least, the estimation of nutrient status also had been done. The outcome indicates that smartphone-based DGCI can be a useful indicator to estimate the plant nitrogen status through colour image feature.

5.2 Recommendation

As for the recommendation, I would like to suggest that the DGCI-based nitrogen estimation using MATLAB code is recommended to compare with other instruments or tools that can directly measure the value of nitrogen content such as SPAD meter or Dualex. The use of the SPAD meter and Dualex here function to validate the data obtained from the image analysis. More set of data obtained can increase the accuracy and precision of the data. Next, the nutrients observation should be done frequently. It would be preferable to collect 3 or more data of the sweet corn plant sample image instead of capturing the image of one plant only, so that we can see clearly the pattern of the graph changes. This means that more intensive field work required. Apart from that, intensive investigation is recommended by applying different doses of fertilizer applications so that variability can be observed. Moreover, it is more convenient if the camera used for capturing the image has high quality and resolution or maybe can used specific camera for image analysis because the value of DGCI are varying according to the type of camera used. Lastly, a low cost Internet of Things (IoT) based fertilizer detection apps can be developed as by using the coding that have been used to determine the value for Dark Green Colour Index (DGCI).

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APPENDICES

Appendix A1: MATLAB CODING for analysing image spectrum

```
%Program: Extraction of image features and calculation of colour indices
%By: Aimi Amira Binti Ab Halim
%Date: April 12, 2019
%Description: To extract RGB component and calculate colour indices for
correlation with Chl content of plant leaf
%Sweet corn leaf image taken from smartphone camera

close all
clear all

%Read in image
img = imread('3.png');

% RGB color space
R = img(:,:,1);
G = img(:,:,2);
B = img(:,:,3);

MaxR = max (R(:));
MaxG = max (G(:));
MaxB = max (B(:));

MinR = min (R(:));
MinG = min (G(:));
MinB = min (B(:));


%Calculate mean of RGB
meanR = mean(R(:));
meanG = mean(G(:));
meanB = mean(B(:));


%Calculate SD of RGB
stdR = std2(R);
stdG = std2(G);
stdB = std2(B);


% %Accessing Pixel Values of RGB Image
% red_value = img(966,1288,1);
% green_value = img(966,1288,2);
% blue_value = img(966,1288,3);

% %Pixel info
% imshow (img);
% impixelinfo;
% size (img);

% %Converting RGB to HSI color spaces
```

```
% hsimg = rgb2hsi (img);
% figure (2), imshow (hsimg), title ('RGB to HSI');
%
% %Calculate mean of HSI
% H = hsimg(:,:,1);
% S = hsimg(:,:,2);
% I = hsimg(:,:,3);
% meanH = mean(H(:));
% meanS = mean(S(:));
% meanI = mean(I(:));
%
% sprintf('Mean value of the hue, saturation and intensity is %d, %d, %d',
meanH, meanS, meanI)
%
% %Accessing Pixel Values of HSI Image
%
% hue_value = hsimg(966,1288,1);
% saturation_value = hsimg(966,1288,2);
% Intensity_value = hsimg(966,1288,3);
% sprintf('Value of the hue, saturation and intensity pixel is %d, %d, %d',
hue_value, saturation_value, Intensity_value)
%
% %Pixel info
%
% imshow (hsimg);
% impixelinfo;
% size (hsimg);

%Calculate Hue
maxRGB = meanG;
minRGB = meanB;
num = meanB - meanR;
% num2 = meanG - meanB;
denom = maxRGB-minRGB;
C = num/denom;
% C2 = num2/denom;
H = 60*(2+C);
% H2 = 60*C2;

%Calculate Saturation
S = denom/maxRGB;


%Calculate Brigthness
B = maxRGB/255;

%Calculate GMR
GMR = meanG - meanR;

%Calculate GDR
GDR = meanG/meanR;

%Calculate VI
VI = GMR/(meanG+meanR);

%Calculate DCGI
M =(H/60)-1;
DCGI = (M +(1-S)+(1-B))/3;
```

```
%Calculate NRI
NRI = (meanR/(meanR+meanG+meanB));

%Calculate NGI
NGI = (meanG/(meanR+meanG+meanB));

%Calculate YCbCr color spaces
Y = (0.257*meanR) + (0.504*meanG) + (0.098*meanB) +16;
Cb = ((-0.148*meanR)- (0.291*meanG) + (0.439*meanB) + 128);
Cr = (0.439*meanR) - (0.368*meanG) - (0.071*meanB) +128;


%// Concatenate data
A = [meanR; meanG; meanB; H; S; B; GMR; GDR; VI; DCGI; NRI; NGI; Y; Cb;
Cr];

%Open file to write
fileID = fopen('3.txt','w');

%// Select format for text and numbers
fprintf(fileID, 'Max value of the red, green and blue is %d, %d, %d \n',
MaxR, MaxG, MaxB);
fprintf(fileID, 'Min value of the red, green and blue is %d, %d, %d \n',
MinR, MinG, MinB);
fprintf(fileID, 'Mean value of the red, green and blue are %.4f, %.4f, %.4f
\n', meanR, meanG, meanB);
fprintf(fileID, 'SD value of the red, green and blue are %.4f, %.4f, %.4f
\n', stdR, stdG, stdB);
% fprintf(fileID, 'Value of the red, green and blue pixel is %d, %d, %d\n',
red_value, green_value, blue_value);
fprintf(fileID, '%6s %6s %6s %6s %6s %6s %6s %6s %6s %6s %6s %6s %6s %6s
%6s %6s\n','meanR',    'meanG',    'meanB',    'H',    'S',    'B',
'GMR',    'GDR',    'VI',    'DCGI',    'NRI',    'NGI', 'Y', 'Cb', 'Cr');
fprintf(fileID, '%.4f \t %.4f \t %.4f \t %.4f \t %.4f \t %.4f \t %.4f \t
%.4f \t %.4f \t %.4f \t %.4f \t %.4f \t %.4f \t %.4f \t %.4f \t %.4f \t
%.4f \t %.4f \t %.4f\t %.4f\t %.4f\t %.4f\n',A);

fclose (fileID);
type ('3.txt');
```