SOIL SURVEY IMPLEMENTATION USING RASPBERRY PI THROUGH COLORIMETRIC DETERMINATION OF NITROGEN, PHOSPHORUS, POTASSIUM, AND PH LEVEL

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KEYWORD: Soil Testing, Macronutrients, Colorimetry, Raspberry Pi, MySQL

ABSTRACT: The study focuses on creating a portable soil testing device that displays measured level of soil nutrients using colorimetry through Arduino using TCS3200 color sensors. The device acquires the data needed through the utilization of soil test kits. A GPS module is used to take the coordinates where the soil sample is taken. Results from the soil testing kit will be saved in the Raspberry Pi and will be displayed in a TFT screen after the color sensors from the Arduino is done measuring. The saved data will be sent to the database using MySQL for the online mapping of the samples. The device was tested using five samples for every macronutrient and pH with ten trials each. The benchmark value of 0.05 and 95% level of confidence is used. The computed Chi-Square method values is equal to 1.4 which is lower than the critical value of 3.84. Since the computed values of Chi-Square are less than the critical value, we can conclude that the device result fits the frequency distribution of the trials of the laboratory test.

1. INTRODUCTION

An important factor in agricultural fertilization is the soil nutrient content, knowing what nutrient is good for your crop will majorly impact its yield and quantities. The three major soil nutrients Nitrogen (N), Phosphorus(P), and Potassium(K) elements play an important role which can affect the growth of plant when not presented in a proper concentration and can lead to degradation of the quality of soil. Each nutrient has its own way of promoting plant growth; Nitrogen makes a plant foliage grow strong, Phosphorus promotes root growth, and Potassium is important for overall plants health for it's responsible for nutrient and water regulation (Agarwal, 2018), (Masrie, 2017), (Yumang, 2016).

Recent improvements were made to make measuring soil nutrients more accessible and inexpensive since most process of soil testing is conducted in a laboratory which will take a couple of days to know the results. Colorimetric testing kits are such examples wherein the NPK values of a specific soil sample can be determined through a color chart (Adhikary, 2015). Aside from knowing the nutrient concentrations, pH level of the soil is also a factor. The pH level determines the nutrient uptake of the soil to determine the feasibility of using the plot of land for agricultural purposes (Agarwal, 2018), (Sreedevi,2016).

The efforts for improving agriculture does not end on improving the quality of the crops but rather making information about agriculture more accessible. Knowing the current state of nutrients in a plot of land will make it easier what to plant or what fertilizer to add in that specific area (Vernekar, 2015), (Caya, 2018). The lack of an available online platform for storing information required for soil surveying in the Philippines is a problem that this study aims to find a solution.

The study aims to contribute to the field of agriculture by creating a portable device which can read and map the soil nutrient level while utilizing soil test kit whose results is similar to that of laboratory-produced results. The proposed system can be used as further reference for profiling other macronutrients in an area. The use of colorimetry is applied in different applications in measuring different substances present in a soil like Nitrogen, Phosphorous, and Potassium (Regalado, 2016). The researchers created a system that uses colorimetric measurement of soil nutrient levels while utilizing a soil testing kit using TCS3200 color sensors, and a GPS module.

The general objective is to develop a system for soil testing that can determine the concentration of Nitrogen, Potassium, and Phosphorus macronutrients and pH level present in a soil using color processing while utilizing the soil test kit. The research specifically aims to: (1) develop a device that can determine pH level of a soil sample and the macronutrients present in the soil by interpreting RGB values through a microcomputer (2) the device must also be able to store its data through connecting to a central database to pass its acquired results for archiving (3) to implement the system in four different planting sites and save its location through GPS and to verify the performance of the system in comparison to the results from the soil testing kit.

2. METHODOLOGY

2.1 Overview of the system

Figure 1 shows the conceptual framework of the system. The color capture section consists of Arduino, color sensors and LEDs which acquires the RGB data from the soil solution sample. The soil solution sample is prepared using a soil testing kit. Through the Raspberry Pi and Arduino microcontroller serial communication capabilities (Regalado, 2016), the measured RGB values is sent to the Raspberry pi from the Arduino which determines the pH and macronutrient present. The TFT touchscreen display shows the graphical user interface (GUI) to operate the system, it also displays the results obtained from the color analysis section. The obtained data can now be transferred to the database whenever a network connection is available which simultaneously updates the online platform.

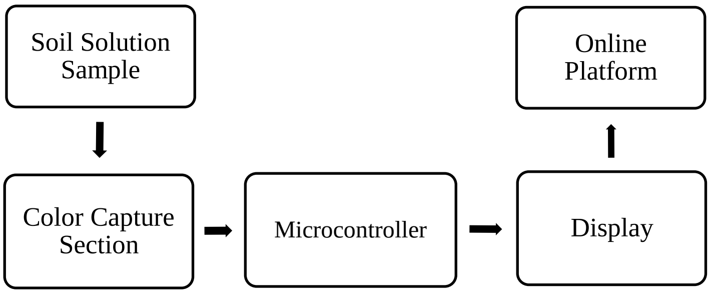


Fig. 1 System Overview

2.2 Soil Surveying Procedures

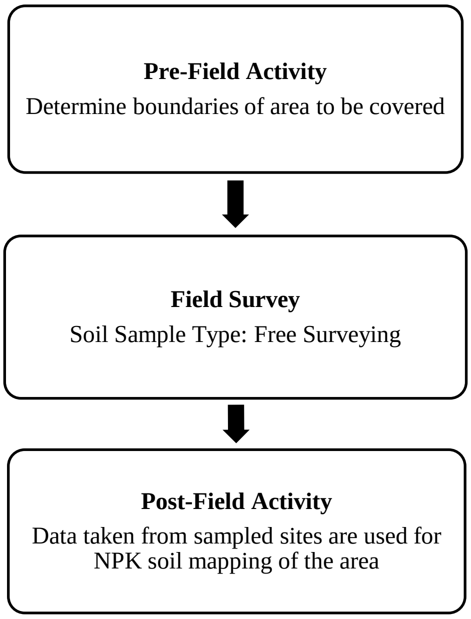
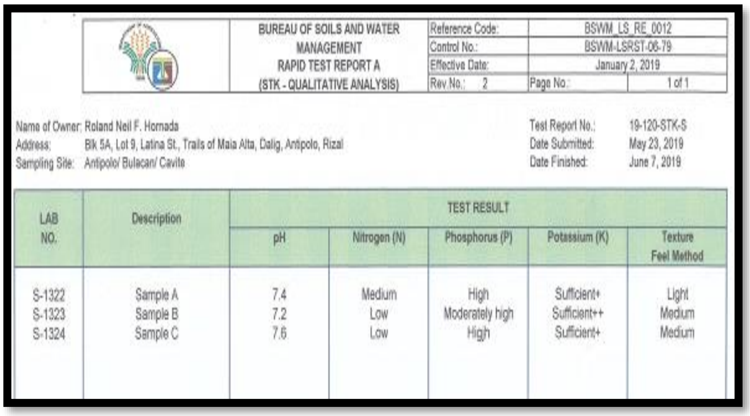


Fig. 2 Soil Survey Procedures

Figure 2 shows the preparations needed to conduct a soil survey. The soil samples taken from the soil survey will be used to create the needed solution for the study using a soil testing kit. Pre-field activities include determining the boundaries of the areas to be covered. Once the areas are determined, we can now proceed to the field activities which involves collecting the soil sample in the chosen area. Free surveying is a type of soil sampling technique which takes as many as necessary samples within the boundaries. The samples should be taken at least 2-4 inches deep as specified by the soil testing kit. After surveying, the data collected will be used to map the area of its NPK and pH level contents.

The color analysis section consists of four TCS3200 color sensor one for each macronutrient and one for pH. It contains an 8x8 photodiode array which contains sixteen clear sensors for having no filter, sixteen each for red, green, and blue light reflectance. The color sensor outputs a frequency which varies directly with the brightness of color detected in square waveform (Cabaccan, 2018), (Jawahar, 2017). The color sensor performs best at a certain distance of approximately 1 cm and the detection area is enclosed to avoid outside light sources that can affect the accuracy of the reading (Supannarach, 2008).

2.3 Soil Sample Laboratory Test and Soil Test Kit



BUREAU OF SOILS AND WATER MANAGEMENT
RAPID TEST REPORT A
(STK - QUALITATIVE ANALYSIS)

Reference Code:	BSWM_LS_RE_0012
Control No.:	BSWM-LSRST-06-79
Effective Date:	January 2, 2019
Rev No.: 2	Page No.: 1 of 1

Name of Owner: Roland Neil F. Hornada
Address: Blk 5A, Lot 9, Latina St., Trails of Maia Alta, Dalig, Antipolo, Rizal
Sampling Site: Antipolo/ Bulacan/ Cavite

Test Report No.: 19-120-STK-S
Date Submitted: May 23, 2019
Date Finished: June 7, 2019

LAB NO.	Description	TEST RESULT				
		pH	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Texture Feel Method
S-1322	Sample A	7.4	Medium	High	Sufficient+	Light
S-1323	Sample B	7.2	Low	Moderately high	Sufficient++	Medium
S-1324	Sample C	7.6	Low	High	Sufficient+	Medium

Fig. 3 Laboratory Result

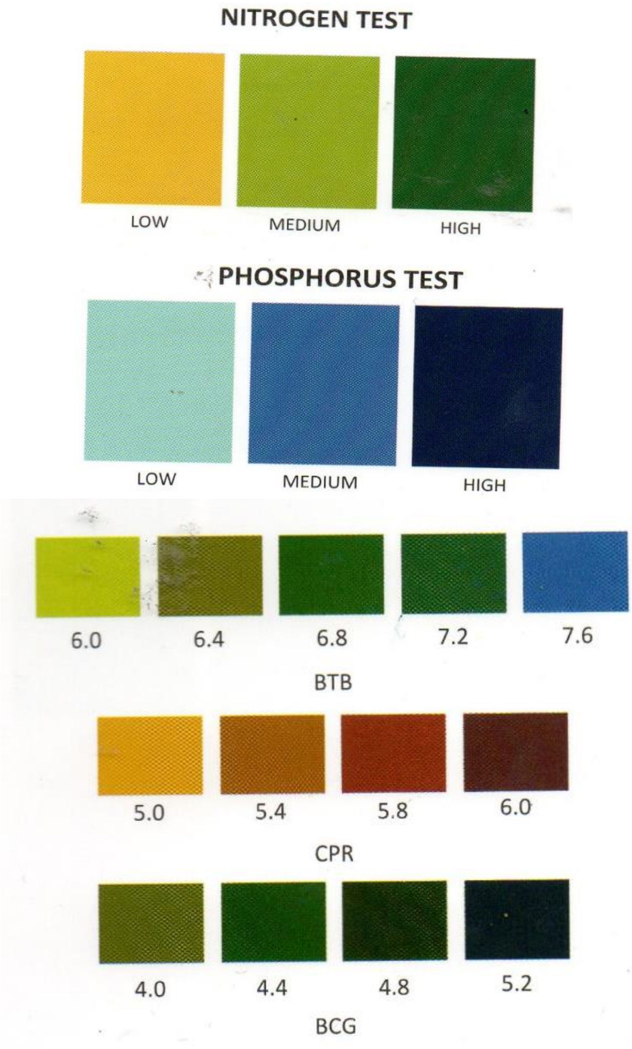


Fig. 4 Color Chart from Soil Test Kit

Figure 3 shows the laboratory result of the soil samples which will be tested by the device. The resulting levels from the laboratory test will be the basis for checking whether the device's nutrient level classification is correct. The device will make use of the solutions from the soil test kit which is accredited by the Bureau of Soils and Water Management under the Department of Agriculture. The device's basis for the RGB values will come from the included color chart in the soil test kit shown in Figure 4. A color picker will be used in extracting the RGB values from the color chart which will then be used as the reference values for the device when reading the color of the sample solutions.

Fig. 5 Soil Test Kit

Figure 5 shows the soil test kit used in making the mixture of the macronutrient and the soil sample. Four test tubes were included in the soil test kit. The N, P, K macronutrients each has a corresponding bottle of solution to be mixed with the soil sample. For the pH level, there are three solutions available. The CPR solution is used to determine whether the pH value is 5.8 or greater, or less then 5.0. If the value is 5.8 or greater, the soil sample will be mixed again using the BTB solution, and if the value is less then 5, the soil sample will be mixed with the BCG solution. An instruction is included in the soil test kit for the preparations of the different macronutrients. Each macronutrient is handled differently from one another such as the duration of letting the solution settle and the duration of mixing the solution.

2.4 Soil Sample Mapping and Level Classification

Figure 6 shows the main flow on how the soil samples will be mapped out. Starting off by the collection of soil samples, the coordinates of each soil samples will be determined to take note of location of the samples. Once soil samples from desired sample locations are acquired, the utilization of test kit will take place. Random IDs is generated which consists of combination of alphanumeric characters to make each sample distinct from each other. To ensure that IDs are not duplicated, a random ID duplicate checker procedure is added. Once the random ID is verified, the longitude and latitude coordinates will be saved with the generated ID in a CSV file which is saved in the raspberry pi microcontroller.

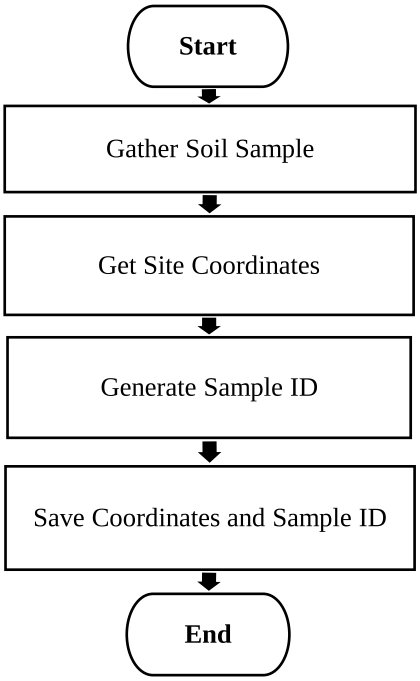


Fig. 6 Soil Sample Mapping Process

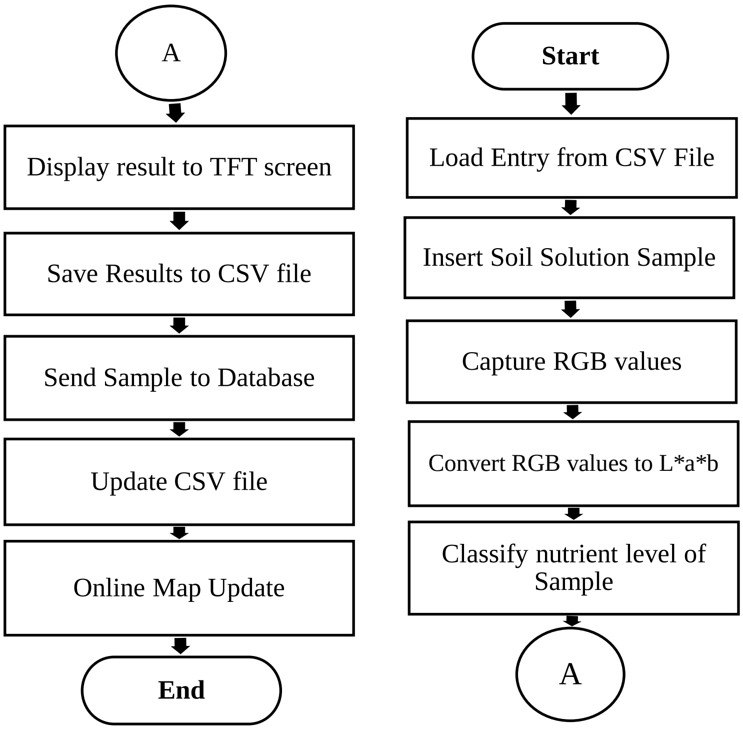


Fig. 7 Sample Entry Nutrient Level Classification

The saved sample entry will be loaded to enter the RGB values captured by the color analysis section and will serve as an input to the soil nutrient classification shown in Figure 7. The RGB values will undergo color space conversion to obtain the Euclidian Delta-E value to classify the concentration level of the sample. The input RGB values is converted to XYZ color space and the XYZ values will then be converted to L*a*b color space to add the luminance effect of the surrounding to achieve accurate representation of the enclosed environment.

A CSV file will serve as a temporary information storage before sending a sample to the database. The Raspberry Pi's network connection connectivity enables sending of data from the Raspberry Pi to the MySQL database server using python programming language (Yumang, 2016). The sent data to the database will automatically update the entries available in the online map.

2.5 Color Space Conversion

Color space conversion techniques are used to properly represent the color readings with the corresponding illuminance to use the Euclidian Method. RGB to XYZ color space is required since there's no direct conversion of RGB to LAB and LAB values is needed to obtain Euclidian delta values and not exceed the limitations (Bolivar, 2015). To convert XYZ to LAB, reference white F7 illuminance is used.

Euclidian Method

$$D = \sqrt{(L_R - L)^2 + (A_R - A)^2 + (B_R - B)^2} \quad (1)$$

Euclidian method is the method used for determining which nutrient level will the RGB values is close to. L_R, A_R, B_R will serve as the reference color while L, A, B will be the sample color that will attempt to match the reference color (Gravesen, 2015). This formula will show how much the difference between the two colors. The delta values show how similar, how opposite, or how it is the same color the generated color from the RGB values is (Charoensawan, 2018).

2.6 Development of Online Platform

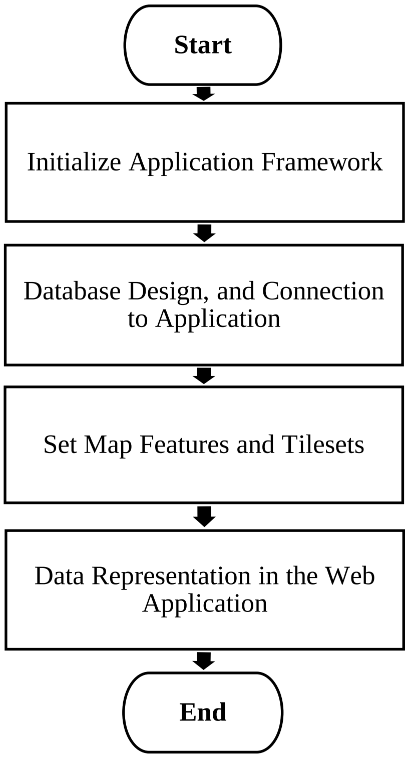


Fig. 8 Development of Online Platform

Figure 8 shows how the online platform was developed. The Laravel framework also can communicate and create SQL commands to the database that is bundled with XAMPP. The database must also be configured to allow the device to communicate with it. It is done through the permission. The SQL query of the soil test device must include a username and password that the database must recognize for it to successfully communicate with it. The online platform must have a Tile set, which is essentially a map which also contains certain geographic features and information. The data is loaded from the database to the online platform. The soil data is bundled through layers. For example, the nitrogen layer will show the nitrogen levels of all the soil samples inside the area that a sample represents.

3. DISCUSSION OF RESULTS

TABLE I

DATA GATHERING TABLE

Sample Name	pH & Nutrient	Laboratory Results (Expected)	Device (Observed)
Soil A	pH	7.6	7.6
	N	Medium	Medium
	P	High	High
	K	Sufficient	Sufficient
Soil B	pH	7.2	7.2
	N	Low	Low
	P	High	High
	K	Sufficient	Sufficient
Soil C	pH	7.6	7.6
	N	Low	Low
	P	High	High

	K	Sufficient	Sufficient
Soil D	pH	7.2	7.2
	N	Low	Low
	P	Low	Low
	K	Sufficient	Sufficient
Soil E	pH	7.2	7.2
	N	Medium	Medium
	P	Low	Low
	K	Sufficient	Sufficient

Table I shows the data gathering table for the five soil samples. The laboratory results and device column are the two methods of testing the soil sample for the level of its macronutrients. Each soil sample has four macronutrients to be tested. Each row for the soil sample shows the level read for the laboratory test and device test for the corresponding macronutrient. The reading for the four macronutrients of each soil sample will be repeated for ten trials which will reflect on the contingency table on Table II.

TABLE II

CONTINGENCY TABLE OF PH AND MACRONUTRIENTS

Sample Name	**pH & Nutrient**	**Laboratory Results (Expected)**	**Device (Observed)**	**Total**
Soil A	Ph	10	10	20
	N	10	10	20
	P	10	10	20
	K	10	10	20
Soil B	pH	10	8	18
	N	10	10	20
	P	10	10	20
	K	10	10	20
Soil C	pH	10	10	20
	N	10	10	20
	P	10	10	20
	K	10	10	20
Soil D	pH	10	7	18
	N	10	10	20
	P	10	10	20
	K	10	10	20
Soil E	pH	10	9	19
	N	10	10	20
	P	10	10	20
	K	10	10	20
Total		200	194	394

Table II is the contingency table for pH and macronutrient. The laboratory result and device columns are the type of testing method done on the soil samples. Five soil samples were tested. N, P, K, and pH will be the macronutrients that will be tested in each soil sample. The rows show the frequency of successful trials of each macronutrient for the laboratory testing and device testing

3.1 Results of Statistical Treatment

Since the study will be dealing with a single sample population with two type of measurement methods (through laboratory tests and through the device) and we want to know whether the results will be similar or different to the observed device's result and with the laboratory results given a number of samples, the statistical treatment to be used for this research is Chi-Square Goodness-of-fit.

$$x^2 = \sum_{i}^{n} \frac{[O_i - E_i]^2}{E_i} \quad (2)$$

H_o ($p \leq 0.05$): The device result fits the frequency distribution of the trials of the laboratory test.
H_a ($p > 0.05$): reject the null hypothesis

To determine the critical value x^2, equation 2 will be used wherein O_i is the observed frequency count and E_i is the expected frequency count. Using the table for critical values, the expected critical values should not exceed 3.84 given that the benchmark value is 0.05 with level of confidence of 95%. From the data collected from Table I in testing the device performance against the laboratory result the computed Chi-Square method values is equal to 1.4 which is lower than the critical value of 3.84. Since the computed values of Chi-Square is less than the critical value we can conclude that the device result fits the frequency distribution of the trials of the laboratory test.

4. CONCLUSION AND FUTURE WORK

The objective of the work soil nutrient level determination system is satisfied through the methods and techniques to finding color of a given sample while having the advantage of easy hardware construction and portability. The experimental results show that the constructed system is accurate in determining the level of the soil nutrient through color detection given the solution from the used test kit.

The measurement of our current system requires the preparation of a solution from a certain testing kit and is limited to the three macronutrients of the soil and its pH level. For future works, the researchers suggest the inclusion of the secondary macronutrients for plants namely; magnesium, sulfur and calcium.

5. REFERENCES

[1] Adhikary, T; Das, A. K.; Razzaque, M. A.; M. E. H. Chowdhury, and S. Parvin, "Test implementation of a sensor device for measuring soil macronutrients," 2015 International Conference on Networking Systems and Security (NSysS), 2015.

[2] Agarwal, S., Bhangale N.; Dhanure, K., Gavhane, S.; Chakkarwar, V. and Nagori, M. "Application of Colorimetry to Determine Soil Fertility through Naive Bayes Classification Algorithm," 2018 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT), 2018.

[3] Bolivar, L. E. P. and Silva, G. A. D. "Solar radiation monitoring using electronic embedded system Raspberry Pi database connection MySQL, Ubidots and TCS-230 sensor," 2015 CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON), 2015.

[4] Cabaccan, C. N.; Reidj, F. and Cruz, G. "Power Characterization of Raspberry Pi Agricultural Sensor Nodes Using Arduino Based Voltmeter," 2018 3rd International Conference on Computer and Communication Systems (ICCCS), 2018.

[5] Caya, M. V. C.; Alcantara, J. T. ; Carlos, J. S. and Cereno, S. S. B. "Photosynthetically Active Radiation (PAR) Sensor Using an Array of Light Sensors with the Integration of Data Logging for Agricultural Application," 2018 3rd International Conference on Computer and Communication Systems (ICCCS), 2018.

[6] Charoensawan, P.; Phongsuphap, S. and Shimizu, I. "Comparison of Fabric Color Naming Using RGB and HSV Color Models," 2018 15th International Joint Conference on Computer Science and Software Engineering (JCSSE), 2018.

[7] Gravesen, J. "The metric of colour space," Graphical Models, vol. 82, pp. 77–86, 2015.

[8] Jawahar, M.; Divya, K. and Thankaiselvan, V. "Sensor based color sorting system for leather shoe components," 2017 Third International Conference on Sensing, Signal Processing and Security (ICSSS), 2017.

[9] Masrie, M.; Rosman, M. S. A.; Sam, R; and Janin, Z, "Detection of nitrogen, phosphorus, and potassium (NPK) nutrients of soil using optical transducer," 2017 IEEE 4th International Conference on Smart Instrumentation, Measurement and Application (ICSIMA), 2017.

[10] Regalado, R. G. and Cruz, J. C. D. "Soil pH and nutrient (Nitrogen, Phosphorus and Potassium) analyzer using colorimetry," 2016 IEEE Region 10 Conference (TENCON), 2016.

[11] Sreedevi, A. A, L. R; A. Sreedevi, "Automatic soil nutrient detection and fertilizer dispensary system," 2016 International Conference on Robotics: Current Trends and Future Challenges (RCTFC), 2016.

[12] Supannarach, S. and Thanapatay, D. "The study of using RGB color sensor to measure the Curcuminiods amount in Turmeric (Curcuma longa Linn.) and Zedoary (Curcuma Zedoarie Rose.) by comparing colors with HSL system," 2008 5th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, 2008.

[13] Vernekar S. R.; I. A. P. Nazareth, J. S. Parab, and G. M. Naik, "RF spectroscopy technique for soil nutrient analysis," 2015 International Conference on Technologies for Sustainable Development (ICTSD), 2015.

[14] Yumang, A. N. ; Avendano, G. O. ; Cruz, J. C. D.; Ballado, A.; Agustin, L. E.; Mundo, D. M. D. ; Dacalos, J. E.; Roble, J. K. and Caya, M. V. "Microcontroller-based fertilizer dispenser for rice crop," 2016 6th IEEE International Conference on Control System, Computing and Engineering (ICCSCE), 2016.

[15] Yumang, A.N.; Paglinawan, A. C.; Perez, L. A. A.; Fidelino, J. F. F. and Santos, J. B. C. , "Soil infiltration rate as a parameter for soil moisture and temperature based Irrigation System," 2016 6th IEEE International Conference on Control System, Computing and Engineering (ICCSCE), 2016.