Nitrogen Fertilizer Prediction of Maize Plant with TCS3200 Sensor Based on Digital Image Processing

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Abstract. Fertilization for maize plants so far does not use the appropriate calculation of crop needs, thus it causes continuous soil damage. Another technique to predict nitrogen content in maize plants is using a leaf color chart. But it has some disadvantages, such as depending on sunlight for color plant reading, and inconsistent accuracy interpretation of leaf color by the eye. Based on problems, the research was aimed to design a nitrogen content prediction system based on digital images with an RGB color index. RGB digital image and nitrogen content are used as a database system to predict nitrogen need for maize plants. Arduino Uno is used for data processor and the TCS3200 color sensor is used as a substitute for a camera on image processing. The performance test uses 40 leaves of maize plants with the age of 15, 30 and 40 days. The results show that the device can detect nitrogen content in maize plants based on the RGB database with a 90% success rate. For R value 447.4-601.6, G value 384.7-510, and B value 519.95-625.16, we obtain that nitrogen need for plant about 175 kg/ha. For R value 325.9-377.5, G value 285.6-311.5, and B value 426.4-456.1, we obtain that nitrogen need for plant about 150 kg/ha. And for R value 290.37, G value 239.12, and B value 385.62, the nitrogen need for plant about 125 kg/ha. The greener the color of maize leaf, the lower the nitrogen fertilizer need, conversely the lower the green color on the leaf, the higher the level of nitrogen fertilizer needs.

Keywrod: Image Processing; Maize leaves; Nitrogen; TCS3200 Color Sensor.

1. Introduction
Like other plants, maize plant also requires nutrients for its growth. These nutrients come from rock weathering in the soil. However, the ability of the soil to provide nutrients for plants is very limited because the microorganisms that play a role in the weathering process differ in number between types and layers of soil. Therefore, fertilization is one way to provide nutrients needed by plants to increase the yield of corn both qualitatively and quantitatively [1]. Fertilizers commonly used for corn plants are organic and inorganic fertilizers (for example urea fertilizer and NPK fertilizer) [2].

Sweet corn plants are plants that responsive to fertilization, especially for the availability of sufficient N during the growth phase. Nitrogen content can be found in urea fertilizer with high N content which is around 45-46%. The nature of urea which dissolves quickly makes it readily available to plants. But if urea is applied on the surface and not put into the soil, the loss of N into the air can reach 40% of the N that has been applied. So, it is necessary to make efficient use of fertilizer through the timing of urea fertilizer application [3-4].
During this time in conducting fertilization for maize plants have not used the calculation of the appropriate fertilizer requirements. Farmers usually make changes in the color of the leaves of corn as a criterion to determine when the corn plants need fertilization. Leaves are considered the best in describing mineral nutrient content compared to other organs present in plants [3], so leaves are most often used as samples in plant analysis. Several studies have also been carried out on the leaves to determine fertilization including determining the dose of rice plant fertilizer [4], nutrient diagnosis of mangosteen plants [5], applying several types of fertilizer to the growth and production of kailan plants [6], and determining the right leaves for diagnosis status nutrients N, P, and K based on the position of the leaf of orange plants [7]. But it has some disadvantages, such as depending on sunlight for color plant reading, and inconsistent accuracy of interpretation of leaf color by the eye. Changes in the color of corn leaf can be analyzed with the help of image processing.

Image processing or digital image processing techniques are images that can be processed by a computer, with an image as an input and the output can be a set of characteristics or parameters related to the image. Image processing has several functions, including being used as a process of improving image quality so that it is easily interpreted by humans or computers, and is used for image processing techniques by transforming images into other images [8-10]. The results of the analysis of corn leaf an image in the form of RGB are associated with the need for corn fertilizer based on leaf color analysis. Leaf color analysis is used as a database to predict nitrogen requirements in maize plants.

The image processing system will not only be able to provide convenience for farmers and agricultural assistants in determining the dose of nitrogen fertilizer but also can help anyone in making decisions to determine the dose of nitrogen fertilizer that must be given to corn plants in kg/ha. Based on problems, the research was aiming to design a nitrogen content prediction system based on digital images with an RGB color index of maize plants.

2. Methods

2.1 Material

The image processing system was built using the Arduino Uno microcontroller as the main microcontroller, the TCS 3200 color sensor as an input component, the I2C LCD Module as the link between the LCD and the Arduino Uno microcontroller and the LCD (Liquid Crystal Display) as the output component. Arduino UNO is a microcontroller based on ATmega328. Arduino UNO has 14 digital input/output pins (6 of which can be used as PWM outputs), 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button [11-13]. TCS 3200 color sensor as an input component will detect and measure the intensity of visible colors. TCS3200 chip has several Photodetectors, with each color filter that is red, green, and blue. The filters are distributed in each array. This module has an oscillator that produces square pulses whose frequency is the same as the color detected [14]. The output component used is the LCD, which is connected to the arduino uno microcontroller using the I2C LCD Module. The use of I2C LCD Module aims to save the use of pins on the Arduino Nano microcontroller. A 5 Volt DC power bank is used as a power source so that this equipment can be carried to the field in a portable manner.

2.2 Method

The method of this research consists of hardware design, electronic system design, and equipment testing.

2.2.1 Hardware design

The body frame of nitrogen content prediction is used 2mm-DOP acrylic type. Acrylic is cut based on the size and the design of the tool. Acrylic is a material with characteristics of not easily broken, light, and also easily carved drilled, smoothed or painted. The 16x2 LCD is used as the output value of the TCS3200 color sensor reading. Sensor-based color sensor TCS3200 is used to measure the color of RGB (Red, Green, Blue) from an object. This sensor module has the facility to record up to 25 color data that will be stored in the EEPROM. The sensor module is equipped with the UART TTL and I2C
interfaces. The distance between the TCS3200 color sensor and object is 3 cm. Arduino Uno, which has been transferred to an RGB color reading program using the Arduino IDE software application, is connected with the TCS3200 color sensor. A power supply of the device uses a power bank with 6000 mAh capacity resulting in an output of 5 V to power the appliance. The design of a nitrogen prediction device can be shown in Figure 1.

To optimize the performance of the color sensor, do not move while shoot the maize leaf to the device. Because the RGB values that appear will also change. If the color sensor has received color from the leaves, it will be sent to Arduino and processed to read the nitrogen fertilizer content in the corn plant, after the next process will be sent to the LCD and the value of the need for corn fertilizer and also the RGB value of the corn leaf will be read on the LCD.

2.2.2. Electronic system design
The electronic system sequence consisted of several components, namely Arduino Uno, 16x2 LCD, TCS3200 color sensor and Powerbank as tool power supply. All components are arranged following the pin/port to be used. The TCS 3200 color sensor will read the RGB value of the object by reflecting the LED light on the object and the object will reflect the light to the photodiode installed on the color sensor. Data received from the TCS 3200 color sensor will be processed by Arduino Uno. The results will be displayed on a 16x2 LCD which contains information from the results of reading the tool on the object. The electronic system circuit can be seen in figure 2.

The TCS 3200 color sensor will perform a scanning process to detect green frequencies in corn leaves. The frequency detected by the sensor is given a minimum value of 0 and a maximum value of 1025. If the detected color frequency is outside the minimum and maximum limits, the system remains in a stand-by state. If the frequency value detected by the sensor is between 0 to 1025, the system will check the button, if button 1 is pressed the system will do the iteration process, calculating the number of frequencies and the average frequency value. If button 1 has been pressed 5 times, this means the scanning process has been done 5 times. Then the system will again calculate the average value of
frequency and give the result value to be true. After the average frequency value is obtained, the system will conduct a selection process to get the nitrogen content data output based on the average frequency value obtained.

2.2.3. Equipment Testing
Equipment testing is carried out to determine the performance of the TCS3200 color sensor and analyze changes in the color of maize leaf. Color sensor testing is carried out by comparing RGB values that are read by the sensor with RGB values using the Photoshop application on the same object. The object used is paper red, green, blue and white. The results of this test are connected by using a graph to obtain the value of $R^2$. Color analysis is carried out by collecting a database of RGB and chlorophyll from the maize leaf, i.e.: 40 pieces of 15 days age, 40 pieces of 30 day age, and 40 pieces of 40 day age. This RGB value data is grouped according to the scale in the leaf color chart (table 1)

| Leaf color | Leaf color chart | Urea (kg/ha) |
|------------|------------------|--------------|
| Light green| < 4              | 175          |
| Green      | 4 – 4.5          | 150          |
| Dark green | > 4.5            | 125          |

This test serves to determine the performance of the use of tools that are functioning properly or not. Performance testing is done to find out whether the device is functioning properly or not. The results of the reading of the tool will be recorded and will be calculated the percentage of success according to [16].

$$\text{success of reading} = \frac{\text{suitable data}}{\text{all data}} \times 100\% \quad (1)$$

3. Results and Discussion
The results of the design of the predictor tool need corn fertilizer has dimensions of 22.5 cm long, 10 cm wide, 19 cm high. With the dimensions of the handle 2.5 cm x 2.5 cm. and the tool weighs 624 grams. Framework for predicting the need for fertilizer for corn plants made of acrylic with a thickness of 2 mm. Figure 3 is the result of the design of the device along with a series of components.

![Nitrogen content prediction device](image)

On the back of the device, several components are visible, namely a 16x2 LCD that functions as information from the results of the reading of the tool for the value of corn plant fertilizer needs. Besides there are ON/OF buttons that are used to turn on and turn off the tool. TCS3200 sensor is placed on the front of the device which functions as an object reader which then reads the results displayed on a 16x2 LCD screen. The USB port is placed on the side to charge the power supply that is inside the device. Inside the device chasing, components are consisting of Arduino UNO as a
regulator of the tool. Cable as a link between components. And Powerbank is used as a resource on the device.

The software design for electronic circuits generates the program code used in electronic circuits functions to direct the performance of the electronic circuits that have been arranged. The application used to carry out the programming process is Arduino IDE software with the Arduino programming language. The circuit programming code is the initial code to read the RGB value, where if the code is set to filter the red color, the photodiode frequency at S2 and S3 is low. To filter the green color, the frequency of photodiode S2 and S3 is high, while in blue the frequency of S2 is low and S3 is high. The final coding is entered according to the database value, which is if the value of R is less than 482, the value of G is less than 404, and the value of B is less than 536, the tool will display the need for corn fertilizer of 150 kg/ha. If the value of R 482 to 568, the value of G 404 to 501, and the value of B 536 to 610 then the tool will display the need for corn fertilizer of 100 kg/ha. As for the R value greater than 569, the G value is greater than 52, and the B value is greater than 611, the tool will display the need for corn fertilizer of 125 kg/ha.

3.1. TCS3200 Color Sensor Calibration

R readings on red paper, G from green paper, and B from blue paper using the TCS3200 sensor are compared with values obtained from image capture through a camera. The images that have been obtained are processed using Photoshop CC 2018. From the test results obtained can be seen in the following Table 2.

| Color | Scanner | Sensor TCS3200 |
|-------|---------|---------------|
| Paper | R       | G             | B         |
| Merah | 255     | 102           | 102       |
|   | 209     | 133           | 166       |
| Hijau | 153     | 204           | 153       |
|   | 160     | 199           | 167       |
| Biru  | 51      | 153           | 255       |
|   | 59      | 146           | 198       |
| Putih | 226     | 224           | 234       |
|   | 242     | 236           | 255       |

The TCS3200 color sensor has worked well and can distinguish red, green and blue well. Where the results of the reading of the TCS3200 color sensor have the same value when compared using digital image processing the value of RGB using a scanner and photoshop application. The difference in the RGB value of the TCS3200 sensor with photoshop is due to the sensor being captured by only one pixel while the photoshop pixel is read on the averaged object.

3.2. Analysis of Color Change in Maize Leaf

Analysis of changes in the color of corn leaves functions to see how the color change of corn leaves based on the level of nitrogen fertilizer. How to analyze it is by firing a device that has been given the initial code for reading RGB. Namely, taking data on the value of the RGB color change on 40 leaves of corn aged 15 HST (days after planting), 40 leaves of corn aged 30 HST, and 40 leaves of corn aged 40 HST. It is known that the need for corn fertilizer is determined by changing the color of the maize leaf [17].

Figure 4 shows that the younger the age of maize plants the higher the intensity of the RGB value, conversely the older the age of the maize plant the average intensity of the RGB value of the lower maize leaf. According to [18], the lower the color level of corn leaf (leads to light green) the greater the value of R, G, B, conversely the higher the color level of corn leaf (leads to dark green) the value of R, G, B is getting smaller. The RGB difference is almost always consistently positive with light green leaves and dark green leaves. These results state that the RGB color component can be used as an attribute in distinguishing the leaf color level. Changes in leaf color in corn are influenced by several factors including the nitrogen content in the soil. The greener the color of corn leaves the more
nitrogen content so that it does not need too much nitrogen fertilizer. Whereas the more yellowish color of the leaves in corn plants, the need for nitrogen in corn plants is also increasing.

![Figure 4. Relationship of Maize Leaf Age to RGB Values](image)

The average RGB values obtained from data collection for 15 HST, 30 HST, and 40 HST are adjusted to leaf color chart of maize leaf so that the following values are obtained on Table 3.

| Grade | Nitrogen fertilizer need (Kg/ha) | R     | G     | B     |
|-------|----------------------------------|-------|-------|-------|
| 2     | 175                              | 601,666 | 510   | 625,166 |
| 2.5   | 175                              | 555,593 | 473,718 | 594,875 |
| 3     | 175                              | 489,055 | 410,166 | 542,166 |
| 3.5   | 175                              | 447,4   | 384,7   | 519,95  |
| 4     | 150                              | 377,545 | 311,454 | 456,090 |
| 4.5   | 150                              | 325,96  | 285,6   | 426,4   |
| 5     | 125                              | 290,375 | 239,125 | 385,625 |

3.3. Comparison of leaf color and chlorophyll content

Figure 5 shows that the higher the chlorophyll content of maize leaf the higher the grade scale value obtained, this is due to the greener surface color of the maize leaf, the higher the chlorophyll content is. In the nitrogen content of corn leaves 30 mg / g or nitrogen rate of 75 kg/ha has a chlorophyll value of 42. While in the nitrogen content of corn leaves 31.5 mg / g or a nitrogen rate of 150 kg / ha, has a chlorophyll value of 45 [19-20] The higher the value of chlorophyll in corn leaves, the lower the demand for nitrogen fertilizer, conversely the lower the value of chlorophyll produced, the higher the need for nitrogen fertilizer. The resulting R2 is quite large, which is 0.6328. The relationship between chlorophyll content and leaf color shows a positive correlation if the R2 value generated is large enough [21].
3.4. The relationship between RGB value and nitrogen fertilizer needs

Based on Figures 6, 7, and 8 show the relationship that the higher the level of aging of corn plants or the RGB distribution value is lower, the green color of corn leaves will be higher so that the need for nitrogen fertilizer in corn plants is also lower. Whereas the younger the age level of corn plants or the higher the RGB distribution value, the green color of the corn leaves will be lower so that the need for fertilizer for corn plants is also higher. According to [17], the lower the color level of corn leaf (leads to light green) the greater the value of R, G, B, conversely the higher the color level of corn leaf (leads to dark green) the value of R, G, B is getting smaller. This shows that the lower the green color index in the tool, the lower the need for plant fertilizer.
3.5. Performance of nitrogen fertilizer prediction device

The results of device testing obtained a value of 90%, results of reading the tools on 40 corn leaves with corn age 15 HST, 30 HST, and 40 HST, which can be seen in Table 8. The suitability of the instrument readings will be compared with the results of identification according to index criteria fertilizer needs in corn plants using maize leaf color chart.

| Leaf number | Leaf color value | Age of maize plant | Nitrogen dosage (Kg/ha) | Result |
|-------------|-----------------|--------------------|-------------------------|--------|
| R           | G               | B                  |                         |        |
| 1           | 565             | 485                | 600                     | 2,5    | 15 HST 150 | suitable |
| 2           | 593             | 501                | 609                     | 2,5    | 15 HST 150 | Suitable  |
| 3           | 601             | 509                | 638                     | 2,5    | 15 HST 0  | Not suitable |
| 4           | 602             | 510                | 626                     | 2      | 15 HST 150 | suitable  |
| 5           | 585             | 497                | 605                     | 2,5    | 15 HST 150 | suitable  |
| 6           | 564             | 486                | 600                     | 2,5    | 15 HST 150 | suitable  |
| 7           | 603             | 511                | 627                     | 2      | 15 HST 150 | suitable  |
| 8           | 540             | 461                | 591                     | 2,5    | 15 HST 150 | suitable  |
| 9           | 573             | 494                | 603                     | 2,5    | 15 HST 150 | suitable  |
| 10          | 593             | 501                | 609                     | 2,5    | 15 HST 150 | suitable  |
| 11          | 395             | 317                | 484                     | 4      | 30 HST 100 | suitable  |
| 12          | 552             | 473                | 596                     | 2,5    | 30 HST 150 | suitable  |
| 13          | 540             | 461                | 591                     | 2,5    | 30 HST 150 | suitable  |
| 14          | 475             | 403                | 535                     | 3,5    | 30 HST 150 | suitable  |
| 15          | 553             | 474                | 597                     | 2,5    | 30 HST 150 | suitable  |
| 16          | 516             | 431                | 574                     | 2,5    | 30 HST 150 | suitable  |
| 17          | 536             | 457                | 587                     | 2,5    | 30 HST 150 | suitable  |
| 18          | 471             | 402                | 535                     | 3,5    | 30 HST 150 | suitable  |
| 19          | 450             | 316                | 520                     | 3      | 30 HST 0  | Not suitable |
| 20          | 491             | 412                | 544                     | 3      | 30 HST 150 | suitable  |
### Table 1: Leaf Color Values and Nitrogen Demand

| Leaf number | Leaf color value | Age of maize plant | Nitrogen dose (Kg/ha) | Result |
|-------------|------------------|--------------------|-----------------------|--------|
|             | Sensor value     | Grade              |                       |        |
|             | R    | G    | B    |     |                       |        |
| 21          | 552  | 473  | 596  | 2.5 | 30 HST                | 150    | suitable |
| 22          | 489  | 410  | 542  | 3   | 30 HST                | 150    | suitable |
| 23          | 539  | 460  | 590  | 2.5 | 30 HST                | 150    | suitable |
| 24          | 482  | 389  | 536  |     | 30 HST                | 0      | Not suitable |
| 25          | 288  | 232  | 378  | 5   | 40 HST                | 50     | suitable |
| 26          | 373  | 300  | 448  |     | 40 HST                | 0      | Not suitable |
| 27          | 329  | 292  | 429  | 4.5 | 40 HST                | 100    | Suitable |
| 28          | 350  | 303  | 441  | 4.5 | 40 HST                | 100    | Suitable |
| 29          | 289  | 236  | 381  | 5   | 40 HST                | 50     | suitable |
| 30          | 339  | 301  | 440  | 4.5 | 40 HST                | 100    | Suitable |
| 31          | 298  | 251  | 402  | 4.5 | 40 HST                | 100    | Suitable |
| 32          | 329  | 291  | 429  | 4.5 | 40 HST                | 100    | Suitable |
| 33          | 291  | 240  | 390  | 5   | 40 HST                | 50     | suitable |
| 34          | 339  | 301  | 440  | 4.5 | 40 HST                | 100    | Suitable |
| 35          | 339  | 301  | 440  | 4.5 | 40 HST                | 100    | Suitable |
| 36          | 292  | 245  | 392  | 5   | 40 HST                | 50     | suitable |
| 37          | 291  | 239  | 384  | 5   | 40 HST                | 50     | suitable |
| 38          | 309  | 265  | 413  | 4.5 | 40 HST                | 100    | suitable |
| 39          | 371  | 308  | 442  | 4   | 40 HST                | 100    | suitable |
| 40          | 300  | 258  | 407  | 4.5 | 40 HST                | 100    | suitable |

**4. Conclusion**

The device can detect nitrogen content in maize plants based on the RGB database with a 90% success rate. For R value 447.4-601.6, G value 384.7-510, and B value 519.95-625.16, we obtain that nitrogen need for plant about 175 kg/ha. For R value 325.9-377.5, G value 285.6-311.5, and B value 426.4-456.1, we obtain that nitrogen need for plant about 150 kg/ha. And for R value 290.37, G value 239.12, and B value 385.62, the nitrogen need for plant about 125 kg/ha. The greener the color of maize leaf, the lower the nitrogen fertilizer need, conversely the lower the green color on the leaf, the higher the level of nitrogen fertilizer needs.

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