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(Research Article)

Effect of light and temperature on growing lettuce crop in greenhouse by using Iot Technology

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Abstract

Lettuce (*Lactuca Sativa*) is an important vegetable in horticulture, but information about the interactive effects of light and temperature on its photosynthetic characteristics was inadequate. This research aims to design, create, and evaluate a hydroponic (lettuce) automation system by monitoring the quality of plant growth that uses LED grow lights and natural light conditions on hydroponics. Checking whether the proposed system has a significant effect on the box Choy hydroponic (lettuce) growth is also an important aspect and becomes the contribution of this paper. The contribution of this paper is by discussing in detail the automation of LED grow lights using RTC modules and relays while also discussing the significance of LED light performance in lettuce growth. On the proposed greenhouse automation systems, light-feeding is done automatically, this can be carried out with the help of a real-time clock (RTC) module and relays. Furthermore, the monitoring function is carried out through temperature and humidity measurement sensors. The data obtained from the sensor will be stored in the database for research on plant quality. The results of a comparison test show that the LED grows lights are superior in terms of fresh weight, the number of leaves, and plant height respectively with an average value of 67.2 grams, 7 leaves, and 9.3 cm on the 30th day. Compared to sunlight, respectively with an average value of 37.3 grams, 5 leaves, and 7.1 cm on the 30th day. T16, T17,T18,T19,T20 &T21 are conducted inside the greenhouse to get maximum production. It shows 18-19°C are most suitable for lettuce crop growth. It can be concluded that the LED grow lights give a significant effect on the fresh weight and leaf growth rate of IoT-based box Choy hydroponics (Lettuce) if compared to sunlight.

Keywords: Greenhouse; Temperature and Humidity sensor; Lettuce; IoT technology

1. Introduction

The cultivation of crops in controlled environments, such as greenhouses, has become increasingly popular due to the ability to optimize growing conditions and enhance crop yields. In this context, the influence of environmental factors, particularly light and temperature, plays a crucial role in the successful cultivation of crops. Lettuce, being a widely cultivated leafy vegetable, is an excellent candidate for greenhouse cultivation, where precise control over environmental parameters can be achieved. Integrating Internet of Things (IoT) technology into greenhouse systems further enhances the precision and efficiency of environmental control.

Although high air temperature may optimize lettuce growth, it may have deleterious effects on composition. The early relative growth rate of lettuce increased from 10 to 22 °C [1]. Among various cultivars, lettuce has more weight at 20°C early in growth, although maximum yield was at 17 °C [2].Leaf weight and area increased to 19°C with air temperature, but root temperature had no effect [3]. Air temperature increased with radiation when variable air temperature was used to maximize lettuce growth.Composition of the shoot tissue of lettuce changes with environment.

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Climate change is one of the causes of good or bad roductivity in agriculture. The delay in the rainy seasonand the progress of the dry season can be based on climate change in Bangladesh and cause the planting calendar to change.Uncertain environmental factors, especially in terms of temperature and humidity can affect the growth and development of vegetables and fruits. Lettuce (*Lactuca sativa*) vegetable varieties that contain lots of substances beneficial to human health [4].The optimum temperature for lettuce growth at 25°C to 28°C and humidity ranges from 80% to 90% [5].Lettuce can also grow in cold and tropical regions, lettuce marketing increases along with economic growth and population.One effort to increase the production of lettuce sustainably is to use hydroponic technology. In regulating the temperature and humidity in a hydroponic home, problems often arise due to mismatch between the normal environmental conditions (temperature and humidity) of vegetable plants and the conditions in a hydroponic home, consequently having an impact on their growth and development. The worst conditions have an impact on disability to production failure. Besides, in some cases the performance of sensors (different sensors) there are also some differences or incompatibility to collect data on environmental conditions (temperature and humidity).Continuous monitoring and using several different sensors within a certain period is needed for this problem, which is certainly difficult for officers or farmers to continuously observe the environmental conditions for 24 hours [6]. Reviewing the problems that occur, it is necessary to have a monitoring system control parameters based on a wireless sensor network environment, with managing huge data (collect data) whether it is organized or unorganized is a major challenging task for the organizations or individual.There is a need for applications and software‘s that are cost efficient with high computational power [7]. This research will focus on designing a prototype system and adding a sensor performance calibration analysis using an automatic control system so that environmental conditions that affect growth can be collected and collected continuously (real time) using several sensors related to the data collect (temperature and humidity). The agriculture data (collect data) will be analyzed to optimize and modify of environment around and referred to as the growing media with treatment [8]. The system designed will use the concept of the Internet of Things thatrefers to conditions of temperature and humidity so that the data taken is matched with the native habitat of the plant (normal conditions using a special digital meter reference).

From the above discussion, the following objectives were undertaken:

- To increase the light intensity and temperature to monitor crop growth by using IoT technology.
- To compare the crop growth rate inside greenhouse and outside at field condition.

2. Materials and Methods

The process of selecting materials and applying methods entails deciding which material and method will be most suitable to satisfy the demands of a particular experiment.To guarantee plant development in an automated greenhouse, it is crucial to provide plants with enough nutrients and optimal growing conditions. In this chapter, the supplies, techniques, and steps for growing lettuce in an automated greenhouse are described.

2.1. Site Selection

Figure 1 Satellite view of the experimental site

The success of crop production is significantly dependent on the selection of the site. It is essential for the greenhouse to be situated in a location that is shielded from strong winds. In this research, the Agricultural and Biosystem Engineering Laboratory was selected as the location for growing lettuce within the automated greenhouse. The geographical coordinates of the experimental site are 24°54'28.3"N 91°54'02.3"E, as illustrated in figure 1.

2.2. Materials

The materials were divided into three categories for the construction of an automated greenhouse for the production of lettuce.The categories were (1) automated system, (2) greenhouse structure,(3) crop production.

2.2.1. Materials for Automated System:

The complete system was designed to incorporate a range of electrical components that form this automated framework. To clarify their specific applications, a detailed specification of these components is provided below:

Table 1 Technical specification of different components

Items	Specifications
Arduino nano	ATmega328
DHT11–Temperature and Humidity Sensor	3.5V to 5.5V, Accuracy=±1°C and ±1%
Soil Moisture Sensor (LM393)	3.3V to 5V DC,15 mA
Relay Module	3.75V – 6V,2 mA
Organic Light-Emitting Diode (OLED)	128 × 64 pixels, AC 3V-5V
DC Buck Converter Power Supply	3V - 40V,ή= 92%(Highest)
12V DC Centrifugal Pump	Max.Pressure =35psi, 12V DC motors
Exhaust Fan	220V, 28 W
100-watt bulb	100W

2.2.2. Materials for Greenhouse Structure

Raw materials that are easily available in the study area were used for the construction of the greenhouse structure. These are:

- ***PVC pipe***: The structural skeleton of the greenhouse was made of 0.5 inches (0.0127 m) diameter PVC pipe.
- ***PVC pipe fittings:*** Pipe fittings were employed to connect multiple pipes, alter the orientation of the pipes, and create angles in the skeleton. Elbow, union, and tee fittings were used for the accomplishment of these activities.
- ***Polythene sheet:*** The structure was covered with a single layer of 6 mili (0.1524 mm) thick polyethylene due to its inexpensive cost and durability to withstand multiple seasons.

2.2.3. Materials for Crop Production

The 'BARI Lettuce-1' variety was selected for crop production since it is invented in our country. Sandy loamy and loamy soils are most suited for productive Lettuce cultivation. Sandy loamy soil was selected for Lettuce production that was collected from a nearby hillock of the Agricultural Engineering and Technology faculty building. Fertilizers like compost , urea, ISP , and MoP were collected Bondor Bazar, Sylhet.

2.3. Design and Construction

2.3.1. Design of Greenhouse Structure

The greenhouse structure (Quonset type) was designed by utilizing Computer-Aided Design (AutoCAD) software before the experiment. For a better understanding and accurate measurement of dimensions, a three-dimensional structure was created. The pictorial view of this 3D model is shown in Figure 2

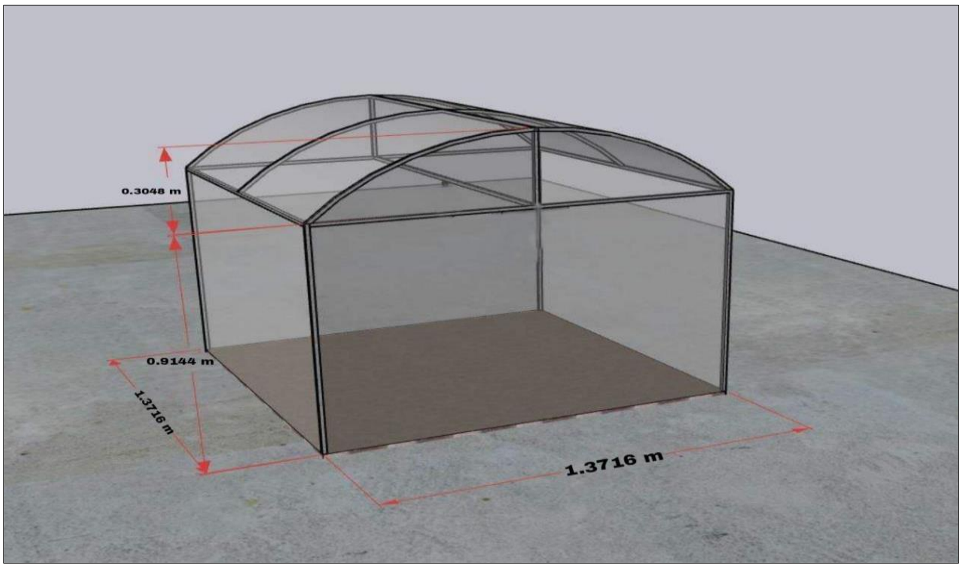

Figure 2 Three-dimensional model of greenhouse structure

2.3.2. Construction of Greenhouse Structure

The skeleton of the greenhouse was constructed using RFL PVC thread pipe (0.5-in diameter) and pipe fittings (elbow, tee, and union). Teflon tape was used to attach the pipes with the help of the fittings. Polythene sheet (6 mm thick) was cut into adjustable lengths and widths to wrap the skeleton. Transparent scotch tape was used to adjoin the polythene sheet with the skeleton. The length and width of the structure were 1.37 m (4.5 ft) as it is square and the height of the structure was 1.21 m (4 ft) including 0.30 m (1 ft) Modified Quonset shape on the top. A typical pictorial view of the greenhouse structure is shown in Figure 3

Figure 3 Pictorial view of greenhouse structure

2.4. Flow Diagram of the Automated System

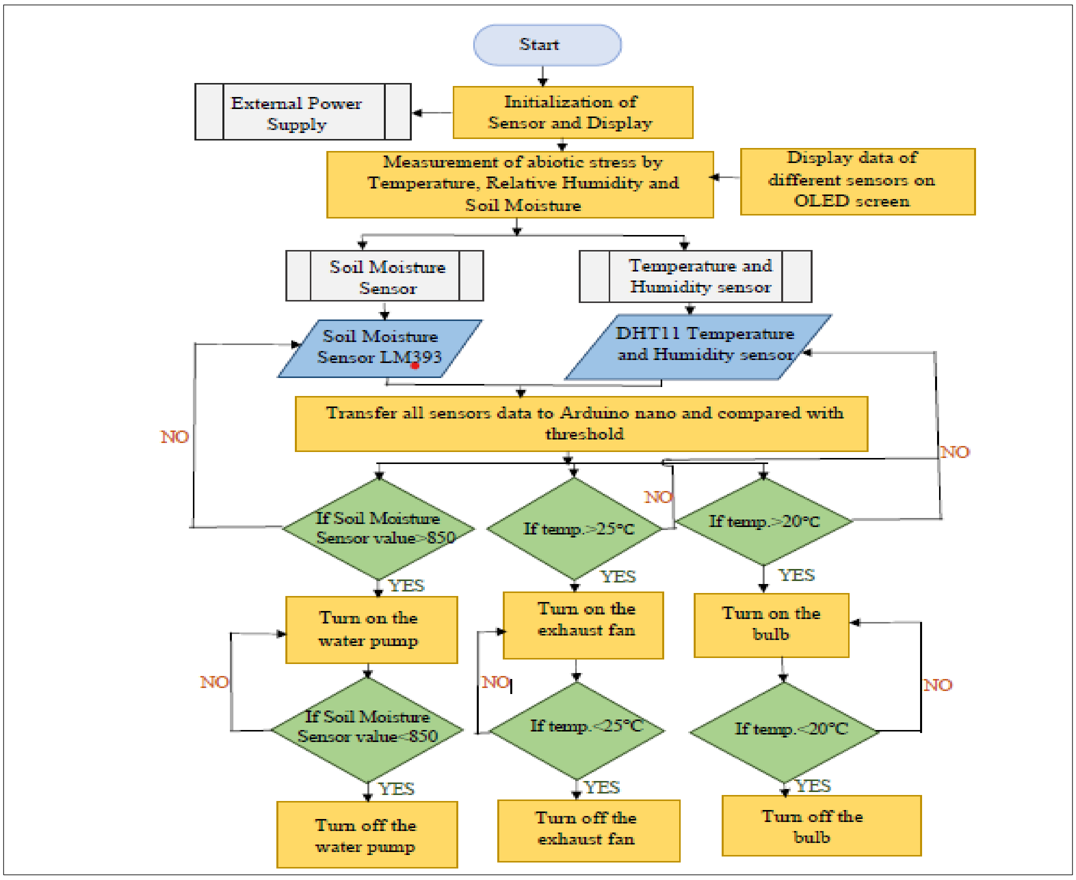

Figure 4 Flow diagram of the automated system for monitoring and controlling the environmental parameters

2.5. Circuit Diagram

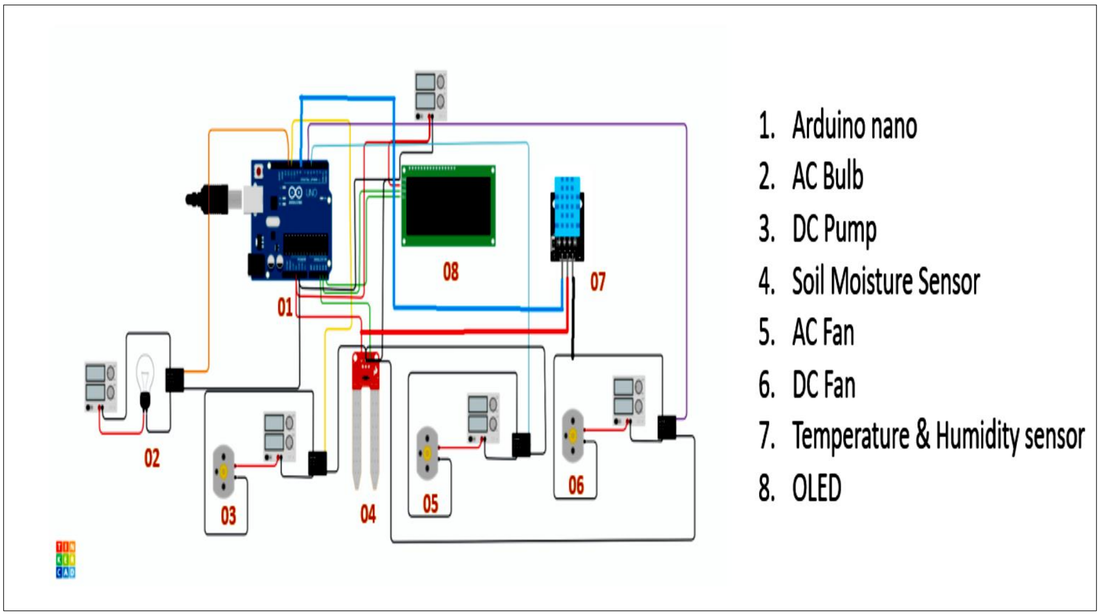

Figure 5 Circuit Diagram

2.6. Plant Layout

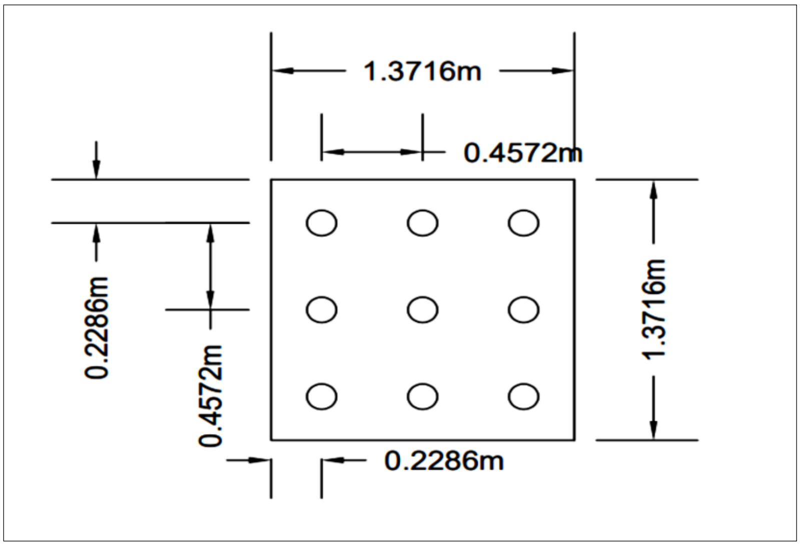

Figure 6 Plant Layout

2.6.1. Soil Preparation

Initially, a wooden block was employed to break apart the clods in the collected soil to ensure proper preparation. Subsequently, soil, compost, sand, and coco-dust were combined in the ratios of 9:3:3:1 to facilitate seed germination, while soil, compost, muriate of potash (MoP), and triple superphosphate (TSP) were blended in the proportions of 5:5:0.01:0.01 for transplanting and promoting seedling growth. Following this, the soil was allowed to decompose at the preparation site for a duration of seven days. To prevent the formation of clods, the soil was thoroughly pulverized. All weights were recorded using a digital weighing scale.

2.7. Irrigation

A drip irrigation system was installed to fulfill the water requirement of the plants.

2.7.1. Data Collection

- Technical data includes temperature (°C) and humidity (%) which were collected three times a day, in the morning, at noon and in the evening, both inside and outside the greenhouse to compare these technical data. The data were obtained with the help of sensors which were displayed on the OLED.
- Crop data includes vegetative growth which involves plant height (cm), and the number of leaves (number) of the crop. These data were collected at ten days interval. Measuring scale were used to collect the crop data.

2.8. Data Analysis

Microsoft Excel 2019 was utilized to perform data analysis and graphical presentation.

3. Results

3.1. Vegetative growth

After 15 days of seed germination, the seedlings were transplanted into bowls having 1 ft soil depth. Nine seedlings for each condition out of total 18 seedlings were transplanted into various bowl both inside and outside the greenhouse. The plants were observed for 30 days from the day of transplantation and crop data (plant height, number of leaves) were collected at 10 days interval for three times.

First data was collected after 10 days of transplantation both inside and outside the greenhouse which are graphically presented in figure 7 and 8.

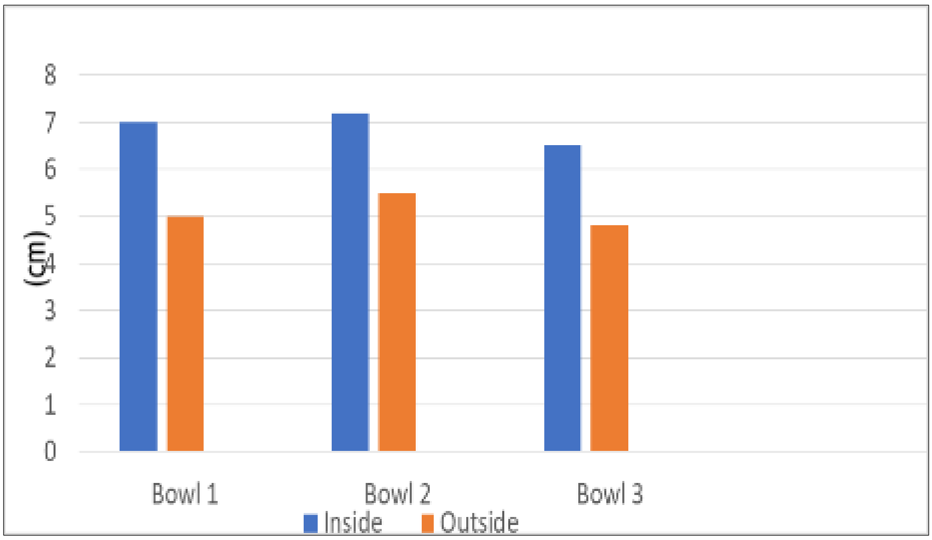

Figure 7 Variation of plant height between inside and outside the GH (after 10 days of transplantation)

From figure 7, it is observed that the highest plant height inside the greenhouse was 7.2 cm, whereas it was 5.5 cm outside.The lowest plant height inside and outside greenhouse were respectively 6.5 cm and 4.7 cm .

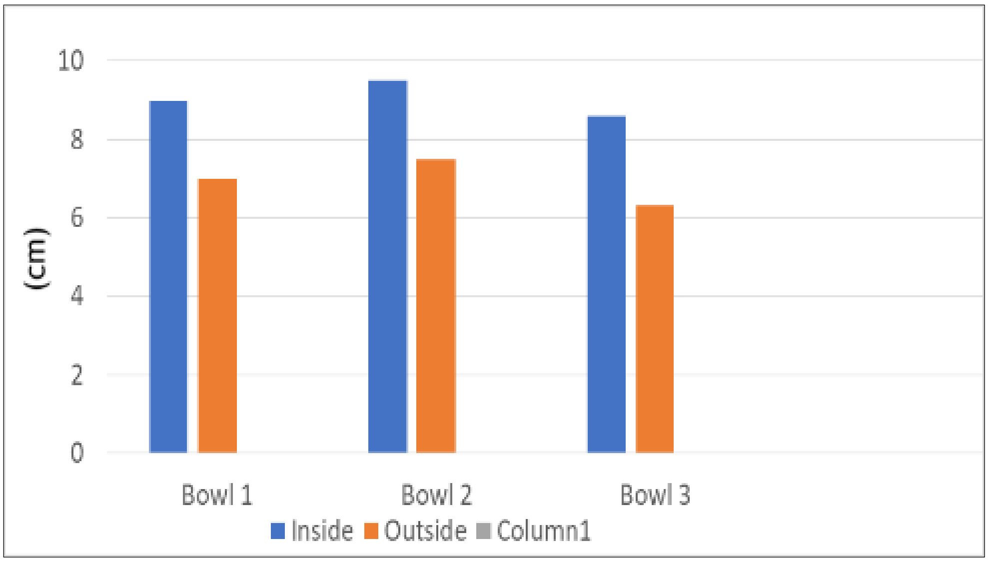

Figure 8 Variation of plant height between inside and outside the GH (after 20 days of transplantation)

From figure 8 it is observed that the highest plant height of inside the greenhouse was 9.8 cm, whereas it was 6.8 cm outside.

Then,Final data was collected after 30 days of transplantation both inside and outside the greenhouse which are graphically presented in figure-4.3, figure-4.4. From figure-4.3, it is observed that the highest plant height inside the greenhouse was 9.5 cm, whereas it was 7.4 cm outside. The lowest plant height inside the greenhouse was 8.5 cm which was higher than the highest plant height outside the greenhouse and that was 4.7 cm.

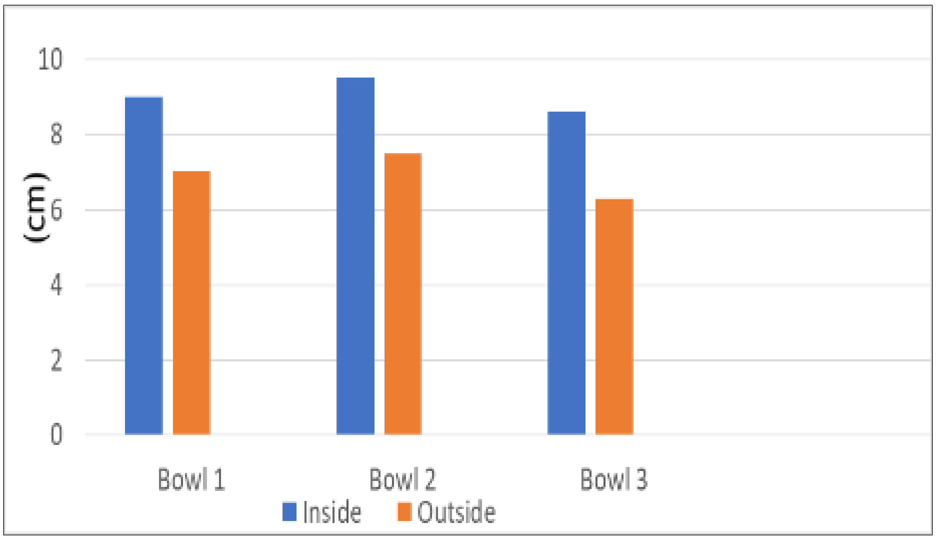

Figure 9 Variation of plant height between inside and outside the GH (after 30 days of transplantation)

From figure-, it is observed that the highest number of leaves inside the greenhouse was 5, whereas it was 4 outside.

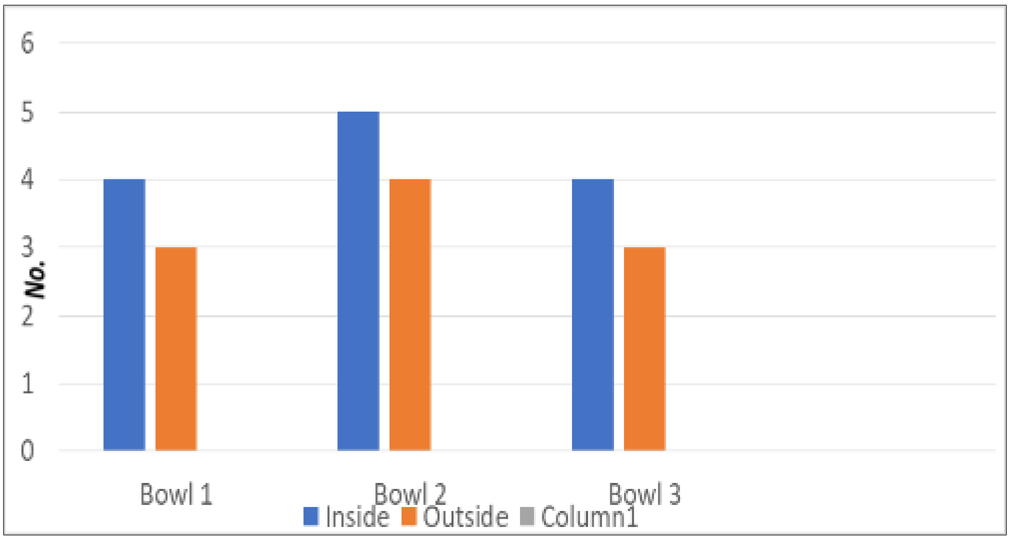

Figure 10 Variation of no. of leaves between inside and outside the GH (after 10 days of transplantation)

After that Finally , the second and third data was collected after20 and 30 days of transplantation both inside and outside the greenhouse which are graphically presented in figure-11, figure-12

From figure-11, it is observed that the highest plant leaves no. in inside was 7 and outside was 5.

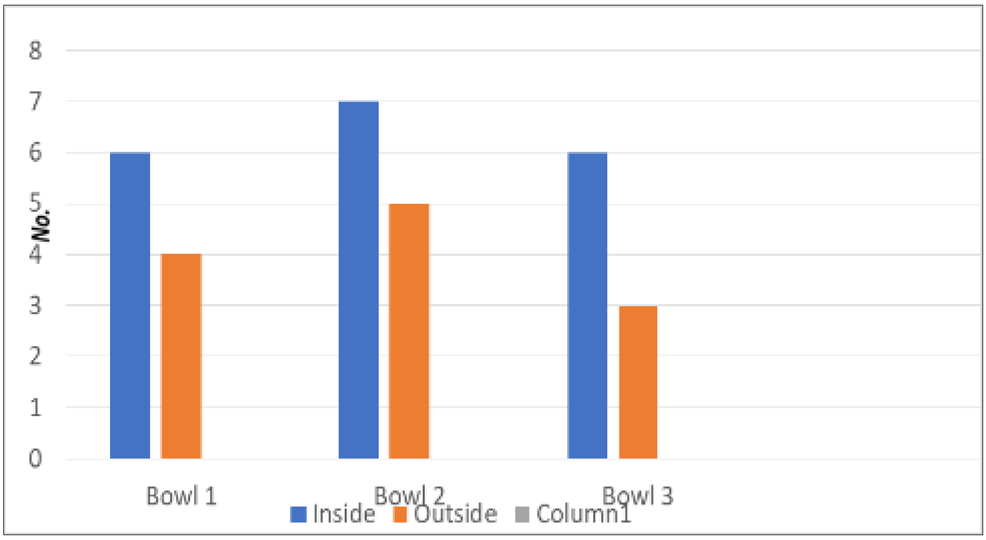

Figure 11 Variation of no. of leaves between inside and outside the GH (after 20 days of transplantation)

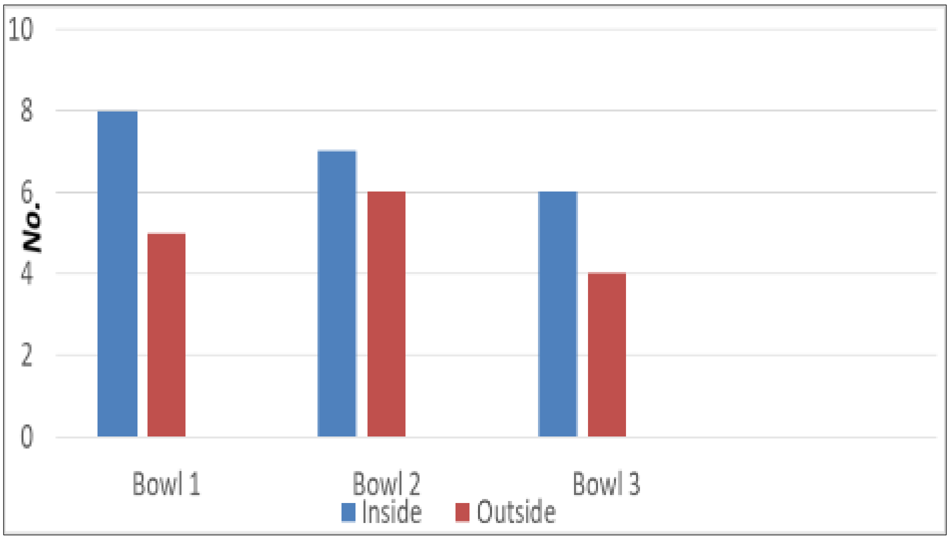

Figure 12 Variation of no. of leaves between inside and outside the GH (after 30 days of transplantation)

From figure-12, it is observed that the highest number of leaves inside the greenhouse was 8, whereas it was 6 outside.

3.2. Environmental Parameters

3.2.1. Temperature

In greenhouse environment, both temperature and light intensity play crucial roles in the growth and development of lettuce crops. Here's a detailed description of how temperature and light intensity interact to support the growth of lettuce in a greenhouse:

Moderate temperature (16-21) °C & light intensity (300-600) μmol·m−2·s−1 are needed to grow the crops. we conducted favorable temperature & light intensity to maximize the lettuce crop growth. Here shows some experimental temperature & light intensity we get from greenhouse.

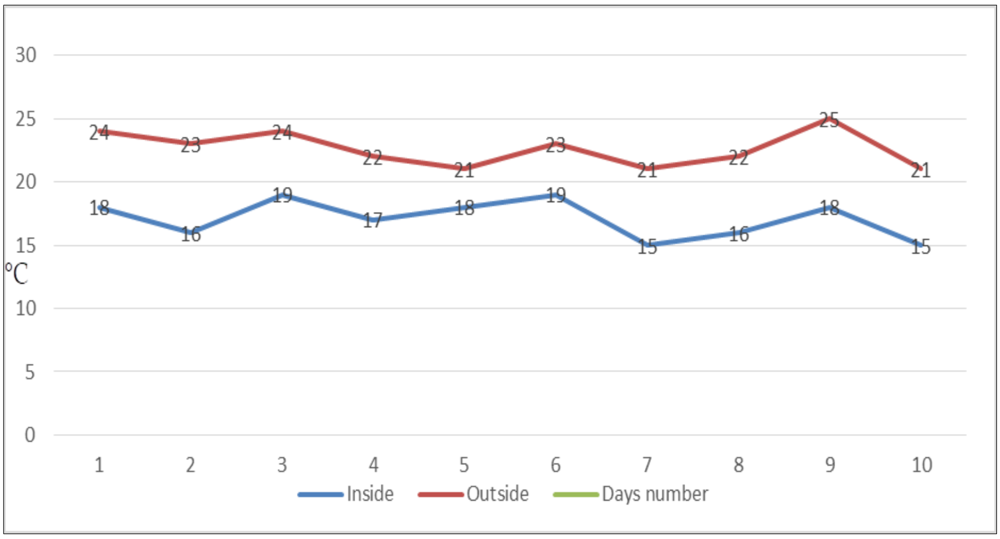

Figure 13 Variation of temperature (After 10 days inside and outside greenhouse)

From figure -13 it is observed that the height temperature of inside and outside greenhouse was 18°C and 15°C. whereas it was lowest temperature in outside respectively was 24°C and 21°C , After 20 days, From figure 14 it is observed that the height temperature of inside greenhouse was 18°C and 17°C. whereas it was lowest temperature in outside respectively was 23°C and 22°C

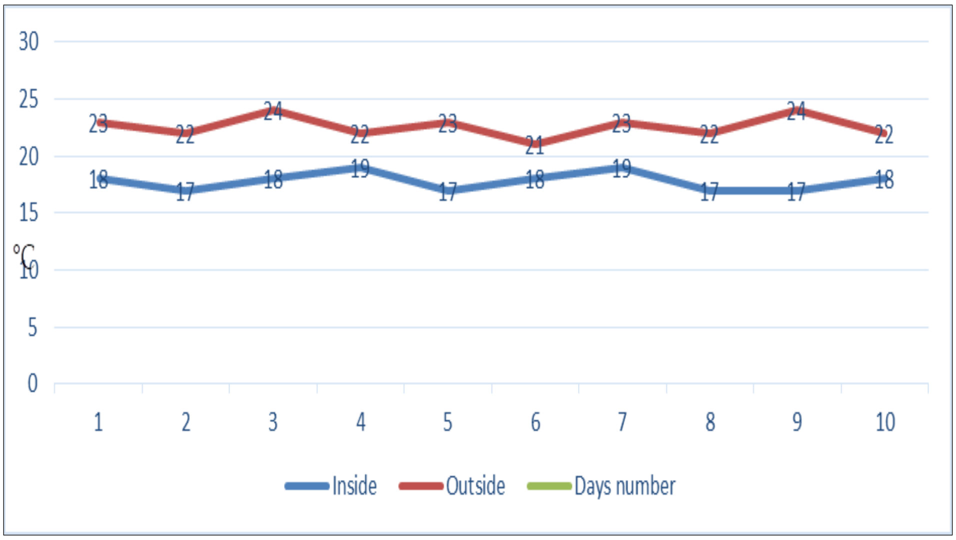

Figure 14 Variation of temperature (After 20 days inside and outside greenhouse)

After 30 days, From figure -15 it is observed that the height temperature of inside and outside greenhouse was 17°C and 16°C. whereas it was lowest temperature in outside respectively was 22°C and 20°C .

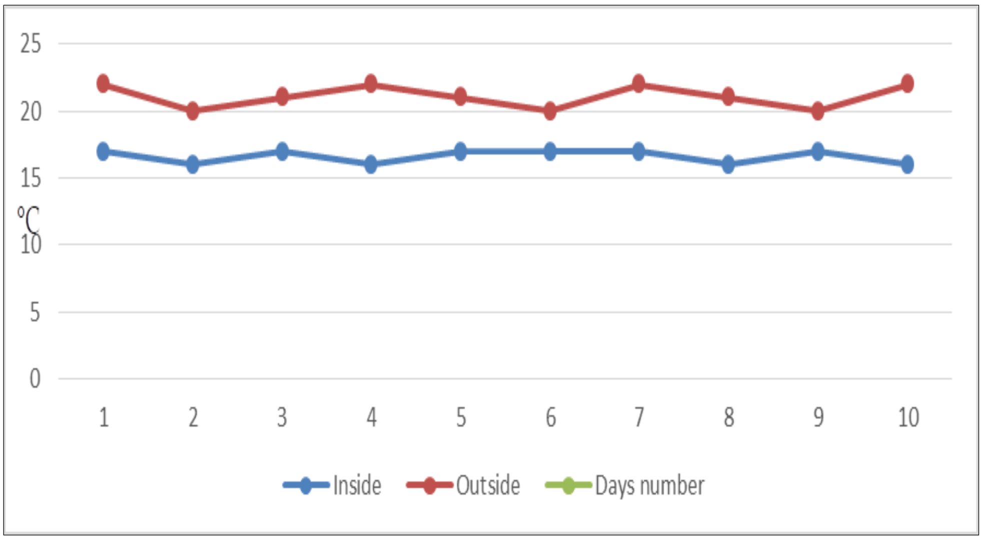

Figure 15 Variation of temperature (After 30 days inside and outside greenhouse)

3.2.2. Light Intensity

The photosynthetic rate, leaf width, fresh weight, soluble sugar, soluble protein, and ascorbic acid contents of both lettuce cultivars increased with the increasing LED light intensity**.** Light intensity of 350–600 μmol·m−2·s−1 is recommended at medium temperatures (23 °C). The range of 500 to 600 μmol·m−2·s−1 is a recommendable light intensity for lettuce grown at high temperatures (28°C).

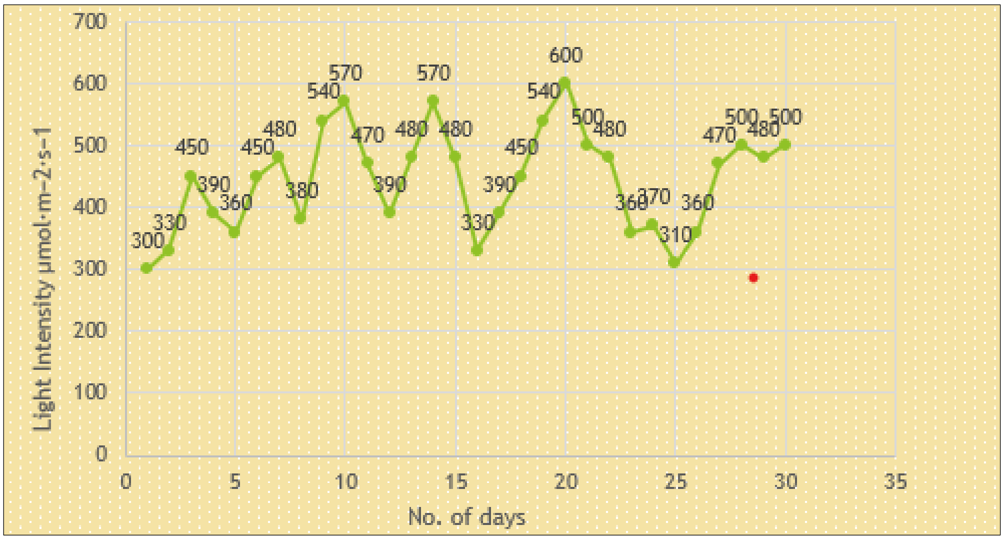

Figure 16 Variation of light intensity (Inside greenhouse)

From figure -16 shows the light intensity vs time (number of days).where we can see that different light intensity in inside greenhouse .The ranges are varies from 300 to 600 μmol·m−2·s−1.If we increase the light intensity within this range then lettuce crops growth are acquired optimum .

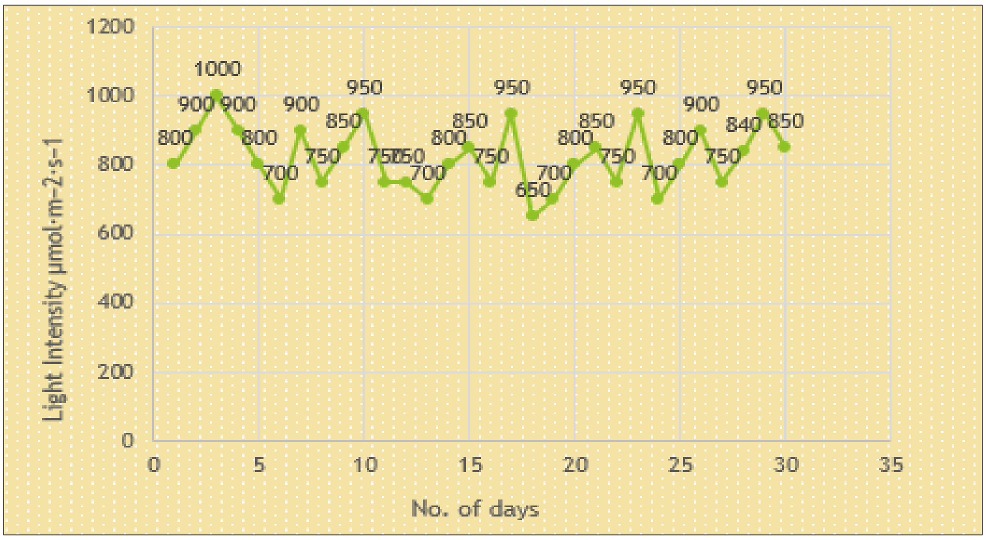

Figure 17 Variation of light intensity (outside greenhouse)

From figure -17 shows the light intensity vs time (number of days) where we can see that different light intensity in outside greenhouse ranges are varies from 300 to 1100 µmol·m−2·s−1.

3.3. Comparison of plant growth

Figure 18 Inside the GH

Figure 19 Outside the GH

4. Discussion

The integration of IoT technology in greenhouse lettuce cultivation marks a transformative shift in traditional farming practices, offering a myriad of benefits that enhance precision, sustainability, and efficiency. By deploying IoT-enabled sensors and smart systems, farmers gain unprecedented control over critical environmental factors such as light and temperature. This precision agriculture approach allows for a tailored cultivation process, adapting to the specific needs of lettuce at different growth stages. Real-time data collection and analytics empower farmers to make informed decisions, optimizing conditions for better crop yield and quality.Establishing complex plant physiological processes was challenging. Therefore, the proposed approaches integrated by FLs, NNs and NFs were used to extract the growth parameters related to lettuce, and the prediction model was established through experimental trials and standard cultivation operations.

5. Conclusion

Greenhouses may be a significant differentiator in today's world for controlling environmental conditions and shielding plants from pests and insects, according to data that is tracked. An efficient and long-lasting greenhouse monitoring system was successfully constructed for this investigation. Since the temperature and humidity sensors were able to gather data and send it to the microcontroller, which evaluates the data and takes appropriate action, the system makes it possible to keep an eye on the greenhouse's temperature and humidity levels.

This study demonstrated how to grow plants in a controlled environment inside a greenhouse and how crop data differed inside and outside of the greenhouse. In terms of the measured crop metrics, it was found that the automated greenhouse system performed better than the traditional approach. This system will improve plant development as environmental conditions change. An overview of the various types of sensor devices that are available is also given by this experiment.

The plant is shielded by the greenhouse from the effects of insects, temperature changes, and other elements. It was found that plants within the automated greenhouse system can produce higher-quality and higher-quantity crops than those outside if the same growing medium is used. Compared to others who have not yet adopted this approach, those who employ automated greenhouse systems will achieve higher crop productivity and sustainability.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there is no competing interest.

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