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Smart Microclimate Controller for Propagation Greenhouse on Growing New Plants from Seeds

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Abstract

Greenhouse provides a stable environment for seeds that are typically started in seedling trays by regulating the soil moisture, temperature, and humidity for seedling production at any time. Production of new plants from seeds in the propagation greenhouse proliferates a large number of plants in a short period, however, environmental factors affect the germination and growth stage of the seedlings. The Internet of Things is growing with its emerging sensor devices offering extraordinary approaches to improve agricultural productivity. In this study, it focuses on growing new plants from seeds using a microclimate controller for propagation greenhouse. The objectives of the study are: to design and develop a smart microclimate controller; to identify the appropriate threshold values of the microclimate parameters and; to evaluate the level of reliability of the smart microclimate controller. Using a survey questionnaire and face-to-face interview methods focused on greenhouses, propagation practices, and environmental conditions, substantial information was obtained from selected greenhouse technicians in the province of Isabela. The various practices were used to develop significant plans and specifications to regulate environment parameters. With the use of a smart microclimate controller along with a propagation greenhouse, the recorded daily average growth rate of seedlings produced is 0.83 cm equivalent to an average of 0.21 cm daily growth rate quicker than of the seedlings produced on traditional propagation greenhouse. Hence, the microclimate controller demonstrates a competitive means of growing new plants from seeds. Furthermore, it promotes quality production of seedlings on minimal supervision but delivers constant service efficiently.

Index Terms: *Agriculture, Microclimate Controller, Propagation Greenhouse, Seedling Production*

I. INTRODUCTION

Propagation of crop from seeds is the best source of plant species that retains important genetic properties, however, the climate is one of the major environmental factors that affect seedling production. The greenhouse is a significant element in agriculture industries designed to provide suitable environmental conditions for better plant growth and development. The microclimate of a greenhouse is influenced by factors such as soil moisture, temperature, and humidity. In spite of good crop genetic properties, soil and fertilizer quality, the poor temperature management, unbalanced humidity level, and unsatisfactory soil moisture may result in a major decrease in productivity [1]. Monitoring and control of greenhouse parameters play an important role to maintain the needed microclimate condition for the germination and growth of seedlings. The greenhouse as a primary form of controlled environment planting combined with the Internet of Things (IoT) as the enabling technology for agricultural applications is capable to monitor and regulate microclimate through sensors and actuators [2, 3]. Providing a microclimate controller

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for propagation greenhouse replaces human labor for more effective microclimate management [4].

Due to the increasing expansion of sensor systems, the IoT architecture in this study is used to promote smart farming [5] on managing microclimate conditions for the propagation greenhouse. The smart microclimate controller for propagation greenhouse is a technical approach that implements provisions to monitor and control automatically the microclimate conditions such as soil moisture, temperature, and humidity enabling propagation of plants throughout the year. The expansion of sensors for environmental parameters facilitates the enhancement of farming operations and decision-making has a great potential in revolutionizing traditional farming techniques to improve propagation productivity and quality from reduced human interaction [6-8], hence, it enables microclimate balancing to ease environmental monitoring and control [9]. The concept of integrating IoT with agriculture is to improve traditional farming methods into a new spectrum of smart farming that opens up multi-dimensional horizons for technological effects on sustainable farming. The use of integrated sensors to monitor the environment within the greenhouse has enabled the growth of IoT to provide a way to automate data collection, storage, assessment, and optimization to improve farming operations and management in real-time situations. The IoT architecture is a fitting choice for smart farming attributable to its large-scale interoperability, scalability, and versatility [10]. Farmers need to consider using technologies to improve the methods of plant propagation and achieve a higher level of competitiveness [11].

The main objective of this study is to design and develop a microclimate controller for propagation greenhouse providing competitive tool on monitoring and control of parameters specifically the level of soil moisture, air temperature, and humidity to intensify the propagation of plants from seeds.

II. METHODOLOGY

This study is a prototype model that focused on the interview, analysis, prototype design, and prototype testing of a microclimate controller for the propagation greenhouse. The sources in this study consist of data from interviews, observations, and literature reviews from journals and related articles. The necessary data is gathered from the 28 respondents involving municipal agriculturists, farm technicians, and farm managers from selected municipalities engaged in vegetable propagation. The selection of respondents is based on a purposive method of sampling. The data are discussed with the available literature to establish a smart microclimate controller architectural plan and specifications to strengthen the efficiency of the propagation greenhouse. Pepper has been selected for the propagation due to its relatively fast period of seedling production. The microclimate controller runs within the 30-day duration of plant propagation.

Fig. 1 shows the overall architecture of the smart microclimate controller based on the observations and analysis of agricultural practices in the province. The smart microclimate controller architecture is typically divided into four parts: data collection layer, data processing layer, management service layer, and communication layer. It involves sensors for reading significant parameters of microclimate and actuators to sustain the appropriate environment condition of the propagation greenhouse steered by a microcontroller to complete the processes such as irrigation, fogging and ventilation.

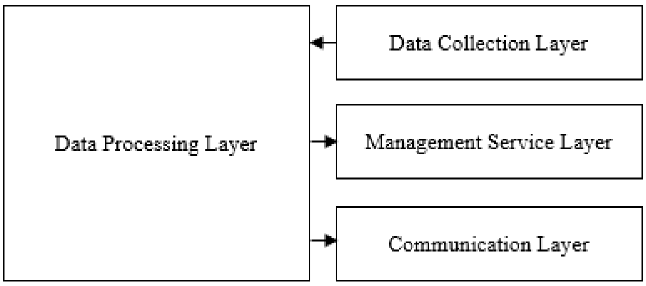

Fig. 1. Smart Microclimate Controller Architecture

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The smart microclimate controller architecture carries automatically to monitor the movements of the parameters and take necessary action to activate the actuators and adjust the environmental conditions. The obtained data and the progress of the microclimate condition are transmitted using the Global System for Mobile Communications (GSM) module via Short Message Service (SMS) to the farmers enabling them to track the environmental conditions of the propagation greenhouse. The threshold is set accordingly to maintain the environmental parameters such as soil moisture, temperature, and humidity that are continuously monitored using sensors [12, 13]. The functions of the different layers used to monitor and control the microclimate condition of the propagation greenhouse are discussed in the following subsections:

A. Data Collection Layer

The data collection layer acts as a pass-through layer that primarily deals with devices used to collect microclimate data such as soil moisture, temperature, and humidity. This layer comprises various components such as soil moisture sensor, temperature and humidity sensor used to measure the reflected energy within the propagation greenhouse. It also performs aggregation and conversion of the captured analog data for further processing. Other devices used on this layer are responsible for measuring the volume of stored water. The data collected from the sensors is transformed into an appropriate unit and stored in the data processing layer [21].

B. Data Processing Layer

The data processing layer manages sensed data from the data collection layer and enables the management service layer to take corrective action and handle the microclimate condition. This layer is also responsible for storing data and transmits the microclimate condition to the farmer through the communication layer. It is the core part of the architecture that stores, analyzes and processes the data received from the data collection layer and passes the final decision to the management service layer which will regulate the microclimate [13].

C. Management Service Layer

The management service layer focuses on providing services to neutralize environmental conditions in line with the instructions provided by the data processing layer. This layer consists of actuators that provide utilities such as irrigation, ventilation, misting, and refiling for the irrigation to maintain microclimate parameters. Using a water pump, the water storage tank will be filled when it drops within 20 percent of the threshold value. The irrigation module utilizes overhead sprinklers that activate through a high-pressure pump when the moisture level falls below the moisture sensor's threshold value and shuts when sufficient water has been delivered. The fogging module is enabled when air moisture becomes weak or temperature becomes strong to provide the appropriate temperature and air moisture using the temperature and humidity sensor.

D. Communication Layer

The communication layer transmits data to the registered mobile number of the farmer through the GSM. This layer serves as a bridge for the transfer of data such as the level of soil moisture, temperature, humidity, and water storage.

III. RESULTS AND DISCUSSION

This study was conducted to design and develop a greenhouse microclimate controller to strengthen the plant propagation program of the local government units in the province of Isabela. The main industry of the province is agriculture which includes plant propagation. Among the 3 particular plants that are highlighted in the different greenhouses for propagation such as eggplant, tomato, and pepper, the researchers focused on pepper seedling production to evaluate the reliability of the smart microclimate controller.

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In managing the propagation greenhouse, respondents commonly ignored the environmental condition that influences plant propagation such as heating and artificial lighting. Based on their observations and experiences, the heating system is not applicable even though the average temperature ranges from 26 to 32 degrees Celsius, and is sufficient to maintain the desired temperature in the greenhouse. Correspondingly, it was clearly observed during the hot or summer seasons that the increase in temperature affects the growth of plants, hence the existence of exhaust fans will rapidly boost new air that reduces plant heat stress to a cooler and more comfortable growing environment [12]. On the other hand, the use of artificial greenhouse lighting is inadequate and causes problems associated with insects. Because of the color heat light intensity, wavelength, direction and time of exposure [14, 15], artificial light sources are significantly affected by the involvement of insects in the environment. In particular, the respondents clearly considered the lighting draws insects that are certain to be harmful to seedling production.

The IoT has demonstrated different directions in the field of innovative agricultural exploration, hence, investigations are carried out on sensors that provide intelligent services for the optimal germination and growth requirements of plants [16] to make the process of monitoring and controlling the environment parameters easier and more efficient [17]. Specific devices such as soil moisture, temperature, and humidity sensors are installed on the propagation greenhouse [18]. It reduces the need for human intervention to monitor the environmental parameters and regulate climate conditions. The augmentation of the existing agricultural practices on plant propagation towards a smart microclimate controller offers an optimal environment along with real-time monitoring is one of agriculture's most useful IoT undertakings. Even in a very usual small span of monitoring the environment parameters varying from several weeks and regulating climate conditions, it evidently demonstrates the serious impact on plant germination and growth [19].

The present management practices suffer from a high frequency of labor and a lack of data management in monitoring the environmental aspects of a propagation greenhouse. Hence, the IoT architecture offers a dynamic high-level non-linear mechanism to maintain microclimate conditions [20]. The greenhouse effect raises the temperature that can be regulated by a fan, natural ventilation, and fogging [21] so as to satisfy the level of plant requirements. The microcontroller as the central processing unit, sensors for physical parameter sensing, relays for controlling actuators, Liquid Crystal Display (LCD) for displaying levels of the parameters, and GSM module for transmitting data to the farmer are the essential components used in this study. The block diagram of the microclimate controller as shown in Fig. 2 is a microcontroller-based device that closely monitor and regulates the environment condition of a propagation greenhouse to reduce human intervention to the best possible level. The sensors are used for data acquisition mounted inside the propagation greenhouse that captures microclimate data influencing the seedling propagation such as soil moisture, temperature, and humidity level. The data collected are sent to the microcontroller for processing and storing. Every time that the microclimate is below safety level, the microcontroller performs the necessary action which will activate the electrically operated devices through automatic controlled switches such as fogger, water pump, and exhaust fan satisfying the microclimate requirements of the propagation greenhouse [21-23]. The microclimate controller is also capable of showing the environment condition through the display unit and transmit data through SMS using the GSM module.

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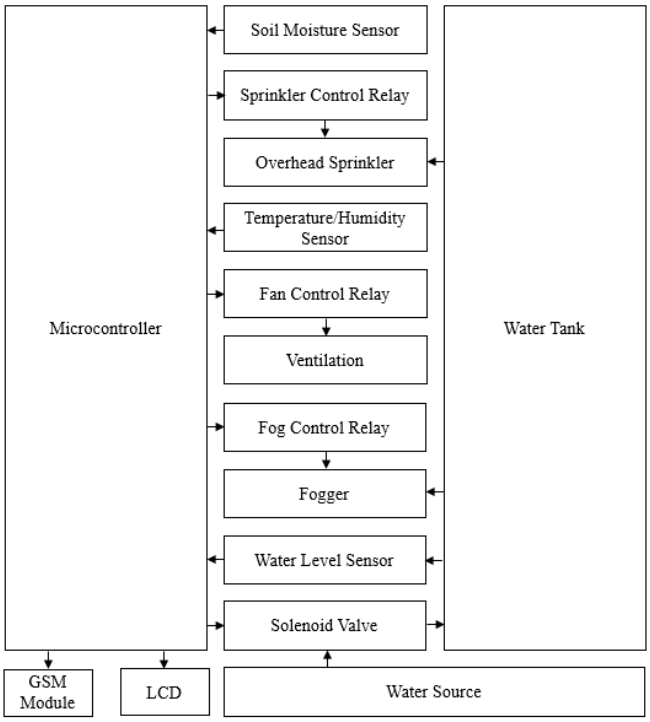

Fig. 2. Block Diagram of the Smart Microclimate Controller

Water is the most important factor in agriculture, but seeds use only enough soil moisture for better germination and faster growth. It is, therefore, necessary to measure soil moisture using sensors to help farmers effectively maintain soil moisture levels [13]. The soil moisture sensor tests the water content by generating a decreasing voltage output when the soil is wet and by increasing the voltage output when the soil is dry [24-27].

The temperature/humidity sensor measures the air temperature and the volume of water vapor inside the propagation greenhouse and sends the data for storage and further processing to the microcontroller. This sensor integrates a resistive measuring component that provides rapid response, anti-interference capabilities, and outstanding long-term stability [13].

The water level sensor measures the water tank level and sends data for possible water refilling to the microcontroller using the solenoid valve, an electromechanically controlled device that allows water to flow into the water tank [13, 25].

The multi-channel 5v relay module is used to switch devices with a higher voltage than the microcontroller. This specific relay module manages individual devices such as sprinkler, exhaust fan, and fogger to regulate soil moisture, air temperature, and humidity, respectively [25].

A. Temperature and Humidity Management

Temperature is the primary factor for growing crops. Preserving the optimum temperature for the greenhouses is necessary, however, the greenhouses of the province have limited capacity to modulate the environmental condition. Furthermore, the cooling method used to minimize sunlight intensity through the sidewall screen and the shade curtain used in the propagation greenhouse of the province is not adequate to regulate temperature during hot and sunny seasons. This study, therefore, used a temperature/humidity sensor (DHT21 AM2301) combined with a fogging device and auxiliary fans for artificial cooling and ventilation. Most plants adapt to an average temperature ranging from 200C to 300C. The maximum temperature in the greenhouse is harmful to most crops for longer periods of more than 350C [1]. Longer low humidity and high temperatures will quickly dry the soil, causing a new plant to die. As a result, ventilation and fogging are important to normalize the temperature and humidity of the greenhouse.

Adequate ventilation is very necessary for optimum seedling production [1]. Ventilation regulates the temperature by ensuring a well-adjusted movement of the air to disperse the heat from the greenhouse [28]. It can be driven either by the wind-induced pressure field around the greenhouse or by fans capable of moving air at relatively low pressure. This method allows fresh air to enter on one side, replacing the dry dusty air that moves out on the opposite side of the greenhouse to reduce the high temperature inside the greenhouse [1]. In extreme cases such as excessive temperatures, a complete lack of ventilation on a summer day can damage

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plant tissues [23]. It is also possible to reduce the high relative humidity levels through ventilation [1].

Plants can transpire rapidly during the summer season due to the accumulation of warm air inside the propagation greenhouse that renders poor moisture, thus losing a large amount of humidity that is not ideal for the plant. Through fogging, these unbalanced situations are avoided when maintaining a humid environment in the greenhouse [22]. Fogging is very essential to regulate humidity through tiny droplets of water coming from nozzles that are sprayed under high pressure. The microclimate controller initiates the relay attached to the fogging nozzles via a motor pump which emits tiny droplets of water and remains suspended in the air to bring down the temperature once the temperature rises above a certain point [26]. Good moisture is important for reducing plant stress to accelerate plant growth while excess moisture causes relatively fungal diseases and pests. Meanwhile, low humidity can also cause stress from the low photosynthesis process [12]. For healthy plant growth, relative humidity in the greenhouse ranging from 60 to 90 percent is often recommended [1]. Through fogging, air temperature can also be reduced [28].

B. Soil Moisture Management

Soil is an essential growth medium for plants. It should be well-drained and yet maintain sufficient water to reduce the need for irrigation. It is important to water the media thoroughly to remove air pockets and ensure that there are no areas of dry media, however, excessive irrigation would have negative effects on the soil, such as increased salinity, waterlogging, plant root air suppression, reduced temperature, increased formation of nitrates, and acidity [6]. Soil moisture is a major environmental determinant that influences the germination of the seeds. The lack of adequate soil moisture can reduce seed germination and slow the growth of seedlings [30]. Due to the difficulty in manually determining the needed soil moisture level, the soil is either kept dry for a long time or flooded excessively, thus, it damages the vital nutrients and minerals of the soil [31]. Measuring soil moisture is important to help farmers manage the irrigation activity more effectively. Hence, identifying soil moisture content is highly necessary in controlling the volume of water keeping the soil in good condition at all times to achieve healthy seedling production [12, 13, 17, 29, 32].

Currently, the farmers moisten the soil on the seedling tray of the propagation greenhouses through manually controlled overhead sprinklers. Considering the difficulty of the farmers to quantify the needed volume of water, this study, therefore, utilizes soil moisture sensor (LDTR-WG0236) to take full advantage of the efficiency of water usage by calculating the volumetric content of water to accurately estimate the irrigation requirement of the soil. Moreover, the soil moisture sensor supports the microprocessor to strategize watering plant method supplying plants with the right volume of water at the right time for proper seed germination and growth [31]. Soil moisture ranging from 20 percent to 80 percent is sufficient to carry the seeds through germination [5, 22].

C. Water Management

Water is the most important resource for farm operations. Seedling production requires enough water to grow plants healthy. Some garden centers use a timer-controlled sprinkler that provides water to plants automatically irrespective of the level of soil moisture. At present, farmers manually distribute water to the propagation greenhouse at a regular interval. It requires labors and is not always reliable which draws risk from using excessive or even insufficient water. Applying water to seedlings is made in the morning with 1-2 days interval as being observed in the cultural practices for traditional propagation. The amount of water applied is just enough to get away from the production of weak seedlings and fungal infection occurring in excessively damp conditions. The water tank used in

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this study is fixed with water level sensors (horizontal float switch) which constantly monitors the water level and measures the available water supply [33]. Moreover, the irrigation mechanism is designed with a feedback control system allowing enough volume of water to be delivered at the right time.

D. Seedlings Production Growth Rate

The reliability of the microclimate controller on the produced seedlings within 30 days is more advantageous compared to the traditional propagation greenhouse as shown in Fig. 3. The traditional propagation method observed only the utilization of water and natural ventilation while the smart microclimate controller considered the soil moisture, air temperature, and humidity parameters. The growth rate of seedlings produced in traditional propagation has a daily average of 0.62 cm while the microclimate controlled reached an average of 0.83 cm per day. Hence, this study demonstrated simplified propagation greenhouse processes that boost consistent germination and seedling production, creates and maintains an ideal environment, promote healthier crops and reduces manual labor.

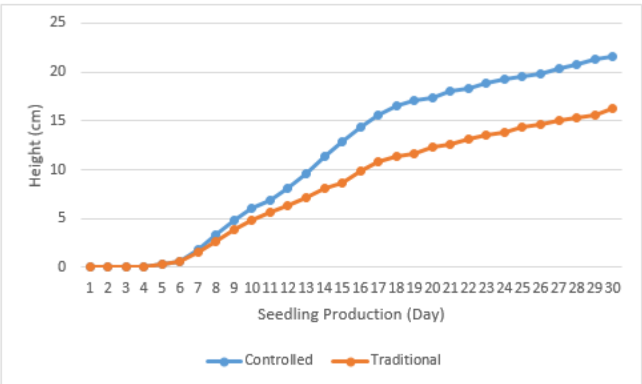

Fig. 3. Daily comparative growth rate on seedling production

CONCLUSION

The expansion of the IoT devices had strengthened the involvement in the agricultural sector. Due to high efficiency in monitoring and controlling environmental conditions, it yields countless assistance to maintain the optimal microclimate condition of the propagation greenhouse. Despite added investment in developing IoT projects for agriculture, lucrative incentives or conveniences in managing agricultural environments are confidently valued. Hence, the designed and developed smart microclimate controller had reduced the human efforts and improved the efficiency of the propagation greenhouse by maintaining a favorable environment needed to produce quality seedlings.

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