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RESEARCH

Water quality monitoring system based on internet of thing for oyster mushroom

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The growth of mycelium and mushroom pinheads is significantly influenced by humidity and temperature. The purpose of this research is to develop a tool that will be able to monitor and control the irrigation system for oyster mushroom plants using the Internet of Things (IoT) technology. The devices operate on an ESP8266 microcontroller that interprets resistance values of mushrooms from an analog waterproof capacitive moisture sensor. The study stresses the importance of oyster mushroom moisture monitoring, while, on the other hand, minimizing the labor and time required for farmers to irrigate their fields. According to the experiment carried out, the soil moisture sensor was quite successful in measuring moisture level and simultaneously sending real-time data to Blynk, which is an IoT-based monitoring platform. Blynk allows users to keep track of and water the mushroom farm from their mobile phones. In addition, the device can work offline and do automatic watering if there is no internet connection. Among the features are a moisture level indicator and an on/off switch, which promote the development of smart agriculture.

Keywords: oyster mushroom farming, soil moisture sensor, ESP8266 microcontroller, internet of things, Blynk platform

Introduction

The Internet of things (IoT) controls the things that are connected to it and transfers the data over the network. This technology enables the collection of real-time data from the farm field using sensors and various electronic components, thereby making IoT a vital part of our daily lives (1). In the field of agriculture, IoT-based technologies can not only keep track of soil moisture, temperature, and fertility but also execute timely actions needed for crops like mushrooms. The method used for soil moisture and water intensity measurement is the Analog Waterproof Capacitive Soil Moisture Sensor, which does so by identifying electrical permittivity (2). The ESP8266 is a microprocessor that fetches values from the sensor and uploads the information to the cloud through a WiFi module, while at the same time, it regulates a relay to turn on/off the water pump, which waters the soil according to its needs (3, 4). "With the expansion of the Wi-Fi network, the device can help control specific limits for soil moisture, thus preventing the soil from either getting too wet or too dry, which is necessary for a plant that keeps at the right conditions, like a mushroom (5). IoT does this by automating the entire process, which removes the human factor completely. The users are in charge of monitoring and control the system, while the internet serves as the medium through which the devices communicate with each other. Increased productivity, quicker workflow, and user-friendliness are among the many advantages that IoT brings along with it. Essentially, IoT makes it possible for communication among things through the Internet network (6, 7).

"The automatic irrigation system has been developed for the purpose of soil moisture monitoring. It uses real-time data readings to determine when and how much to water the plants (8). With the irrigation process being automated, farmers are able not only to eliminate water waste but also to keep the soil in its best condition. Apart from this, farmers need no longer to be present at the farm, as they can control the irrigating process from a distance, thus saving time for their other activities. Moreover, there are several extra gadgets that have been developed to work even when the Wi-Fi connection is not very stable, thus enabling the system to have continuous operation and to perform effectively in a variety of circumstances (9, 10). To address the issue of unstable network conditions in agricultural areas, the automatic plant watering system is also equipped with an offline version, allowing the system to operate properly even without human intervention."

This study aimed to develop an automatic watering device for mushroom cultivation based on the Internet of Things (IoT). This tool seeks to enhance efficiency and effectiveness in agricultural practices, supporting technological advancements and enhancing resource management for farmers. Through the assistance of the iOS and Android software Blynk, users may operate microcontrollers online. Blynk is an application available on smartphones that allows users to monitor and manage devices remotely. Designed specifically for the Internet of Things (IoT), Blynk capable of steering hardware, displaying sensor data, archiving the information that is presented, and many more functions (11–13). The system is designed not being suited for small-scale farming monitoring but also to integrate with and operate a larger farming watering machine that can cover more ground. The tool is equipped with additional switches so it can be connected to a larger water or plant watering machine to control the watering of larger agricultural land.

Methodology

The NodeMCU8266 is a widely used WiFi module admired by hardware developers for its affordability and versatility. As a system on chip, it can be programmed directly, avoiding the need for an extra microcontroller. One of its main benefits is the capacity to serve as both an access point and a client simultaneously, enhancing connectivity options. For soil moisture measurement, an analog sensor composed of rust-resistant material is used (**Figure 1**). This sensor is inserted into the soil to measure the moisture content of cultivated land. The higher sensor result indicated the higher moisture levels. This reliable measurement system helps ensure optimal soil conditions for plant growth (14). Mushrooms have varying growth requirements, with oyster mushrooms particularly thriving in tropical climates. They need high relative humidity of 80% to 85% and temperatures between 30 and 38 °C. The optimal pH for their growing medium falls between 5.0 and 8.0, with most fungi being more tolerant of acidic rather than alkaline conditions (15).

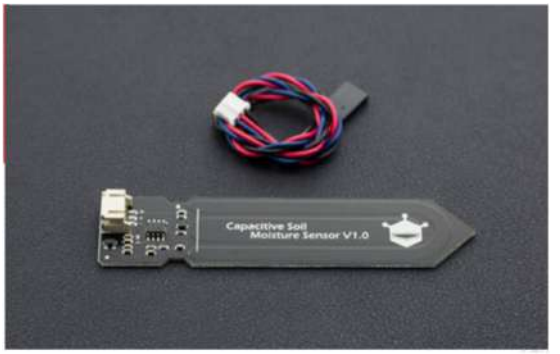

FIGURE 1 | Analog waterproof capacitive soil.

The system block diagram provides the main components, including the input block, process control block, and output block, functioning both online and offline. More details are presented in **Figures 2** and **3**.

The hardware and software system is designed with a number of essential components in order to allow both online and offline operation of the soil moisture monitoring system. A comprehensive schematic of the network layout is presented in **Figure 4**.

The automatic mushroom watering system has been successfully designed by combining several components, including the ESP8266 microcontroller, soil moisture sensor, LCD display, relays, and power supply. This configuration enables effective controlling and monitoring of the watering process in response to current soil moisture levels. When sensors, relays, and power sources are properly connected, the system switches on the water pump as needed, thereby ensuring the proper moisture levels for growing mushrooms. The tools are integrated with relay modules and an AC-DC converter to provide smooth communication between low-power control signals and high-power electrical components. In addition, this system is supposed to minimize manual labor and guarantee continuous irrigation based on environmental conditions. The programming language procedure in the software follows the flowchart as shown in **Figure 5**.

Results or finding

The hardware and software components of the system include the following: the ESP8266 NodeMCU, which serves as a microcontroller for data processing and wireless connectivity; an analog waterproof capacitive soil moisture

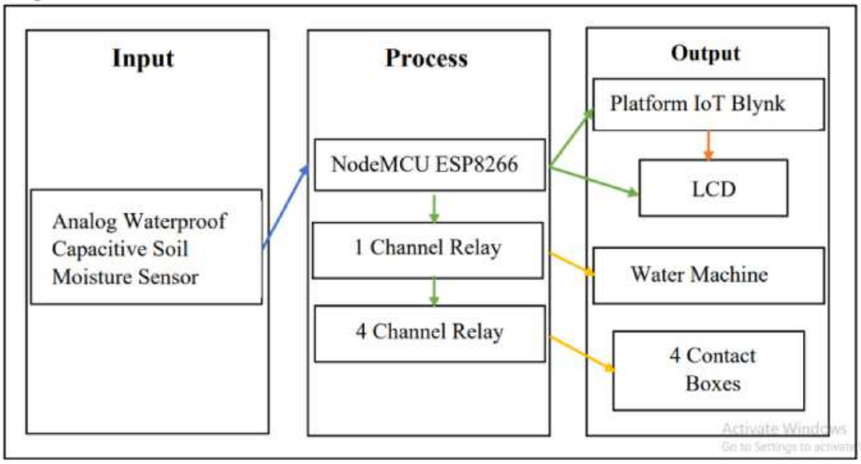

FIGURE 2 | The block diagram for the online system.

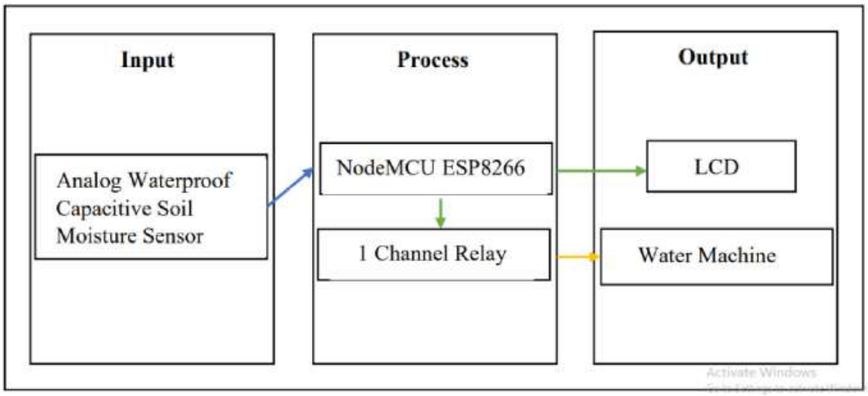

FIGURE 3 | The block diagram for the offline system.

sensor that measures soil moisture levels; a water pump and relays that automatically control irrigation based on soil moisture levels; an LCD display that offers real-time data visualization; a power supply and AC-DC converter that ensure efficient power distribution; and the Blynk platform, which displays real-time data and enables remote monitoring. The mushroom watering development is illustrated in **Figure 6**.

The ESP8266 microcontroller, soil moisture sensor, LCD display, relay modules, and power supply are among the parts that are connected to create hardware circuit. Firstly, a soil moisture sensor measures moisture levels of soil. The ESP8266 receives the data from the soil moisture sensor and uses it to control the relays that turn on the water pump when needed based on real-time soil conditions. This system is equipped with 4 relays and 4 stop contacts for an external water pump and 1 relay for an internal pump that operates using a 12V DC power supply to regulate irrigation in a relatively small mushroom farm.

The software design employs an algorithm to set up the device's system. The program is then uploaded to the hardware system immediately following the algorithm that was successfully written in the Arduino IDE programming language. **Figure 5** shows a flowchart or working principal display of automated watering for IoT-based mushroom seeds. Comprehensive hardware and software testing was used to evaluate the implementation and performance. It is anticipated that the information gathered will be precise and trustworthy, guaranteeing that the system functions as planned. The collected data is expected to be accurate and reliable, ensuring that the system operates as intended.

Testing revealed that the IoT-based automatic plant watering tool, which employs an analog waterproof capacitive soil moisture sensor, functions effectively. Results from tests conducted on a mushroom poly bag demonstrated that the soil moisture sensor could accurately detect moisture levels in both online and offline modes. The tests carried out the validation of program functionality, assessment of soil moisture sensor accuracy, analysis of data transmission via Blynk, offline system performance testing, and data visualization on the server, which included user notifications. The following are the findings from the research on the development of an IoT-based automatic watering tool for oyster mushroom cultivation using the Blynk application, as demonstrated when the tool is online, as shown in **Figure 7**.

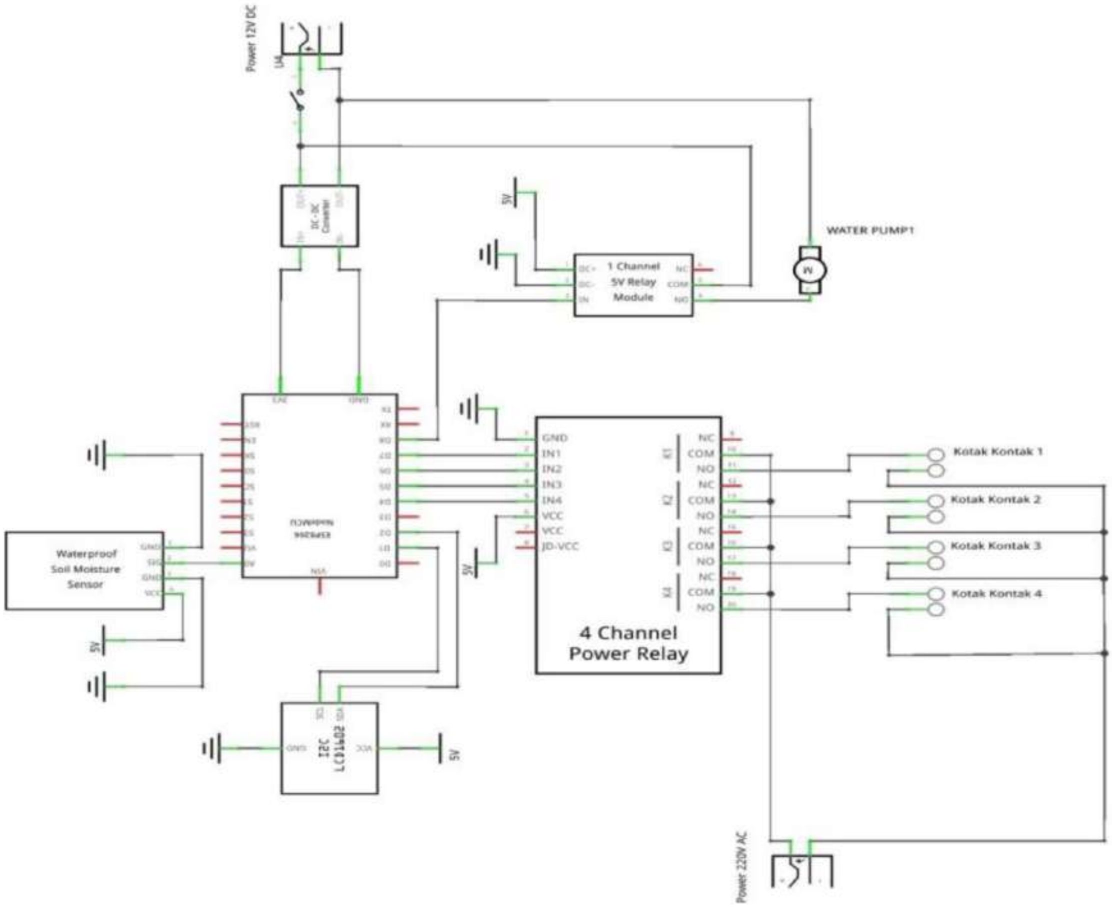

FIGURE 4 | Automatic watering circuit schematic.

Discussion

After successfully installing the software on the hardware device, the IoT protocol was integrated into the automatic oyster mushroom watering device. The next progression is evaluating the device's performance in measuring soil moisture. The soil dielectric permittivity, which gets more prominent with the moisture rise, is monitored by the capacitive analog soil moisture sensor. This sensor produces an analog voltage output representing the soil moisture level. The ESP8266 microcontroller performs signal processing through its analog-to-digital converter (ADC), which gives numbers from 0 to 1023. The calibration process leading to the determining of ideal moisture for oyster mushroom cultivation was between 220 and 640. Hence, this value is integrated into an IoT-based control system, allowing the device to regulate watering automatically by switching the pump on or off according to real-time calibration data. If the moisture is low, the LCD or smartphone will indicate a high value; conversely, it will show a low value. This is due to the operation of the sensor being based on the dielectric permittivity value of the soil.

The automatic irrigation system is designed with three output ports or external pump connections (External Pump 1, External Pump 2, and External Pump 3) which can be linked to external equipment. The system is able to function either in fully automatic offline mode or in areas with unreliable internet, thus making it ideal for locations with weak network coverage. Furthermore, it also possesses the capability for large-scale irrigation, thus being able to manage watering over a larger area for oyster mushroom production. The Blynk dashboard features four control buttons: one for the internal pump integrated into the system and three for external pumps that can be connected to additional machinery.

Data collection at the mushroom cultivation site in Konda District utilized only the internal pump, as the relatively small cultivation area was sufficiently served by a single unit. Analog waterproof capacitive soil moisture sensors are positioned on a baglog of oyster mushroom plants. The hardware is then activated, and every 5 minutes, data is transmitted via the Blynk application. Three days of testing in both online modes were used to record different soil conditions. The results were monitored and analyzed through the Blynk IoT platform. The results of the development of the automatic watering tool for oyster mushrooms based on IoT are as shown in **Table 1**.

Results

The system testing was conducted at Lestari mushroom farm in Konda district, Southeast Sulawesi, Indonesia, which served as the study site. The IoT-based automatic watering system was specifically designed for oyster mushroom cultivation, consisting of approximately 1,000 polybags. A purposive sampling technique was employed, selecting 40

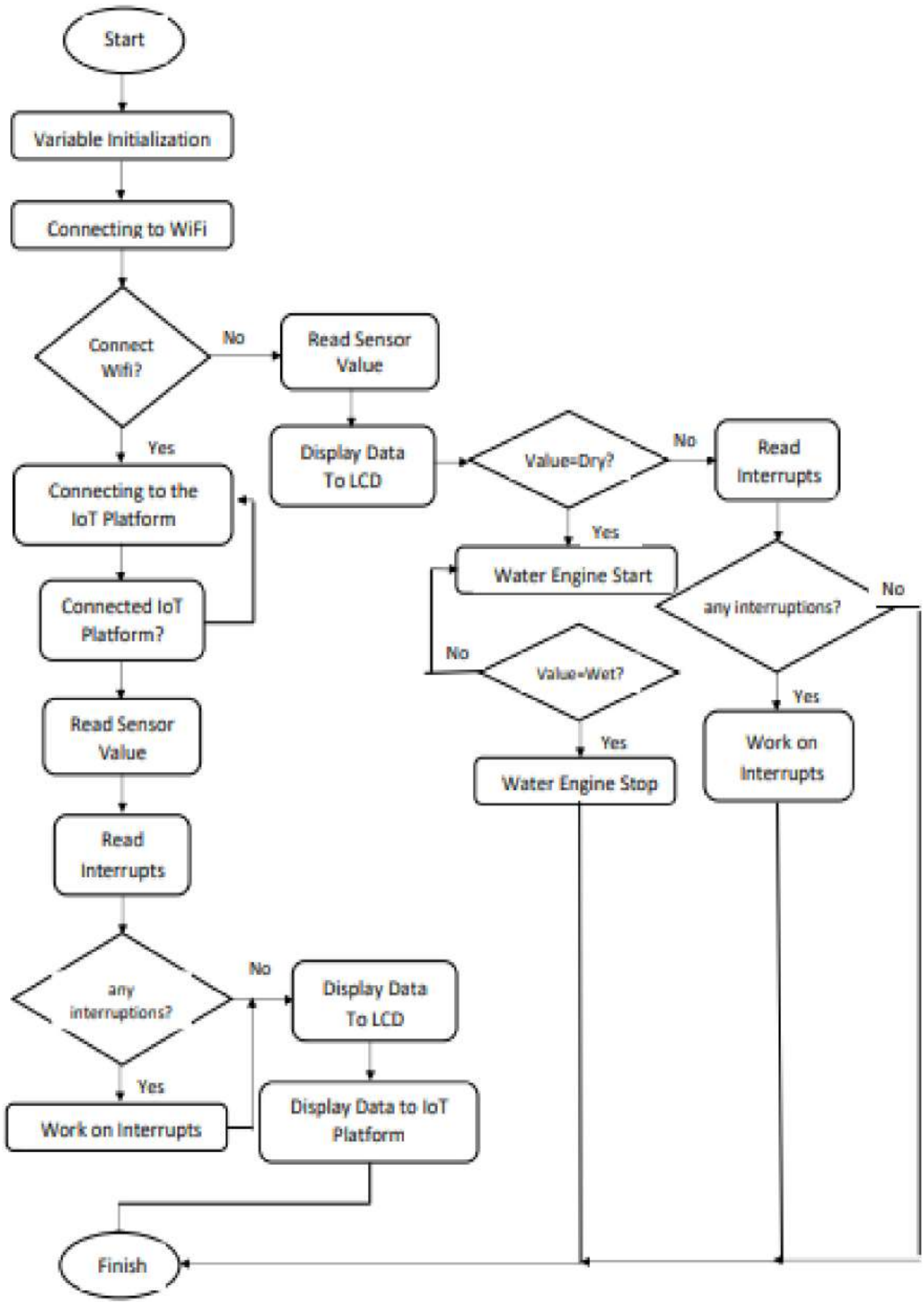

FIGURE 5 | Automatic plant watering flowchart.

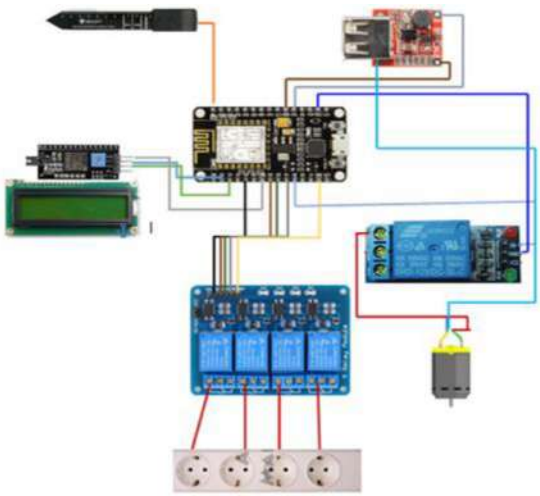

FIGURE 6 | The automatic IoT-based watering for mushroom plants.

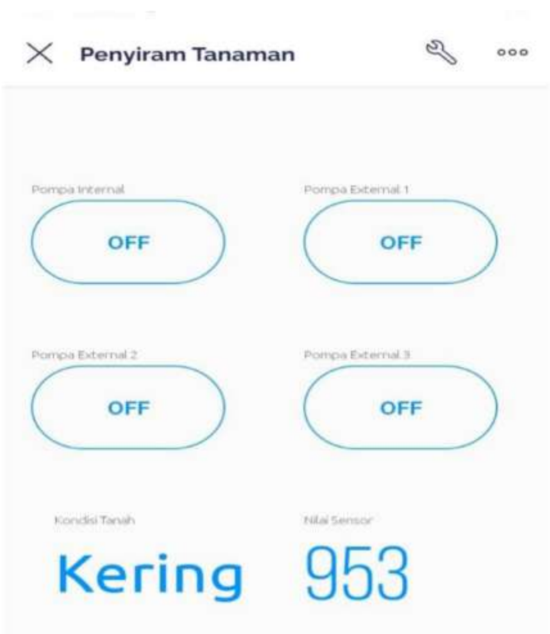

FIGURE 7 | Blynk IoT platform dashboard view on user's smartphone.

TABLE 1 | Observation data from tool testing.

No	Time	Oyster mushroom soil moisture level	Soil conditions
11 November 2024			
1	08.38	635	Dry
2	09.43	639	Dry
3	10.48	630	Dry
4	11.53	628	Dry
5	12.58	544	Quite wet
6	13.03	421	Quite wet
7	14.08	339	Wet
8	15.13	347	Wet
9	16.18	340	Wet
10	17.23	326	Wet
12 November 2022			
11	07.41	542	Quite wet
12	08.46	509	Quite wet
13	09.51	486	Quite wet
14	10.56	456	Quite wet
15	11.01	324	Wet
16	12.06	232	Wet
17	13.11	221	Wet
18	14.16	211	Wet
19	15.21	203	Wet
20	16.26	202	Wet
13 November 2024			
21	10.24	633	Dry
22	11.29	628	Dry
23	12.34	611	Dry
24	13.39	606	Dry
25	14.44	602	Dry
26	15.49	538	Quite wet
27	16.54	511	Quite wet
28	17.59	478	Quite wet
29	18.04	349	Wet
30	19.09	331	Wet

baglogs irrigated using the automatic system and another 40 baglogs watered manually as a control group. All samples were maintained in a humid environment and protected from direct sunlight to ensure uniform growth conditions.

An analog waterproof capacitive soil moisture sensor was installed in one of the automatically watered baglogs to continuously monitor moisture levels. The system regulated irrigation automatically based on real-time sensor data, while the other, watered manually, remained separate from the IoT-controlled setup. The experiment used 2-week-old mushroom spawn. Results showed that mushrooms receiving automated irrigation reached maturity within 2–3 weeks, whereas those irrigated manually required 3–4 weeks to develop, as presented in **Figure 8**. Although temporal sensor data were recorded (as presented in **Table 1**), no statistical analyses, such as average number of stalks or weight of mushrooms produced, standard deviation, or an inferential comparison between the observed variable (automatic watering) and the control variable (manual watering), were conducted. Consequently, the conclusions of this study are based on direct observational comparisons rather than statistical validation. This automatic watering device is integrated with the Blynk platform installed on the user's smartphone, functioning to display real-time soil moisture readings along with buttons to turn the watering system on or off. This system reports soil moisture data in real-time, as shown in the graph in **Figure 9**. The y-axis represents the soil moisture levels of the oyster mushroom substrate recorded from 11 to 13 November 2024. The

FIGURE 8 | Appearance of oyster mushrooms in the 3rd week: manually watering (left) and automatic watering (right).

axis is inverted, as lower sensor readings correspond to higher moisture levels, providing a more understandable visualization where increasing soil moisture is represented by decreasing values.

The system functioned effectively, as shown by successful remote control and monitoring through the Blynk platform in the smartphone application, demonstrating that both the sensor and the soil moisture monitoring system operated reliably during the testing period. This device provides convenience for users, especially in the agricultural industry.

Additionally, Blynk offers control features that let users use an Android smartphone to operate the device. It is not limited to a specific microcontroller but requires compatible hardware support. Online operation within the Internet of Things environment is made possible by the NodeMCU's Wi-Fi and ESP8266 module connections to the internet. Blynk, as a backend service, manages communication between the smartphone application and the hardware. In this case, data from the microcontroller are sent through the internet and received by the Blynk application on the smartphone. This

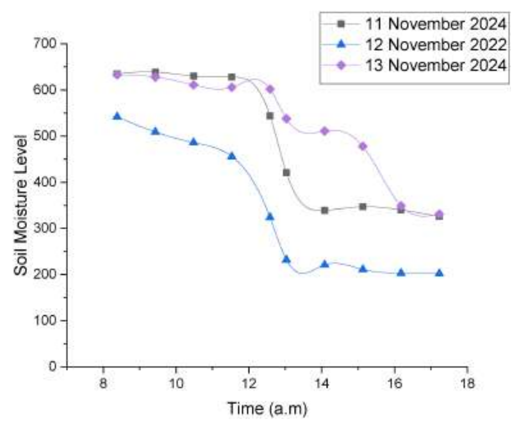

FIGURE 9 | Soil moisture level of oyster mushroom.

tool is intended to be a market-ready product. This automatic mushroom watering tool is equipped with an offline mode, which is suitable for local farmers with erratic internet connections. The tool is designed to continue working even when there is no internet connection or in situations where users or farmers are not familiar with Blynk or other internet protocols. This automatic mushroom watering tool simply needs to be connected to a power source. The tool is also equipped with three additional switches and outlets so it can be connected to a watering machine or a larger plant watering system. The device can also regulate the watering of larger plants, like gardens or farmland, once it is connected.

Conclusion

The IoT-based automatic watering system effectively monitors and maintains soil moisture for the growing of mushrooms. The integration of ESP8266 and the Analog Waterproof Capacitive Soil Moisture Sensor in an automatic irrigation device can help oyster mushroom farmers increase their production, reduce manual labor, and monitor the growth conditions of their mushrooms optimally. The system shows consistent performance regardless of being online or offline, so it is a very suitable option for smart farming applications.

Author contributions

All authors contributed to this research. The first author contributed to the design, research, and writing of the article. The co-authors took part in all activities concerning the research, in particular, data collection and analysis. The manuscript has been read and approved by all authors.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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