ISSN: 2455 - 1597

International Journal of Engineering Research and Generic Science (IJERGS)
Available online at: https://www.ijergs.in

ijergs Open Access

Volume - 12, Issue - 3, May – June – 2026, Page No. 76 – 85

Green Guard: Monitoring Plant Using Arduino Technology

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Abstract

Living things like plants, food, and flowers add to our planet's beauty and production. For best growth, they need a healthy environment with enough light, air, temperature, water, and nutrients. But a lot of plants can't adapt to harsh alterations in their surroundings, which may hinder their development. For plants to thrive, the right habitat must be provided. Additionally, it's critical to make effective use of the water that is available during times of scarcity. In order to solve this problem, an effective It is necessary to develop an automation system. With developments in technology, it is now feasible to customize environmental circumstances to satisfy each plant's unique requirements. Technology can also be applied to precisely track and manage environmental elements in compliance with the standards of the plants. This paper describes a water and temperature system that uses programming to maximize water use, regulate the surrounding temperature, and boost plant yield while reducing human intervention. An Arduino kit is used to build the system, which has a moisture sensor, a water pump, fan, and temperature sensor. Users can opt to operate the system in either manual or automated mode, depending on their preferences. A larger fan or other more effective component should be added to the system to enhance cooling capabilities. parts. Future developments in smart lifestyles and precision agriculture may result from the adoption of this technology[1]

Keywords: Arduino, Moisture Sensor, Temperature Sensor, Irrigation System, Plant Monitoring.

Introduction

For optimum growth, plants require certain environmental conditions, such as enough light, air, temperature, water, and nutrients. The surroundings, such as the temperature and Plant development may be impacted by soil moisture (Lee, Bhandari, Lee, C Lee, 2019; Onwuka, 2018). Variations from these ideal temperatures can have an impact on the growth and development of certain plants. Low temperatures can induce plant dormancy and postpone flowering and fruiting, while high temperatures can stress plants and hinder their growth (Niu C Xiang, 2018). For plants to grow and flourish, light intensity is also crucial.

Photosynthesis, the process by which plants transform light energy into chemical energy, uses light as a source of energy. varied plants require varied amounts of light; some require intense light to grow to their full potential, while others can flourish in environments with little light (Paradiso C Proietti, 2022).

Another essential component for plant growth and development is soil moisture. Water is necessary for many physiological functions of plants, including transpiration, photosynthesis, and nutrient uptake. Plant growth and development can be impacted by water constraint, which can result in wilting, leaf shedding, and decreased production (Dai, Yang, Patch, Grozinger, C Mu, 2022). For their growth and development, plants also need a variety of nutrients, such as elements like potassium, phosphorus, and nitrogen. Lack of certain minerals can have an impact on plant growth and development, resulting in decreased production, stunted growth, and other problems. As a result, it's critical to meet the unique needs of plants for growth and development, such as ideal soil moisture, temperature, light intensity, and nutrition.

Healthy growth and development can be ensured by proper plant care, leading to higher yields and enhanced production. A crucial component of horticulture, agriculture, and botanical research is plant monitoring. It entails routinely monitoring and measuring a range of physiological, environmental, and plant growth characteristics. This aids in comprehending the general performance, growth rate, and health of the plant. Conventional plant monitoring entails human professionals manually observing and measuring different plant parameters. This entails the professionals visiting the plants' site on a regular basis to examine and measure the physiological, environmental, and growth characteristics of the plants. There are a number of benefits to this plant monitoring technique.

It makes it possible to directly observe and evaluate the health and growth rate of the plant. Using their knowledge and skills, the specialists can spot any issues or anomalies in the plants and take the necessary action to fix them. Traditional plant monitoring also makes it possible to get thorough and in-depth information on the plants. This can aid in comprehending how the plants grow, react to their surroundings, and function as a whole. The information can be utilized for additional analysis and study to raise plant yield and productivity. However, there are a number of drawbacks to conventional plant monitoring. It is time-consuming and labor-intensive, requiring frequent trips to the factories. Because the measurements and observations rely on the knowledge and precision of the experts, it is also vulnerable to human error.

In a standard irrigation system, farmers apply constant watering without taking into account crop water requirements or field fluctuations. This method uses less water and may over-irrigate some areas of the farm while under-irrigating others, which could stress the plants (Mitchell, Weersink, C Erickson, 2018).

Furthermore, large-scale plant monitoring applications like greenhouses and agricultural areas are not appropriate for typical plant monitoring. Additionally, it is not appropriate for rural areas with little access to human specialists. As a result, even while traditional plant monitoring has its benefits, not all plant monitoring applications can benefit from it. To get beyond the drawbacks of conventional plant monitoring, alternative techniques are required, such as automated plant monitoring systems. Researchers studying greenhouse agriculture have shown a growing interest in smart controlled environment agriculture over the last fifteen years, according to published literature (Shamshiri et al., 2018).

Due to their potential uses in emerging technologies, automatic plant monitoring systems have received special attention in recent years (Kishore, Sai Kumar, C Murthy, 2017). Additionally, smart agriculture lowers farming's detrimental effects on the environment, enhances soil resilience and health, and lowers farmers' costs (Santiteerakul, Sopadang, C Tippayawong, 2020). The market now offers a wide range of commercial plant monitoring solutions.

For example, irrigation scheduling based on empirical knowledge of the dynamics of meteorological elements and soil and plant attributes is possible because the majority of commercially available irrigation controllers are preprogrammed to supply water at predefined intervals (Lozoya et al., 2014).

These pre-programmed irrigation controllers might not account for current circumstances, including recent rainfall or exceptionally high temperatures, that could influence the requirement for watering. Furthermore, pre¬programmed controllers might not be able to adjust to changes in the landscape, including the addition of new plants or a shift in the soil's composition. This has motivated a number of academics to create low-cost plant monitoring tools[2]. Farm monitoring and data collection are made easier by these monitoring systems, which are designed to automatically gather, send, and display data via mobile devices or the internet.

The design and development of a monitoring system for plants that can sustain a constant temperature and soil moisture level in their immediate environs is presented in this research. The goal is to create a prototype of an Arduino-based monitoring system that tries to offer a setting that is appropriate for each plant's requirements and developmental stage. A well-liked open-source platform for creating microcontroller-based projects and electronic circuits is Arduino. For programming and interacting with a variety of sensors, actuators, and other electrical devices, it offers an easy-to-use interface. The system is intended to be inexpensive, user-friendly, and able to deliver precise and trustworthy plant monitoring data[3].

When compared to conventional techniques, it is anticipated that the inclusion of Arduino in a plant monitoring system will greatly increase the effectiveness and dependability of data collecting. This is because to the ease with which Arduino systems may be configured to gather data automatically at predetermined intervals, eliminating the need for human intervention. In addition to saving time and money, this can lessen the possibility of human error in data collection. Based on the aforementioned crucial components, we restrict the prototype's functionality to control soil moisture and temperature by supplying water and air circulation to reach the intended level. As a result, we did not explicitly observe any particular plant species[4].

The following are the research's hypotheses: Temperature and moisture are just two of the physiological factors of plants that may be precisely measured by an Arduino-designed plant monitoring system. When compared to conventional techniques, the efficiency and dependability of data collecting in a plant monitoring system can be greatly increased by utilizing Arduino. Implementing an Arduino-based plant monitoring system can yield important information on the development and well- being of plants, enabling more efficient cultivation condition optimization. Real-time plant monitoring and remote control are made possible by the suggested plant monitoring system, which makes plant management more effective and efficient. An affordable way to automate several plant care processes, like fertilizer and irrigation, is through the integration of sensors and actuators[5].

Method

This study's research methodology used design and development research techniques, such as the phases of Analysis, Design, Development, Implementation, and Assessment. The design of the hardware and software components of the new system, such as the sensors, actuators, and Arduino microcontroller, was influenced by the literature review of current plant monitoring systems, including both automated and traditional systems, as well as their performance and limits. Arduino, an open-source hardware kit with a microcontroller and software development environment, was used to construct a plant monitoring system based on these criteria. The Arduino Uno R3 development board was chosen due to its ease of use and adaptability. It has a 16 MHz crystal oscillator, 20 digital input/output pins, 6 analog input pins, USB connectivity, a power jack, and a reset button. Programs can be uploaded to the device using the Arduino Integrated Development Environment (IDE).[6]

Figure 1 displays the monitoring system's circuit diagram. The primary components of the system comprise a breadboard, an Arduino R3 microcontroller, a dirt water pump, fan, LCD screen, moisture sensor, and DHT11 temperature sensor. The environment's temperature and humidity are displayed on an LCD. The pump for water continually circulates water through the system to keep the atmosphere cool. The fan introduces air into the system to keep the temperature near the plant constant. The water pump will automatically start to supply the water if the soil moisture level in the pot drops below a certain threshold. In a similar vein, if the ambient temperature above a the fan will start to pump cool air into the plant when it reaches a specified threshold.[7]

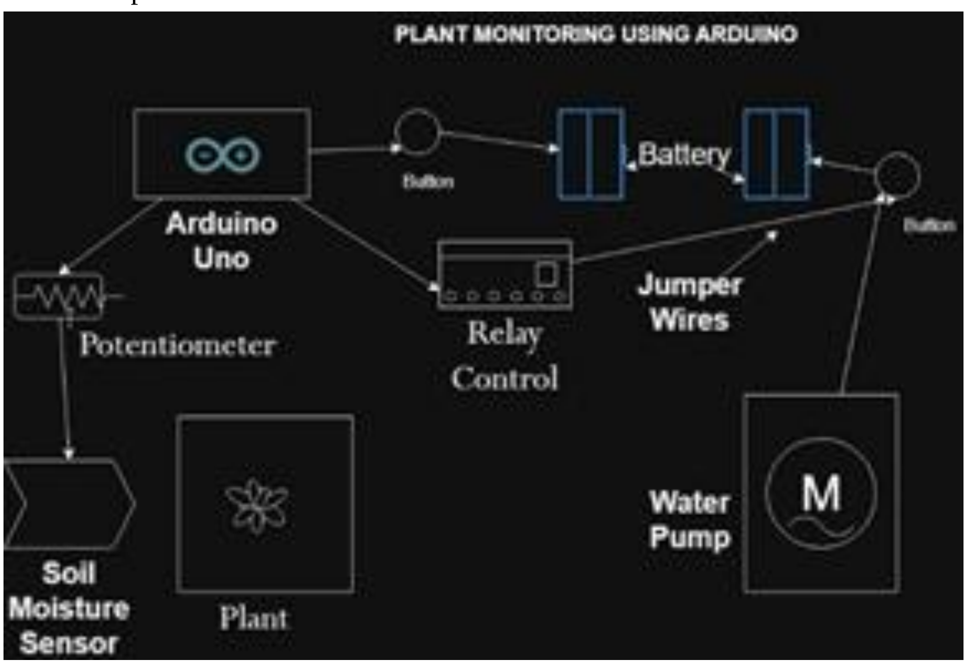

Figure 1: Schematic Plant Monitoring System Diagram

Relays are electrical switches that enable a single, low-power signal to control one or more circuits. Relays were employed in long-distance communication networks to transport and amplify signals between circuits. In our Relays are currently used to start or stop the flow of energy to parts that need independent power, like fans and water pumps.

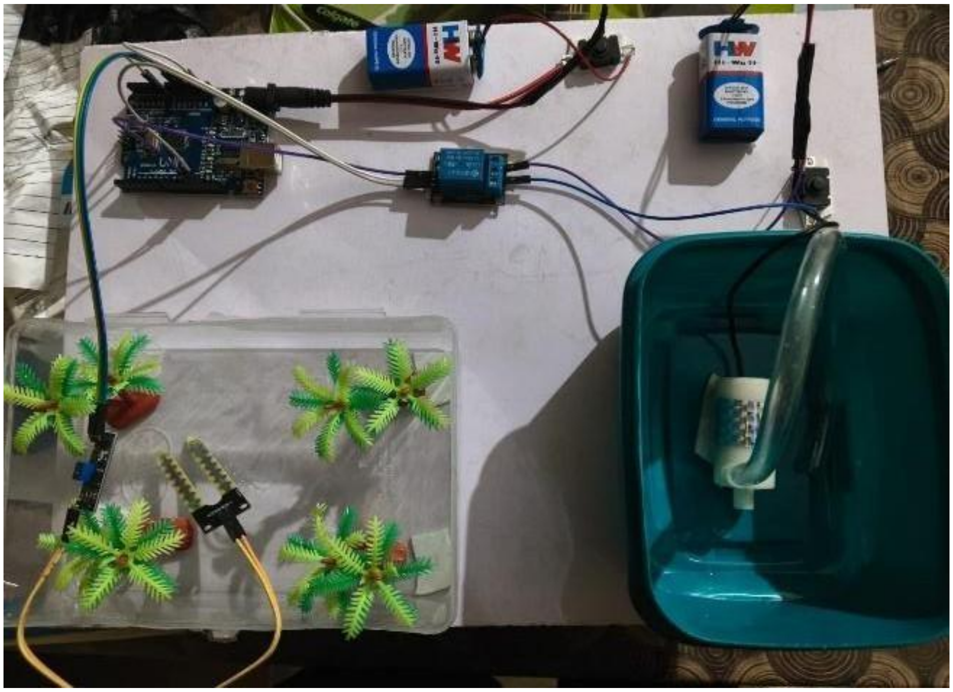

Figure 2: Arduino-based Monitoring System Circuit

An Arduino Uno R3, an LCD, a temperature sensor, a soil moisture sensor, a fan, and a water pump make up the system's entire Arduino circuit design, which is shown in Figure 2. Every part of the plant serves a distinct purpose. system for monitoring: The microcontroller board is the Arduino Uno R3, which offers an easy-to-use interface for programming and interacting with different sensors and actuators. It is the system's central component, directing the operations of the other parts and processing the information gathered by the sensors. Temperature, humidity, soil moisture, and other plant monitoring data are displayed on the LCD. It receives data for display and is linked to the Arduino board.

- The temperature of the plants and their surroundings is measured by the temperature sensor. It is linked to the Arduino board, which processes the sensor data before displaying it on the LCD. The moisture content of the soil in which the plants are growing is measured by the soil moisture sensor. Additionally, it is linked to the Arduino board, which interprets the sensor data and prepares it for LCD display[8].
- The fan regulates the airflow around the plants. A relay that is linked to the Arduino board allows it to be turned on or off in response to the temperature and humidity readings from the sensors.
- The plants' watering is managed by the water pump. Additionally, it is linked to the Arduino board via a relay that can activate or deactivate it in response to the soil moisture measurements obtained from the sensors.
- Connecting these parts to the Arduino board, programming the Arduino board to regulate the sensors' and actuators' operations, and displaying the gathered data on the LCD comprise the circuit for the plant monitoring system. The system keeps an eye on the plants' temperature, humidity, soil moisture, ventilation, and watering requirements, and offers precise and trustworthy data for plant monitoring. Figure 3 depicts the implementation of the suggested system prototype, including how it is set up for testing.

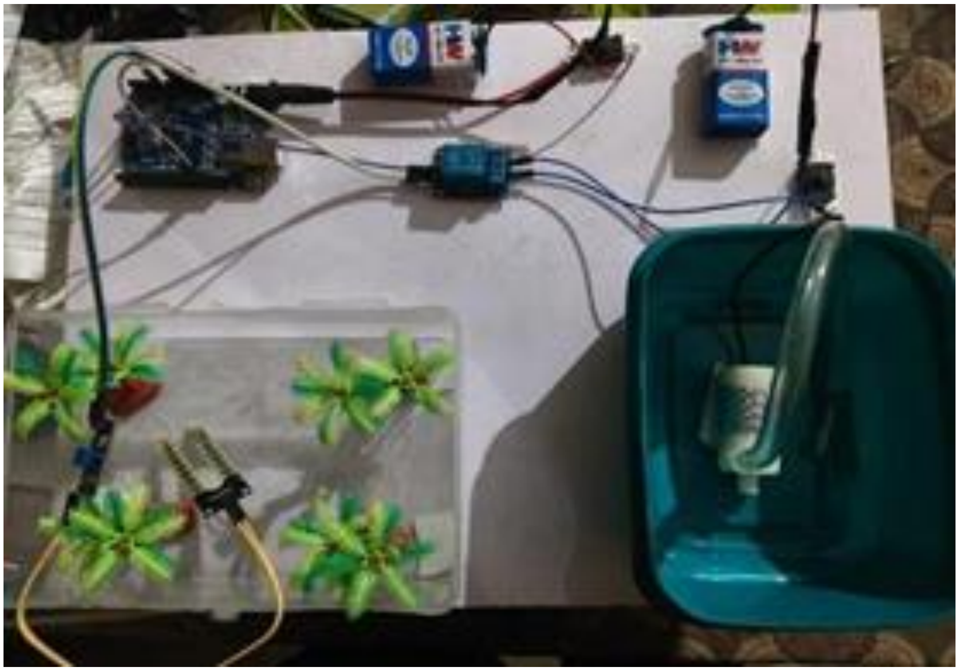

Figure 3: Hardware Setup

The setup of the suggested system prototype in an experimental setting is depicted in Figure 3. and how the various parts work together to keep an eye on and manage the the plant simulation's surroundings. The water-connected plant monitoring system water pump and reservoir on the left. A watering hose is attached to a water pump. that leads to a plant simulation that is set up on a tray on the right. The plant simulation is outfitted with a fan positioned above the plant, a temperature sensor, and a soil moisture sensor. Temperature and soil moisture data are shown on an LCD monitor. The soil humidity sensor starts by scanning the soil to ascertain the degree of soil dryness. degree of moisture. The Arduino Uno R3 receives the data from the sensor after that. The temperature data from the plant environment is then read by the temperature sensor. The sensors then send the temperature and moisture levels to the Arduino microcontroller. The suggested monitoring system can function in both automated and manual modes. By customizing the moisture and temperature threshold values for each sensor, the system gives the user complete control and monitoring capabilities over soil moisture and ambient temperature. The user could Pressing the watering button on the Arduino will manually carry out the watering process. The display of a moisture meter will show an increase in moisture level in real time when the watering process is over. The flowchart in Figure 4 shows the full process.9

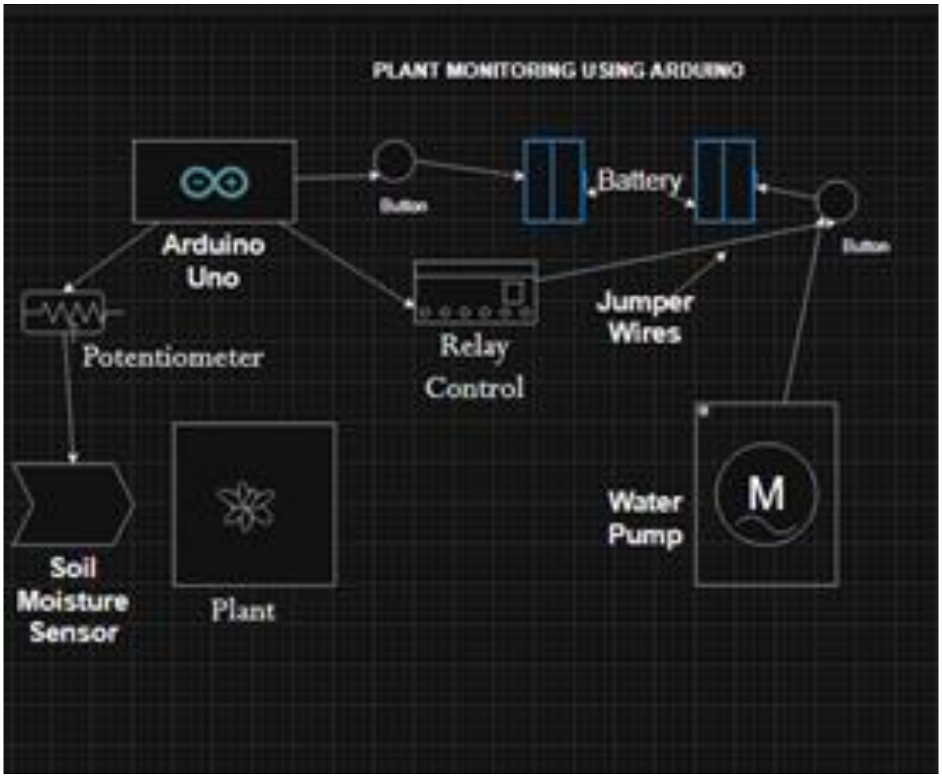

Figure 4. Flow Chart of the Monitoring Process

The temperature sensor will measure the air temperature while the device is operating. and a soil moisture sensor will measure the moisture content of the soil. The acquired value will be transmitted to the serial LCD and port monitor. If the algorithm determines that the soil moisture is below the desired level, then The software will also verify if the pump is turned on. If the relative humidity exceeds the target, it will keep checking to see if the detected temperature is lower than the target. When the pump is on, then the program checks whether the pump timer has run out. The program will determine how long it will take to irrigate and set the timer if the pump is off. and activate the water pump. After that, the software keeps checking to see if the temperature is below the desired level.

The system will shut down if the pump timer expires and the humidity drops below the desired level. turn off the pump. The program will keep checking to see if the temperature is below the target if the pump timer hasn't run out yet. The fan will shut off and the program will restart and loop if the temperature falls below the desired level. The program will determine whether the fan is on if the temperature is not lower than the desired level. If not, the software will restart and turn on the fan. If the fan is already on, the software will instantly restart from the start. The soil's moisture content is measured via a soil moisture sensor. We employed a measurement using volumetric water content (VWC), which is the proportion of soil volume to water volume (Clayton et al., 2021).

VWC=VoW/VoS.......................................(1)

Where:

Volumetric water content, or VWC VoW = Volume of water

VoS = Volume of soil

The volumetric water content for a specific surface area can be represented as a ratio of water depth to the depth of the soil.

VWC=DoW/DoS......................................(2)

Where:

DoW = Depth of water

DoS = Depth of soil. Another way to state equation (2) is as a percentage.

A plant vase with a surface area of 100 $cm2$ and a height of 10 cm was used as the experimental environment in a controlled experiment to assess the plant monitoring system's performance. Water was added to the vase via a water pump, and the experiment was carried out in an open space with room temperature as the ambient temperature[10].

Results And Discussion

The accuracy and efficacy of the suggested plant monitoring system are evaluated. The plant monitoring system in the experiment was set up to keep the temperature at 25°C and the humidity at 50%. Tests were conducted in a variety of scenarios where the humidity deviated from the intended value, both above and below, in order to evaluate the operation of the plant monitoring system. The following is a summary of these tests' findings:

Table 1: Watering system experiment results

No.	Initial Humidity	Target Humidity	Watering Time	Resulted Humidity	Volume of Water Given	Result
1	33%	50%	7 seconds	50%	165 ml	Successful
2	65%	50%	0 seconds	65%	0 ml	Successful
3	25%	50%	11 seconds	50%	290 ml	Successful
4	12%	50%	15 seconds	50%	400 ml	Successful

Table 1 illustrates the outcomes of the watering system trial. The "Initial Humidity" column represents the starting humidity level, the "Target Humidity" column indicates the desired humidity level, and the "Watering Time" column indicates the amount of time that the There was a watering system in place. The "Resulted Humidity" column shows the final humidity level after the test, the "Volume of Water Given" column shows the amount of water utilized in each trial, and the "Result" column indicates if the watering system was effective in achieving the target humidity. In all four trials, the watering system was able to reach the desired humidity level of 50%, according to the data in Table 1. The "Resulted Humidity column shows that in every instance, the final humidity level was 50%. The only exception is the second trial, in which the initial humidity was already 65%, and thus no watering was required. All things considered, the experiment was successful in reaching the required humidity level. through the use of watering system[11].

Table 2: Result of cooling system experiment

No.	Initial Temperature	Target Temperature	Fan Status	Resulted Temperature	Result
1	29°C	25°C	On	28°C	Unsuccessful
2	28°C	25°C	On	28°C	Unsuccessful
3	25°C	25°C	Off	25°C	Successful
4	24°C	25°C	Off	24°C	Successful

Table2 illustrates the results of the cooling system experiment. The "Initial Temperature" column provides the starting temperature of the system, the "Target Temperature" column indicates the goal temperature, and the "Fan Status" column indicates whether the fan was on or off during the test. The "Resulted Temperature" column shows the final temperature after the test, and the "Result" column indicates if the cooling system was effective in attaining the target temperature. Based on the results shown in the table, the cooling system was unable in achieving the target temperature of 25°C in the first two trials despite the fan was on. On the contrary, the cooling system was effective in sustaining the target temperature of 25°C in the third and fourth trials while the fan was off. These findings imply that the cooling system is ineffective at reaching the ideal temperature in an open space environment.

Conclusion

In order to evaluate the accuracy and efficacy of the suggested plant monitoring system, experiments were conducted under a variety of scenarios where the temperature and humidity varied from the intended values. The results of the studies reveal that the system is highly effective in attaining the aim humidity levels.

This observation confirms the conclusions of prior studies (Kumar C Magesh, 2017) that automatic plant irrigation based on soil moisture using Arduino can be implemented successfully. However, the results of the temperature monitoring system were not as good and suggest that more modifications in the cooling system are necessary to increase its efficacy in open-space settings. This study found some limitations of the system, including its restricted capacity for temperature control and monitoring within a specific range, which may be troublesome in large-scale and open-air plant monitoring applications. These constraints can potentially be solved through further research and development efforts, such as increasing the cooling system with larger fans or more advanced cooling systems, and enhancing the system's performance using better algorithms and signal processing techniques.

We also discovered that the suggested approach was simple to use and set up. The user interface and controls were intuitive and easy, making it accessible for individuals with minimum technical ability. Overall, our research indicates that the Arduino-based plant monitoring system has the potential to deliver precise and trustworthy plant monitoring data, and its affordability, effectiveness, and user- friendliness make it a useful tool for raising plant yields and productivity.12

Acknowledgements: This research is partly financed by The Ministry of Education, Culture, Research and Technology of The Republic of Indonesia in conjunction with The Indonesia Endowment Fund for Education (LPDP) under scientific research grant in 2021.

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