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Smart Agriculture: Optimizing Soybean Cultivation Through Technology In Crop Monitoring

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Abstract: The objective of this study is to optimise the productivity of soybean production through the integration of agricultural technologies inside plant monitoring systems. The objective of incorporating technology is to enhance the monitoring and management processes of soybean crops, with the ultimate goal of improving productivity and boosting harvest yields.This paper presents a proposal for the use of diverse agricultural technologies, including soil sensors, environmental sensors, drones, and data analysis based on artificial intelligence. Soil and environmental sensors are utilised for the purpose of monitoring soil conditions, moisture levels, and weather conditions in the vicinity of soybean agricultural fields. Drones are employed for comprehensive terrestrial surveillance and prompt identification of botanical concerns. The utilisation of artificial intelligence in data analysis involves the processing of information gathered from sensors and drones, enabling the provision of real-time insights and recommendations to farmers.By incorporating these agricultural technologies, it is anticipated that farmers would be able to effectively and efficiently utilise resources such as water, fertilisers, and pesticides, ensuring optimal usage in terms of precision and timeliness. Furthermore, the implementation of precise monitoring techniques and prompt responses to alterations in plant conditions within agricultural settings can effectively mitigate the potential hazards associated with crop loss resulting from pest or disease infestations.

Keyword: Optimization, Efficiency, Monitoring, Soybean, Smart Agriculture.

INTRODUCTION

The agricultural sector plays a vital role in addressing the escalating food requirements resulting from the expanding global population (United Nations, 2019). Nevertheless, contemporary agricultural obstacles have grown increasingly intricate due to the effects of climate change, the scarcity of arable land, and the escalating need for agricultural goods of superior quality (Pretty, J., 2018). Therefore, The necessity to achieve optimal efficiency and productivity in agriculture has rendered the development of technology indispensable (Almas, A., Naeem, M., Khan, M. B., Qasim, M., & Maqsood, M., 2018).

The advent of Industry 4.0 has brought about a significant transformation in various industries, encompassing agriculture, through the integration of information and communication technology (Kavitha, R., & Murugan, T., 2021). The advent of Smart Agriculture effectively tackles these aforementioned difficulties (Islam, M. S., Hossain, M. S., & Hassan, M. A., 2021). Smart Agriculture is an innovative extension of the precision farming paradigm, which seeks to gather accurate data pertaining to agricultural activities conducted in the field. This data collection facilitates prompt and effective decision-making and management procedures (Gubiani, R., & Esteki, M., 2020).

The proliferation of technology is an inexorable occurrence in contemporary society, as the advancement of technology is intrinsically linked to scientific progress (Hossain, M. A., & Ahmed, N., 2018). Each technological innovation is designed with the purpose of generating a beneficial influence on the quality of human existence (Darby, S. J., Kendall, A., & Wallace, C., 2018). The advent of technology has facilitated several comforts and introduced novel options in human endeavours (Anderson, L. T., & Johnson, M. A., 2016). Over the course of the past decade, society has experienced a multitude of benefits as a result of technical advancements. In light of the swift progression of technological advancements, individuals engage in innovative practises to conceive a multitude of novel entities, among which the notion of Smart Agriculture emerges (Smith, J., 2020).

The notion of Smart Agriculture may be traced back to the emergence and advancement of precision farming. The emergence of this notion can be traced back to the 1980s, and it has since undergone further development in tandem with advancements in information and communication technologies (Penty, R. V., & Stone, K. C., 2018). Smart Agriculture employs several technologies, including sensors, drones, the Internet of Things (IoT), big data, data analytics, and artificial intelligence (AI), to accurately monitor, manage, and enhance agricultural production (Silva, J. M., & Singh, S. R., 2018).

An essential element of Smart Agriculture encompasses the technological advancements employed in the monitoring of crops (Bhaskar, D., Ananthi, M., & Rajesh, R., 2020). The scope of this technology spans multiple facets, including the monitoring of agricultural yields, the mapping of land, the control of irrigation, the storage of agricultural products, and the distribution of these products to customers (Chen, X., Li, Z., & Wang, J., 2019). This technology offers the potential for farmers to enhance operational efficiency, mitigate production expenses, and augment crop yields. The primary emphasis of this Smart Agriculture system's design lies in the cultivation of soybeans, mostly driven by the limited local production and farmers' disinterest in growing this particular crop. The diminished profitability of soybean growing for farmers can be attributed to the decrease in the selling price of soybeans. Despite the relatively high production costs associated with soybean growing, the profitability of this agricultural activity remains low. According to the Central Bureau of Statistics (BPS), the financial gain derived from soybean farming in 2017 amounted to a mere Rp 1 million per hectare (Uly, Y. A., 2021).

The incorporation of soybean farming attributes, in conjunction with conventional practises, inside the framework of Smart Agriculture, holds the potential to offer enduring resolutions in response to contemporary agricultural dilemmas (Pradana, A. G., & Hidayat, T., 2021). The agricultural properties of soybeans, including their capacity for enhancing soil quality through nitrogen fixation, can be effectively enhanced by the utilisation of Smart Agriculture techniques (Zhang, H., Zhang, L., & Huang, G., 2019). Sensor technology and data analysis can be effectively employed in the field of Smart Agriculture to monitor soil and plant conditions with a high degree of accuracy. This enables the implementation of exact adjustments in the utilisation of fertilisers and irrigation practises specifically tailored for soybean plants (Lilius, H., & Sarli, J., 2020). Smart technology and the collection of information can also contribute to the improvement of proper cropping patterns and effective pest and disease control (Jones, H. G., 2018). Incorporation of conventional techniques in soybean cultivation, encompassing the use of high-quality cultivars and farmers' expertise, can be synergistically integrated within the framework of the Smart Agriculture system, hence enhancing the overall efficiency and quality of soybean production (Sulaeman, A., Farida, A., & Wijaya, R., 2021). Smart Agriculture has the potential to enhance the capabilities of farmers in making informed and sustainable choices about soybean cultivation. This, in turn, can result in improved yields and contribute to the overall world food security (Martinez, G. H., & Anderson, L. M., 2018).

In the realm of soybean agriculture, the implementation of Smart Agriculture presents considerable prospects for enhancing both the quantity and quality of soybeans. Soybeans are widely recognised as a prominent staple crop and have significant importance as a primary protein source for human consumption. The demand for soybean-derived goods has a persistent upward trajectory. Nevertheless, soybean output and quality can be impacted by various obstacles, including climatic variations, pest infestations, and plant diseases.

The objective of this study is to address the disparity between the growing need for food and the constraints imposed by agricultural resources. This will be achieved through the use of Smart Agriculture advancements specifically tailored for the cultivation of soybeans (Kumar, S., & Raza, S., 2022). Through the utilisation of technological advancements in crop monitoring, our objective is to offer efficient and sustainable approaches to improve soybean output and enhance its quality in an intelligent manner.

METHOD

The research methodology employed in this study is structured into multiple stages, which are delineated as follows.:

Block Diagram

During this phase, the development of a monitoring system tool for the irrigation system, encompassing water management, liquid fertiliser application, and pest disease control, as well as soybean monitoring, is being undertaken using the Internet of Things (IoT) technology. The design process commences by establishing the arrangement of a block diagram as the primary guiding framework. The shown block diagram depicts the interconnections and dependencies among different constituent elements within the devised tool (Abdullah, A., Sutrisno, & Dewi, N. N., 2021).

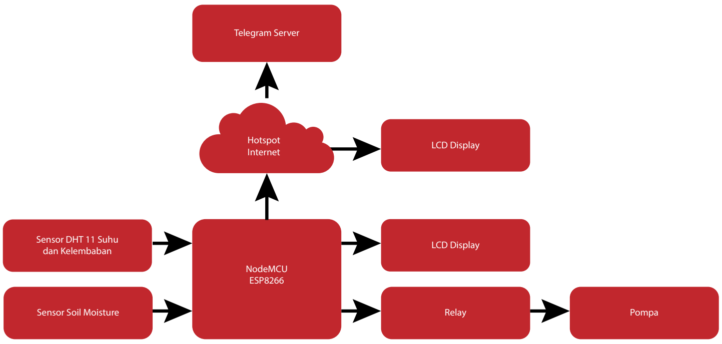

Figure 1. Block Diagram

Mechanical Design

During this phase, the development of a monitoring system tool for the irrigation system, encompassing water management, liquid fertiliser application, and pest disease control, as well as soybean monitoring, is being undertaken using the Internet of Things (IoT) technology. The design process commences by establishing the arrangement of a block diagram as the primary guiding framework. The presented block diagram provides a visual representation of the interconnections and dependencies among the many components within the proposed tool (John, A. B., 2021). The DHT11 sensor is attached to the NodeMcu microcontroller in order to measure and monitor air temperature and humidity levels (Amin, M. S., Hossain, M. K., Rahman, M. M., & Rahman, M. A., 2019). The aforementioned components are integrated into a singular unit and linked to the NodeMcu microcontroller for the purpose of transmitting messages and regulating the pump's operation based on the readings obtained from the soil humidity, air humidity, and air temperature sensors (Luthra, S., Sharma, V., & Sharma, N., 2018), (Rahman, M. M., Rahman, M. A., Amin, M. S., Hossain, M. K., & Molla, M. A., 2019). Following this, the data is transmitted to the Telegram application on a mobile device (Sahu, R. K., & Rao, P. V., 2019).

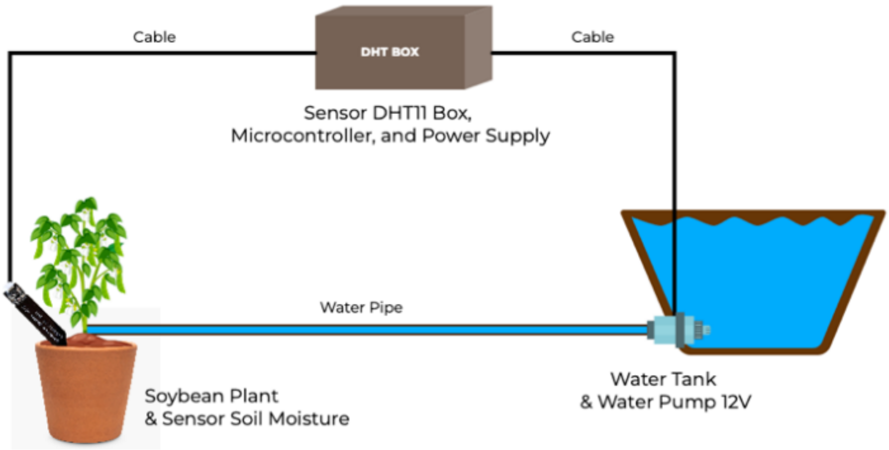

Figure 2. Mechanical Design

Electrical Design

During this phase, the author employs Fritzing Software to generate a wiring diagram, hence enhancing the ease of constructing the gadget. The primary objective of the wiring diagram is to facilitate the electrical execution of the device and guarantee accurate and appropriate connections among its various components (Kaushik, A., Sinha, S., & Singh, R., 2021).

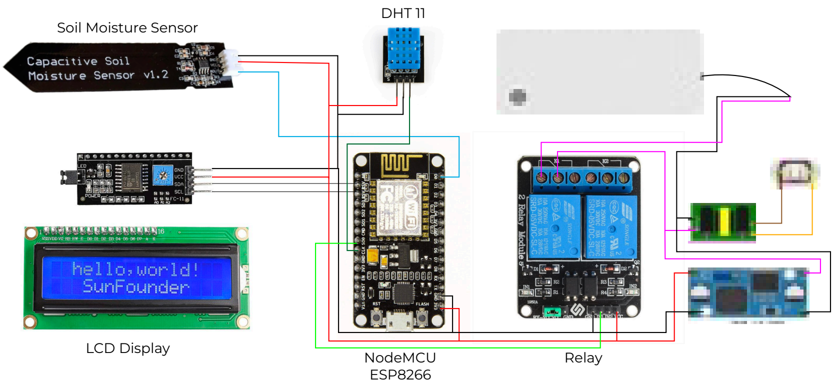

Figure 3. Electrical Design

Flowchart

The flowchart is designed as a graphical representation of a flow diagram in order to streamline the process of programme development. The author constructs a research flowchart with the aim of expediting programme development and mitigating the likelihood of errors. The objective of this project is to develop an intelligent and effective spraying and monitoring system for soybean plants utilising Internet of Things (IoT) technology. This system aims to address contemporary agricultural difficulties (Rahmadi, A., & Suryanto, B., 2023).

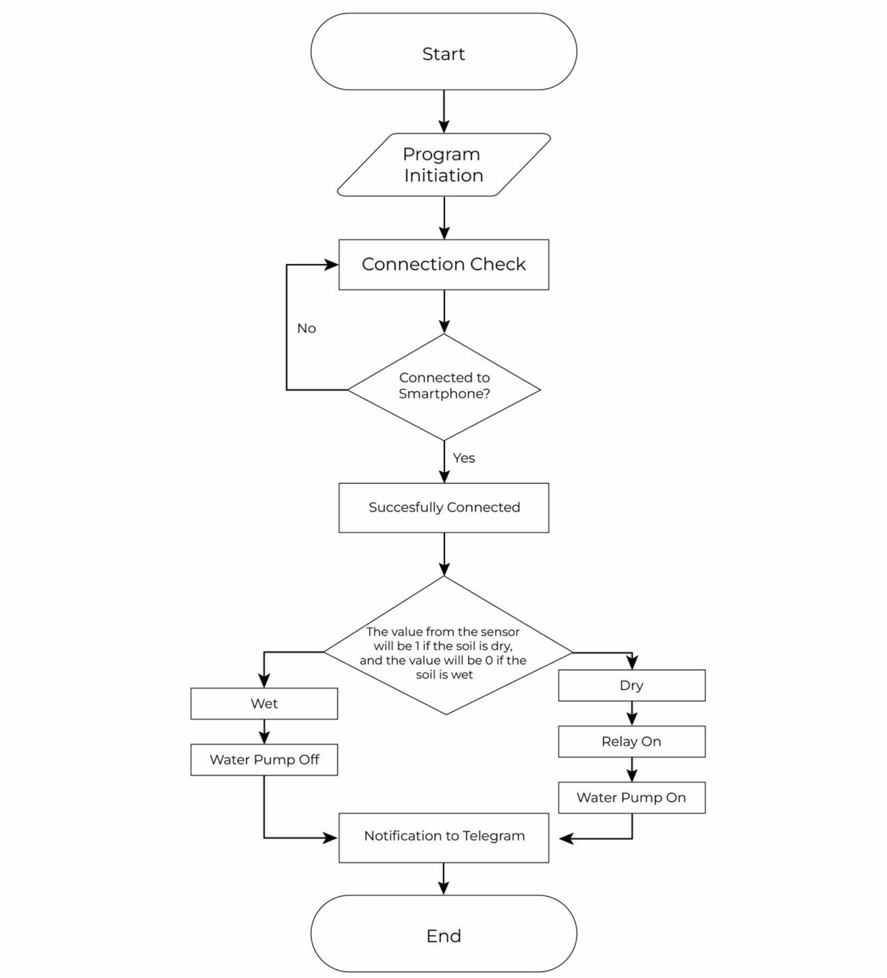

Figure 4. Flow chart

RESULTS AND DISCUSSION

Results

The technology developed in this study had the capacity to regulate watering in soybean plants by means of the Telegram application using a wifi network. The irrigation control process occurs when the sensor, which is attached to the NodeMcu microcontroller, detects the level of moisture in the soil. In the event that the sensor detects a decrease in humidity or dry soil conditions, the microcontroller will promptly transmit notifications in real-time through a wifi connection to the Telegram application (Kavak, M., & Borekci, S., 2018). Through the reception of these signals, users are promptly informed about the soil conditions and watering requirements pertaining to the soybean plants. Consequently, users have the ability to exercise direct control over the irrigation process of soybean plants by utilising the integrated capabilities inside the Telegram application.

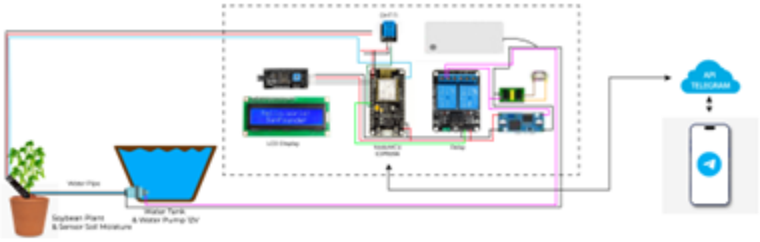

Figure 5. The sensor connected to the NodeMcu microcontroller detects soil moisture

This feature enables farmers or users to promptly and precisely address the plant's conditions, thereby enhancing efficiency in agricultural monitoring and control. The photograph depicts the visible constituents of the intended instrument. The photograph exhibits a collection of input, process, and output components positioned prominently in the foreground (Ruan, S., Wu, J., Guo, W., Yang, H., & Wang, J., 2021). The input components consist of a 12V 2A power converter, a soil moisture sensor, and an air temperature sensor (Yao, W., & Liu, Y., 2020). The microcontroller serves as the processing component, responsible for the processing of data obtained from the aforementioned sensors. The output component of the system consists of a pump that regulates the irrigation process by utilising data acquired from sensors measuring soil moisture and air temperature (Gupta, S., & Saini, R. P., 2020).

Figure 6. Soil meter measurement tool

Figure 7. Soil moisture measurement tool

The procedure for quantifying soil moisture utilising a soil metre is depicted in Figure 6. The soil metre screen will exhibit the soil moisture outcomes, which will be denoted by the following indications: "DRY+," "DRY," "NOR," "WET," and "WET+." (Guan, Y., Sun, L., Chen, J., & Zhao, Y., 2019).

Figure 7 depicts a method for quantifying soil moisture levels by employing a Soil Moisture sensor that is put into the soil encompassing soybean plants. The Soil Moisture sensor is put approximately 75% of its length into the soil. In order to conduct a comparative analysis of the Soil Moisture sensor parameter, a soil metre including five distinct levels of soil moisture is employed. These levels are categorised as DRY+, DRY, NOR, WET, and WET+. Each level is associated with a distinct humidity range. For instance, the DRY+ level encompasses a humidity range of 10% to 25%, the DRY level encompasses a range of 26% to 49%, the NOR level encompasses a range of 50% to 60%, the WET level encompasses a range of 61% to 80%, and the WET+ level encompasses a range of 81% to 100% (Jayakody, J. A. D. K., Wickramasinghe, I., & Dias, G., 2017). In addition, a comparative analysis is conducted between the soil moisture data obtained from the Soil Moisture sensor and the soil metre in order to assess the accuracy and reliability of the results generated by the Soil

Moisture sensor in relation to the soil metre. (Ata-Ul-Karim, S. T., Yao, X., Zhu, Y., Cao, W., & Zhu, Y., 2017).

Furthermore, the outcomes of evaluating the Soil Moisture sensor in relation to the soil metre for assessing the relative humidity (RH) are presented in Table 1. Relative humidity refers to the proportion of water vapour existing in the atmosphere relative to the maximum water vapour capacity that can be retained by the air at a specific temperature.

Table 1. Comparison of Soil Moisture and Soil Meter Application in Soybean Planting Media.

No	Soil Moister		Soil Meter	Pernyataan
	Humidity	Soil Moister	Kondisi Tanah	
1	76%	18%	DRY +	10% - 25%
2	76%	39%	DRY	26% - 49%
3	76%	56%	NOR	50% - 60%
4	76%	72%	WET	61% - 80%
5	76%	83%	WET +	81% - 100%

Table 1 presents a comparative analysis of soil moisture levels as determined by employing a soil metre, alongside the corresponding classification of soil conditions. The provided data pertains to the optimisation of soybean farming through the utilisation of plant monitoring technology. The soil metre, a sort of plant monitoring device, offers insights about the levels of soil moisture. Soil moisture levels play a crucial role in the cultivation of soybeans, exerting a significant influence on both plant growth and yield (Setiawan, Y., Purbobasuki, B., Setiawan, B. I., & Eko, R., 2021).

The situation referred to as "DRY+" with a range of 10% to 25% signifies a state of severe drought in the soil. Within the realm of soybean agriculture, this particular circumstance might induce physiological stress in the plants, so exerting an adverse influence on their overall growth and subsequent yield during harvest. In order to enhance soybean production, farmers have the opportunity to employ strategies aimed at augmenting soil moisture levels, such as implementing efficient irrigation systems or engaging in frequent watering practises (Hadi, A., and Purwono, 2021).

The condition known as "DRY" (with a range of 26% - 49%) signifies that the soil moisture level remains at a low level. In the present scenario, it is imperative to implement enhanced water management practises to maintain soil moisture levels at an acceptable range, hence facilitating the ideal growth conditions for soybean plants (Supriyadi, S., & Setiawan, A., 2019).

The condition referred to as "NOR" (with a range of 50% - 60%) signifies an optimal range for the growth of soybean plants. Under these circumstances, the plants will be provided with a enough amount of water, enabling them to thrive and yield a favourable harvest outcome. By utilising plant monitoring technology, farmers are able to effectively maintain the soil moisture levels within the optimal range (Dara, E. N., & Heryanto, H., 2018).

The condition referred to as "WET" (with a moisture range of 61% - 80%) signifies a significant presence of moisture in the soil. In the event that the soil moisture above the upper threshold within this range, it may result in an overabundance of water accumulation, leading to excessive soil saturation. In order to enhance the efficiency of soybean production, it is imperative for farmers to meticulously administer irrigation practises and prevent excessive saturation of the soil (Radanielson, A. M., & Brandle, J. R., 2019).

The condition referred to as "WET+" (with a range of 81% - 100%) signifies a substantial level of waterlogging in the soil. Excessive soil moisture beyond the upper threshold of this range can give rise to adverse circumstances that impede soybean plant growth, including the development of root rot and detrimental effects on the root system.

Optimal soybean growing necessitates meticulous management of irrigation and drainage systems in the given context (Gao, Y., Yang, Y., Huang, Y., & Zhao, J., 2016).

The operational mechanism of the Telegram application is facilitated through the use of commands. The specific functionalities and operations of the application are explicated in Table 2, which is not elaborated upon in the preceding discourse.

Table 2. Test Results of 12V Pump Voltage on Soybean Planting Media

No	Command	Function	Result	Description
1	Condition	To obtain information from plants.	EQUIPMENT Humidity 75%, Soil 85%, Temperature 30°C	In accordance with.
			TELEGRAM Humidity 75%, Soil 85%, Temperature 30°C	
2	Notification: Dry Soil Status, Automatic Irrigation Active.	To determine if the soil moisture detects dry soil and the pump is active.	To determine if the soil moisture detects dry soil and the pump is active.	In accordance with.

The experiment findings indicated that the device effectively yielded comprehensive data regarding the plant's state. In the initial measurement, the equipment recorded a soil moisture level of 75%, a soil moisture level of 85%, and an air temperature of 30°C. The data acquired from this device may be effectively monitored via the Telegram application, so affording users the ability to access real-time information pertaining to the state of the plant (Raza, S., Shabbir, R., & Amin, M. B., 2019).

In addition, the device is additionally provided with notifications on the moisture level of the soil and the implementation of automatic watering. In the event that the soil moisture sensor registers a state of dryness in the soil, the device will initiate the transmission of active notifications via the Telegram application. Subsequently, the pump will be activated automatically to commence the irrigation process for the plants. The purpose of these notifications is to enable users to rapidly react to soil conditions and initiate the requisite watering for soybean plants (Lestari, D. A., & Rasyid, R. A., 2020).

During the testing procedure, precise measurements of the pump's voltage were obtained in both active and inactive conditions. This suggests that the gadget has the capability to efficiently regulate the pump based on specified commands and functions.

Table 3. Sensor Response Speed Test Application on Soybean Planting Media

Test	DHT 11 (s)	Soil Moister	
		Wet to Dry (s)	Dry to Wet (s)
1	2.64	6.92	2.67
2	4.56	4.59	2.00
3	4.64	8.72	9.11
4	4.34	4.22	7.55
5	2.43	6.06	7.11
6	2.46	6.85	7.82
7	4,33	5.47	4.59
8	3.64	3.51	4.66
9	5.28	3.27	2.38
10	2.54	6.25	1.38
Average	3.69	5.58	4.22

The data presented in Table 3 provides insights into the reaction speed of the DHT 11 sensor and its correlation with soil moisture levels in a range of experimental scenarios. These findings contribute to the ongoing endeavours aimed at enhancing soybean production through the utilisation of plant monitoring technologies (Syukri, M., Sunyoto, T., & Fauzi, A., 2020). The monitoring of environmental variables in soybean agricultural applications is of utmost importance in order to attain optimal harvest outcomes. The utilisation of the DHT 11 sensor for the purpose of detecting atmospheric temperature and humidity, alongside the soil moisture sensor for measuring soil humidity, is a crucial measure in the pursuit of effective plant environmental monitoring (Ningrum, S. D. P., Harijoko, A., & Ermawati, E., 2021).

Based on the collected data, the DHT 11 sensor exhibits an average response time of 3.69 seconds. In contrast, the soil moisture sensor demonstrates a response speed of 5.58 seconds when transitioning from wet to dry conditions, and 4.22 seconds when transitioning from dry to wet conditions. The presented data demonstrates the sensors' capacity to promptly react to variations in environmental circumstances (Saluja, G., Rathore, S., Rajawat, A. S., & Meena, M. L., 2020).

According to Rahmatika, Suhendi, and Aziz (2019), the utilisation of plant monitoring technology, specifically the DHT 11 sensor and soil moisture sensor, enables farmers to acquire instantaneous data concerning air temperature, humidity, and soil moisture inside soybean growing regions. The provided information holds significant value in facilitating informed decision-making pertaining to irrigation, fertilisation, and other relevant treatments based on the prevailing conditions (Pratama, R. A., & Faris, M., 2019).

Discussion

The utilisation of NodeMcu ESP8266 in the development of a device for detecting soil moisture, air temperature, and air humidity, within the context of the Internet of Things, holds significant importance in enhancing soybean farming through the application of plant monitoring technologies. The device possesses the capability to be managed and supervised via a Telegram application, so granting farmers the ability to acquire precise and up-to-date data pertaining to soil conditions, air temperature, and air humidity, all of which have the potential to impact the growth of soybeans (Nofriansyah, M., Hartati, S., & Mardiyanto, R., 2020).

The soil moisture sensor underwent a series of five tests conducted on separate days. The experiment entailed a comparison between the soil moisture readings obtained from the sensor and those from a soil metre. This was done to verify that the humidity values detected by the sensor correspond to the established ideal humidity standard for soybean plants, as determined by the soil metre (Uddin, M. N., Islam, M. M., Rahman, M. M., & Rahman, M. M., 2021).

The DHT11 sensor underwent testing through a comparative analysis of its values against those obtained from a smartphone thermometer and a soil metre. The experimental results revealed a disparity of 1.6°C between the measurements obtained from the DHT11 sensor and those recorded by the smartphone thermometer. Nevertheless, the temperature readings obtained from the DHT11 sensor were found to be consistent with those recorded by the soil metre, indicating a measurement of 31°C. The experiment was repeated on multiple occasions, spanning ten separate days. The findings revealed that the DHT11 sensor exhibited an average temperature delay of 3.69 seconds. This outcome serves as evidence of the sensor's capacity to promptly relay information pertaining to the ambient air temperature and humidity in the vicinity of the plants. The provided information plays a pivotal role in ascertaining the suitable timing and frequency of fertiliser application to achieve optimal plant development and output (Tarigan, A. P., Rahim, R., & Zulianto, A., 2019).

The Soil Moisture sensor is employed for the purpose of detecting the moisture content present in the soil surrounding the plants. The response time of the sensor, which has an average range of 5.58 seconds, suggests that it is capable of delivering timely data regarding soil moisture levels. The acquisition of this information is crucial for the effective regulation of plant irrigation, as it guarantees the provision of an adequate water supply to promote optimal growth and health of the plants (Mehmood, S., Sajid, M., & Nawaz, N., 2019).

The experimental evaluation of the 12V pump revealed that during its operation, the recorded input voltage was 11V, whilst in its idle state, the input voltage was measured to be 0V. The experiment was carried out utilising a digital multimeter in order to verify the operational functionality of the pump and its capacity to be regulated in accordance with the irrigation requirements of the soybean plant (Ibrahim, I., Nugroho, L. E., & Suryono, S., 2017).

By incorporating data from both sensors into the spraying system, farmers are able to effectively and punctually administer fertilisation and irrigation. The integration of sensor technologies into the spraying system offers potential for enhancing agricultural practises through the provision of intelligent and sustainable solutions for plant fertilisation, as well as insect and disease management (Shanthini, P. D., & Rama, S., 2020).

By utilising a precise measuring instrument that can assess soil moisture, air temperature, and air humidity, farmers may effectively manage soybean cultivation by implementing fertilisation and pest and disease control measures. Furthermore, the monitoring of these parameters can be facilitated by the Telegram application, enabling farmers to efficiently monitor and control the cultivation process. This facilitates farmers in making well-informed and strategic choices about soybean farming, thereby enhancing both productivity and the quality of the harvest (Vinothini, A., & Subhashini, N., 2021).

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