Classification of rice plant fertilizer needs based on leaf color chart using radial basis function neural network

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Abstract. Management of nitrogen fertilizers in rice plants plays an important role in the productivity of rice plants. Excessive use of fertilizers may result in rice leaves becoming pale, yellowish that can lead to its death. Fertilizer should be given based on the content of nitrogen in rice leaves which is indicated by the color of rice leaf. The color of rice leaf can be checked through tools called Leaf Color Chart (LCC). However, farmers are still likely to experience differences in color perception while classifying the color of the leaf so that farmers sometimes give an inaccurate dose of nitrogen fertilizer. Therefore, this study has the objective to organize the needs of rice nutrient based on leaf color chart and to provide information on the fertilizer dose which is recommended to be given to reduce errors in the use of nitrogen fertilizer. This study used the classification process by looking at the greenish color of the leaf based on leaf color chart using the Radial Basis Function (RBF). The classification process was divided into three classes, namely Green1, Green2, and Green3. This study used 60 images as training data and 30 images as testing data with 90% of accuracy rate.

1. Introduction

Nitrogen fertilizer is a chemical compost containing nitrogen element, either in a single or complex form which is usually in the form of nitrate, ammonium, amino and cyanide compounds. Samples of nitrogen composts are Urea (NH₂CONH₂), ammonium nitrate (NH₄NO₃), calcium cyanide (CaCN₂) and many more. For rice plants, the control of nitrogen compost plays an important role in the enhancement of rice crops productivity. The management of nitrogen fertilizer should be in accordance with the dosage by examining the leaf color using a tool called Leaf Color Chart (LCC).

Leaf Color Chart (LCC) is a tool utilized as the indicator to determine the nutrient status of a rice plant. It has a rectangular shape that has four color scale boxes, ranging from light green to dark green depicting the greenishness of the rice plant [1]. The tool usually uses directly in the field, as lighting is the most crucial factor for the tool.

However, the peasants still tend to experience differences in color perception when measuring rice using leaf color chart. Therefore, this research has a purpose to classify the compost needs of a rice plant based on the Leaf Color Chart and to suggest the proper amount of the fertilizers given to the plants so it can minimize errors in the application of nitrogen fertilizer.

The need for nitrogen or compost in rice plants using Leaf Color Chart has been used by some farmers as a tool to calculate the amount of fertilizer that needs to be given to produce a quality rice
plant. Rice plants that have been tested using the Leaf Color Chart are still read manually by comparing the level of a greenish color to the four-leaf scale boxes ranging from light green to dark green. This leads to differences in color perception when testing the rice plants using the Leaf Color Chart so that sometimes peasants incorrectly provide the dosage of nitrogen fertilizer. Therefore, an approach is required to determine the dosage of nitrogen compost for a rice plant based on the level of greenish color on Leaf Color Chart (LCC).

Several studies on nitrogen needs of a rice crop have been conducted by some researchers. The first study conducted by Astika [2] implements the pattern recognition method of K-Nearest Neighbors to measure the required dosage of fertilizer for rice plants based on leaf color chart using an android cell phone. The K-Nearest Neighbors method with a background of palms and color benchmarks has an accuracy rate of 78% and an average fertilizer dose error of 4.0kg / ha [2].

Another research was conducted by Tewari et al. [3] to determine the status of nitrogen compound in a rice plant using a box-shaped tool that has four manually-operated trolley wheels to control the light on the field of rice crops. This study implemented color feature extraction using the RGB method with system accuracy of 75% [3].

Following research performed by Teoh et al.[4] to monitor the amount of the fertilized rice seeds in 25x25 cm frame then the framed rice was captured. E photographed plants then went through feature extraction process to calculate of r, g, b values then classified them according to the minimum distance of the r, g, b values. The results of this study indicated that the area of the framed plants that have fertilized could increase the number of paddies with an accuracy rate of 92.7% [4].

Further research conducted by Gunarno[5] implements Euclidean Distance, Z test and black-box test on rice plants by calculating the required dosage of nitrogen fertilizer. Based on the result of calculation on Z Test, the value of Z is not less than 0.6, so it can be ascertained that the value of the leaf scale generated by the application does not differ significantly with the scale of Leaf Color Chart (LCC) although the camera specifications are different [5]. Since we plan to do image processing with neural classifiers we also read several related research which is our previous work also talking about image processing with classifier such as ribbed smoke sheet with learning vector quantization [7], red blood cell image with self-organizing map (SOM) [8], and dipstick urine image [9].

2. Methodology
The method proposed to classify the application of urea fertilizer using Leaf Color Chart in this study consists of several stages. The steps performed are as follows: image acquisition using mobile phone camera where the images will be used as a training and test data; feature extraction using HSV; and image classification using artificial neural network Radial Basis Function.

After all the stages are completed, the system will generate the output of urea fertilizer classification based on the green color of the leaf. The general architecture of the system can be seen in Figure 1.

2.1 Image acquisition
Image acquisition is the process of capturing the images. At this stage, the image acquisition was performed to obtain the images to be inputted with the exact distance for each image so the classification result can be more accurate. The images of the rice were taken using a 10 MP mobile camera with a resolution of 768 x 1024 pixels and the samples placed on a white background.
2.2 Rice plant images
This study used data of rice crop images that will be classified as Green2, Green3, and Green4. The data were taken through image acquisition process at TanjungMorawa Rice Seed Centre. The number of images to be used in this research is 90 images with ten images served as training data of each classification and the other 60 as the test data. The image size for this study is 768 x 1024 pixels while the area of rice field has a size of 400m². Figure 2 illustrates the rice image Green2, Green3, and Green4.

![Figure 2](image)

(a) Green1; (b) Green2; (c) Green3

2.3 Rice image transfer to server
After image acquisition process is complete, the rice image will be sent to the server to proceed to the next stage. The server will perform the feature extraction process using HSV [6] and classification using Radial Basis Function method.

2.4 Feature extraction
HSV color feature extraction stage is performed to obtain the color characteristic of the inputted rice image. The steps performed on feature extraction of HSV color values in this study are as follows:
Retrieving r, g, b values on every pixel of the rice images. Before converting the r, g, b values to HSV, the values need to be normalized [6]. The normalization values can be obtained using the equation as follow:

\[ r = \frac{R}{255} \]  
\[ g = \frac{G}{255} \]  
\[ b = \frac{B}{255} \]  

1. After the value of r, g, b is normalized then the next step is to convert the image r, g, b to hsv using the following equation 4 to 6

\[ H = \begin{cases} 
0^\circ, & \text{if } \Delta=0 \\
60^\circ \times \left(\frac{g-b}{\Delta} \mod 6\right), & \text{if } C_{\text{max}}=r \\
60^\circ \times \left[2+\frac{b-g}{\Delta}\right], & \text{if } C_{\text{max}}=g \\
60^\circ \times \left[4+\frac{r-g}{\Delta}\right], & \text{if } C_{\text{max}}=b 
\end{cases} \]  
\[ S = \begin{cases} 
0, & \text{if } C_{\text{max}}=0 \\
\frac{\Delta}{C_{\text{max}}}, & \text{if } C_{\text{max}}\neq0 
\end{cases} \]  
\[ V = C_{\text{max}} \]

2. The process continues to quantization calculation of each color component. The pixel value originally numbered (768 x 1024) or 768432 is likely to be quantized to 162 (18x3x3). With hue ranging from 0 to 17, saturation ranges from 0 to 2 and value range from 0 to 2.

3. Quantization result of each bin will be normalized by dividing the probability value (total occurrence) with the number of pixels in the image.

2.5 Radial basis function classification

After the feature value of the image obtained, the next step is image classification using radial basis function (RBF). In this study, the architecture of the designed radial basis function consists of 162 neurons in the input layer, three neurons in the hidden layer, one bias and three neurons in the output layer. The number of 162 neurons in the input layer was determined based on the result of feature extraction, while three neurons in the output layer were determined based on the target output value. The classification steps are as follows:

1. The process from input to hidden layer. Initialization of the initial center value determined from the input data taken randomly using the k-means algorithm.

2. Calculate data distance with center value using Euclidean distance equation below:

\[ d(X_i, C_j) = \sqrt{\sum_{j=1}^{n} (X_j - C_j)^2} \]  

3. Update the center value by calculating the mean of group values which can be expressed by the following equation.

\[ c_j = \frac{1}{n} \sum_{i=1}^{n} x_i \]
4. After the new center value obtained, step 2 and 3 will be repeated until center value does not change anymore. If the new center value does not change then the search process of the center value with k-means algorithm has been completed.

5. After the center value attained, the next step is to calculate the Gaussian value (φ) with the spread value (σ) using the following equation.

$$
\phi = \exp\left\{ -\frac{\|x_i - c_j\|}{2\sigma^2} \right\}
$$

(9)

6. The next step is the process of the hidden layer to output layer. This stage calculates new weight (W) by multiplying pseudoinverse of the Gaussian matrix with the target (d) from data training using the equation below:

$$
W = G^+d = (G^TG)^{-1}G^Td
$$

(10)

7. Calculate the output value of network Y(n) using the formula:

$$
y(x) = \sum_{t=1} wG(\|x - t\|) + b
$$

(11)

8. Save the training result to be used on the test. The stored training data are center1, center2, center3, output value, and standard deviation value of radial basis function training process. Flowchart of the training process using RBF method is shown in Figure 3.

![Figure 3. Radial Basis Function flowchart](image)

3. **Result and analysis**

System testing performed to determine whether the system can classify the color of rice image. The test conducted using 60 rice images obtained from Medan Rice Seeds Center.
In system testing, a factor that can affect the classification process of the rice images is light. The test went through two image acquisition processes which are back-light and facing direct sunlight captures.

3.1 Identification test using images captured opposite direction of the sunlight
Image testing with a photo captured in the opposite direction of the sunlight was used to test the system accuracy. The test conducted using 30 images; the test result is shown in Table 1.

| No. | Image name | Result          | Status |
|-----|------------|-----------------|--------|
| 1   | 2.3.jpg    | Color Chart 2   | True   |
| 2   | 2.2.jpg    | Color Chart 2   | True   |
| 3   | 2.8.jpg    | Color Chart 2   | True   |
| 4   | 3.1.jpg    | Color Chart 3   | True   |
| 5   | 3.2.jpg    | Color Chart 4   | False  |
| 6   | 3.3.jpg    | Color Chart 4   | False  |
| 7   | 4.1.jpg    | Color Chart 4   | True   |
| 8   | 4.2.jpg    | Color Chart 4   | True   |
| 9   | 4.3.jpg    | Color Chart 4   | True   |
| 10  | 4.4.jpg    | Color Chart 4   | True   |
| 11  | 2.7.jpg    | Color Chart 2   | True   |
| 12  | 2.6.jpg    | Color Chart 2   | True   |
| 13  | 2.5.jpg    | Color Chart 2   | True   |
| 14  | 2.4.jpg    | Color Chart 2   | True   |
| 15  | 3.4.jpg    | Color Chart 3   | True   |
| 16  | 3.5.jpg    | Color Chart 4   | False  |
| 17  | 3.6.jpg    | Color Chart 3   | True   |
| 18  | 3.7.jpg    | Color Chart 3   | True   |
| 19  | 4.5.jpg    | Color Chart 3   | True   |
| 20  | 4.6.jpg    | Color Chart 3   | True   |
| 21  | 2.9.jpg    | Color Chart 2   | True   |
| 22  | 2.1.jpg    | Color Chart 2   | True   |
| 23  | 3.8.jpg    | Color Chart 3   | True   |
| 24  | 3.10.jpg   | Color Chart 3   | True   |
| 25  | 3.11.jpg   | Color Chart 3   | True   |
| 26  | 3.12.jpg   | Color Chart 3   | True   |
| 27  | 4.7.jpg    | Color Chart 4   | True   |
| 28  | 4.8.jpg    | Color Chart 4   | True   |

3.2 Identification test using photo that faced direct sunlight
Image testing with photo capture facing direct sunlight is used to test the system. The test was performed using 30 images of rice photographed by facing direct sunlight. The test result can be seen in Table 2.

| No. | Image name | Result          | Status |
|-----|------------|-----------------|--------|
| 1   | 2.3.jpg    | Color Chart 2   | True   |
| 2   | 2.2.jpg    | Color Chart 2   | True   |
| 3   | 2.8.jpg    | Color Chart 2   | True   |
| 4   | 3.1.jpg    | Color Chart 3   | True   |
| 5   | 3.2.jpg    | Color Chart 4   | True   |
| 6   | 3.3.jpg    | Color Chart 4   | True   |
| 7   | 4.1.jpg    | Color Chart 4   | True   |
| 8   | 4.2.jpg    | Color Chart 4   | True   |
| 9   | 4.3.jpg    | Color Chart 4   | True   |
| 10  | 4.4.jpg    | Color Chart 4   | True   |
| 11  | 2.7.jpg    | Color Chart 2   | True   |
| 12  | 2.6.jpg    | Color Chart 2   | True   |
| 13  | 2.5.jpg    | Color Chart 2   | True   |
| 14  | 2.4.jpg    | Color Chart 2   | True   |
| 15  | 3.4.jpg    | Color Chart 3   | True   |
| 16  | 3.5.jpg    | Color Chart 4   | True   |
| 17  | 3.6.jpg    | Color Chart 3   | True   |
| 18  | 3.7.jpg    | Color Chart 3   | True   |
| 19  | 4.5.jpg    | Color Chart 3   | True   |
| 20  | 4.6.jpg    | Color Chart 3   | True   |
| 21  | 2.9.jpg    | Color Chart 2   | True   |
| 22  | 2.1.jpg    | Color Chart 2   | True   |
| 23  | 3.8.jpg    | Color Chart 3   | True   |
| 24  | 3.10.jpg   | Color Chart 3   | True   |
| 25  | 3.11.jpg   | Color Chart 3   | True   |
| 26  | 3.12.jpg   | Color Chart 3   | True   |
| 27  | 4.7.jpg    | Color Chart 4   | True   |
| 28  | 4.8.jpg    | Color Chart 4   | True   |
| No. | Image name | Result          | Status  |
|-----|------------|-----------------|---------|
| 1.  | 4.11.jpg   | Leaf Color Chart 4 | True    |
| 2.  | 4.12.jpg   | Leaf Color Chart 4 | True    |
| 3.  | 4.13.jpg   | Leaf Color Chart 4 | True    |
| 4.  | 4.14.jpg   | Leaf Color Chart 4 | True    |
| 5.  | 3.11.jpg   | Leaf Color Chart 4 | False   |
| 6.  | 3.12.jpg   | Leaf Color Chart 4 | False   |
| 7.  | 3.13.jpg   | Leaf Color Chart 4 | False   |
| 8.  | 2.11.jpg   | Leaf Color Chart 2 | True    |
| 9.  | 2.10.jpg   | Leaf Color Chart 2 | True    |
| 10. | 2.12.jpg   | Leaf Color Chart 2 | True    |
| 11. | 4.15.jpg   | Leaf Color Chart 4 | True    |
| 12. | 3.14.jpg   | Leaf Color Chart 4 | False   |
| 13. | 3.15.jpg   | Leaf Color Chart 4 | False   |
| 14. | 3.16.jpg   | Leaf Color Chart 2 | False   |
| 15. | 2.13.jpg   | Leaf Color Chart 2 | True    |
| 16. | 4.15.jpg   | Leaf Color Chart 4 | True    |
| 17. | 4.16.jpg   | Leaf Color Chart 4 | True    |
| 18. | 3.17.jpg   | Leaf Color Chart 3 | True    |
| 19. | 3.18.jpg   | Leaf Color Chart 3 | True    |
| 20. | 3.19.jpg   | Leaf Color Chart 3 | True    |
| 21. | 2.14.jpg   | Leaf Color Chart 3 | False   |
| 22. | 2.15.jpg   | Leaf Color Chart 2 | True    |
| 23. | 4.16.jpg   | Leaf Color Chart 4 | True    |
| 24. | 4.17.jpg   | Leaf Color Chart 4 | True    |
| 25. | 4.17.jpg   | Leaf Color Chart 4 | True    |
| 26. | 4.19.jpg   | Leaf Color Chart 4 | True    |
| 27. | 3.20.jpg   | Leaf Color Chart 3 | True    |
| 28. | 3.21.jpg   | Leaf Color Chart 3 | True    |
| 29. | 3.22.jpg   | Leaf Color Chart 3 | True    |
| 30. | 3.23.jpg   | Leaf Color Chart 3 | True    |

Based on the test result conducted on the classification of the fertilizer use for rice crops based on the leaf color chart using backlight image, the accuracy rate of this research is 90% This result is obtained through equation below:

\[
\text{Accuracy rate} = \frac{\text{Correctly identified image}}{\text{Image total}} \times 100\%
\]

\[
= \frac{27}{30} \times 100\% = 90\%
\]

4. Conclusion

Based on the color classification system test on rice image, it is concluded that the method proposed in this research can perform well in color of rice image. The lighting of rice image can affect the result of image classification. The accuracy level of identification process using an image captured from the opposite side of the sunlight is higher than 90% compared to the one facing direct sunlight which is 80%.
For future research, it is expected to overcome the changes of different lights to obtain more accurate classification results. Furthermore, another green color should be added to the Leaf Color Chart in compost classification.

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