TENCON 2023 - 2023 IEEE Region 10 Conference (TENCON)
31 Oct - 3 Nov 2023. Chiang Mai, Thailand

The Effects of Soil Nutrient NPK Indicator and Recommendation System for Brassica Rapa subsp. Chinensis or Taiwan Pechay Bokchoy

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***Abstract*— Agricultural fertilization plays an important part in maintaining and increasing the yield capacity and growth of plants. Fertilizer application must be accompanied by the correct fertilizer recommendation. This study aims to develop a system that can measure the NPK contents of soil and provide fertilizer recommendations for Bok Choy and determine if there will be a significant difference in the plant's average leaf length and weight when compared to a method that uses a complete fertilizer application. Two different setups were done in the study to grow the plant. Setup A used fertilizer recommendations based on the system while Setup B used only complete fertilizer. Data shows that in terms of leaf length and weight, Setup A produces on average, longer leaves and heavier yields, respectively. However, based on the t-test analysis, both the p-value for the average length of leaves and weight were greater than the significance level, indicating that there was no significant difference in the results when using Setup A compared to Setup B. In conclusion, the use of an NPK recommendation and fertilizer recommendation system does not significantly affect the average length of leaves and weight of Bok Choy plant when compared with the use of a complete fertilizer setup.**

Keywords—NPK, soil nutrients, soil nutrient indicator, fertilizer, fertilizer recommendation

I. Introduction

Brassica Rapa subsp. chinensis or commonly known as Bok choy belongs to cruciferous vegetable family and is considered one of the nutritious leafy vegetables containing antioxidants helpful in preventing chronic diseases [1]. Agricultural fertilization plays an important part in maintaining and increasing the yield capacity and growth of the plant. Knowing and understanding the correct nutrients needed can impact the total output and quality of a crop [2]. Nitrogen (N), Phosphorus (P), and Potassium (K) are three of the major soil macro-nutrients that affect the growth of a crop. Nitrogen is responsible for providing the protein needed by the plant tissue, Phosphorus is for stabilization of roots and seeds, and Potassium is for respiration process and water movement [3]. Most growing methods for Bok choy do not use soil nutrient testing, leading to over-fertilization which negatively affects the soil quality and yield of the plant [4][5][6].

Soil testing is the process of determining soil's nutrient content to determine nutrient deficiencies [7]. Although there can be hindrances in maintain soil fertility such as uncontrollable weather [8]-[11], development of methods that conduct soil testing progresses to acquire more information about the effects of current nutrient values to the growth of the crop [12]-[15]. The most common soil testing is through laboratory analysis which may take days to finish. Since manual soil testing can be time consuming, other methods which are more accessible and faster are being developed. Soil nutrient determination through the principle of calorimetry and the use of optical transducer are some of the methods being used today. As demonstrated in [16], values of NPK were determined by using a system with colour sensor, colorimetry, and Naïve Bayes classification algorithm. The detection of NPK in [16] had 80 percent accuracy; however, the limitation of the system is that it does not provide fertilizer recommendation. In [17], the researchers were able to directly detect NPK values without including colorimetry by using an optical transducer consisting of multiple LEDs, a light source, and a photodiode as a light detector. The system in [17] was able to determine the nutrient contents of the soil in ranges of low, medium, and high; however, the system was solely built for NPK determination and does not provide proper fertilizer application.

Most of the existing systems with nutrient detection function do not have a recommendation system. Systems relating to fertilizer recommendation on the other hand require the use of soil testing kits, mobile devices, or the internet. Farmers without access to regional testing laboratories or basic technology will remain practicing trial and error when applying fertilizer. The lack of a system for testing soil with fertilizer recommendation for Bok Choy is the problem that this study aims to address.

The main objective of this research is to determine the effects of using soil nutrient indicator and recommendation system on Bok Choy. This research specifically aims to: (1) Develop a system that can measure the NPK content of soil and provide necessary fertilizer recommendation, (2) Implement the system on Bok Choy, and (3) Use a two-sample t-test to determine the effect of the system on the length of leaves and weight of the plant.

The development of the system will contribute to the field of agricultural fertilization. Farmers will be able to measure the NPK values of their soil without the use of any soil testing kit or without using other tools such as mobile phones/internet. The system will also help guide backyard farmers on choosing the appropriate and correct amount of fertilizer to be applied in their soil.

In this study, the variety of Bok Choy to be planted is Taiwan Pechay Bok Choy. Two plots with an area of 0.1858 m^2 are used as planting sites. The type of soil to be used is loam soil. The layer depth for testing the soil for NPK is 20 cm. The type of fertilizers to be recommended are Urea, Ammonium Phosphate, Complete Fertilizer, Muriate of Potash, and Duofos. The program was implemented using Arduino Uno. For the output, the measured NPK and the type and amount of recommended fertilizer were displayed using OLED.

II. METHODOLOGY

A. *Researcher Methodology*

The researchers propose a system that can read NPK values of the loam soil where it can provide fertilizer recommendation based on the needed NPK of the soil. The system and its fertilizer recommendation are designed specifically for Bok Choy plant. The system will help address the problem of improper management and over-fertilization of the soil. The effects of the system recommendation were compared with the different setup which used a complete fertilizer application. The development of the system required Arduino Uno, Modbus module, a battery, NPK sensor and OLED display for visualization. The conclusion and recommendation were provided for further development and additional resources to the topics related to study.

B. *Conceptual Framework*

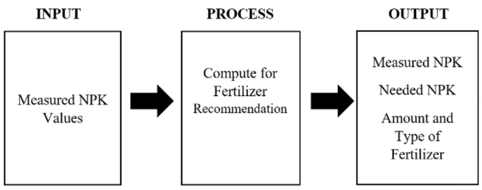

Fig. 1. Conceptual Framework

Figure 1 shows the conceptual framework of the system. The macronutrients (N, P, and K) will be acquired by the system and will serve as the input. The measured N-P-K values will be obtained using an N-P-K sensor and will be read in terms of mg/kg by the system. After receiving the measured NPK, the microcontroller will process the data by first getting the difference between the standard NPK value for optimum growth of Bok Choy [18] and the measured NPK value – obtaining the needed NPK of the soil. After computing for the needed NPK, the values will be used to select the appropriate type of fertilizer to be applied to the soil. Then, the outputs will be shown in an OLED display including the measured NPK, needed NPK of the soil and the recommended fertilizer.

C. *Conceptual Framework*

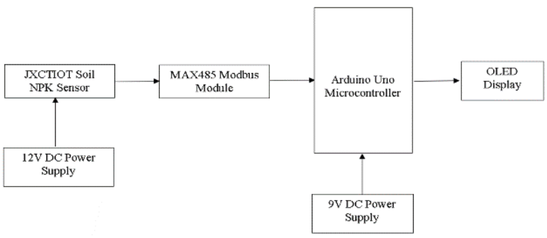

Fig. 2. Block Diagram of Hardware Prototype

Figure 2 shows the block diagram of the proposed hardware prototype. NPK values are detected by the JXCTIOT Soil NPK sensor by inserting the probe in the soil sample. Since the sensor cannot be used directly with a microcontroller, a MAX485 Modbus module must be first interfaced. The Modbus module is connected to the Arduino Uno Microcontroller. The whole system is powered by a 12V DC power supply. The outputs will all be displayed using an SSD1306 OLED display.

D. *Software Development*

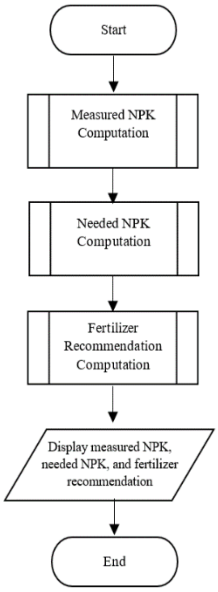

Fig. 3. Main System Flowchart

Figure 3 shows the main software flowchart of the system which consists of three sub-processes needed for the fertilizer recommendation. Initially, measured NPK readings from the sensor will be stored in the system. Using the measured NPK value, the amount for the needed NPK can be computed. After the amount of needed NPK is determined, fertilizer type can be selected. The amount will also be computed and will be displayed together with measured and needed NPK using an OLED Display.

E. *Experimental Setup*

There are two different setups for the study: (A) growing Bok Choy with fertilizer application based on the recommendation of the system and (B) using complete fertilizer. Both setups used loam soil and each container were filled with it up to 25 cm. The fertilizer application was done every 7 days for 4 weeks after transplanting.

Fig. 4. Container Setup for the System

The first setup, Setup A, grew the Bok choy seedlings in the container shown in Figure 4. The container has five 8 cm slits where the NPK sensor can be inserted to detect the current nutrients of the soil. Each slit is used to accumulate multiple readings of the soil's macronutrients. The mean of the five soil nutrient readings is calculated and used in processing fertilizer recommendation. Applying the type and amount of fertilizer in Setup A were based on the recommendation of the system.

Fig. 5. Container Setup for Complete Fertilizer Application

Figure 5 shows the container setup for Setup B. Unlike setup A, the container used in setup B does not have slit since the macronutrients in the soil in setup B were not checked; however, the type of container and the amount of loam soil to be applied in both setups were the same. The fertilizer application in setup B did not vary and only used complete fertilizer. A teaspoon of the complete fertilizer was mixed with 2L of water until the granules are all diluted and watered to the soil. The soil nutrients in setup B were not monitored before the application of complete fertilizer. Both setups had the same treatment with watering and sunlight exposure.

F. Data Gathering

(a) (b)

Fig. 6. Measured Leaf and Weight of Bok Choy Plant

Two setups were created namely Setup A and Setup B. Each setup contains six Bok choy plants for a total of twelve plants for the two setups. Setup A utilized the Soil Nutrient Indicator and Recommendation System while Setup B used complete fertilizer during fertilization. The Bok choy plants were harvested on the 35th day after transplant [19],[20]. After the harvesting stage, the plant's average leaf length and weight were measured. For the average leaf length, the plant was placed on a table and was measured vertically from the end of the petiole to the top of the plant. For plant's weight, the whole plant including the leaves and the root was measured using a weighing scale. Figure 6 show the process of measuring the leaf length and weight of the Bok Choy plant, respectively.

G. Statistical Analysis

The statistical treatment to be used in this study is two sample t-test. A two-sample t-test is used to measure if the population means of two groups are equal or not. In this study, the two-sample t-test was used to test if there is a significant difference in the mean in using the proposed system and in using the traditional method of growing Bok Choy. Two setups (A and B) were used to represent each method. The length of the leaves and the total weight of each plant per setup were measured. The means for each setup were also computed. The mathematical statement for the two-sample t-test is stated as:

$$t = \frac{x_A - x_B}{\sqrt{s^2\left(\frac{1}{n_A} + \frac{1}{n_B}\right)}} \quad (1)$$

where *x* is sample mean, s is the standard deviation, and *n* is the number of samples.

The null hypothesis states that there is no significant difference in the length of leaves and the total weight of plant using the proposed system and the traditional method. The null hypothesis is mathematically stated as:

$$H_o: x_A = x_B \quad (2)$$

The alternative hypothesis states that there is a significant difference in the length of leaves and the total weight of plant using the proposed system and the traditional method. The alternative hypothesis is mathematically stated as:

$$H_o: x_A \neq x_B \quad (3)$$

A significance level of α = 0.05 and a degree of freedom *df = 10* was be used in this study.

III. RESULTS AND DISCUSSIONS

TABLE I. AVERAGE LEAF LENGTH PER SETUP

Setup	Average Leaf Length (cm)						
	P_1	P_2	P_3	P_4	P_5	P_6	*Mean*
A	10.82	11.46	7.36	8.98	13.48	10.34	10.41
B	10.46	6.98	11.20	9.15	7.91	7.45	8.86

TABLE II. PLANT WEIGHT PER SETUP

Setup	Weight (g)						
	P_1	P_2	P_3	P_4	P_5	P_6	*Mean*
A	18.02	14.04	16.73	6.43	11.60	4.14	14.19
B	11.20	7.13	7.36	7.45	8.23	6.50	10.89

The results for the average leaf length and weight are illustrated on Table I and Table II, respectively. The mean value for average leaf length of plants under Setup A is 10.41 cm while 8.86 cm was recorded on plants under Setup B. For plant weight, the average value for Setup A is 14.19 g and 10.89g for Setup B. A visual inspection of the induvial plant between two setups shows that plants under Setup A are bigger in size than the plants under Setup B. The longest recorded average leaf length was measured in P_5 under Setup A which is 13.48 cm. The heaviest weight on the other hand was also recorded on P_1 under Setup A which is 18.02 g.

TABLE III. T-TEST ANALYSIS OF SETUP A AND B

t-test Analysis	Average Length of Leaves		Weight	
	A	*B*	*A*	*B*
Mean	10.41	8.89	14.19	10.89
Standard Deviation	2.10	1.71	5.57	1.67
Number of plants	6	6	6	6
t	1.519		1.521	1.521
p-value	1.51		1.39	1.39

Table III shows the summary table for the t-test analysis for Setup A and Setup B. In terms of the average leaf length, a test statistic value of 1.519 and a p-value of 1.51 was determined. The p-value is greater than the significance level of $\alpha = 0.05$. This means that there is not enough evidence to conclude that there is a significant difference on the average leaf length when using Setup A versus in using Setup B. In terms of weight, a test statistic value of 1.521 and a p-value of 1.38 was determined. The p-value was also greater than the significance level of $\alpha = 0.05$ which means that there is no significant difference on the weight when using Setup A compared to Setup B.

IV. Conclusion and Recommendation

The researchers were able to create a system that can measure the NPK contents of the soil and provide fertilizer recommendations. The system was implemented and tested on 6-week grown Bok Choy plants. After the harvesting period, the researchers measured the average length of leaves and weight of the plants. In terms of the average length of leaves, a test statistic value of 1.519 and a p-value of 1.51 was determined. The p-value was greater than the significance level of $\alpha = 0.05$. Thus, failing to reject the null hypothesis. In terms of weight, a test statistic value of 1.521 and a p-value of 1.38 was determined. Thus, failing to reject the null hypothesis. In conclusion, the use of an NPK indicator and fertilizer recommendation system does not significantly affect the average length of leaves and weight of Bok Choy plant when compared with the use of a complete fertilizer setup.

To enhance the accuracy and effectivity of Setup A, it is recommended to create a database of different soil samples from various agricultural fields where Bok Choy are planted. Using the database, a more accurate recommendation can be given depending on the soil types and region. Additionally, explore machine learning algorithms from the database to improve the classification and recommendation capability of the system. It is also recommended to add a pH sensor to detect the acidity and basicity of soil which may improve the overall analysis of samples. Moreover, the integration of real-time weather data into the system using IoT can be used to help formulate an accurate NPK recommendation. Lastly, the portability can be improved by using only an ATmega328P microcontroller instead of the whole Arduino Uno board. For Setup B, it is recommended to have a more standardized way of applying the complete fertilizer and the amount of water to be used. This is to ensure that everything is consistent resulting in a more reliable result. It is also important to take to consideration the external factors that may influence the growth of the plants. To improve the statistical analysis, it is recommended to have a bigger setup to accommodate a larger number of samples.

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