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Temperature Sensor Working Protocol in the Vegetable Growing Systems

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Abstract— *Every year, powerful businesses get more interested in growing plants efficiently. However, herbivores remain as a challenge, as it costs million dollars of damage. Hence, consistency of monitoring the damage is crucial. The current existing methods to measure the damage are considered unaffordable and require laboratory facilities. The latter involves expensive devices with complex usage. The most changing conditions for growing a single plant are climate variables such as carbon dioxide, air temperature, humidity, dissolved oxygen, potential hydrogen, electrical conductivity, and root-zone temperature. In order to yield various phenotypic expressions in the plants, many conditions might be monitored and controlled within a growing chamber. To cope with the challenge, a new growing methodology is freshly discovered. The methodology is fascinated by a constructed device which enables the user do the full monitoring. From one side this vegetable growing system allows to measure the damage and reduce it, the result is highly efficient. The Vegetable growing system is a newly discovered mechanism, described as a mini controlled system. Due to the various conditions, the device uses robotic systems connected to micro-computer called Raspberry-PI to control and monitor climate, energy, and the growth process inside of a specialized growing chamber.*

Keywords— *Phenotyping; temperature; plants' growth; agricultural sensors.*

I. INTRODUCTION

Plants' type is a major factor to take into consideration to study the effect of temperature on the process of plants 'growth as presumed by Hatfield et al. (2015). With the abrupt change of the climate is going through, the air temperature is not always adequate to the plants' growth especially when the plant is exposed to the sun. Nonetheless we should not omit the cool season plants that get affected by sunny days as the temperature rises according to Hatfield et al. (2008, 2011). Each plant type needs a different temperature value range according to the season in which this plant is growing and thus each plant response is different as stated by Prasad et al. (2001, 2002, 2003, 2006a, 2006b, 2008). The objective of our research is to create the temperature needed for each plant which means creating the right environment with being independent of the weather (Shah et al., 2011).

Barlow et al. (2015) confirmed that high temperatures or low temperatures represent both a danger if we do not know the impact of temperature when it exceeds the appropriate interval. We expect that the temperature of water in which the hydroponic system is taking place, it has an impact on the saturation which is directly related to the plant's growth. Observations in controlled environment studies show that plant growth is better monitored in terms of temperature. Temperature effects interact with the soil water status which would suggest that variation in warm temperatures would increase the bad effects on the plant production.

II. MATERIALS METHODS

To study the effect of temperature on plants growth, we decided to construct our growing chamber, we considered a box with 4 faces of plexiglass plates, the back plate is covered. The top and bottom plates are supplied by thin wood plates. The aim of the wood plate in the top side is to hold 4 bulbs while in the bottom plate is to hold the reservoir, all together with the electronic circuit. The electronic circuit consists of a circuit board. A Raspberry Pi micro-computer hosts the software that allows us to control the system from a computer, while an Arduino microcontroller links to the temperature sensor that collects data about the environment and communicate it to us. Moreover, the reservoir is equipped with an air stone and air pump. The components of the electronic unit are placed inside and outside the growing chamber. The fundamental purpose of the growing chamber enclosure is to separate the interior environment from the exterior environment. We want the interior environment to be independent and different from the exterior environment. To support this environmental separation; where the environment on one side of the enclosure is different from the environment on the other side of the enclosure. The enclosure must provide the critical control function; thermal control. High levels of insulation may provide greater flexibility in the mechanical system design of the chamber by making feasible certain heating and cooling strategies that are not appropriate for conventionally insulated systems. For this purpose, we agreed to choose plexiglass material as a source of separation between the growing chamber and the outer environment. Plexiglass is another name for acrylic plastic sheets. Acrylic plastic is a handy building material that has a variety of uses. It offers certain advantages over conventional glass sheets. Plexiglass is durable and resistant. Figures 1 and 2 show the reservoir and the four bulbs placed on both plates; the bulbs are placed on the upper plate while the reservoir is placed on the bottom plate.

To design a successful growing chamber, it is important to make it useful to users. That is why we focused on the central aspect of it; the choice of the growing chamber capabilities. This particular choice is one of the innovations of the growing chamber design. The sensors, fans, and light of the growing chamber represent a wide range of devices that could be found in several engineering sub-fields. The mechanical structure and the different hardware components composing the personal growing chamber as well as the connection diagram of these components. Therefore, in our work, we focused on tracking the temperature. We tried on a daily basis to control it and interfere if needed. The purpose of this design is to ascertain whether a growing chamber can be implemented to control and monitor the way we grow our food. There are five main components of the personal chamber: enclosure part which includes the chassis, lighting, circuit and power, reservoir and growing supplies. We summarized the most important parts of the design in the table below and we will describe them in this chapter.

TABLE I. Equipment for the design of the growing chamber

Component class	Component
Enclosure	12 Iron bars and 6 plexiglass sheets
Lighting	4 GE Lighting 32304 LED Bright Stik 16-watt
Circuit and power	Raspberry Pi, humidity sensor and power Supplies
Reservoir	Air Pump, Tubing, and Air Stones
Growing supplies	Rock Wool, PH Control Kit and Digital EC Meter

Figure 1. Reservoir placed inside the growing chamber

Figure 2. Enclosure with plexiglass

Automatically growing plants and food is the main purpose of the growing system technology, and the control-based sensors are the key feature of such a device. In this paper we focused more on the temperature sensor and its protocol inside the growing chamber while constructing our own vegetable growing system. In order to see how we will attempt to connect the components of the circuit design, we have decided to use the circuit online tool, and connect the components. To connect the fan to the circuit, we need to insert two intermediates to close the circuit. The fan needs a source of power. Therefore, we used a power supply adapter for CCTV security surveillance connected to DC power cable female connector plug. The design contains two main elements which need continuous control of the current and the voltage. To do so, we plugged the 4-channel relay module which is a convenient board, it can be used to control high voltage, a high current load such as lamps and AC load. It is designed to interface with a microcontroller such as Raspberry PI, Arduino, PIC, etc. The relays terminal (COM, NO, and NC) is being brought out with a screw terminal. And, finally, for daily tracking of the temperature, we had to think about adding to the circuit a sensor that controls this variable. Temperature sensor is one of the finest & highest-accuracy device that could be used. We chose the SHT31-D sensor which has an excellent ±2% relative humidity and ±0.3°C accuracy for most uses. This version is sorted with a PTFE filter, it stays clean while still allowing humidity measurements to work. In figure 3, we can see the multiples components of the brain assembly connected.

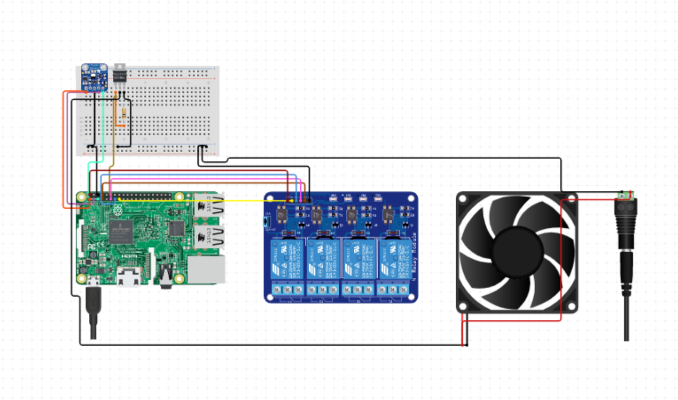

Figure 3. Circuit Diagram of the brain assembly

The design considerations were evolved based on the criteria that were suggested previously. Consequently, the concept phase was based on a permanent process including improvements throughout the entire process.

Growing chambers differ a lot in size, resolution, and shape, the used lighting method is needed to be a more flexible solution. Therefore, the idea arose to develop a code for controlling light and the rest of the variables. With respect to the claim of a more friendly user device, the raspberry PI microcontroller gives access to a friendly user interface.

The software which is an open data source can be seen as the central control unit of the growing chamber. Any modification regarding temperature might be recorded. For supporting all types of farmers, the software should be written in an open platform database programming language. Since multi-functions are related to the chamber, all functions should be controllable by the user interface. The purpose is that non-programmers can also adapt the code to their growing chamber without prior knowledge of programming. The manipulation of the growing chamber is an easy one based on the created design, daily control of the pH, and EC values are highly important in order to know how to proceed. The user interface communicates to the user the temperature change so the lighting can be adjusted if needed and the temperature values.

Figure 4. Design aspects of growing chamber

To evaluate our design, we moved with the prototype realization with testing the device afterward, using iron bars and electronic equipment. The process of choosing the right design and the right tools for the growing chamber was performed as well.

The electronic circuit is based around a Raspberry Pi and Python code, with the time-based software Cron used as the scheduler. Sensor data is stored in the flat file on the Pi's SD card. An Adafruit SI7021 temperature/humidity sensor is the standard sensor; though there are open GPIO pins and one relay of 4 channels available for expansion.

TABLE II. Brain assembly components' characteristics

Function	Component
Single-board computer	Raspberry Pi 3B
Automatic switch	ARDUINO 4 RELAYS SHIELD A000110
Connecting cables	Zip ties and jumper wires
Power cable connector	DC Power Cable Female Connector Plug
Power Supply Adapter	12V Power Adapter
Construction base for circuit	Breadboard

Table II shows the components located outside of the box; on the left plate of the growing chamber. This position's purpose is to eliminate the possibility of components damage if put inside. It was first developed based on the idea to make the manipulation easier for the user.

Although hardware & software used in our growing chamber prototype are quite simple, it was challenging to localize the components.

We believe that the growing chamber prototype is a huge step for urbanizing food production. It will enable farming with Information Technology rather than a shovel and pick.

The left side plate has three directories, Raspberry Pi, Relay of four-channel, Breadboard, and a bunch of female jumper cables for connecting the components together.

Figure 5 shows the components outside of the growing chamber placed on the left plexiglass plate.

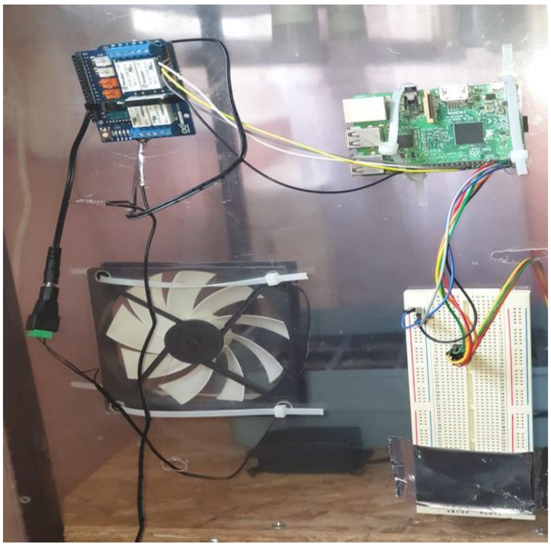

Figure 5. Brain assembly on the left plate of growing chamber

The growing chamber must be designed in such a way the sensor can access the inside growing chamber so that the measurement data are registered and saved into the single board computer. The humidity sensor data were collected using a SI7021 Temp/Humidity I2C sensor mounted inside the box, this sensor for Silicon labs has ± 3% relative humidity measurements with a range of 0–80% RH, and ±0.4 °C temperature accuracy at a range of -10 to +85 °C. It uses I2C for data transfer so it works with a wide range of microcontrollers.

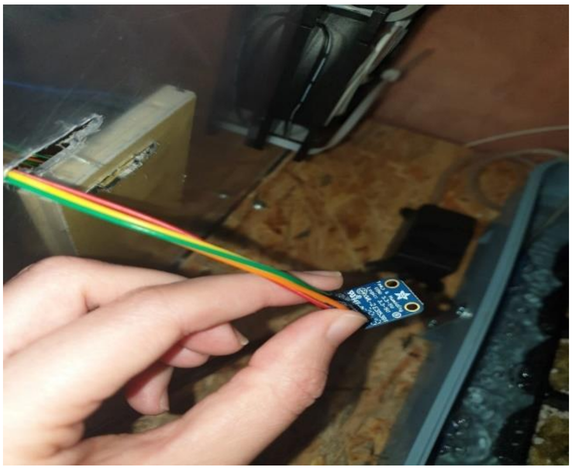

Figure 6. Humidity-Temperature sensor

Figure 6 shows the Adafruit (PID 3251) Si7021 Temperature Sensor placed inside the growing chamber, while connected to the Raspberry PI through the Breadboard.

Figure 7. four LEDs placed on the upper plate

The creativity inside the growing chamber and the capture of new technologies remains on how to monitor the reservoir for better growing the plants. We needed to bring lots of compact and efficient nutrient solutions to the chamber for being a portable cooling application where space and weight are of high concern to our prototype.

Figure 8. Figure mm Air stone and quarium pump inside the reservoir

III. RESULTS AND DISCUSSION

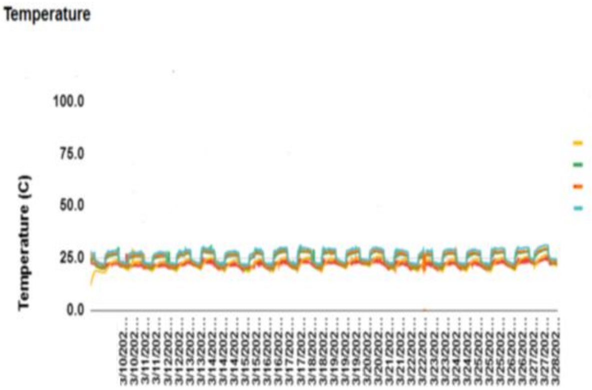

Figure 9. Temperature graph

If we look to the temperature chart, we can see a continuous drop on temperature, that's when the lights are turned off, the temperature is logged every 20 minutes, therefore the LEDs warm up the box even if the exhaust fan is on. Once the exhaust fan turned on, it regulates the temperature to within a degree of 31°C. We opened up the door for checking the pH and EC values and with the door open the temp dropped to 22°C as we see in the yellow curve. This is important because crops can double speed for every 10°C temperature increase.

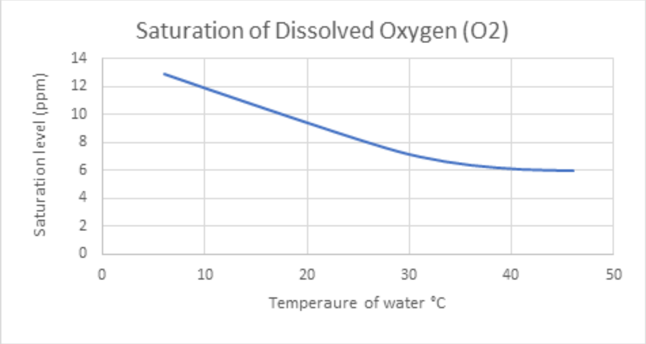

Figure 10. Saturation of Dissolved Oxygen

Dissolved oxygen improves plant growth and reduces crop time, here is a correlation between temperature and dissolved Oxygen. We experimented that air stones completely saturate water and therefore the more temperature of the water is small the better the saturation level.

IV. CONCLUSION

The growing chamber is the future of agriculture. The long box, under glowing LED lights, lettuces, and other legumes might be grown up and sprout up, their roots, free of dirt, monitored by a digitally controlled environment. It's a tiny, low-water, soil-free, and climate-controlled agriculture system, designed for growing food. The machine is plugged into a network, so all the environmental information runs into a database, where other users can see how much water and light the plants are getting and use that data to improve the way they grow their crops.

The new device is a way to program how we grow what we eat. It's a digital interface that controls a physical object. What's interesting is that at the end of the growing cycle we get a digital recipe. If we want to grow the same crop again, we would get the same thing every time. We can email the basil recipe other users, and they can run the program again and get the same result with few changes if needed.

The vegetable growing system is an innovative controlled-environment device not only for growing plants, but it is also useful to teach a wide range of sciences from agriculture to technology. For its size and capabilities, the growing chamber is a global system that can be used not only as a research platform inside universities but also as an educational tool inside schools. The opensource vision of the growing chamber improves the quality of the support for the users by providing full access to the information and knowledge at all levels.

Open data platform

The future of growing environments is pointing into a constantly updated network system, where the individual users can receive fresh information about the plant's recipes from other users of the growing chamber. The measured data of a crop grown inside the growing chamber device can provide important inputs for the online open data source, and this information can be used for avoiding the damage caused by the environment to the plants, or to approach the growing process with a more cautious attitude. Since the present prototype is showing usable results from the Raspberry PI, the actual measurement system can be developed for different devices as well.

Internet of Things

Another area of research may be the use of an IoT based food computer system in conjunction with GPS. As a result, we can detect locations on world maps where growing chambers' users are located. Recorded plant recipes data can be collected in the application shared among growing chambers' users. Locations where different Growing chambers can be built with an open online forum disseminate the research progress made on the Growing Chamber project.

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