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An Automated Soil and Climatic Conditions Controlling Greenhouse: A Preliminary Study

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Abstract : ***In this system, the process is initiated by collecting data of the growing environment measured by sensors and transmitted as inputs to the Arduino processing unit. The controlling system works by processing these data to adjust climate conditions inside the greenhouse. Values of soil moisture, soil temperature, inside air temperature, inside air humidity, inside visible light intensity, ultra violet (UV) light intensity, outside humidity, outside temperature, and outside visible light intensity are measured by sensors of the system. Among these parameters the system is capable to control temperature, humidity and soil moisture levels as per the requirement. A database developed for climatic and soil parameters, both inside and outside the greenhouse, can be used for further analysis. The communication between the Arduino processing unit and computer is achieved via PLX-DAQ software, which also facilitates visualising data using MS Excel and Liquid Crystal Display (LCD). This automated greenhouse is the best solution for the people who are interested in cultivating at domestic or greenhouse levels. Furthermore, this system can be used for research purposes where growth of particular plant is monitored under control climate conditions.***

Keywords : Arduino, automatic climate control, sensors, greenhouse, PLX-DAQ, data acquisition

I. Introduction

Greenhouse technology is used to provide a controlled micro environment for optimum crop growth protecting the plants from unfavourable weather conditions such as coldness, heat, and rain in different seasons of the year [1]. Greenhouses are covered with a transparent material provided with the optimum conditions for crop growth. Primary environmental parameters such as temperature, relative humidity (RH) etc. are controlled by regulating the conditions inside the structure, e.g. providing heat in extreme cold conditions. Environmental control also includes cooling the system to mitigate excessive temperature, controlling soil moisture level by adding water when water depletes, light control by shading or adding supplementary light, and maintaining RH by adding or removing water vapour [2].

During the recent past decade, there was a significant trend to automate growing conditions of the micro level cultivating areas, for example, mushroom growing boxes, micro-organism growing containers, domestic growing areas and so on [3]. The main purpose of those developments was to automate the water supply and control temperature of the cultivating area. However, under such situations, the researchers used soil moisture and air temperature sensors for receiving data from the environment. Later on, micro processors like Programmable Interface Controllers (PIC), micro controllers or Arduino micro controller-based kits were used in the systems to process data and control water pumps and cooling fans in addition to maintaining moisture level of the soil and temperature of the system at a desired level. The term of Garduino (Gardening + Arduino) was created in the same decade given the usage of Arduino for the domestic gardening purpose. Finally the Garduino was developed into the GardenBot, which of course can monitor water supplement to plants without any help of human being [4]. At a more advanced stage, new systems were developed as embedded systems for monitoring and controlling the greenhouses by measuring the RH and temperature levels, which could also be conducted through an Android Smart phone [5]. Thereafter, these systems were advanced by use of wireless sensor network systems with X-bee and open source hardware platforms such as Arduino, Arduino Ethernet shield, and neural networks techniques [6].

The main objective of this proposed greenhouse was to reduce the cost for automation and thereby to enhance the efficiency of monitoring and controlling growing environment. Accordingly, the system has been developed as an advanced way to monitor inside and outside environmental conditions such as temperature, RH, and visible light. However, inside the greenhouse, soil moisture level and ultra violet (UV) light intensity were also measured. The system is capable of controlling temperature, RH, and soil moisture level using appropriate actuators, visualising sensor data on the Liquid Crystal Display (LCD), and further transferring in to a computer for analysing purposes. A specific unit in the automated system has been designed to change the optimum values for environmental factors such as inside temperature, RH, and soil moisture level. Also, in this system, many sensors such as soil moisture sensors, soil temperature sensors, UV light sensors, humidity sensors, and a light dependent resistor (LDR) both inside and outside of the greenhouse are used as analog sensors.

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The Arduino Mega 2560 board is used to process the data. Further, the system includes output components like exhaust fan and space heater for controlling air temperature level, mist sprinklers for maintaining appropriate RH level, and normal sprinklers with electric solenoid valves for controlling soil moisture and temperature. Data about the current situation of the greenhouse are saved in a Microsoft Excel worksheet through PLX-DAQ software and those data can be then used for further analysis, as needed. The reference values of various growing conditions, according to the different stages of plant and different type of crops can be changed by using the push button panel manually. In this study, sweet green pepper (*Capsicum annuum)* was used as the test crop given the wide use of this crop under greenhouse condition and effectiveness of the automated system on that crop. For sweet green pepper, temperature must be at least 22 °C for seed germination, and soil should be at least 19 °C [7].

II. Material and Methodology

A. Establishment of greenhouse

A greenhouse was built up using pipe arches that were supported by pipe purling running along the length of the greenhouse. UV treated polyethylene was used to cover the structure. The height, width and length of this greenhouse were 2, 1.8, and 3.6 m, respectively. 0.6 m height from the bottom was covered by lumbers and the structure also consisted with a wooden door. There were two main areas inside the greenhouse *i.e.* circuit located area and planted area. Within the planted area of the greenhouse ten pots were placed in two rows as given in Figure 1. Number of pots was determined based on the space requirement of sweet pepper plants and the availability of the space within the greenhouse. Peppers prefer to the soil that is rich in organic matter, moisture retentive but well draining and pH of 5.5 to 6.5. The soil sample was made by mixing with compost and created a loose soil texture so the roots can spread easily. The pots were 10-12 inches deep and wide with the sufficient drainage holes.

B. Sensors and inputs

Temperature and relative humidity inside and outside of the greenhouse were monitored by two DHT11 sensors, which multifaceted with a calibrated digital signal output feature so that it encloses high accuracy and stellar long-term steadiness [8]. Six Negative Temperature Coefficient (NTC) Thermistor temperature sensor with the Waterproof Probes were used to measure soil temperature of the pots. ML8511 sensor was used for acquiring UV intensity and was equipped with an internal amplifier, which converts photo-current to voltage depending on the UV intensity. This sensor detects 280 – 390 nm light more effectively [9].

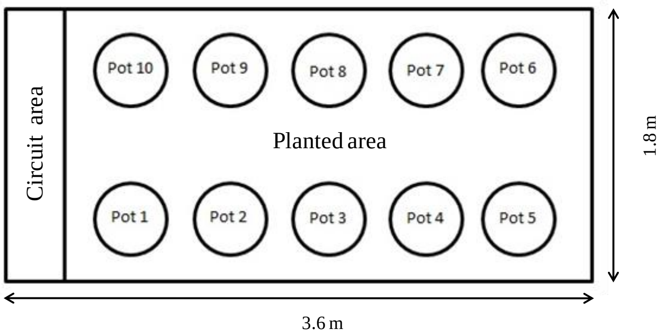

Figure 1: Pots arrangement inside the greenhouse

The visible light level was detected by a Light Dependent Resistor (LDR), which works on the principle of photo conductivity [10]. Soil moisture sensors were used to determine how much water is needed to irrigate the plants. Resistive type of moisture sensor has two probes to pass current through the soil and in turn read resistance to get the moisture level of soil [11]. Soil moisture sensor was prepared and arranged as follows in the system. 10 cm long two pieces of galvanised wire were used to make probes. A lead wire was soldered to one end of each probe and 9 cm of the probe was insulated. A block of plastic was sliced to make the top of the sensor. Two holes were made within the block and the two probes were inserted through the plastic block (Figure 2). RTC module (DS 3231) was used to acquire real time data into MS Excel worksheet for analysis. While keeping track of the time and date, this module also has a small EEPROM, an alarm function, and an ability to generate a square-wave of various frequencies [12]. The push button panel was used to change optimum reference values of the environmental factors (Figure 3). Altogether, it consists of 10 buttons as inputs for changing the temperature level, humidity level, and soil moisture level.

Figure 2: soil moisture sensor

Figure 3: button panel

C. Processing platform

ArduinoMega 2560, which was used as the processing platform in the present study to sense the environmental parameters by receiving input from a variety of sensors. It can make influence on its surroundings by controlling actuators or outputs. The multiplexer or demultiplexer Integrated Circuit (IC) CD 4051 enabled expanding the inputs and outputs on the Arduino board. The CD4051 is an 8 channel analog multiplexer/demultiplexer, and when it acts as a multiplexer, it can choose one input between 8 different inputs and select at the time [13].

D. System outputs

Outputs of the system are basically a series of actions required for adjusting the level of climate parameters inside the greenhouse in order to keep them at optimum level. They are activated when current sensor value is different than the optimum reference value. The system used in this study comprised six system outputs: (i) Air cooling system – with a cooling fan on or off, (ii) Air heating system – with a space heater on or off, (iii) Humidification system – with a solenoid valve with mist sprinklers on or off (iv) Dehumidification system – with an exhaust fan and space heater on or off (v) Watering system – with a two solenoid valve with small sprinklers on or off (vi) Lighting system – with a bulb on or off. Also, seven different output devices were used in this system: cooling fan, exhaust fan, space heater, a bulb operating with 230VAC, and three electric solenoid valves operating with 12VDC. These devices were connected to the Arduino through relays, which provide electrical isolation between two circuits [14]. Parallax Data Acquisition tool (PLX-DAQ) software add-on for Microsoft Excel was set to acquire up to 26 channels of data from (any) Parallax microcontrollers and drop the numbers into columns as they arrive. In the transferring mechanisms the PLX-DAQ control used a set of commands to perform the specific actions. These commands are in the form of a string of characters, which are sent through the COM (Component Object Model) interface using RS232 communication [15].

E. System architecture and working principles

The automated greenhouse control system was made up of two principal units: (i) sensors and actuators station, and (ii) data station. The sensors/actuators station was the heart of the system that is responsible for regulating the greenhouse environment. The data station was responsible for transferring sensor data to the computer, storing and visualising the output. The functions of this greenhouse system were divided into four parts: (i) monitoring current values of the environmental factors, (ii) changing optimum reference value of the environmental factors, (iii) controlling output components according to the sensor data, and (iv) visualising and storing the data. The current values of the environmental factors were monitored by the sensors; two DHT11 humidity and temperature sensors, both inside and outside. Each row of pots contained three soil temperature sensors (NTC thermistor, temperature sensors, and waterproof probe). Average value was taken as the current soil temperature value. Each row of pots also contained three soil moisture sensors and average value was taken as the current soil moisture value. Moreover, two LDR, a UV Sensor (ML8511), and RTC module (DS3231) were used to monitor inside and outside visible lights, inside UV intensity, and real time and date, respectively, in this automated system.

The push button panel (Figure 3) was used to change optimum reference values of the environmental factors. It consisted of 10 buttons as the inputs for changing maximum air temperature level, minimum air temperature level, maximum humidity level, minimum humidity level, and soil moisture level; each level was maintained using 2 buttons as level up and down. This system worked as a close-loop control system and the environmental factors of this greenhouse system were controlled according to the user given reference values. The Figure 4 shows the system architecture of the developed automated greenhouse soil and climate condition control system.

F. Visualization and storing the data

The real time sensor values were displayed on LCD display. The sensor values for UV intensity, inside – temperature, RH, visible light intensity, and outside –temperature, RH, visible light intensity, soil temperature (both left and right sides), soil moisture (both left and right sides) were able to be displayed at every 20 seconds. The Microsoft Excel work sheet was used to store the sensor values with real date and time. PLX-DAQ software was connected to the Arduino for starting the data acquisition to the Excel worksheet.

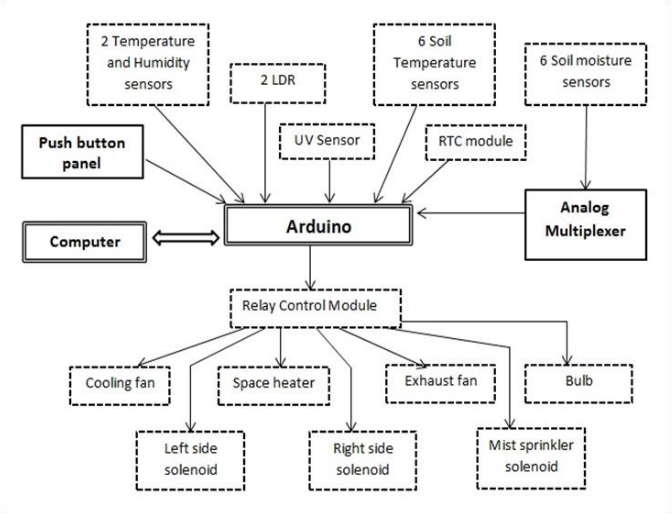

Figure 4: Automated soil and climate condition control greenhouse system architecture

III. Results

A. Soil and climatic parameters

Data were recorded in the system for the given parameters such as temperature (°C) both inside and outside, soil moisture (%) both left and right sides, soil temperature (°C) both left and right sides, relative humidity (%) both inside and outside, visible light both inside and outsides, and UV intensity (mw cm^{-2}), under the present automated system. Temperature, RH, and soil moisture level inside the greenhouse were successfully controlled by the actuators. Optimum reference environmental factor values could be changed by the external button panel and then the system was executed according to the new reference values. Sensor data were visualised on the LCD display, transferred to the computer, visualised and stored in an MS Excel worksheet for further analysis.

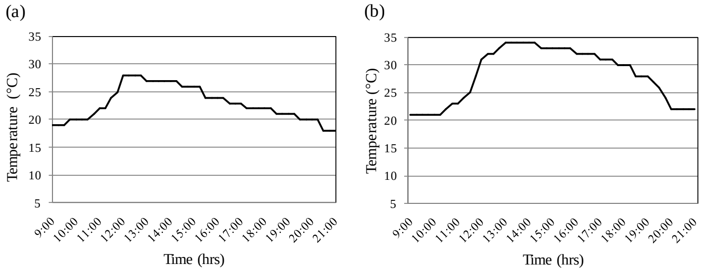

Figure 05: Temperature variation (a) inside and (b) outside of the greenhouse for 12 hours time period during 9.00 to 21.00 hrs.

According to the Figure 5 (a), inside temperature was less than 20 °C from 9.00 a.m. to 9.45 a.m. The minimum reference value for the air temperature was 20 °C and therefore, the space heater was turned on until 9.45 am. Thereafter, the temperature gradually increased up to 28 °C by 12.00 noon. The maximum reference value for the inside temperature was 26 °C and at that time cooling fan was turned on and kept working until 2.30 pm. Then, the temperature seemed to be gradually decreasing with the time. The change of outside temperature over the time is given in Figure 7 (b). The temperature at 9.00 a.m. was ~21 °C and at 9.00 p.m. it was around 22 °C. The maximum temperature of the outside (~ 34 °C) reached at 1.00 p.m.

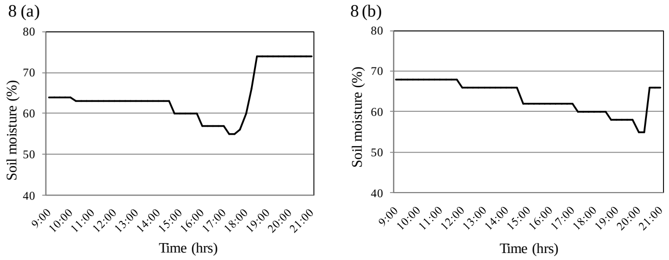

Figure 6: Soil moisture level variation in pots placed on the (a) left hand side and (b) right hand side of the greenhouse for 12 hours time period during 9.00 a.m. to 21.00 hrs.

According to the Figure 6 (a) and (b), soil moisture levels for both sides (left and right) of pots decreased gradually over the time starting from ~ 62 and 64 % on the left and right sides, respectively. In the system, the reference value for the soil moisture level had been given as 50 %. When the soil moisture level is less than 50 %, electric water solenoid valves with small sprinklers were supposed to be turned on so as to increase the moisture level. However, throughout the detection time (12 hrs) the moisture level was maintained at above 50 %.

As shown in Figure 7 (a) and (b) when the soil moisture was decreased, soil temperature of both sides was increased and the opposite happened when the soil moisture level was increased. Thus, soil temperature was automatically controlled according to the soil moisture level. The temperature at the commencement of measurements was 28 and 27 °C on the left side and right side pots, respectively. Those values existed for 8 hrs on the left side and 5 hrs on the right side. On the left side pots, the temperature then gradually decreased and the reading was 25 °C at the end of the measurements made. On the right side, after 5 hrs the temperature increased by another 1 °C and that value exited until 8.15 p.m. At last, similar to the left side the temperature reached to 25 °C.

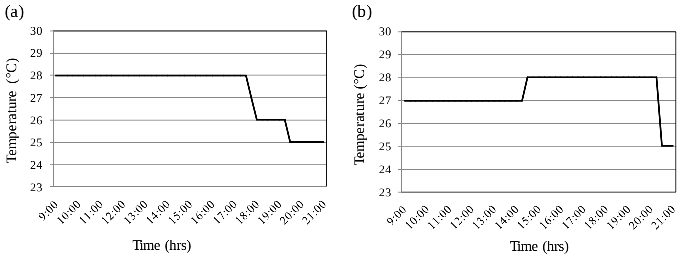

Figure 7: Soil temperature variation in pots placed on the (a) left side and (b) right side of the greenhouse for 12 hours time period during 9.00 to 21.00 hrs.

Figure 8 (a) and (b) show RH variation inside and outside the greenhouse, respectively, for 12 hrs time period during 9.00 a.m. to 9.00 p.m. Accordingly, inside RH was more than 83 % at 10.15 am to 1.15 pm. The maximum reference value for the air RH was 83 % and therefore, the exhaust fan was turned on until 1.15 pm. Then, the RH inside the greenhouse gradually decreased up to 74 % by 4.00 pm. The minimum reference value for the inside RH was 74 % and because of that decrease of RH the electric water solenoid valve with mist sprinklers in the system was turned on until 6.45 pm. As a result, the RH of the greenhouse gradually increased over the time and reached up to 78 % by the end of the monitoring time. The RH variation outside the greenhouse is depicted in Figure 10 (b). Compared to inside RH, outside RH was always lower at any time. The distribution pattern of RH however existed in similar way although the lowest level (~69 %) reached by 2.30 p.m. which is some minutes earlier to the inside RH.

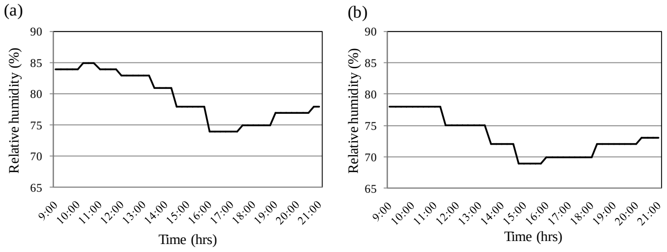

Figure 8: Relative humidity variation (a) inside and (b) outside the greenhouse for 12 hrs time period during 9.00 to 21.00 hrs.

Figures 9 (a) and (b) show the visible light variations of inside and outside of the greenhouse, respectively. When the visible light was dark inside the greenhouse a bulb was turned on until it got middle light. Although, the outside visible light level existed at 3 until 6.00 p.m. the inside visible light was at its middle level during the first ~1.5 hrs. Thereafter, the level reached to 3 (light) and the same existed for 6 hrs. By the end of the monitoring time, both inside and outside light levels reached to 1, which is dark.

Figure 10 presents how UV intensity variation took place for 12 hours time period during 9.00 a.m. to 9.00 p.m. As such, UV intensity increased until 12.00 noon starting from 0.8 and existed at 1 for nearly 3 hrs. From that level, the UV intensity decreased gradually until 6.00 p.m. reaching to the level 0.01 that existed for 3 hrs until 9.00 p.m.

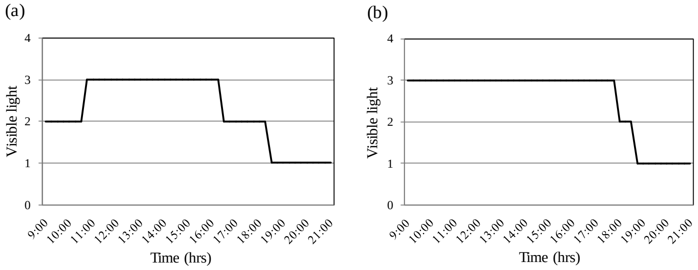

Figure 9: Visible light variation (a) inside and (b) outside the greenhouse for 12 hrs time period during 9.00 to 21.00 hrs (1 = dark, 2 = middle light, 3 = light).

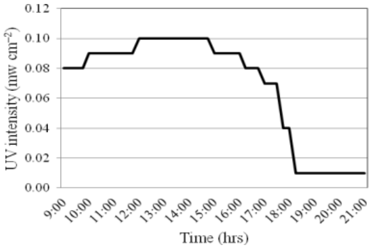

Figure 10: UV intensity variation for 12 hours time period during 9.00 to 21.00 hrs.

B. Plant growth

As per the visual observations made throughout the experiment, the growing rate of the crop inside was greater than that of the outside crop. This difference was clearly observed with the height of the plants. Also, disease infection rate of the inside crops was lesser than the rate of the outside crop. It was observed that the outside crop was attacked by some snails as well as by some fungi. Apparently, flowering of inside crop was earlier compared to that of the outside crop; hence, fruits were also set earlier in the inside crop over the outside plants.

IV. Conclusion

As observed in the present development, there is a possibility that the environmental conditions can be controlled and sensed their changes using an automated system. In particular, we were able to monitor inside and outside temperature, RH, and visible light. Further, inside the greenhouse, soil moisture level and UV light intensity were also measured. The system also showed an ability of transferring and storing data in an Excel worksheet. Therefore, the sensed data can be used for further analyzing purposes in future.

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