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IoT Based Irrigation and Fertigation System for Smart Smallholder Farming Application

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Abstract

Integrating Internet of Things (IoT) technology with irrigation and fertigation systems has transformed traditional farming methods by enabling reliable monitoring and control of critical environmental parameters. This project aims to design an automated irrigation and fertigation system as a prototype to reduce water wastage and monitor the pH level in the soil, temperature, soil dryness and detection of intruders. Sensors strategically placed throughout the system monitor and control these elements. This system has several important features, including the ability to automatically control water pumps to maintain proper hydration levels, detect intruders within a range of one to six meters of the plant by using the Blynk app, and monitor pH levels through the same app to ensure appropriate neutral levels. Automation and control features are also assessed to confirm that sensors, pumps, and other components precisely respond in line with predetermined requirements. This evaluation helps to determine the overall health of the farmed plants as well as the effectiveness of the system. Finally, the irrigation and fertilizing system for the targeted smallholder farming area has been developed. The resulting smart irrigation and fertigation system is not only a practical solution but also an effective alternative to modern agricultural methods.

1. Introduction

Agriculture offers us a variety of benefits. We may survive by planting crops, and agriculture yields a wide range of goods, including cotton, rubber, wool, and other products [1]. Planting crops is essential because they are one of the primary food sources. Irrigation is the process of supplying a controlled amount of water through artificial means such as pipes, ditches, and sprinklers. The main goals of irrigation systems are to support agricultural crop growth, maintain landscapes, and lessen the impact of insufficient rainfall.

In contrast, fertigation is the process of introducing a combination of nutrients into plants through an irrigation system that can reduce water consumption and soil erosion by controlling fertilizer usage [2]. Small farmers in our country have used manual irrigation control methods. The land is irrigated regularly and at the same time each season. In this process, only a few plants in the zone receive more water, and only a few plants in the rest of the zone receive water late due to the drying of the crops. To save water, an irrigation controller that considers soil moisture sensors in each zone for water conservation is needed within the residential and commercial irrigation industry [3].

On the contrary, technological advances have led to a more efficient, less costly farming method that requires less time and labor but does not need any additional effort. They call it smart farming. The term "smart farming" refers to managing agricultural holdings that use technologies such as the Internet of Things, robots, drones and artificial intelligence to improve product quality and increase production volume whilst decreasing labor costs

[4]. Using fewer chemical pesticides and fertilizers will lessen soil, water, and air pollution. It also reduces dependence on resources and water, resulting in a sustainable farming practice by reducing GHG emissions from the agriculture sector. The proposed automated irrigation system will also be equipped with a PIR sensor. It detects intruders and protects plants at night, especially if disturbed or destroyed [5]. Hence, modern technology, like sensors, is used in smart farming to acquire essential data with less time and effort.

2. Methodology

In this section, the methodology is discussed in more detail, including the block diagram and flowchart for the system and the process, hardware, or software used to fulfil the objectives of the project. The suggested automated irrigation system is constructed as a prototype in the first phase of implementation. It uses a soil moisture sensor to measure the moisture content of the soil and helps conserve water. The motor pump automatically supplies the plants with water if the soil dryness is more than 50%. Conversely, the motor pump will automatically shut down if the value is below 50%. In the second phase of implementation, the user can also monitor the pH level from time to time in the Blynk application to make sure the pH level is always neutral to improve the plant's growth, and it can also monitor the temperature of the water. Additionally, the accuracy of the PIR system was validated by conducting experiments with hindrance and without hindrance. The result obtained showed that the PIR sensor can detect intruders within a one-meter range and constantly alert the users.

2.1 Block Diagram

Fig. 1 shows the block diagram of the project. The Arduino Durian UNO is used to meet all the requirements. The research utilized physical data through the use of sensors. These sensors precisely measured the soil moisture, amounts of water supply and detection of intruders. In the meantime, a water pump and a fertilizer pump assist in providing the plant with the necessary amount of water and fertilizer. If the pH value is alkaline or acidic, users need to manually adjust it by adding or decreasing the nutrient values of the water. Its pH level should be appropriate for the plant to be unaffected. Once the pH value is all set, the fertilizer pump delivers fertilizer to the plants at a set level. Output data is connected to Wi-Fi, and data can be stored on Blynk and monitored remotely and conveniently.

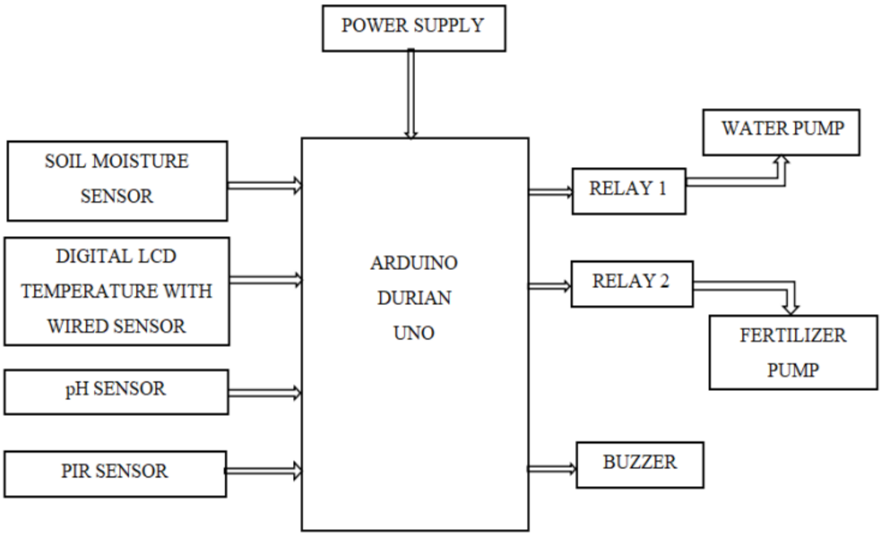


Fig. 1 *Block diagram of the project*

2.2 Flowchart of The Operating System

Fig. 2 shows the flowchart for the soil dryness monitoring and controlling system. According to Suhendri et al., the soil moisture needed by chilli plants ranges from 60-80% [6]. If the percentage of soil dryness is lower than 50%, the water pump will be in OFF condition. If the soil dryness percentage is over 50%, the water pump will automatically be ON to maintain the moisture that is suitable for the chilli plant.

Fig. 3 shows the flowchart for the pH value monitoring system that was set as required for the crop chosen. The range of pH values is from 1 to 14, with 1 indicating the most acidic and 14 indicating the most alkaline. A neutral material with a pH of 7. This project uses liquid fertilizers such as nitrogen, potassium and phosphorus. The important three tanks of fertilizers used, such as nitrogen, ensure good plant growth, phosphorus helps to grow roots, and potassium supports the growth of flowers and fruit. In the first four months of cultivation, chilli plants are cultivated with a greater nitrogen fertilizer [7]. As a result, an NPK value of 4:1:3 ratio indicates that the fertilizer used in this project includes the ratio of nitrogen 4, the ratio for phosphorus 1, and the ratio for potassium 3. Therefore, the coding for pH value calculation has been converted into percentages such as 0-50%, which is indicated as acidic. In addition, 51-69% indicated alkaline, and 70-100% indicated neutral. The percentages of fertilizer indicate the weight of each nutrient in the total weight of the fertilizer, while the NPK ratios are a shorthand way of showing the ratios of these nutrients. Therefore, the relationship between percentages and NPK ratios allows users to quickly understand nutrient content and make decisions about the fertilizer's suitability for specific plants and growth stages. For example, suppose the amount of fertilizer is below the required amount, less than 70%. In that case, the Arduino Durian Uno will automatically turn on relay 2, which is connected to the fertilizer pump. The result will then be displayed on the Blynk application.

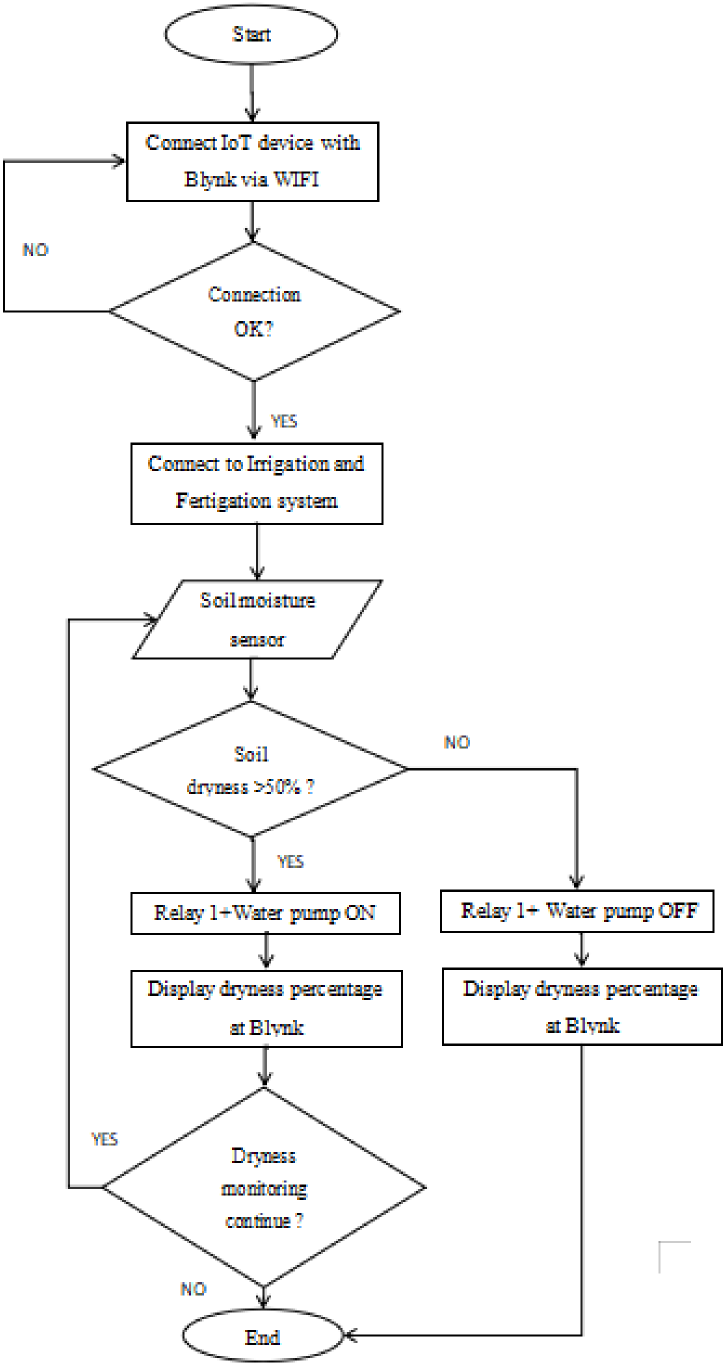


Fig. 2 *Flowchart for the soil dryness monitoring and controlling system*

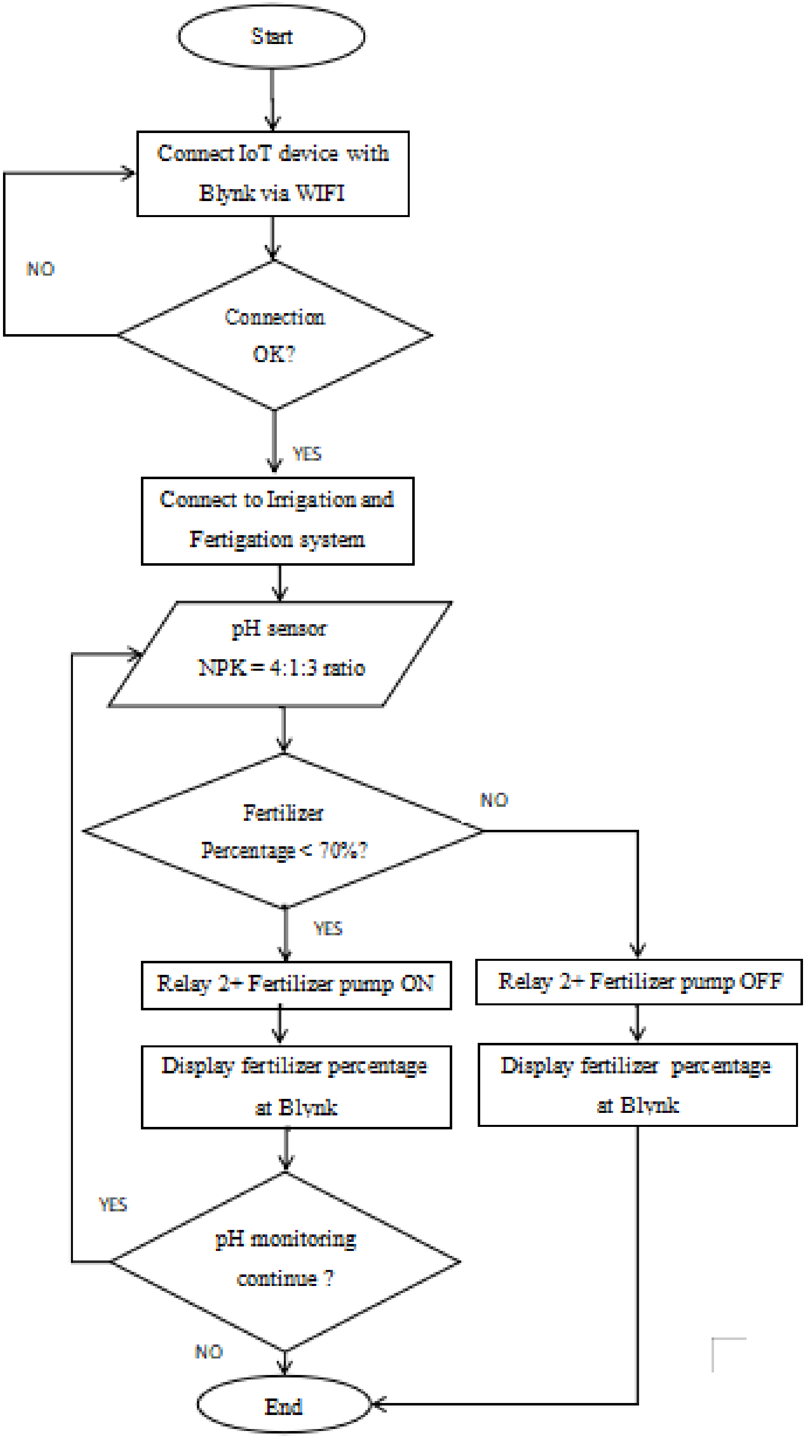


Fig. 3 *Flowchart for the pH value monitoring system*

Fig. 4 shows the flowchart for the motion detection monitoring system. In order to build the PIR sensor with the proposed system, the first step would be connecting the PIR sensor with ESP8266 via jump wires. This hardware is connected to alert the user when intruders are detected within a range of one to six meters from the plants. When an animal or human body emits infrared light, a PIR sensor can detect those motions with ease. As soon as the movement is detected, the ESP8266 will send the command to alert the user via the Blynk app, and the buzzer will automatically activate to create ultrasonic sound waves at a frequency of 25 kHz. The user's mobile device will receive a notification that states, "Motion detected near the plant," alerting them to the intruder. This may prevent animals or intruders from destroying the plants, especially at night and within a six-meter radius.

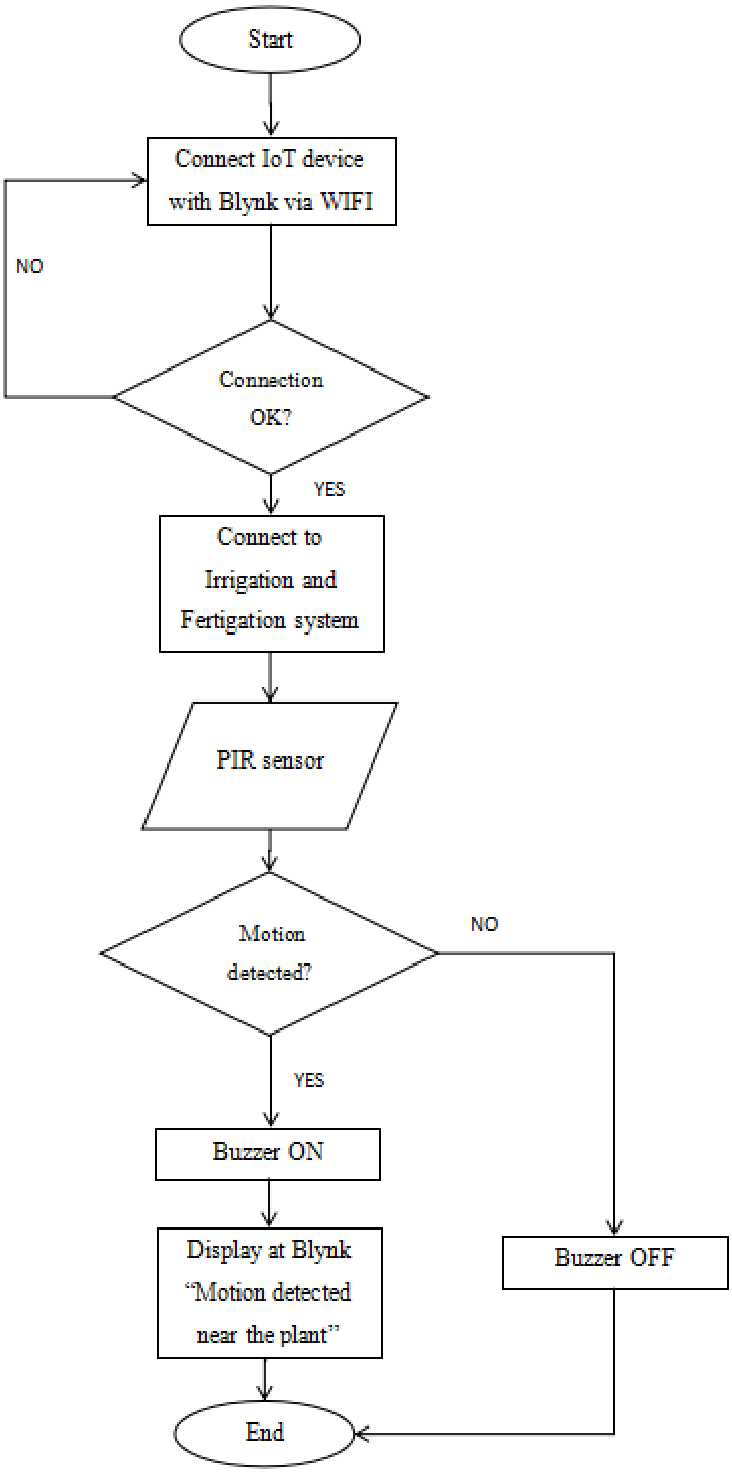


Fig. 4 *Flowchart for the motion detection monitoring system*

3. Results and Discussion

After all the sensors are completely installed in the prototype of the irrigation and fertigation system, the plant development, results, and data analysis are collected and presented here. This analysis can also determine the advantages and disadvantages of the system, as well as the success of this project.

3.1 Project Development

Fig. 5 shows the progress of the chilli plant by weeks. It shows that the plant's growth is healthy. The plant is also a proven success in this project, as it is ready to harvest.

Week 1 Week 2

Week 3 Week 4

Fig. 5 *Progress of the plant growth*

3.2 Temperature Monitoring Inside The Water Tank

Fig. 6 shows the reading for the temperature of water detected by placing the temperature sensor into the water tank, and its data is displayed on the digital LCD temperature. In general, chilli plants prefer water that is typically between 21°C and 28°C (70°F and 82°F) for their growth [8]. For chilli plants, temperatures above 32°C (90°F) can be stressful and result in lower yields or lower-quality fruit in which the hot water can damage roots. In contrast, the cold water can slow down biological processes.

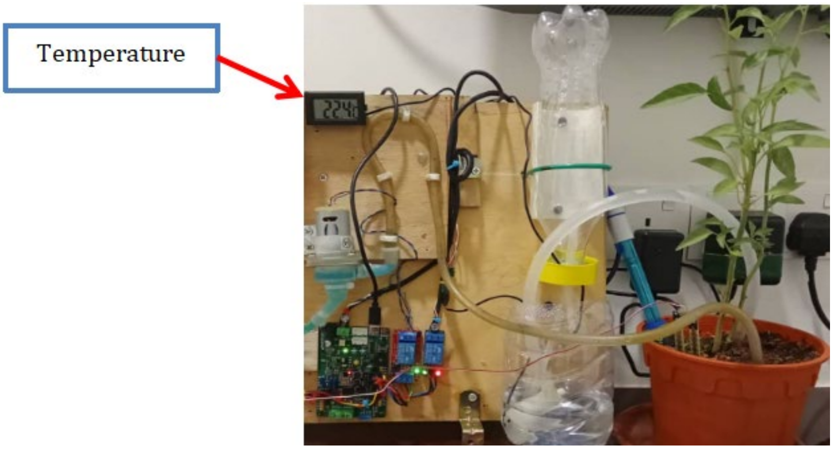


Fig. 6 *The reading for the temperature inside the water tank*

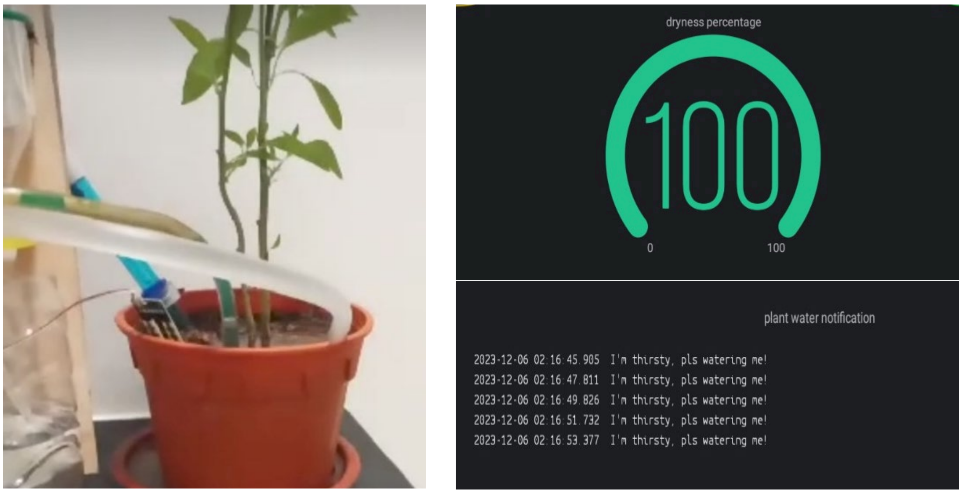
Table 1 shows the real-time monitoring of water temperature data collected by days. Based on the results obtained in Table 1, the average value of watering plants per day for chilli plants is one time a day. Furthermore, for a week, it rained three times, on day 3, day 4, and day 6. Therefore, no water is given to the plant on a rainy day (day 4). This is because it rained sequentially for two days, and the soil was still in wet condition. On sunny days, the water temperature is between 28°C to 32.5°C. It can be observed that the temperature of the water differed every day due to the unpredictable weather.

Table 1 *Daily reading for temperature inside the water tank*

Days	Plant watering per day	Temperature of water (°C)	Weather
1	1 times	26.5	Cloudy
2	1 times	28.0	Sunny
3	1 times	22.4	Rainy
4	0 times	20.2	Rainy
5	2 times	32.5	Sunny
6	1 times	25.8	Rainy
7	1 times	30.9	Cloudy

3.3 Water Supply Automation System Based on Soil Dryness

Fig. 7 and Fig. 8 show the percentage of soil dryness and automated water flow in the proposed system. Fig. 7, it is shown that if the percentage of soil dryness detected by the soil moisture sensor is above 50%, it will give a notification such as “I’m thirsty, please water me” in the Blynk application, and the water pump will start to irrigate the plants, automatically. Otherwise, when the percentage of soil dryness drops to below 50%, it will also give a notification such as “I’m full”, and the water pump will stop the water flow automatically, as shown in Fig. 8. By doing so, the water is irrigated to the plants whenever they are in need, which encourages their growth and reduces water wastage at the same time.



```
2023-12-06 02:16:45.905  I'm thirsty, pls watering me!
2023-12-06 02:16:47.811  I'm thirsty, pls watering me!
2023-12-06 02:16:49.826  I'm thirsty, pls watering me!
2023-12-06 02:16:51.732  I'm thirsty, pls watering me!
2023-12-06 02:16:53.377  I'm thirsty, pls watering me!
```

Fig. 7 *The water is supplied automatically when the percentage of soil dryness reading goes above 50%*

```
2023-11-28 16:13:08.848  I'm FULL
2023-11-28 16:13:10.645  I'm FULL
2023-11-28 16:13:12.531  I'm FULL
2023-11-28 16:13:14.376  I'm FULL
2023-11-28 16:13:16.208  I'm FULL
2023-11-28 16:13:18.054  I'm FULL
2023-11-28 16:13:19.895  I'm FULL
2023-11-28 16:13:21.745  I'm FULL
2023-11-28 16:13:23.588  I'm FULL
```

Fig. 8 *The water supply is stopped automatically when the percentage of soil dryness drop below 50%*

3.4 Percentage of The Fertilizer

Fig. 9 displays a graph indicating the percentage of fertilizer in the Blynk application. The graph shows that the pH level remained in the neutral range during week 3, which is ideal for the chilli plant growth; however, it decreased drastically from week 4 to week 5, with a percentage drop of 45% to 25%. Hence, the graph displays changes in the pH value within seven days, with both increases and decreases occurring regularly depending on the conditions of the soil and the amount of liquid fertilizer such as nitrogen, phosphorus and potassium used.

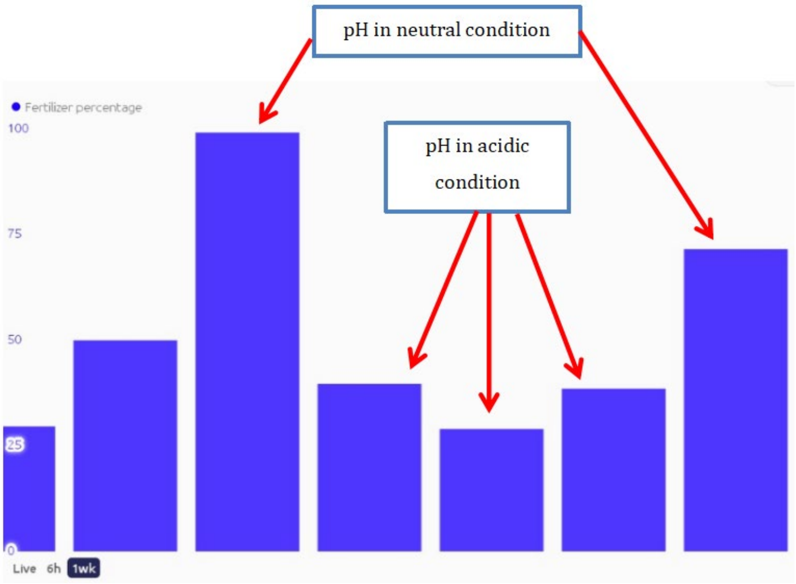


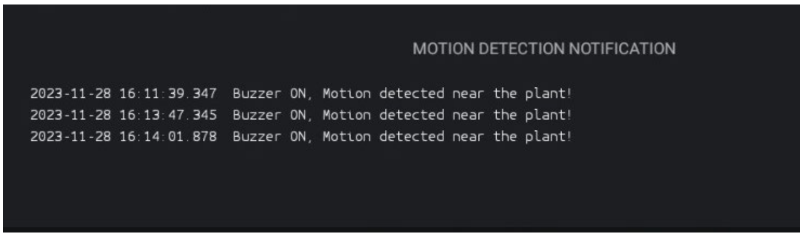
Fig. 9 *Graph for the percentage of fertilizer*

3.5 Detection of Intruder

As shown in Fig. 10, this experiment evaluates the accuracy of the PIR sensor in capturing the infrared light emitted by the human or animal body. The PIR sensor is mounted near the chilli plants, which can be seen clearly in Fig. 10. This ensures that the PIR sensor covers the area of the chilli plants equally; thus, it can detect intruders and prevent the destruction of plants. Two experiments were conducted to test the accuracy and functionality of the PIR sensor. In the first experiment, the accuracy of the functionality of the PIR sensor was tested by bringing the hand closer to the PIR sensor at a distance of 0.5-6 meters. Fig. 10 shows a test performed at a distance of about 0.5-0.8 meters. When the hand moves towards the PIR sensor, the buzzer will automatically turn on to produce ultrasonic sound waves of 25kHz frequency, and it starts spamming alert messages to the user's mobile phone through the Blynk app, such as "motion detected near the plant". Spam is necessary so that users are constantly warned about intruders, especially at night.

As shown in Fig. 11, the PIR sensor does not send spam alerts to users because there are no obstacles. Therefore, the same result in Fig. 11 is given when the intruder is not within six meters because the PIR sensor can only detect within six meters. This shows that the PIR sensor is very effective and accurate in detecting intruder movements to secure/protect the plants, especially at night.

Result:

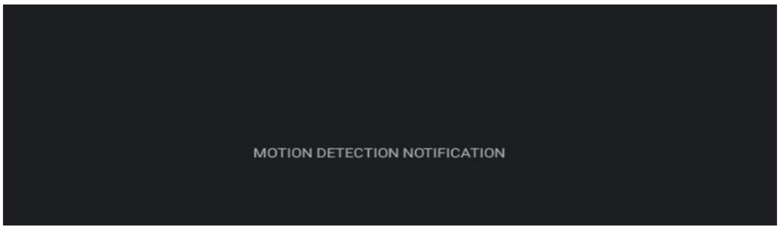


```
MOTION DETECTION NOTIFICATION

2023-11-28 16:11:39.347  Buzzer ON, Motion detected near the plant!
2023-11-28 16:13:47.345  Buzzer ON, Motion detected near the plant!
2023-11-28 16:14:01.878  Buzzer ON, Motion detected near the plant!
```

Fig. 10 *Testing the PIR sensor with hindrance*

Result:



MOTION DETECTION NOTIFICATION

Fig. 11 *Testing the PIR sensor without hindrance*

3.6 Discussion

The results obtained from the system and development include designing and implementing a software simulation model capable of handling an irrigation and fertigation system connected to an IoT platform. Implementing irrigation and fertigation systems has significant contributions to smallholder farming systems. It can provide a reliable and consistent water supply, ensuring crops receive adequate moisture throughout the growing season. Moreover, it enhances nutrient use efficiency by directly delivering fertilizer in a soluble form to the plants. These targeted nutrients, such as nitrogen, phosphorus and potassium delivery, can enhance plant growth and maximize yield. Therefore, this system shows that chilli plants grown using this method can thrive and produce healthy crops. This indicates that smart irrigation and fertigation systems could be a viable alternative to traditional gardening and farming methods. However, the system requires further testing and monitoring to fully assess its long-term effectiveness and potential for commercial use.

4. Conclusion

In conclusion, this project developed a prototype for an IoT-based irrigation and fertigation system to reduce water wastage, maintain soil moisture, and, at the same time, provide enough nutrients to the plants. Besides saving time costs in the long term, farmers' efforts and promoting growth for the chilli plant are also important. In addition, the proposed system has the additional function of detecting intruders to protect plants from damage or destruction, especially at night. The results obtained through analyzing the irrigation and fertigation systems based on IoT are satisfactory. This system has many advantages over the manual irrigation system. This system saves water and reduces costs. If the user knows the humidity and soil condition through the Arduino Durian UNO using a soil moisture and pH sensor, they can monitor their plant even when they are not at home. Overall, the user can know and check the status of plants directly through their mobile phone. Thus, the functionality of the project is working successfully.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Hema Losini Jayashanker, Nurmiza Othman;* ***data collection:*** *Hema Losini Jayashanker;* ***analysis and interpretation of results:*** *Hema Losini Jayashanker, Nurmiza Othman;* ***draft manuscript preparation:*** *Hema Losini Jayashanker, Nurmiza Othman. All authors reviewed the results and approved the final version of the manuscript.*

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