*Section A-Research paper*
*ISSN 2063-5346*

# SPECTROMETRY FOR NITROGEN AND PHOSPHOROUS MACRONUTRIENTS DETECTION IN A SOIL

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Keywords:

*Absorption Principle; Nitrogen; Phosphorus; Soil Nutrient Tester*

A B S T R A C T

*Soil testing is a tool to diagnose the fertility status of the soil by determining the number of essential nutrients such as NPK macronutrients. The study developed a Soil Nutrient Tester (SNT) that uses the visible light spectrum and absorption principle to measure Nitrogen (N) and Phosphorous (P) in soil. This study aims to develop an inexpensive soil N-P nutrient tester and have an accuracy comparable to the spectrophotometer used in the laboratory. The SNT utilizes an RGB color sensor to detect the transmitted light passing through the sample solution. It used Arduino Uno Microcontroller as the brain of the device and an RGB LED as a light source that emits 450 nm and 700 nm wavelengths for N and P, respectively. The device results were compared and calibrated with the measurements of the Hitachi U-1800 Spectrophotometer to improve its accuracy and precision. Results revealed that the device is 97% accurate in measuring the concentration of the nutrients. The device was also able to reduce cost and the time spent evaluating N-P nutrient content. This device will allow farmers and home gardeners to regularly check their soil's N-P nutrient status to decide the proper amount of fertilizer to apply.*

## 1. INTRODUCTION (ALL CAPS – TIMES NEW ROMAN 11pt, BOLD, LEFT, HANGING 0.5cm)

Soil Testing is a tool to diagnose the fertility status of the soil. It determines the concentration of essential nutrients in a soil sample. If deficient, it allows the recommendation of the right kind of fertilizer or other soil ameliorants at the right amount and timing of application. Soil tests are essential in ensuring the health of your lawn or ploughland where vegetable crops or plants are cultivated. To warrant a high yield of produce during harvest, plants should receive a balance of the proper nutrients it needs.

These soil nutrients are the N-P-K macronutrients. These three nutrients are essential to the survival of every plant. Nitrogen (N) is vital to chlorophyll, allowing plants to carry out photosynthesis and it aids in the compounds that allow for energy storage and use. Phosphorus (P) promotes roots and growth. At the same time, Potassium (K), sometimes referred to as the "Quality Element," is essential in regulating processes in the plant, such as osmosis and enzyme activities. Measuring and provisioning the amount of these three soil nutrients are vital for proper plant growth and adequate fertilization. It is impossible to tell just by

looking at the soil if it receives enough nutrients. Thus, researchers and interested individuals find ways to test their soil regularly without consuming time and spending money on a local testing laboratory whenever they need soil testing.

Today, there are two methods to test N-P-K macronutrients available at the regional soil laboratory. The Soil Test Kit or STK shows how much Nitrogen, Phosphorous, and Potassium your soil holds through the color change it has undergone. Although cheap, test kits sometimes don't provide the most accurate results. The second method is having it tested using the UV-Visible Spectrophotometer. The result will give you a precise quantity of the N-P-K nutrients and make it a better choice than the former on choosing a fertilizer, but testing is expensive. In search of a cheaper solution, many researchers have tried to develop NPK detection devices from various methods, including optical, electrochemical, acoustic, electromagnetic, and mechanical sensors. Among these methods, the optical detection method was recently identified to have a higher potential for real-time detection because of its extreme sensitivity and fast response.

There are various reasons why farmers are not having their soil tested despite its benefits. The first is the high testing fee, 750php for the three major nutrients. Some even choose a cheaper STK (Php 100.00) that will give a rather vague result but is better than not having their soil tested at all. Another major factor limiting farmers in performing soil tests is time and distance. Soil analysis processing time is long because tests are conducted by batch to maximize chemical solutions used in soil sample preparation. Also, chemical analysts would then have to draft the test results and interpret them manually before giving fertilizer recommendations. These tests are conducted only in regional soil labs; thus, they must travel far, which adds to the farming costs, which most farmers do not have.

This study aims to create a soil nutrient tester using LED as its optical transmitter based on the absorption principle that will give a real-time detection of the content of each nutrient in a sample of soil. Specifically, this aims to answer the following questions:

1. Is there a significant difference between the measurements of the quartz cuvette being utilized at the Department of Agriculture Region V Soils Laboratory and the glass cuvette used by the proponents?
2. What are the best light wavelengths to produce accurate results?
3. Are the device measurements accurate and precise compared to the concentration measurements of the Regional Soils Laboratory?
4. Will the device reduce the time spent evaluating the amount of Nitrogen and Phosphorus nutrients in a soil sample?
5. Is the device a cheaper method of testing Nitrogen and Phosphorus nutrients?

This study is limited to designing, developing, and evaluating a soil nutrient tester for Nitrogen (N) and Phosphorus (P) macronutrients in soil. The resulting output will be the content of each nutrient in the sampled soil through ranges set at HIGH, MEDIUM, and LOW parameters, which apply for both Nitrogen and Phosphorus. The results were compared using the Hitachi U-1800 Spectrophotometer at the Department of Agriculture Region V Soils Laboratory.

Soil Testing is a tool to diagnose the fertility status of the soil. It determines the concentration of essential nutrients in a soil sample. If deficient, it allows the recommendation of the right kind of fertilizer or other soil ameliorants at the right amount and timing of application. Soil tests are essential in ensuring the health of your lawn or ploughland where vegetable crops or plants are cultivated. To warrant a high yield of produce during harvest, plants should receive a balance of the proper nutrients it needs. This study is significant to the following recipients:

**Farmers and home gardeners.** The device will allow them to check their soil's health status regularly. The device is cheaper than the Hitachi U-1800 Spectrophotometer used at the Regional Soils Laboratory and will help farmers save the money they will spend every time they go and request a soil test. The device will also reduce their time evaluating nitrogen and Phosphorus nutrients in a soil sample.

**Department of Agriculture.** This device can provide a cheaper alternative to the currently used Spectrophotometer.

**Future Researchers.** This research can provide new insights into spectroscopy in measuring nutrients in a soil sample.

## 2. METHODOLOGY

This study employs a qualitative descriptive research design to explore, describe, and understand the broad collective challenges of soil testing and create an innovative solution to address the challenges. This approach will gather descriptive quantitative items of the sample's nutrient content and compare the result to the commercially procured soil testing equipment the Regional Soil Laboratory is currently using. Elements of the real-time data capture will also be used to test the

reliability, accuracy of the device, and speed in displaying test results. This approach is used to understand the research problem and give an elegant solution through experimentation and analysis. It aims to describe the characteristic of the sample and assess both the performance and cost. Use of qualitative description permits. The data vital to this research will be gathered by experimentation in the Regional Soil Laboratory.


**Figure 1.** Conceptual Framework

Fig. 1 illustrates the conceptual framework of the Soil N-P Nutrient Detector. The first step is calibrating the device using the cuvette with distilled water. After calibration, the second step is to put the soil solution's cuvette. The device will then test the sample, and the Arduino Microcontroller processes the resulting absorption level and calculates the test result. The LCD will then display the qualitative characteristics of the soil sample with ranges of Low, Medium, and High. These results can now be a basis for choosing a suitable crop fertilizer.

## 2.1 Design Discussion


**Figure 2.** Block Diagram

Fig. 2 illustrates the process and interconnection of the components of the device. First, incident light flashes at the soil solution, and an absorption process occurs. The sensor will then read the transmitted radiation that passed through the solution. Afterward, the microcontroller will read the output from the sensor and process it for further computation of the concentration of a nutrient in the sample. Finally, the LCD shows the soil nutrient levels.

## 2.2 Program Flowchart

The program flow of the device is illustrated in Fig. 3. The program starts with the calibration – a cuvette filled with water is inserted in the sample compartment – and after the LED flashes a different wavelength of light, the LCD will display a notification that the calibration has been completed and will now start the testing process. The LCD will display directions for the user's convenience. The testing process will begin with Nitrogen; the LCD will ask the user to insert the desired soil sample solution and press the mode button that commands the program to continue to the next test. When done, the program will test the Phosphorus content of the same soil sample. After testing, the microcontroller will perform algebraic operations to compute the nutrient concentration in the soil sample. The result displayed in the LCD is based on the proponent's set range for each parameter.


**Figure 3.** Program Flowchart

## 2.3 Device Model Design

The designed model of the device is composed of a few parts. The said parts are LCD (Liquid Crystal Display), Push Buttons, Switch, Sample Compartment, Sensor, LED (Light Emitting Diode), Cuvette, and a charging input. The designed device is shown in Fig. 4. The figure shows the developed model from various viewing angles. It also shows the position of the different parts of the designed model.

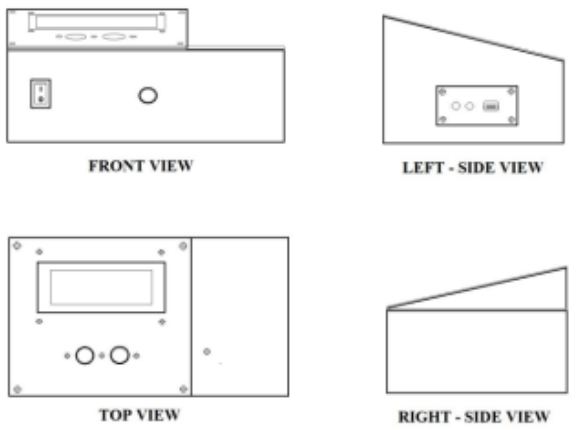


**Figure 4.** Device Design

## 2.4 Schematic Diagram

This section discusses the schematic design of the device. This includes the component used, its function, and how the specific element for the device was chosen. The schematic diagram in Fig. 5 shows the different components used in the devices and how they are connected for proper circuit operation.

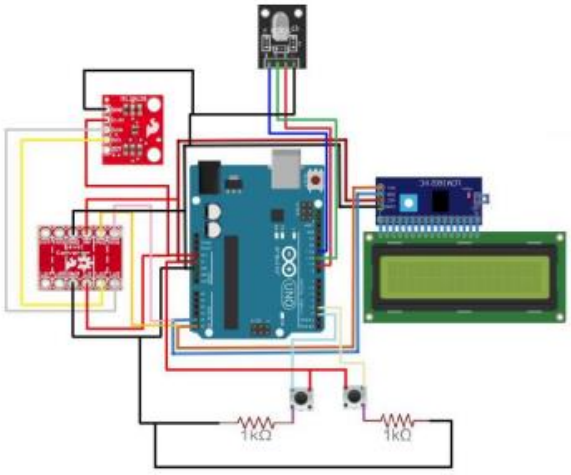


**Figure 5.** Schematic Circuit Diagram

A single pole single throw (SPST) switch is the main switch connected to the power source, a rechargeable lithium battery. It enables the user to switch the device on and off. The ISL 29125 RGB Sensor is used to read the color absorption. It measures the light intensity passing through the soil sample and converts it to electrical signals. The sensor has an on-chip ADC converting electrical signals to digital counts. The ISL 29125 is chosen for its high sensitivity and accurate RGB spectral response. The sensor is also easy to interface with the microcontroller. This sensor runs on 3.3V logic, requiring a bidirectional logic level converter that steps down the 5V power from the microcontroller. The level converter is easy to use. The board needs to be powered from the two voltage sources (high and low voltage) that the system is operating, in this case, 5V and 3.3V.

For the microcontroller, Arduino Uno is used. The microcontroller will act as the brain of the device. It processes the acquired data from the sensor and performs algebraic operations. The proponents chose this microcontroller because it provides enough RAM (Random Access Memory) and ROM (Read Only Memory) for the proper operation of the device. The RAM is the one that provides the smooth flow of functions of the microcontroller, and the ROM is responsible for the storage of the main program on the microcontroller. Arduino Uno is also chosen because the device only utilizes a few components.

The device uses a 20 x 4 LCD (liquid crystal display) to show the Nitrogen and Phosphorus nutrient content in each soil sample. The user will view if the soil has a Low, Medium, or High range of the nutrient being tested. Initially, the LCD shows various instructions that shall be followed by the user for proper testing procedures when using the device. The LCD will then display what button should be pressed and what sample shall be placed inside the sample compartment. After following the instructions shown in the LCD, it will now display the content of each nutrient on a soil sample in its specified ranges.

An RGB LED module is utilized as the light source of this device. This LED plays a vital role because the illuminated light is the basis for the absorption in the sample. The instrument used a diffused common cathode LED, and the wavelength of the light was varied in the program using HEX codes. The RGB LED is located inside the sample compartment and placed directly parallel to the cuvette and sensor.

## 2.5 Determining the Concentration Equations

The Soil Nutrient Tester device contains one (1) RGB color sensor that detects the transmitted light that passed through the sample. The ISL 29125 RGB color sensor has three photodiode arrays that convert light transmitted into the current readings. The current output is converted to a digital count by an on-chip Analog-to-Digital Converter (ADC) at the light-to-signal processor. The ADC converter resolution is selectable from 12 to 16 bits with a full-scale ADC code of 65535 counts. The proponents used the ADC count value that was read by the sensor. It is integrated into the Beer–Lambert's Equation as the baseline, which indicates the value for when the light passed through an optically

transparent solution (i.e., water), and the current reading, which specifies the amount of absorption that took place when the light passed through a soil solution. The equations are as follows:

For Nitrogen,

$$A_N = \log_{10}\left(\frac{baseline}{currentReading}\right) \quad (1)$$

For Phosphorus,

$$A_P = \log_{10}\left(\frac{baseline}{currentReading}\right) \quad (2)$$

Now that we have a result for the absorption that took place for each nutrient, the microcontroller will continue to determine each nutrient's concentration on the soil sample. The proponents used the calibration standard shown in Tables 1 and 2 used during the initial tests conducted at the Regional Soils Laboratory to obtain equations for the concentration of each nutrient.

**Table 1.** Calibration Standards for Phosphorus

| Standard No. | Vol. of 50 mg/L Stock solution (mL) | Final Volume (mL) | Concentration of working std. (mg/L P) | Equivalent concentration in soil (mg/L P) |
|---|---|---|---|---|
| 1 | 1 | 250 | 0.2 | 4 |
| 2 | 1 | 100 | 0.5 | 10 |
| 3 | 2 | 100 | 1.0 | 20 |
| 4 | 4 | 100 | 2.0 | 40 |
| 5 | 6 | 100 | 3.0 | 60 |
| 6 | 8 | 100 | 4.0 | 80 |

**Table 2.** Calibration Standards for Nitrogen

| Standard No. | Mass of O.C. (mg) | Sucrose Solution (mL) | $H_2O$ (mL) | $K_2Cr_2O_7$ (mL) | $H_2SO_4$ (mL) | $H_2O$ (mL) |
|---|---|---|---|---|---|---|
| 1 | 0 | 0.00 | 2.00 | 2 | 5 | 18 |
| 2 | 1 | 0.25 | 1.75 | 2 | 5 | 18 |
| 3 | 2 | 0.50 | 1.50 | 2 | 5 | 18 |
| 4 | 3 | 0.75 | 1.25 | 2 | 5 | 18 |
| 5 | 4 | 1.00 | 1.00 | 2 | 5 | 18 |
| 6 | 5 | 1.25 | 0.75 | 2 | 5 | 18 |
| 7 | 6 | 1.50 | 0.50 | 2 | 5 | 18 |
| 8 | 7 | 1.75 | 0.25 | 2 | 5 | 18 |
| 9 | 8 | 2.00 | 0.00 | 2 | 5 | 18 |

Fig. 6 shows the relationship of the concentration and absorbance generated from the calibration standard for the Nitrogen Test set up at the Soils Laboratory.

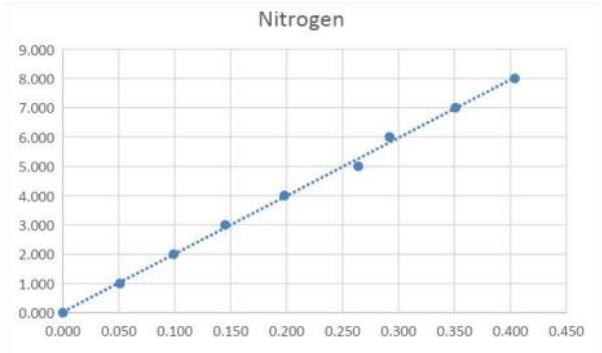


**Figure 6.** Calibration Standard for Nitrogen Result

To generate an equation from the graph, the linear best-fit function in excel was utilized. The regression line can be considered an acceptable estimation of the actual relationship between concentration and absorbance.

$$absorbanceN = 19.822 concentrationN + 0.0044 \quad (3)$$

It is notable to mention that the R-squared indicated after generating the regression equation represents the proportion of the variance for the concentration explained by the absorption shown in the regression model. The output is considered good when the R-squared is not lesser than 0.995; wherein, 1 is the most desirable proportion. A low R-squared value, in this research, accounts for an improper setup of the chemicals prepared for testing and will lead to a not very accurate measurement of the concentration.

From this equation, the formula for the Nitrogen concentration can be derived:

$$concentrationN = 0.05044899606497830693 absorbanceN - 0.0013520330945141862 \quad (4)$$

The generated equation for Nitrogen concentration was used to determine the Organic Carbon. The result will then be integrated and processed to determine Nitrogen's Percent Organic Matter (%OM) content.

$$OC = \frac{concentrationN}{0.5 \times 1000} \times 100$$
$$OM = OC \times 1.72 \quad (5)$$

$$N = OM \times 0.05$$

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*ISSN 2063-5346*

*where:*
*OC = Organic Carbon*
*OM = Organic Matter*
*N = % OM of Nitrogen*

Sequentially solving for the indicated equations will provide the %OM content of Nitrogen which can now be translated to the following Soil Test Characteristic based on the Regional Soils Laboratory Standard Operating Procedure (SOP):

$High: \%OM \geq 4.5\%$
$Medium: \%OM\ is\ between\ 2.1 - 4.5\%$
$Low: \%OM \leq 2.0\%$

Similar procedures were conducted to determine the concentration of Phosphorus. Fig. 7 shows the relationship between the concentration measured and absorbance generated from the calibration standard for the Phosphorus Test that was set up at the Soils Laboratory.

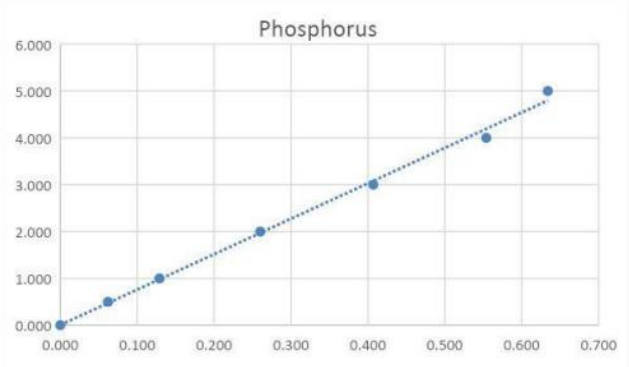


**Figure 7:** Calibration Standard for Phosphorous Result

The regression equation generated from the linear best-fit function gives an acceptable estimation of the actual relationship between concentration and absorbance for Phosphorus.

$$absorbanceP = 7.5608 concentrationP + 0.0044 \quad (6)$$

The equation for the concentration of Phosphorus is derived from the regression equation.

$$concentrationP = 0.13226113638768394298 absorbanceP - 0.00581949000105808909 \quad (7)$$

The Phosphorus concentration equation is multiplied by a factor of 20 to find the Parts per Million (PPM) equivalent. The result is then translated to the Soil Test Characteristic for Phosphorus based on the Soil Lab Standard operating procedures.

$High: PPM \geq 20$
$Medium: PPM\ is\ between\ 10 - 20$
$Low: PPM \leq 10$

## 3. DATA GATHERING

To determine the reliability of the proponent's device, several tests were conducted at the Regional Soils Laboratory, a branch of the Department of Agriculture (DA), in Del Rosario, Naga City. Tests were conducted by comparing results with the reference device, Hitachi U-1800 Spectrophotometer, and the researcher's device. The samples used were taken from different places in Camarines Sur, such as San Juan Pagao, Bombon (sample 1), Paolbo, Calabanga (sample 2), and Carolina, Naga City (sample 3).

### 3.1 Soil Procurement

1. Prepare the following tools: bucket, shovel, bolo, and a pouch or sack.
2. Divide the perimeter of the land according to
    a. Soil color
    b. Texture
    c. Amount of Fertilizer
3. Every soil sample is taken from a 5-hectare perimeter, divided according to the type of crop planted, kind of soil, and topography needs a (1) kilo of the composite sample. Get a soil sample after the harvesting season or before putting a fertilizer. Don't get a soil sample in the same place the fertilizer was embedded or where crops are planted.
4. Using the shovel, dig in the soil a 20 cm deep V-shaped sample, 2 cm thick and 5 cm wide. Place it in the bucket, then repeat the process until ten samples are taken. Gently blend and grind the samples.
5. Lay the composite sample in a sack, then air-dry. Make sure not to mix the soil samples and that no dirt will be included.
6. When dried, crash it again until fine, then divide it into four (4) parts. Take the 2nd and 4th portion, then throw the 1st and 3rd. Repeat four (4) times until it weighs a half kilo. Afterward, store it in a pouch.

### 3.2 Preparation of Soil Solution

Materials:

1. Measuring cups
2. Container (e.g., plastic bottle)
3. Distilled water
4. Soil

Instructions:

1. Measure two teaspoons of soil and put them in the container.
2. Measure a ¼ cup of water and put it in the container with the soil.
3. Mix the soil and the water for 1 to 2 minutes.
4. Wait for 3 to 5 minutes for the undissolved soil to rest at the bottom of the container. 5. Slowly transfer the soil solution to the cuvette and avoid the undissolved soil transferred to minimize the error.

## 4. RESULTS AND DISCUSSION

### 4.1 Comparison of Quartz and Glass Cuvette

The device utilizes a glass cuvette as it is cheaper than the quartz cuvette used at the Department of Agriculture Region V Soils Laboratory. This test will determine whether there is a significant difference in absorbance between the two cuvettes. Using the calibration standards made by the chemist at the soil's laboratory, glass and quartz cuvettes were tested in the reference device.
Table 3 shows the test results when comparing a glass cuvette with a quartz cuvette using calibration standards for phosphorus.

**Table 3.** Comparison of Quartz and Glass Cuvette using Calibration Standard for Phosphorus

| Standard No. | Quartz Cuvette | | Glass Cuvette | |
|---|---|---|---|---|
| | ABS | CONC | ABS | CONC |
| 1 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 0.061 | 0.500 | 0.077 | 0.500 |
| 3 | 0.143 | 1.000 | 0.144 | 1.000 |
| 4 | 0.266 | 2.000 | 0.278 | 2.000 |
| 5 | 0.411 | 3.000 | 0.416 | 3.000 |
| 6 | 0.543 | 4.000 | 0.554 | 4.000 |
| 7 | 0.640 | 5.000 | 0.652 | 5.000 |
| | p-value = | 0.9516 | α = | 0.05 |

To identify whether there is a significant difference between the two cuvettes in terms of absorbance in Phosphorus, a t-test was conducted. The statistical test revealed that the p-value, 0.9516, is greater than the level of significance, 0.05; thus, we fail to reject the null hypothesis. This means that there is no significant difference between the absorbance of the two cuvettes. This suggests that using a glass cuvette will not affect the results of the device for Phosphorus.

Table 4 shows the test results when comparing a glass cuvette with a quartz cuvette using calibration standards for nitrogen.

**Table 4.** Comparison of Quartz and Glass Cuvette using Calibration Standard for Nitrogen

| Standard No. | Quartz Cuvette | | Glass Cuvette | |
|---|---|---|---|---|
| | ABS | CONC | ABS | CONC |
| 1 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2 | 0.051 | 0.500 | 0.060 | 0.500 |
| 3 | 0.099 | 1.000 | 0.118 | 1.000 |
| 4 | 0.145 | 2.000 | 0.173 | 2.000 |
| 5 | 0.198 | 3.000 | 0.229 | 3.000 |
| 6 | 0.264 | 4.000 | 0.288 | 4.000 |
| 7 | 0.292 | 5.000 | 0.367 | 5.000 |
| 8 | 0.351 | 6.000 | 0.411 | 6.000 |
| 9 | 0.404 | 7.000 | 0.455 | 7.000 |
| | p-value = | 0.6449 | α = | 0.05 |

To identify whether there is a significant difference between the two cuvettes in terms of absorbance for Nitrogen, a t-test was conducted. The statistical test revealed that the p-value, 0.6449, is greater than the level of significance, 0.05; thus, we fail to reject the null hypothesis. This means that there is no significant difference between the absorbance of the two cuvettes. This suggests that using a glass cuvette will not affect the results of the device for Nitrogen.

### 4.2 Comparison of Quartz and Glass Cuvette

This test is conducted to identify the best wavelength to be used when measuring Nitrogen and Phosphorus. The results are compared to the results of the reference device. The reference device utilizes the wavelength 627 nm for N and 882 nm for P. Initially, the wavelength of the proposed device was set to these wavelengths, and the samples were tested. The results show that the average percent error is above the designated 5% tolerance of the device's design, as shown in Table 5.

The percent error is calculated using the formula:

$$\%error = \frac{Output_{reference} - Output_{proposed}}{Output_{reference}} \times 100 \quad (10)$$

**Table 5.** Initial Test for Wavelength (N = 627 nm and P = 882nm)

| | Nitrogen | | | Phosphorus | | |
|---|---|---|---|---|---|---|
| | Reference Device | Proposed Device | Percent Error | Reference Device | Proposed Device | Percent Error |
| 1 | 3.14 | 3.58 | 14.01% | 23.82 | 39.61 | 66.29% |
| 2 | 0.41 | 0.29 | 29.27% | 22.02 | 39.61 | 79.88% |
| 3 | 3.71 | 3.41 | 8.09% | 24.42 | 39.61 | 62.20% |
| | | Ave = | **17.12%** | | Ave = | **69.46%** |

Several wavelengths were tested to determine the wavelength that will produce the best results, and the percent error was calculated. Based on the results, the wavelengths that had the least error are 450 nm for nitrogen and 700 nm for phosphorus. This is parallel to the study results by Yusof et al.

## 4.3 Test for Accuracy

To test the accuracy of the proposed device, its reading is compared to a reference device specifically, Hitachi U-1800 UV/VIS Spectrophotometer, the instrument used in the Regional Soil Lab. The percent error is used to determine if the proposed device is accurate or within the tolerance.

For Nitrogen, the test results revealed that for three samples, the device is 96.97% accurate. Table 6 summarizes the results of the accuracy test for Nitrogen.

**Table 6.** Accuracy Test: Nitrogen

| Sample | Reference Device | Proposed Device | Percent Error (%) |
|---|---|---|---|
| 1 | 3.14 | 3.252 | 3.57 |
| 2 | 0.41 | 0.421 | 2.68 |
| 3 | 3.71 | 3.605 | 2.83 |
| | | Average | 3.03% |

p-value = 0.93248 α=0.05

To identify whether the measurements are within the acceptable standard measurements, a paired t-test is conducted. The statistical test revealed that the p-value, 0.93248, is greater than the level of significance, 0.05; thus, we fail to reject the null hypothesis. This means that there is no significant difference between the measurements of the two devices for Nitrogen.

The same test was conducted for Phosphorous. The test results revealed that for three samples, the device is 98.98%. Table 7 summarizes the results of the accuracy test for Phosphorus.

**Table 7.** Accuracy Test: Phosphorus

| Sample | Reference Device | Proposed Device | Percent Error (%) |
|---|---|---|---|
| 1 | 23.82 | 22.87 | 3.99 |
| 2 | 22.02 | 22.87 | 3.86 |
| 3 | 24.42 | 24.124 | 1.21 |
| | | Average | 3.02% |

p-value = 0.825295 α=0.05

The statistical test revealed that the p-value, 0.825295, is greater than the level of significance, 0.05; thus, we fail to reject the null hypothesis. This means that there is no significant difference between the measurements of the two devices for Phosphorous.

These two results show that the device measurements are highly accurate and reliable, with an accuracy rate of 97% for Nitrogen and Phosphorus.

## 4.4 Precision Test

A precision test was conducted to determine whether the device could be trusted and reliably reproduce accurate results time after time. The three samples are measured for ten trials, and the standard deviation is calculated. Table 8 summarizes the results.

**Table 8.** Precision Test

| **Device** | Cost |
|---|---|
| **Hitachi U – 1800 Spectrophotometer** | P 398, 660.00 |
| Proposed Device | P 4,324.00 |

| Trial No. | Sample 1 | | Sample 2 | | Sample 3 | |
|---|---|---|---|---|---|---|
| | N | P | N | P | N | P |
| 1 | 3.31 | 22.87 | 0.43 | 22.87 | 3.63 | 22 |
| 2 | 3.27 | 22.87 | 0.43 | 22.87 | 3.56 | 24.96 |
| 3 | 3.27 | 22.87 | 0.42 | 22.87 | 3.54 | 24.96 |
| 4 | 3.2 | 22.87 | 0.42 | 22.87 | 3.61 | 24.96 |
| 5 | 3.27 | 22.87 | 0.42 | 22.87 | 3.57 | 22.87 |
| 6 | 3.24 | 22.87 | 0.42 | 22.87 | 3.59 | 22.87 |
| 7 | 3.26 | 22.87 | 0.42 | 22.87 | 3.67 | 24.96 |
| 8 | 3.23 | 22.87 | 0.42 | 22.87 | 3.64 | 24.96 |
| 9 | 3.25 | 22.87 | 0.42 | 22.87 | 3.59 | 22.87 |
| 10 | 3.22 | 22.87 | 0.41 | 22.87 | 3.65 | 24.96 |
| Standard Deviation | 0.031198 | 0 | 0.005676 | 0 | 0.04223 | 1.217767 |

The results revealed slight variation among the results for all three samples, as seen in the small values of the standard deviation. The results indicate that the proposed device is precise in giving its measurements.

### 4.5 Latency Test

The Latency Test compares the speed of the proposed device to the reference device to determine which is faster in giving the result. Table 9 shows the time it takes to determine the nutrient levels, starting from when the cuvettes were placed inside the sample compartment of each device to the result being translated to its quantitative equivalent. Through a Stopwatch, the proponents could determine the speed for each test conducted in a minute-second.

**Table 9.** Latency Test

| Trial | Reference device (minute: second) | Proposed Device (minute: second) |
|---|---|---|
| 1 | 3:49 | 1:35 |
| 2 | 4:13 | 1:28 |
| 3 | 4:05 | 1:34 |
| 4 | 3:56 | 1:29 |
| Average | 4:00 | 1:31 |

The latency test reveals that the device successfully reduced the nutrient testing time. The proposed device is 2.63 times faster than the reference device in measuring nutrient concentrations.

### 4.6 Cost Comparison

Table 10 shows the cost comparison between the reference device and the proponent's device. The cost for the reference device refers to its market price, and the cost of the proponent's instrument is the total expense of the proponents in constructing the device. This reveals that the proposed device is 100 times cheaper than the device available in the market.

**Table 10.** Cost Comparison

## 4. CONCLUSION

After extensive research and further study related to the research, the study has successfully achieved its objectives. The device measured the concentration of Nitrogen and Phosphorus in a soil sample using Arduino Uno Microcontroller and ISL2915 RGB Sensor. The device utilizes the absorption principle to provide the nutrient concentrations of a soil sample in a glass cuvette. The device uses wavelength of 450 nm and 700 nm for measuring N and P, respectively.

The proposed device can substitute for the laboratory device in terms of accuracy and precision. The device has a significantly high accuracy rate of 97%. Also, as revealed by statistical analysis at a 95% confidence level, the device can provide accurate and precise measurements for Nitrogen and Phosphorous macronutrients in a soil sample within the tolerable margin of error.

The device was also able to successfully reduce the time spent evaluating Nitrogen and Phosphorus nutrients in a soil sample compared to the reference device. The device gives the results at an average time of 1 minute and 31 seconds which is 2.63 times faster than the reference device.

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*ISSN 2063-5346*

The Soil P-N Nutrient Tester device is also cheaper compared to Hitachi U-1800 Spectrophotometer used in the laboratory. The Hitachi U-1800 Spectrophotometer is recorded to cost 398,660.00 pesos, while the proponents' device has a price of less than 4,000 Php. The cost comparison demonstrates that the proposed device is a hundred times more affordable than the spectrophotometer on the market.

**Acknowledgement:** Special thanks to the College of Engineering and Architecture – Electronics Department and the Research Center of the University of Nueva Caceres for the support given to the researchers as this is carried out.

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