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Microcontroller-Based Aeroponics Farming Management System

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Abstract: With the growing number of technological advances in many fields related to the production of food and with the growing desire of food providers to provide high quality and nutrient–rich food items, it is only a matter of time before people are able to fully utilize the use of technology to control and monitor the food while it is still being cultivated. Having this type of system for the growth and development of farm produce is a big step in ensuring the quality of produce and also allows the consumers to monitor the compatibility of the plant species with this study. By doing this, farm costs are minimized and production maximized because all produce are closely scrutinized to provide optimal output.

It is the goal of this study to help its consumers maximize their output and ensure the commercial viability of their produce. At a time where people are becoming more and more conscious about the source of their food, it is essential to provide a means through which both producer and consumer are satisfied with the way that the produce is prepared.

The study focused on Aeroponics, a procedure that allows nutrients to be evenly distributed to the plants being cultivated in a farm through air distribution. It regulates the amount of nutrient received by the plants at any given time, therefore keeping their growth at a steady pace. The plant species used for this study is the lettuce. We used various data gathering techniques, experiments to determine whether the lettuce plant actually receives the nutrients it requires by measuring the amount of light, the temperature, moisture and humidity that are necessary for optimum growth. This method can create commercially viable products that are high quality and standardized.

Key Words: Arduino; Aeroponics; SMS;

1. INTRODUCTION

Economic and technological growths, nowadays, equate themselves to industrialization and urbanization. As developing countries, such as the Philippines, try to go with the flow of the fast paced innovations and inventions of the latest gadget craze, some of the most basic necessities are overlooked. Every enormous building, facility and factory built to manufacture and improve our cars, cellular phones and laptops is a significant chunk of land less to support one of our most basic human needs, food. These replace the vast fertile lands fit for growing crops that can support the whole of the surrounding communities for months. With these in mind, the gradual shrinking of lands for crop growing propose a great threat for the future's food security.

A nation's food supply deficiencies have been dealt with by every country through importation. However, it still is nothing but a short-term solution to the ever-recurring problem – and not to mention the taxes that come along with these imported goods.

Geoponics is the term used to describe a farming practice which uses soil. This process is the basic method used for growing plants; however scientists found infecting microbes that could affect the quality of plants. Thus, they decided to research on alternatives that could lessen this kind of scenario. In late 1960's, water culture had been very popular and through this popularity they started the research of using water as a medium of growing plants, until they came up with a new method called Hydroponics. Hydroponics is a subset of hydroculture and the process of growing plants with the use of mineral nutrient solutions through water and without the existence of soil. It was discovered that these plants may be grown with their mineral nutrient solution but only when they are placed in an inert medium such as perlite, gravel, mineral wool, expanded clay or coconut husk. In this kind of process, water remains in the system and is able to be reused. However, evolution on a research continuously took place until they came up using Root Mist Technique which later on became known to be Aeroponics.

Aeroponics is defined as a process of growing plants in an environment that utilizes air or mist. Thus, in this plant-growing process there is an absence of soil or even an aggregate medium, which lessens the use of pesticides and fertilizers, and there would be minimal use of water. This process gives more advantages in terms of producing high quality products that does not even need soil for growing plants and had lessened the use of water.

Modern plant cultivation technologies in agriculture under controlled environment: a review on aeroponics [1] describes a novel approach to plant cultivation under soil-less culture. This review concludes that aeroponics system is considered the best plant growing method for food security and sustainable development. The system has shown some promising returns in various countries and recommended as the most efficient, useful, significant, economical and convenient plant growing system than soil and other soil-less methods.

The work done in Aeroponics and Sand Hydroponics: Alternative Technologies for Pre-basic Seed Potato Production in Ethiopia [2] uses Aeroponics, sand hydroponics and tissue culture based seed multiplication techniques for increasing potato productivity and decreasing different bottlenecks of the crop. Thus, accelerating the supply of disease-free seed potato.

The work done in LED integrated vertical aeroponic farming system for vegetable production in Singapore [3] focuses on the lighting system as a key factor that determines the success of aeroponic system. The provision of sufficient uniform and effective light to the plants to enhance photosynthesis and thus maximize crop productivity.

The study aims to come up with a system that manages the different parameters and conditions vital to plant growth in aeroponic farming. The system will be microcontroller-based and will control conditions such as temperature, humidity and lighting.

2. DESIGN CONSIDERATION

This project is composed of hardware and software that will help in controlling the system. The monitoring system for plant growth uses sensors that are connected to an Arduino Microcontroller. The sensor inputs are utilized and processed by the microcontroller. It decides what to do with the systems connected to its output pins. Timers are also employed for activation and deactivation of the parameters these timing devices are attached to. In terms of system monitoring, whenever a sensor reads measurements that are beyond defined limits, a warning will be sent to the user via SMS. Manual adjustment of the system follows when an error occurs. All systems will be utilized for plant growth and monitoring. Sensor readings will be updated through SMS.

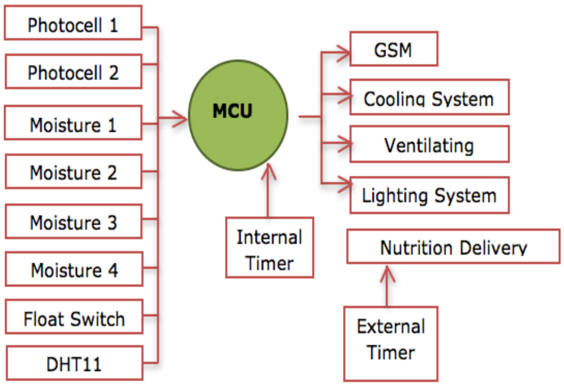

Fig. 1 System Block Diagram

2.1 Cooling System

DHT11 sensor is used for monitoring the temperature of the plant chamber. When the sensor is activated, the microcontroller will read its output. AC will flow from the source to its pins and the Cooling System will be powered on. The temperature is in degrees centigrade. 0-19 is too cold and will turn the ventilating system ON. 20-25 is the suitable temperature range, the ventilating and cooling systems are kept off. Any reading above 25 will be considered too hot that will turn the cooling system ON.

2.2 Ventilating System

The variables that will be used are temperature and humidity, which will be provided by the DHT11 sensor. Ventilation control is dependent on digital Arduino pin. When the chamber's temperature reaches the too low mark; or when the humidity level inside reaches the minimum wet mark, the ventilation system will turn on. The initial state of the system will be off. Ventilating system's main parts are two DC fans that are connected on either side of the chamber.

2.3 Lighting System

An internal clock from the microcontroller is use for the lighting system. When the condition for the timer switch is satisfied and Arduino sends a high signal to its digital pin, LED trays will be activated. This system is made up of LED lights that are placed directly above the plant boxes at a height of 12 inches. Each LED tray is composed of 5x5 inches PCBs that has blue LED lights and are spaced 1 inch apart from each other. This system provides artificial sunlight for plants that will be turned on and off for 12 hrs. Photocell sensor is used in determining the light intensity of the chamber.

2.4 Irrigation System

Plants nutrition is one of the factors that would affect the plant growth and the irrigation system is the one that allows its delivery to each plant. It is the most important process that is needed for plant growth. Constant supply of nutrients assures faster and better growth quantity and quality of produce. The prototype utilizes sub-irrigation, or seepage irrigation, which allows the plants' root zone to be directly moistened. Nozzle sprinklers, pipe, and submersible pump is used for the nutrition cycle of the plant inside the chamber. A float sensor is used for the monitoring of water level from the reservoir.

3. RESULTS AND DISCUSSION

In order to determine if the set values of the growing parameters of the produce are implemented properly, different sets of experimentations were tried. The experimentation setups are tabulated and explained.

The following major blocks were tested. Temperature and humidity are continuously monitored, readings of which are processed and used to control the cooling and ventilating systems to regulate the same parameters. The lighting system is programmed to turn ON/OFF at pre-set intervals.

3.1 Cooling System Test Results

Table 1. Cooling System Test

TEST #	TEMP	EXPECTED STATUS	ACTUAL STATUS	REMARKS
1	$27^{o}C$	ON	ON	SUCCESS
2	$26^{o}C$	ON	ON	SUCCESS
3	$25^{o}C$	ON	ON	SUCCESS
4	$24^{o}C$	ON	ON	SUCCESS
5	$23^{o}C$	ON	ON	SUCCESS
6	$22^{o}C$	ON	ON	SUCCESS
7	$21^{o}C$	ON	ON	SUCCESS
8	$20^{o}C$	ON	ON	SUCCESS
9	$19^{o}C$	OFF	OFF	SUCCESS
10	$18^{o}C$	OFF	OFF	SUCCESS

Table 1 shows that at low temperatures, the cooling system should be deactivated, as seen in Tests 9 to 10. When the temperature rises, to 20oC and beyond, it should be triggered, this is evident in Tests 1 to 8.

3.2 Ventilating System Test Results

Table 2.Ventilating System Test

TEST #	TEMP	HUM	EXPECTED STATUS	ACTUAL STATUS	REMARKS
1	18°C	90%RH	ON	ON	SUCCESS
2	19°C	36%RH	ON	ON	SUCCESS
3	19°C	34%RH	ON	ON	SUCCESS
4	20°C	83%RH	ON	ON	SUCCESS
5	22°C	24%RH	OFF	OFF	SUCCESS
6	23°C	58%RH	OFF	OFF	SUCCESS
7	24°C	34%RH	OFF	OFF	SUCCESS
8	26°C	72%RH	ON	ON	SUCCESS
9	27°C	60%RH	OFF	OFF	SUCCESS
10	28°C	67%RH	ON	ON	SUCCESS

Table 2 shows the data gathered during the ventilation test. When either of the values of temperature and humidity is supposed to turn the fans ON, the fans are automatically activated. .Of the 10 total trials, 10 came out successful.

3.3 Lighting System Test Results

Table 3. Lighting System Test

TEST #	INITIAL STATUS	TIME 1	NEXT STATUS	TIME 2	ACTUAL INTERVAL	REMARKS
1	ON	9:30 PM	OFF	9:30 AM	12 HR 0 MIN	SUCCESS
2	OFF	9:30 AM	ON	9:30 PM	12 HR 0 MIN	SUCCESS
3	ON	9:30 PM	OFF	9:30 AM	12 HR 0 MIN	SUCCESS
4	OFF	9:30 AM	ON	9:30 PM	12 HR 0 MIN	SUCCESS
5	ON	9:30 PM	OFF	9:30 AM	12 HR 0 MIN	SUCCESS
6	OFF	9:30 AM	ON	9:30 PM	12 HR 0 MIN	SUCCESS
7	ON	9:30 PM	OFF	9:30 AM	12 HR 0 MIN	SUCCESS
8	OFF	9:30 AM	ON	9:30 PM	12 HR 0 MIN	SUCCESS
9	ON	9:30 PM	OFF	9:30 AM	12 HR 0 MIN	SUCCESS
10	OFF	9:30 AM	ON	9:30 PM	12 HR 0 MIN	SUCCESS

Table 3 shows the success rate of the activation and deactivation of the system being tried. Of 10 trials, 10 correct status changes occurred at their expected times.

3.4 Irrigation System Test Results

Table 4 shows the data gathered for the efficiency test of the pump timing. Since the timer employed is analog—uses a potentiometer to adjust the interval—inconsistencies are to be expected.

Table 4. Irrigation System Test

TEST #	INITIAL STATUS	NEXT STATUS	ACTUAL INTERVAL	REMARKS
1	ON	OFF	4 MIN 53 SEC	SUCCESS
2	OFF	ON	4 MIN 53 SEC	SUCCESS
3	ON	OFF	4 MIN 53 SEC	SUCCESS
4	OFF	ON	4 MIN 53 SEC	SUCCESS
5	ON	OFF	4 MIN 53 SEC	SUCCESS
6	OFF	ON	4 MIN 53 SEC	SUCCESS
7	ON	OFF	4 MIN 53 SEC	SUCCESS
8	OFF	ON	4 MIN 53 SEC	SUCCESS
9	ON	OFF	4 MIN 53 SEC	SUCCESS
10	OFF	ON	4 MIN 53 SEC	SUCCESS

3.5 Final Test

Table 5. Weight Assessment in Grams for 3 Set-up

HOLE	Hydroponic	Aeroponic 1Plant/hole	Aeroponic 2Plants/hole
1	22 grams	57 grams	115 grams
2	23 grams	64 grams	121 grams
3	23 grams	57 grams	111 grams
4	27 grams	58 grams	116 grams
5	34 grams	62 grams	121 grams
6	29 grams	59 grams	109 grams
AVERAGE	26.33 grams	59.5grams	115.5 grams

After the initial phase of testing the system, the group decided to divide testing into two set-ups. The first set-up would be one plant per hole and the second set-up would be two plants per hole. The output would also be compare to hydroponic set-up. Table 5 shows the comparison of the average weight of the plant per hole between the hydroponic and aeroponic.

4. CONCLUSIONS

Two main concerns needing constant addressing were found by the group upon drafting the system blueprint, namely: monitoring and management. Knowing that this study demands the former, we have provided the system multiple sensors for constant monitoring of various plant development parameters. On the other hand, in order to address the latter and provide results in growing the specified crop, we attached different subsystems, which were closely regulated using a microcontroller. In addition, we have also addressed the need for early detection of system error. The ability to easily sendoff warnings to the users via SMS offers great advantage to minimize interruptions of project usage.

One of the main goals of this machine is to make agricultural activities easier by ensuring that the products and wares are monitored 24/7. This aim is realized and proven through the system runs and the data gathered during these runs. Moreover, apart from the above objective, the group also aims to provide not just a working system, but also one that can be of practical use.

Also, part of proving the commercial viability of the system is choosing a crop that is profitable. The test crop was chosen via a couple of researches, and the requirements were to choose a crop 1) which has high demands in market places; and 2) which would greatly take advantage of what the system is able to provide.

Lastly, to help prove the possibility of the system's profitability, the group interviewed a number of commercial vegetable growers and suppliers. Collating different responses from agricultural business professionals and contrasting them with the data gathered from the experiments, the group was able to arrive at a practical conclusion. Though the prototype is fully functional, the main difficulty the system encountered is the cost of building, operating and maintaining the system. With the significant increase in expenses, comes the substantial marking-up of produce price—up to quadruple the normal price in the market, risking salability—which concludes that automated aeroponics would not be able to compete with geoponics and hydroponics, the two most popular farming systems in the Philippines.

Recommendation for future work would be to improve the design to come up with a more cost-effective solution. Perhaps better system integration along with improved efficiency may help improve the viability of implementing such system.

5. RECOMMENDATION

The system can be further improved with the following ideas:

- Look for cheaper materials to be used in the prototype. It can help in saving a lot of money in creating the whole system.
- Explore on the possibility of attaching an uninterrupted power supply.
- Delayed SMS update can occur due to poor service provider reception, having a backup monitoring notification system accessible online would be highly beneficial.
- Using highly sensitive optimized sensors can also be used for maximum plant growth monitoring. More accurate sensors can produce more efficient harvest in a given time.
- Explore different types of nutrient solutions to be used in the system. Soilless farming, nowadays, is fast-developing, thus the availability of nutrition options for faster growth and bigger and better produces should be taken advantage of.

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