Smart Melon Farm System: Fertilizer IoT Solution

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Abstract

Embedded systems are increasingly being employed for a wide range of applications. Small and large enterprises can benefit from sensor networks and Internet of Things technologies. Farmers, particularly the next generation of farmers, are tremendously interested in the smart farm system. This is due to Thailand's favorable geography, and young farmers are becoming more technologically literate. However, smart farm systems on the market are still too expensive and don't meet small farms' needs. Consequently, the study proposed a low-cost irrigation and fertilizer system for high-quality melon farms in Chiang Rai, Thailand. The system can properly carry out irrigation and fertilization operations on the melon farm, which require specific attention at various stages of production. As a result, the technique reduces human work while simultaneously supplying adequate water and nutrients to the entire plant. Moreover, farmers with Internet access can manually monitor or supervise the operation at any time, from any location, and on any device. The developed system may gather information from sensors and operational procedures for further analysis in order to increase output and reduce waste.

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The system is affordable since it was constructed primarily using open-source software and low-cost embedded components with an ergonomic architecture. The results of the comparison show that the automatic method outperforms the human approach in terms of quality and production yield.

Keywords: Smart farm, fertilization, irrigation, melon, IoT.

1 Introduction

Currently, the globe is experiencing the largest food crisis in recent history. Unless immediate action is made to address the threats of war, climatic shocks, and the economic crisis, the number of hungry people will increase. This contact is making life more difficult for the world's poorest people daily and is reversing prior development gains. This hunger issue is caused by four things. 60% of the world's hungry reside in war-torn regions. The events in Ukraine demonstrate how violence magnifies hunger by driving people from their homes and destroying their means of support. People's ability to eat is hindered by climate shocks, which destroy lives, farms, and livelihoods. The economic consequences of COVID-19 are generating unprecedented hunger. Consequently, the cost of life or buying goods is increasing [1]. As of December 19, 2022, the cost of basic products continues to climb at a high rate in most wealthy nations. From August to November 2022, unemployment was high in most of the world's least developed and least developed countries, with 88.2% of low-income countries, 90.7% of lower-middle-income countries, and 93% of upper-middle-income countries having unemployment rates of more than 5%, with a few reaching 10%. In high-income countries, food price inflation is becoming more widespread. This category now contains 81.8% of the world's nations. The number of victims in Africa, North America, Latin America, South Asia, Europe, and Central Asia's developing nations is excessive [2–4]. Food consumption is increasing as the world's population grows and lifestyles change. Crop yields are levelling off in many parts of the world, ocean quality is declining, and natural resources, such as soils, water, and biodiversity, are becoming critically depleted. Agriculture's great sensitivity to climate change exacerbates the problem. Climate change is already having a severe influence on agriculture, with rising temperatures, greater weather unpredictability, shifting agroecosystem boundaries, invasive crops and pests, and more frequent extreme weather events. Climate change is diminishing agricultural yields, the nutritional quality of main grains, and animal output on farms. Moreover, climate change alters rainfall patterns. This means heavier rain and longer dry periods. Temperature shifts, rising average temperatures, more intense heat throughout the year, fewer chilly winter days, and more cold-season thaws will harm farmers everywhere. Therefore, global warming and climate change have several effects on agriculture. For example, warming reduces yields because crops mature faster, generating less grain. Higher temperatures hinder plants' capacity to absorb and utilize water. When temperatures rise and plants transpire more, soil evaporation increases. Climate change has reduced the resources available for agricultural operations, and much of the land that is appropriate for farming is already occupied by other companies, such as construction. As a result, the only option to raise volume is to boost production efficiency. There is no doubt that smart farming may help to solve this problem; in fact, it appears that finding a solution will be difficult without it.

Technologies are being developed to increase agricultural yields and productivity. Information and communication technology (ICT), artificial intelligence (AI), and the Internet of Things (IoT) enable remote administration of equipment and systems, leading to the employment of robots to harvest and weed and drones to fertilize fields and monitor crop progress. Smart agriculture solves many agricultural production difficulties since it allows for the monitoring of changes in climatic conditions, soil properties, soil moisture, and so on. IoT technology can connect numerous distant sensors, such as robots, ground sensors, and drones since it enables devices to be connected over the internet and controlled automatically. This is to enhance spatial management methods to boost crop yield while avoiding the abuse of fertilizers and pesticides. Furthermore, the AI models have been applied to many sorts of data, such as agricultural systems such as irrigation and soil and water management. A smart agriculture system based on IoT technologies provides several benefits for all agricultural operations and activities in real-time. Among these benefits are irrigation and plant protection, as well as improved product quality, fertilization management, and disease prediction. The following is a short summary of the advantages of smart agriculture: (1) obtaining more real-time agricultural information; (2) remotely monitoring and managing farmers; (3) taking control of water and other natural resources; (4) more efficient livestock management; (5) more accurate soil and crop evaluation; and (6) increasing crop yields [5–22].

When it comes to agricultural exports, Thailand is among the top five countries in the world. The country is a significant rice grower and exporter, as well as a big exporter of a wide variety of vegetables and fruits. Higher production costs and production procedures that have not been enhanced as much as they should have been to improve the quality of life and the economy of the country's farmers and people continue to keep most Thai farmers from earning adequate living wages. Therefore, the government has a strategy to advance Thailand toward Thailand 4.0, which will result in an innovative economy. That is, the national development strategy advocates for a shift away from the existing economic paradigm of "do more, get less" and toward one of "do less, get more." Consequently, there is a shift from traditional farming to modern farming, with an emphasis on management and the use of technology to improve farming, boost output quality, and raise farmers' incomes until they reach the level of entrepreneurial farmers equipped with the requisite information, experience, and training to increase their yields and enhance their ability to compete in global markets. It's no surprise that natural or organic farming has gained favor during the last decade. Thailand is not the only country experiencing a period of awakening and growth; numerous countries throughout the eastern and western hemispheres are experiencing similar phenomena, including China, India, and several European nations, including the United States. The growth of the organic market in response to the issue of chemical contamination in vegetables has an immediate impact on the well-being of humans, nonhuman animals, and native plants around the globe. This is thanks to government laws in each country that encourage organic farming. Beneficial insects and animals, such as bees, butterflies, and bats, have a profound impact on human well-being and the quality of our lives. Consequently, organic farming is an essential agricultural practice since it is a kind of environmentally and socially responsible agriculture. However, contemporary organic farming requires the control of several elements to avoid contamination from chemicals that may be present in a variety of environments, including soil and water. Organic farming requires a significant amount of care from farmers to improve soil conditions for growth, including the acquisition and use of water from natural, clean water sources, which are limited resources and must be utilized in line with the kind of plants produced. The success of a farm depends on the quality of the soil, the types of vegetables planted, and the availability of clean water. Environment, climate, and natural insects and pests are excluded since they are difficult to control.

Due to the rapid development of internet technology over the past ten years, as well as the development of microcontroller and microprocessor technology that is more efficient and less expensive, the Internet of Things

(IoT) has been developed as a framework to connect sensors and control devices for use in more processes. The technology has been in use for a long time, but only lately has it gained popularity. This is a consequence of inexpensive internet technology and embedded system hardware, which has led to the creation of a variety of automated or intelligent systems. Among them is the creation of agriculture sector automation systems. As described in the concept and explanation for the absence of an integrated system for medium or small farms, the cost of a system that operates a big factory is costly, sophisticated, and difficult to implement and use. In addition, research on fertilization procedures and applications has accounted for less than 10% of IoT in agricultural research over the previous decade, despite these issues [13–50]. The prototype system for mixing fertilizer has been developed in a variety of methods, such as for mixing organic fertilizer [41], constructing a system for mixing fertilizer for a hydroponic planting system [42–44], or utilizing GIS and fuzzy logic techniques for fertilization applications [45–50]. Depending on the quality of the soil and the types of plants cultivated in each region, the fuzzy principle may be used to assess and optimize sensor data in order to increase the effectiveness of mixed fertilizer. In addition, a greenhouse environment sensor and the fuzzy approach are utilized to determine how to apply fertilizer, decrease overfertilization, and increase crop yield. However, despite the fact that the prototype mentioned above can increase work efficiency compared to conventional methods and reduce labor and expenses, it is still in the research phase and requires additional development before it can be implemented or meet the needs of farmers. Therefore, this study's aim is to provide a method for automated melon farming. The system's primary function is to address the melon farm's pressing issue of inefficient use of water and fertilizer. For the farmer to put in the time and energy to maintain or add additional systems in the future, the system must be built to endure the environment in the greenhouse and be used in practice, and it must cost less than the equipment or systems employed by the huge agricultural business today. Consequently, the system was built using a cheap microcontroller and free, publicly available software. The sensors, as well as the units themselves, are designed. The sensors will collect data on environmental factors like temperature and humidity to help regulate irrigation and fertilizer automatically. The system can also track soil moisture and irrigation data over the course of an entire crop cycle, which can then be utilized to optimize operations, plan for the following growing season, and optimize water and nutrient consumption.

2 The Proposed System

We have learned about the benefits and drawbacks of IoT technology through research and implementation. This includes the ability to improve or construct a system that fits the specific needs. Additionally, system modifications that are adequate for certain applications and may reduce total system costs. Both the hardware and the software framework were designed to be compatible with the solution and appropriate to the farm's needs. The designed system contains sensors that will be put in the working area and will store data in online databases, as well as applications for collecting, controlling, and displaying data for analysis. This will increase the system's efficiency and make it suitable for actual deployment. The proposed system was designed and tested at the Ozone Farm in Chiang Rai, Thailand. The farm's objective is to become the top producer of superior graded, pesticide-free watermelon. As a result, the melon planting is prepared by using hygienic materials as planting mediums, such as sand and coconut husks, and the planting ratio is 1: 1. Furthermore, in a greenhouse 5 by 20 meters in size, white bags 8 by 16 inches in size were used to plant one melon tree per bag, for a total of 204 trees per house. The spacing between the bags in the house is 50×50 cm, and they must be treated in a methodical manner due to the requirement to control the watering and fertilizing systems. The expertise of a human operator is typically required for such error-prone activities. The fundamental difficulty is now to use physical effort to manage and monitor the watering and fertilizer solution system. The watermelon fertilizer solution formula was created by combining the six major fertilizer solutions that must be applied at each stage of growth to generate optimal yields. When the number of greenhouses increases, and the cultivation period varies from house to house. This can occasionally lead to improper fertilization, watering, or maintenance.

Furthermore, due to COVID-19 issues, all businesses have been impacted, making it difficult to sustain labor and run the business. As a result, farmers require a system that can control fertilizer and water management in the greenhouse. The needed system should be cost-effective and capable of controlling the watering and fertilization formula at different times. The technology should eliminate or reduce human-caused fertilization and watering errors. As a result, the system can relieve pressure on farmers and other employees, allowing them to take on more physically demanding tasks. Furthermore, fertilization and watering process data can be collected alongside environmental sensor data during each production phase. These data can be examined and analyzed further to improve the system and productivity

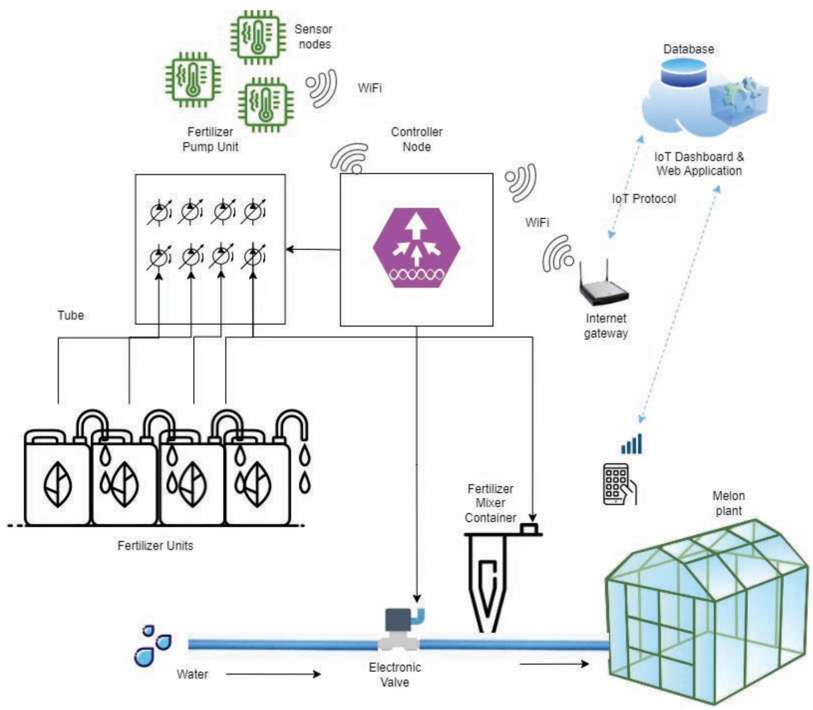

Figure 1 The fertilizer and irrigation system.

while lowering production costs. As a result, the major goal is to aid in overcoming the primary challenges related with controlling the watermelon farm's fertilization and irrigation systems. The Internet of Things technology, low-cost embedded hardware, and open-source software will be used to create a low-cost system. Figure 1 illustrates the proposed framework.

2.1 The Designed Hardware

The designed system consists of the fertilizer unit, the fertilizer pump, the electronic valves, the fertilizer mixer container, the sensor nodes, and the cloud database and application. A single controller node will support one melon farm. The farmer can control the melon farm using multiple nodes. Local analysis can be performed by the sensor or controller nodes. As illustrated in Figure 1, the data is stored in the cloud, and the application is cloud-based. The system includes both local and cloud-based nodes that can subscribe to and receive information collected in the cloud from IoT devices. The controller node can process data and use it to control fertilizer or irrigation operations. The sensor node will transfer the data to the cloud database. The data can be utilized to activate the control function for fertilization and irrigation activities. The sensor nodes are independent of one another. It can be applied to various controller nodes or services. The sensor data, as well as the controller node's operational status (fertilization and irrigation), can be observed in real time. The application is designed in two modes: automatic and semi-automatic. The automatic mode will give irrigation based on average sensor data such as air temperature and humidity, soil humidity, light intensity, soil pH, and NPK. For the semi-auto, the farmer can program the fertilizer formulas, which are the result of a combination of six liquid fertilizers according to the needs of premium-grade melons, which require different fertilizers at different growing phases.

The system is designed to work with either direct current or alternating current. At 5 and 12 volts, alternating electricity is converted to direct current to power a variety of electronic devices, such as a microcontroller board. It controls the motors that power the six fertilizer pumps as well as the electrical valves that control the water flow. For the MCU board, a low-power system on a chip (SoC) with a Wi-Fi and Bluetooth module, ESP32, is being used. The board is powered by 5 VDC, while the motor and valves are powered by 12 V. The circuit uses IC OPTO to control the pump and valve via the MOSFET circuit, which acts as a switch to protect the system's control circuit. Figures 2 and 3 depict the designed controller board.

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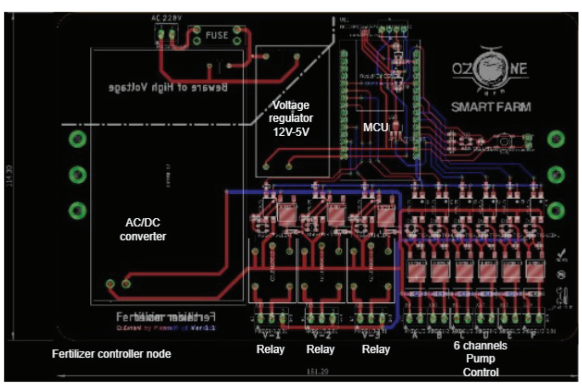

Figure 2 The controller module's PCB design.

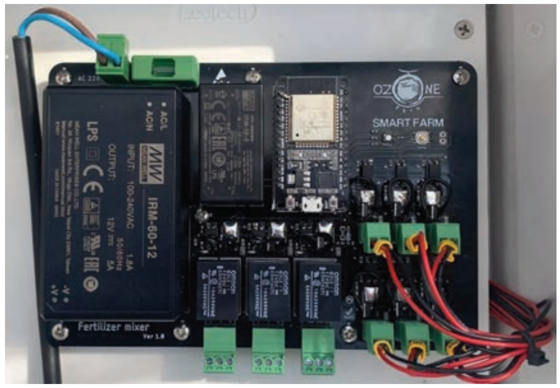

Figure 3 The assembly's final controller module.

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2.2 The Designed Application

To lower the total cost of the system applications, multiple open-source frameworks have been used. The web application is built using the Laravel PHP framework. The MQTT broker, EMQX, an open source MQTT broker, is utilized for the IoT communication protocol between the server and the embedded system. The designed web application will receive user working process for fertilization and irrigation. In terms of the database, the NoSQL-based MongoDB database was chosen since its JSON object format can read data exceptionally rapidly, allowing the system to perform faster. Furthermore, Node-RED is utilized to define the behavior of the system. API (Application Program Interface) is used to communicate between the server and the control board, with the system's major goal being the capacity to collect fertilizer independently, combine fertilizer, and manage fertilizer and water supply autonomously. Because it can accommodate six pumps and manage the level of fertilizer in milliliters based on pump performance,

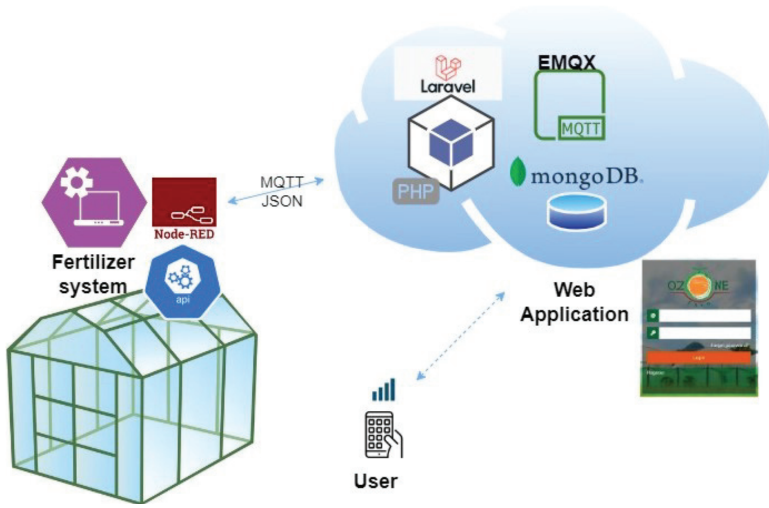

Figure 4 The application architecture.

it can generate or mix up to sixty-six unique fertilizer formulations at the same time. Furthermore, the watering interval can be adjusted in seconds. This provides for precise control over the time of fertilizer and water supply, which may be customized according to the requirements of the plant and the user. The controller module will be essential in the system. The application's architecture is depicted in Figure 4.

The following are the application's key functions: The web application will get the time and volume of each liquid fertilizer once the fertilization or irrigation time is established. The controller module will regulate the water valve and the fertilizer dosing pump. The dosing pump will be activated in the predetermined quantity, drawing liquid fertilizer from the liquid fertilizer tank into the mixed liquid fertilizer container to mix and generate the required amount of fertilizer. The electronic dosing pump will be disabled once the required volume of solution or liquid fertilizer has been delivered. The water control valve will thereafter be opened. Water must flow in a predefined order through the water supply pipe, the water valve, the venturi-type fertilizer mixing valve, and lastly to the melon farm. The valves are electronically closed to stop functioning until the timer runs out. Figure 5 shows the system algorithm.

The core algorithm may appear simple, yet it clearly describes the system's essential function. Many detailed processes, such as collaboration between hardware and software, must be considered when creating the

Algorithm 1: Fertilizer mixing and irrigation processes

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Input: The fertilizer formular and irrigation schedule
Output: The mixed fertilizer and irrigation
Fertilizer formular ← Set the required fertilizer formular
Irrigation ← Set the amount of water
Duration ← Set the fertilizer and irrigation time
while (current time = scheduled time) do
    Turn on fertilizer pumps // collect the required liquid fertilizer from each pump
    if (each fertilizer volume = setting amount) then // check fertilizer quantity
        Turn off each fertilizer pumps
        Turn on irrigation valves
        if (irrigation time = setting period) then
            Turn off irrigation valves
        end
    end
end
```

Figure 5 The mixed fertilizer and irrigation system algorithm.

practical application and system. For example, if the chosen fertilizer pump can function at 100 ml per minute, the program will calculate the amount of fertilizer necessary based on this specification.

3 System Implementation

There are six melon plants. Farmers cultivate melons differently for each plant so that they can produce melons at different times of the year. As a result, each plant requires different fertilizers and irrigation. In addition, each plant requires one controller module. In addition, a Wi-Fi gateway router is installed to ensure that the system may connect to the internet without sharing bandwidth with other users or apps. The controller node was placed in the plant's front part. The plant is constructed with two doors to keep insects out and contaminants out of the growth area. As a result, the plant is protected by a metal nest and greenhouse cover film. This will also raise the temperature within the greenhouse, making it more suited for growing the melon. Because it is constructed of steel and is difficult to shake when the fertilizer pumps are

Figure 6 Installation of the system at the melon plant.

running, the controller module can be mounted to the green house frame. Figure 6 depicts the fertilizer system's installation.

The web application is responsive, which means that the user interface or design changes to user behavior and the surrounding environment based on screen size, orientation, and device. It is accessible by computer or mobile device. As seen in Figure 7, the farmer can remotely monitor and operate the connected farm. The user can manually enter the fertilizer formula, or the farmer can construct the necessary fertilizer and irrigation data for the entire growing season, and the data can be activated and continually functioning from day one. Furthermore, as illustrated in Figures 8 and 9, the farmer can monitor the environmental parameters of the melon farm and control fertilizer and irrigation operations in real-time or on a predefined schedule based on the melon's needs throughout each growth cycle. The application's intelligent

Figure 7 Login page and system information for each plant.

Figure 8 Fertilization and irrigation data for each growing period and its working status.

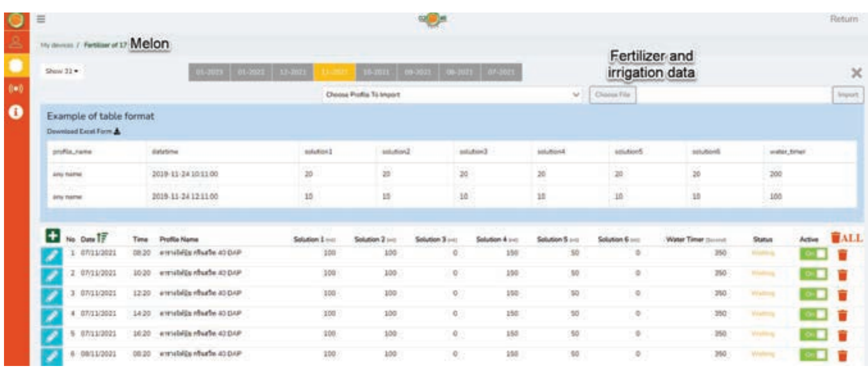

Figure 9 Fertilization and irrigation data can be uploaded and activated.

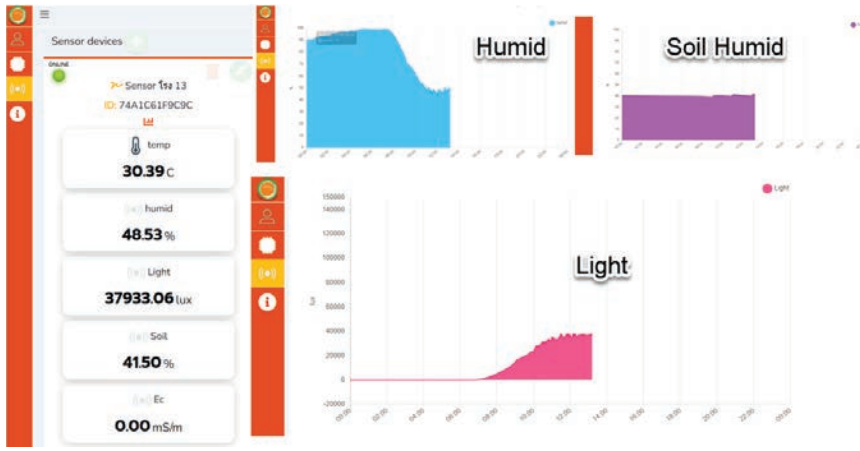

Figure 10 Sensor menu and real-time information.

agriculture services are divided into two categories: devices and sensors. The device menu displays controller node information and status for each farm, as well as the location of each controller unit and its operational conditions. As seen in Figure 10, the sensors menu enables for the real-time collection and monitoring of sensor data. The monitoring menu allows end users to analyze the temperature, humidity, and lighting of the connected farm, among other environmental conditions. Every ten seconds, all environmental data was collected and plotted on a graph. The sensor module can be configured to connect with the controller module to operate the irrigation system based on sensor data. The specific needs and work practices of the farmers affected the design of the user interfaces. As a result, the proposed IoT-based fertilizer mixing and irrigation system is user-friendly and easy to use, which were the primary design goals.

4 Results and Discussion

The amount of time required to maintain a melon greenhouse may vary depending on the farm's individual characteristics and production strategy. In general, a farmer must put in significant effort to monitor temperature, humidity, and other environmental variables; water and fertilize the plants; manage pests and diseases; and harvest the melons.

Farmers would typically need to monitor the state of the plants, the irrigation and fertilizer systems, and the environmental conditions within the greenhouse at least four times per day, and more frequently during critical development phases. There are thirteen watermelons for the ozone farm, and the system is set up for six plants; it takes two farmers and about five hours every day to care for the entire plant. Because premium melons require five doses of fertilizer per day during certain growth seasons, the farmer must be precise with the fertilizer mix and watering schedule for each plant. In addition, they must perform tasks such as greenhouse harvesting and cleaning. In addition, this may take a large amount of time. However, when the fertilizer and irrigation systems have been in place for a year, the use of sensors and automation may reduce the amount of time spent on some tasks, such as monitoring environmental conditions and operating the irrigation and fertilization systems. The farmer can use the data to make more informed decisions, lowering the amount of time spent on greenhouse management. The liquid fertilizer may be produced for a week's use, and the farmer should just verify the system's dependability every morning. This resulted in less time spent on tasks like watering and fertilizing, however they may still have to spend time maintaining and debugging the equipment. The average daily time spent on melon plant management ranges between one and two hours. By utilizing the technique, the farmer saves almost sixty percent of his daily time. As a result, these systems can drastically reduce the amount of labor necessary on a farm. Furthermore, with the fertilizer and water budgets set, the system can optimize fertilizer and water utilization, resulting in a more efficient and effective use of resources.

Furthermore, the findings show that plants that use the system produce higher quality and have fewer infections than those that run manually. If one or more melons become infected, the entire melons plant is compromised, and the farmer loses the entire harvest. Throughout the cold season, the melon's skin will be challenging to break. The problem is most usually caused by a nutritional deficiency or a sudden change in temperature or humidity within the plant. Figure 11 depicts the outcomes of a comparison between system-operated melon plants and farmer-operated melon plants. 80% of manually operated facilities discovered the cracked melon problems. Furthermore, plants that use the traditional approach have smaller melons and leaves. The problems could have been caused by human error. Farmers may fail to perform some fertilizer or irrigation tasks, or the fertilizer mixture may be of poor quality. Variations on this task are conceivable due to the requirement for knowledge and training. A new employee or farmer may estimate or mix fertilizer differently for each plant and not to the same standard. Furthermore, the technology may make it easier for farmers to comply with fertilizer and

Figure 11 Production of the system- and farmer-operated melons.

water consumption regulations, as well as reduce the environmental impact of agriculture by reducing the amount of fertilizer and water that is wasted or applied inconsistently. In general, intelligent farm fertilization and irrigation systems may be an effective technique for increasing agricultural output and sustainability.

5 Conclusion

The research proposes the design and development of an intelligent fertilizer and irrigation system based on IoT. The premium-grade melons require different fertilization and irrigation at different growth phases. The procedures are designed to meet the needs of farmers who need to improve their work processes while caring for these melons. Farmers must also collect environmental data and work methods to maximize or improve productivity. The results show that the proposed method is simple and delivers adequate fertilization and watering throughout the growing season.

Furthermore, when comparing production statistics to those of a manually controlled plant, human error can unexpectedly cause the entire plant to fail. Finally, the system may improve the efficacy and efficiency of resource usage, resulting in improved agricultural yields, reduced costs, and increased production. Furthermore, the technology may make it easier for farmers to follow fertilizer and water use regulations and reduce the environmental impact of agriculture by reducing the amount of fertilizer and water wasted or misapplied. Furthermore, the technology may reduce the effort required for other agricultural chores, such as monitoring environmental conditions and controlling the watering and fertilizer of the melon plants. Moreover, the technology may assist farmers in making better-informed decisions, lowering the time spent on farm management. However, remember that the exact results and benefits will vary depending on the farm and the operations performed. Additionally, intelligent farm systems may increase the person-hours required for additional activities, such as keeping the equipment working and repairing it when it malfunctions.

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