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Detection of Nitrogen, Phosphorus, and Potassium (NPK) nutrients of soil using Optical Transducer

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***Abstract*—An optical transducer is developed to measure and to detect the presence of Nitrogen (N), Phosphorus (P) and Potassium (K) of soil. Such transducer is needed to decide how much extra contents of these nutrients are to be added to the soil to increase soil fertility. This can improve the quality of soil and reduces the undesired use of fertilizers to be added to the soil. The N, P, and K value of the sample are determined by absorption light of each nutrient. The optical transducer is implemented as a detection sensor which consists of three LEDs as light source and a photodiode as a light detector. The wavelength of LEDs is chosen to fit the absorption band of each nutrient. The nutrient absorbs the light from LED and the photodiode convert the remaining light that is reflected by reflector to current. The system utilizes an Arduino microcontroller for data acquisition therefore the output from the transducer is converted into a digital display reading. Testing on various samples of soils, showed that the optical transducer can evaluate the amounts of NPK soil content as High, Medium and Low.**

Keywords—Optical transducer, NPK soil, LED, photodiode, Arduino.

I. Introduction

In the world of advanced technology now various types of technology have been created to facilitate the daily activities of man. As well as in agricultural technology, a variety of tools that have been created to help farmers make their agricultural activities and get a good crop. To get a good crop, one of the important things that should be there is land that has adequate fertilizer. Adequate fertilizer can help plants produce good yields and quantities, to meet the needs of a world that is increasingly rising in need of food and food production. To improve the quality and quantity of crops, every country must contain sufficient nutrients, which consists of Nitrogen (N), Phosphorus (P), Potassium (K). These three elements nutrients promote the growth of the plant in different ways [1]; Nitrogen promotes the growth of leaves and vegetation, Phosphorus promotes root and growth and Potassium promotes flowering, fruiting and keeps regulation of nutrient and water in plant cell.

Previous researcher have developed NPK detection devices from various methods, including optical, electrochemical, acoustic, electrical and electromagnetic, and mechanical [2]. The optical detection method was recently identified to have higher potential for real-time detection because of its extremely sensitive as well as its fast response [3]. Several reports on NPK soil detection using optical method were reported [1, 4-6] in which the soil is illuminated by a light source and the absorption rate was evaluated by a light detector. Most of the developed devices were using additional optical component such fiber optic to drive the light to the soil [4, 5].

Optical detection method based on absorption principle is implemented in this study due to the optical characteristics own by NPK soil. The method of the detection does not need any additional component therefore it is considered as a direct detection method. LEDs are utilized as the light source as the soil interacts by absorbing the light. The remaining light is detected and the absorption rate is evaluated using photodiode that has the capability converting the light into current. The output from the photodiode is manipulated using Arduino microcontroller, as a result the output current is converted and displayed as output voltages.

II. Method

The overview of optical transducer for NPK soils detection is illustrated in Fig. 1. The optical transducer was formed by the integration of light transmission system and light detection system. The Arduino microcontroller was used to operate the light source in a transmission system. Apart from that, it was also used as a data acquisition from the light detection system and provides liquid crystal display (LCD) control functions to operate the display.

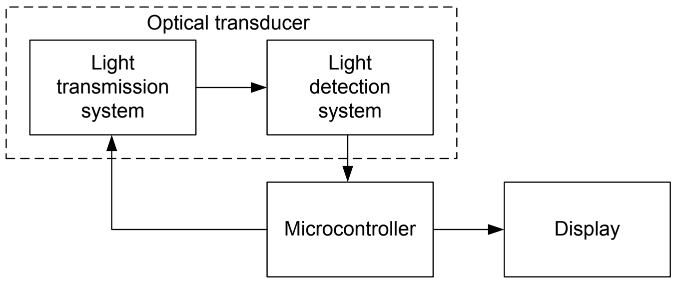

Fig. 1. Block diagram of integrated optical transducer with microcontroller

he light transmission system utilized three LEDs with different wavelength. Each of the LED was chosen according to the spectrum absorption wavelength by the NPK soils. Table I lists optical characteristics of NPK soil absorption and the corresponding LED emittance. The photodiode sensor module was applied as a light detector in the light detection system. Photodiode is a semiconductor that converts the light into current. Photodiode received the light reflected from the soil where the soil received the light from the LED. The light was converted into current by the photodiode and the data was sent to the Arduino controller for further analysis such as digital conversion and display. The overall optical transducer with microcontroller is shown in Fig. 1 and the schematic diagram is in Fig. 2.

TABLE I. OPTICAL CHARACTERISTICS OF NPK SOILS AND LED EMITTANCE

Nutrient	**Absorption wavelength (nm)**	**LED type**	**Wavelength (nm)**
Nitrogen (N)	438-490	LED 1	460-485
Phosphorus (P)	528-579	LED 2	500-574
Potassium (K)	605-650	LED 3	635-660

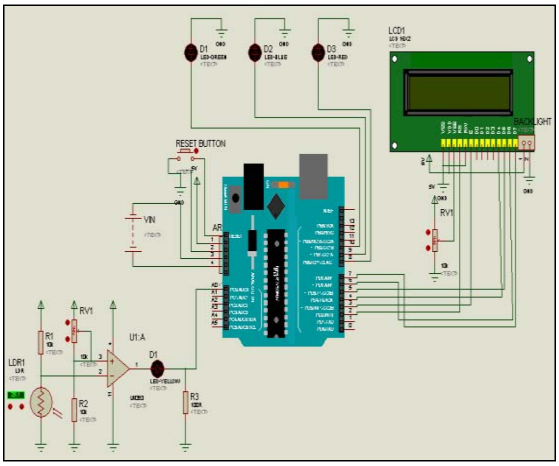

Fig. 2. Schematic diagram for overall optical transducer integrated with Arduino microcontroller

A. *Experimental Set-Up*

Before conducting the soil test measurement, the transducer was initially optimized by varying the distance between LED, reflector and photodiode sensor module as shown in Fig. 3 During measurement, the LED and the photodiode was positioned in parallel facing both in the same direction. The light gets reflected by the reflector and get detected by the photodiode. The effect of the incident light emitted to the detector was investigated to determine an optimum optical path length of the transducer. The LED substantially collimated the incident light in the range from 1 to 4 cm based on the requirement of the LED datasheet. The measurements were performed by varying the position of the LED and photodiode from the shortest to the longest distance.

The soil test absorption measurement was conducted using the developed optical transducer with six types of soils as illustrated in Fig. 4. Three types of the soils with different nutrient were obtained from a nursery shop while the other three were taken from residential areas. The sample specification is listed in TABLE II. Each of the soil samples with optimum thickness was placed on top of the reflector under the illumination of LED light. According to Beer's Law, absorbance (A) has the following equation;

$$A = -\log_{10} \frac{I_I}{I_0} \tag{1}$$

where I_1 is transmitted light and I_0 is incident light [7]. The difference in light intensity level was evaluated by the photodiode and the absorption rate was measured through the reflected light detected by the photodiode sensor module and convert into voltages. The detected voltage for each nutrient was compared with a threshold values that was developed by the Arduino microcontroller which was used to determine the deficiency of nutrient content in soil into three voltage levels; High, Medium and Low. These values were determined based on the absorption rate of each nutrient during the sample measurement.

TABLE II. SOIL SAMPLE SPECIFICATION

Soil sample	**Nutrient content**
Sample 1	High Nitrogen
Sample 2	High Phosphorus
Sample 3	High Potassium
Sample 4	Low nutrient
Sample 5	Low nutrient
Sample 6	Low nutrient

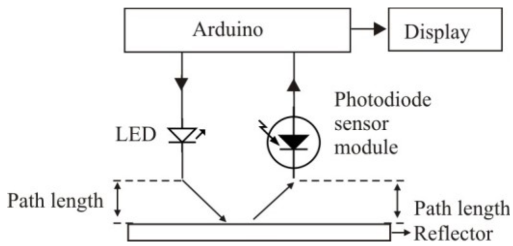

Fig. 3. Schematic diagram of the experimental setup for measuring light path length

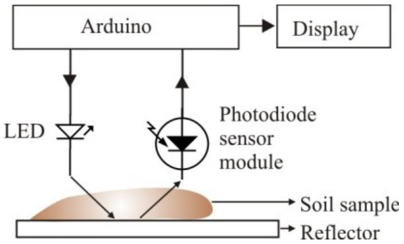

Fig. 4. Schematic diagram of the experimental setup for measuring soil sample

III. RESULTS AND DISCUSSION

The responses of the photodiode sensor module, due to LED illumination for different light path lengths are illustrated in Fig. 5. The comparison of all these responses is to determine the optimal path length within 1.0 to 4.0 cm. As it can be seen in Fig. 5, at a shorter length at 1 cm the highest amount of UV light was received by the photodiode. By increasing lengths of 2 - 4 cm, the voltage values showed a significant reduction in the quantity of voltage detected. Therefore, based on this analytical result and in comparison with other light path lengths, the optimum light path length of 1 cm was chosen due to its highest light intensity. TABLE III shows the threshold values for NPK soils in three voltage levels; High, Medium and Low. The value x indicates the voltage absorption for each nutrient.

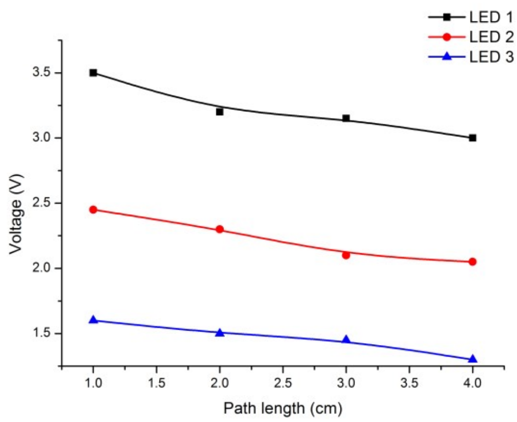

Fig. 5. Determination of optimum light path length

TABLE III. THRESHOLD VALUE FOR LOW, MEDIUM AND HIGH NUTRIENT IN SOIL SAMPLE

Nutrient	Low (V)	Medium (V)	High (V)
Nitrogen	3.5<x<3.8	3.8<x<4.1	x>4.2
Phosphorus	2.45<x<2.8	2.9<x<3.3	x>3.4
Potassium	1.6<x<2.2	2.3<x<2.8	x>2.9

The bar charts in Fig. 6. shows the voltage responses from the photodiode due to light illumination to the samples contain Nitrogen (N). The highest amount of Nitrogen contained in sample 1 as the value exceeded the threshold voltage at 4.51 V. Sample 2, 3, 4, 5 and 6 contain low of Nitrogen. Sample 2 contains High of Phosphorus, while Medium in sample 3 which is at 3.65 V and 3.5 V respectively as illustrated in Fig. 7. The threshold value for High Potassium in sample 3 is 3.83 V (Fig. 8.). Table 4 summarized the nutrient content in Sample 1, 2, 3 ,4, 5 and 6 based on the threshold value in Table 3. Therefore, the NPK soil content in each sample can be easily determined with only particular nutrient should be dispensed to the sample.

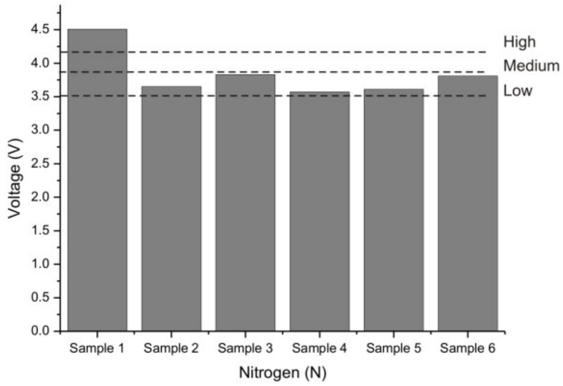

Fig. 6. Voltage responses for different soil samples containing Nitrogen

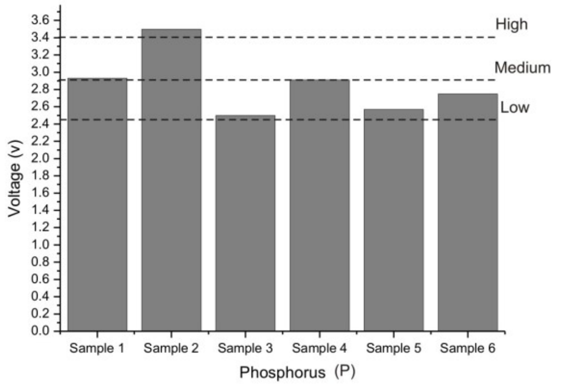

Fig. 7. Voltage responses for different soil samples containing Phosphorus

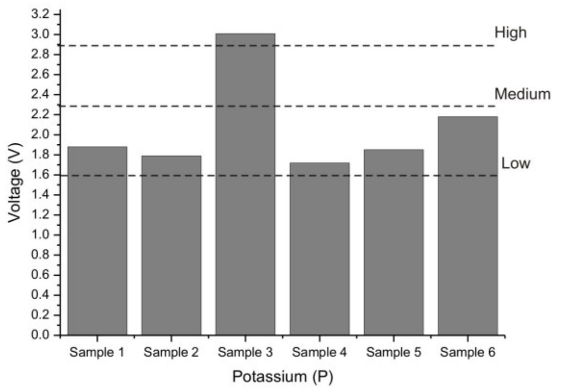

Fig. 8. Voltage responses for different soil samples containing Potassium

TABLE IV. THE NUTRIENT CONTENT LEVEL IN ALL SAMPLES

Sample	Nitrogen (N)	Phosphorus (P)	Potassium (K)
1	High	Medium	Low
2	Low	High	Low
3	Low	Low	High
4	Low	Low	Low
5	Low	Low	Low
6	Low	Low	Low

IV. CONCLUSIONS

As a conclusion, the optical transducer; LEDs and photodiode with Arduino microcontroller as an alternative method of determination of the deficiency N, P or K in the soil is successfully developed and tested. This project can reduce the problems in determining the amount of nutrients in soil with a cheaper cost with other technology. It can also reduce the undesired use of fertilizers to be added to the soil which can cause dead plants and reduce plant quality and quantity. This can be determined through to the light absorption of nutrients by the optical transducer and developed threshold values for each nutrient which decide the level of nutrients into three voltage levels: Low, Medium and High in the display. Based on the experimental results, the High nutrient of NPK soils found in Sample 1, 2 and 3.

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