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Smart and Precision Polyhouse Farming Using IoT Technology

Ganesh K.[1,*], N. Kapilan[2], Amith Shetty K.[3], Bharath M.P.[4], Saksham Tiwari[5], Sumiksh Bukitagar[6]

Abstract
The emergence of the Internet of Things (IoT), one of its revolutionary advancements, signaled the beginning of a spectacular age in information technology in the 21st century. Managing crops in greenhouses is one application of precision farming in agriculture. Because it is so easy to establish predictable climatic conditions in greenhouses, they are the perfect environment for the use of precision farming. Precision farming will work better in a greenhouse because it is simpler to create identical environmental conditions there. The Arduino or Raspberry Pi microcontrollers are used for Internet of Things development in greenhouses. The hardware may make decisions depending on the data it gathers by employing sensors to monitor what is happening in the greenhouse. Temperature and humidity sensors, sensors for measuring soil moisture, and sensors for measuring light are among sensors that are frequently used in precision farming. The information that the hardware has gathered will then be wirelessly transferred in the Internet of Things Wi-Fi, Bluetooth, and ZigBee Protocol are the three most widely utilized wireless connection protocols. Wi-Fi has a greater range than Bluetooth and ZigBee connections, especially when linked to the Internet. In this research, the data shown in the figures emphasizes the consistent achievement of appropriate temperature and humidity levels within the polyhouse during morning, afternoon, and night sessions, offering the best conditions for crop development in comparison to the open field (normal) environments.

Keywords: IoT, Arduino Uno, Polyhouse, Precision Farming, Automation.

INTRODUCTION
Polyhouse
The most demanding form of greenhouse is a polyhouse, which has a covering material made of UV-stabilized polyfoil and a structure composed of galvanized iron. This construction makes use of the ability to modify climate so that plants can grow properly in different seasons. A polyhouse can range in size from a tiny house to an industrial building, depending on the needs and available space, in order to accommodate the extra requirements for polyhouse farming. A poly house is an enclosed area where the plants are nurtured on a platform that is controlled and is independent of location and other physical conditions [3].

Precision Farming
Precision farming is a revolution in agricultural management, maximizing the application of state-of-the-art technologies to monitor and expedite the agricultural production process. It is a cycle of observation and data collection, then assessment and analysis of the information obtained to help

*Author for Correspondence
Ganesh K.

[1]Assistant Professor, Department of Mechanical Engineering, Nitte Meenakshi Institute of Technology, Bangalore, Karnataka, India
[2]Professor and HoD, Department of Mechanical Engineering, Nitte Meenakshi Institute of Technology, Bangalore, Karnataka, India
[3-6]Student, Department of Mechanical Engineering, Nitte Meenakshi Institute of Technology, Bangalore, Karnataka, India

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with decision-making. Precision farming is a technique that assists farmers in managing agricultural variables and weather conditions on the farm in order to maximize revenues, yields, harvest quality, and reduce costs [2].

IoT Technology

Smart farming is a farming technique that uses IoT technologies to reduce waste, enhance productivity, and efficiently utilize resources. IoT smart farming solutions use sensors to monitor crop fields and automate irrigation systems. This enables farmers to keep an eye on field conditions from any location.

Wireless technology is typically used in Internet of Things applications. There are three short-range IoT technologies: Bluetooth and Zigbee. Wi-Fi is generally used for long distances. These technologies have different power consumption, transmission distances, and interference levels. The best wireless technology for a greenhouse will depend on the specific field conditions.

MATERIALS AND METHODOLOGY

Methodology

In this comprehensive greenhouse monitoring project, an Arduino serves as the central control unit, seamlessly integrating a variety of sensors. These sensors include a temperature sensor for greenhouse temperature monitoring, an LDR sensor to gauge sunlight intensity, and humidity sensors for both air and soil moisture levels. The Arduino collects data from these sensors, applying predefined thresholds to trigger actions such as activating fans to regulate temperature, adjusting artificial lighting for inadequate sunlight, and controlling moisture levels by operating water pumps and buzzers. This real-time data is then transmitted to an IoT module, specifically an ESP8266 microcontroller, via Wi-Fi, connecting the greenhouse to TCP/IP networks. Ultimately, this information reaches your laptop and smartphone, enabling remote monitoring and control of the greenhouse conditions [1].

COMPONENTS

Arduino Uno

Interactive electronic gadgets are made using the open-source Arduino hardware and software platform. Inputs from sensors, such as light sensors, finger sensors, or Twitter messages, can be read by Arduino boards and transformed into outputs, like starting a motor or turning on an LED. By giving the microcontroller commands, they may be managed. These instructions were written in a language known as Arduino. To develop and upload Arduino code to the board, utilize the software program known as the Arduino IDE (Integrated Development Environment). They are used to build a wide range of projects, from easy to difficult.

WIFI ESP8266

An open source IoT platform called NodeMCU has firmware that utilizes an ESP8266 Wi-Fi module. C/C++ programming or Lua scripting is done with the Arduino IDE. The 16 GPIO pins on the NodeMCU can be used to operate various peripheral devices, such as switches, LEDs, sensors, etc. Data storage capacity is 4M Bytes. NodeMCU operates at a 5V voltage. It has an L106 32-bit processor with a speed range of 80-160 MHz [10].

DHT11 Sensor

The DHT11 is one of the most basic and affordably priced digital sensors that measures temperature and humidity. It operates between 3 and 5 volts with a maximum current of 2.5 mA. The humidity percentage ranges from 20% to 80%, and the temperature ranges from 0°C to 50°C [4]. It makes use of a five-wire interface, which guarantees outstanding overall design efficiency and high precision. A resistive-type humidity sensor, an NTC temperature sensor, and an 8-bit microcontroller are all included in the sensor to deliver the best levels of accuracy, responsiveness, and economy [1].

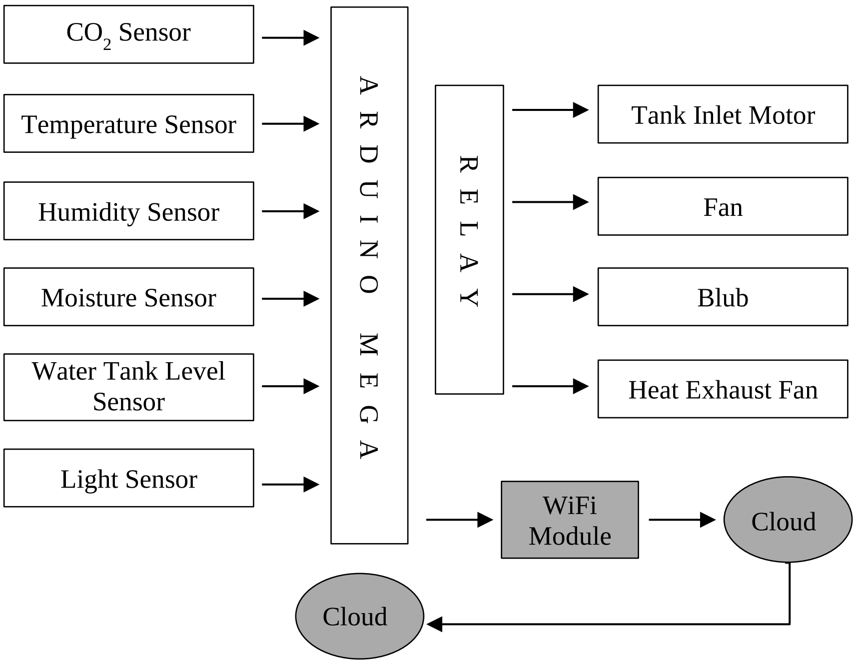

Figure 1. Methodology.

Figure 2. NodeMCU ESP8266 [10].

Figure 3. Temp and Humidity (DHT11) sensor [1].

Soil Moisture Sensor

When detecting the amount of water in soil, soil moisture sensors use a dielectric permittivity measurement characteristic. The sensor generates a dielectric acceptable voltage based on the amount of water in the soil. Lower dielectric permittivity results from greater water in the soil [10]. It is possible to gauge the volumetric or gravimetric water content of soil using this method. Gravimetric water content refers to the weight of water in each weight of soil, whereas volumetric water content measures the quantity of water in each volume of soil. Applications for it include crop management, irrigation, and environmental monitoring.

LDR Sensor

The LDR sensor module is used to gauge light intensity. It has two output pins, one for digital output and one for analog output. According to how much light the LDR is exposed to, the analog output pin produces a voltage. When the LDR is exposed to light, the digital output pin is high, and when it is not, it is low. The resistance of the LDR decreases with increased light exposure. The LDR has a very high resistance when it is not exposed to light. Additionally, the sensor contains a potentiometer that can be used to change the LDR's sensitivity.

Arduino IDE

Arduino Integrated Development Environment (IDE) is the name of the official software created by Arduino.cc. This IDE comprises essential components, including a script editor, a message box, a text console, a straightforward toolbar, and various menus. The Arduino IDE serves as a vital interface for connecting to the software created and establishing communication with Arduino hardware. Utilizing this platform, code can be efficiently written and uploaded to an Arduino board [1].

Polyhouse Model

The intended design for the polyhouse was constructed, leading to the development of a prototype to validate the real-time functionality of the concept. The prototype polyhouse model measures (3*2*4) feet and is enclosed with a combination of polythene and polycarbonate sheets. It is firmly supported by a robust welded iron frame. The lower section of the structure is constructed using water-resistant plywood and is further shielded with a sturdy black sheet for added protection.

Figure 4. LDR Sensor [1].

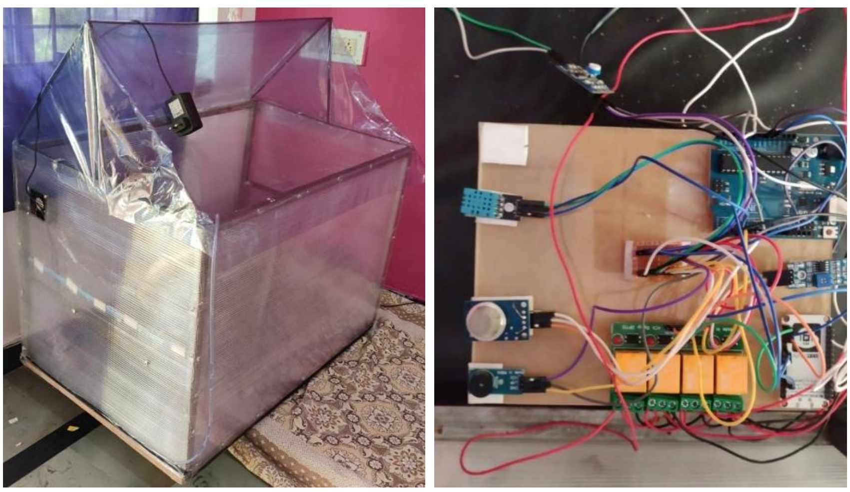

Figure 5. Polyhouse Model.

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RESULTS AND DISCUSSION

To establish a structured arrangement for cultivation, the model was divided into two sections and separated from one another by a foam sheet. A mixture of soil and manure was used to fill the model's two sides, and an irrigation system inside the model making watering easier.

Two particular crops, Corn and Mustard, were selected for production and both required careful maintenance of the following parameters.

The ideal parameters for optimal crop development are shown in the following table:

After sowing the seeds of Corn crop, we meticulously monitored and inspected the cultivation environment for a week, diligently recording data on the surrounding conditions. Ideal parameters within the polyhouse were consistently maintained and tracked using the BLYNK app. Subsequently, we relied on the Blynk IoT console to continuously monitor and regulate temperature and humidity levels. This involved active control of variables such as temperature, humidity, soil moisture, and water levels to ensure the polyhouse remained at the desired conditions for optimal crop growth. Throughout this period, we maintained a favorable environment to facilitate crop development. The collected data included temperature and humidity readings, and we present detailed graphs comparing these actual conditions with the ideal parameters inside the polyhouse, with the orange and red regions on the graph signifying the ideal humidity and temperature range.

In Figure 6 and Figure 7, the graphs illustrate the fluctuation in humidity and temperature levels in both an open field (normal) and a polyhouse setting during the first day of corn cultivation. It is evident from the data that the parameters inside the polyhouse have achieved the ideal conditions necessary for the optimal growth of the corn crop.

In Figure 8 and Figure 9, the graphs depict the variations in humidity and temperature levels in both an open field (normal) and a polyhouse environment on the seventh day of corn cultivation. The data indicates that, by the seventh day, the parameters within the polyhouse have maintained the ideal conditions required for the corn crop's healthy development, contrasting with the potentially less consistent conditions observed in the open field during the same period.

Table 1. Ideal parameters essential for optimal crop development

Crop	Temperature Range (°C)	Humidity Range (%)	Soil Moisture
Corn	28-33	70-80	Evenly Moist Soil (High)

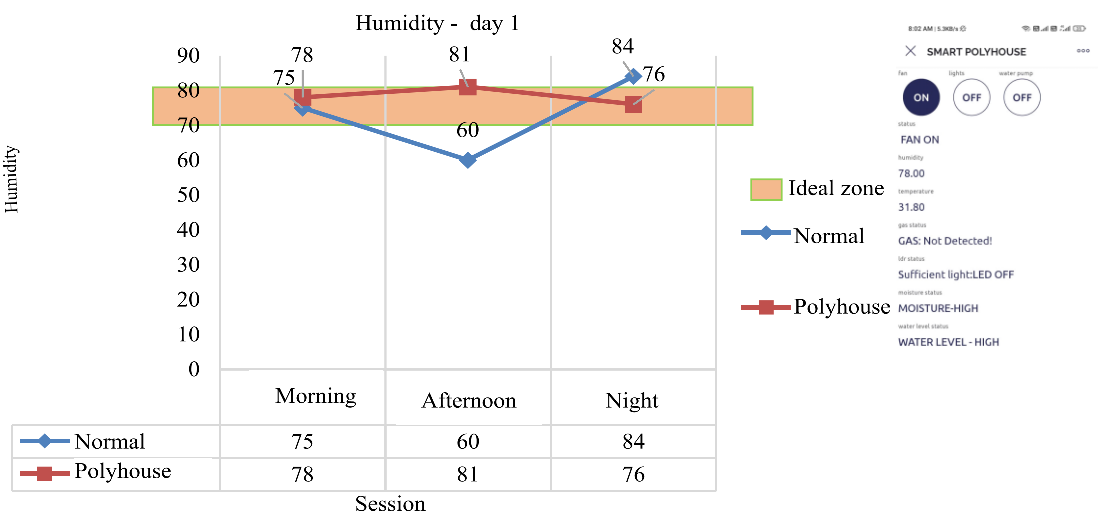

Figure 6. Variation of Temperature in Open field (Normal) and Polyhouse for Day 1.

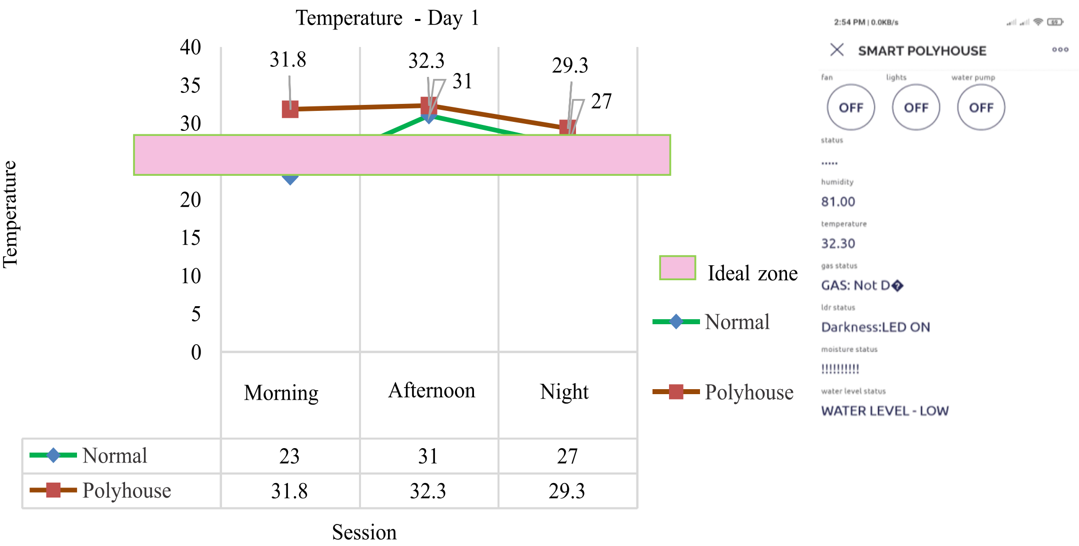

Figure 7. Variation of Temperature in Open field (Normal) and Polyhouse for Day 1.

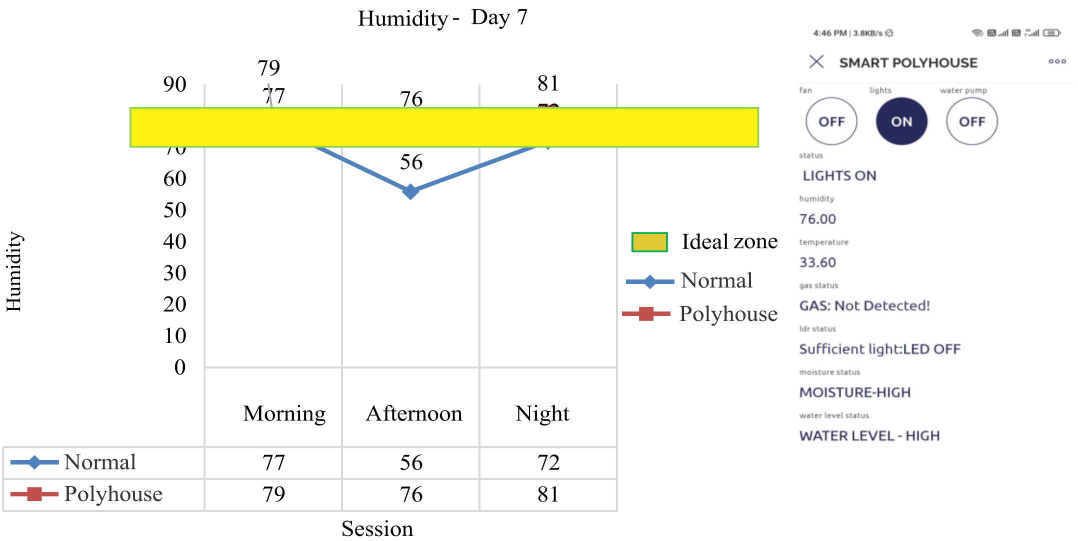

Figure 8. Variation of Humidity in Open field (Normal) and Polyhouse for Day 7.

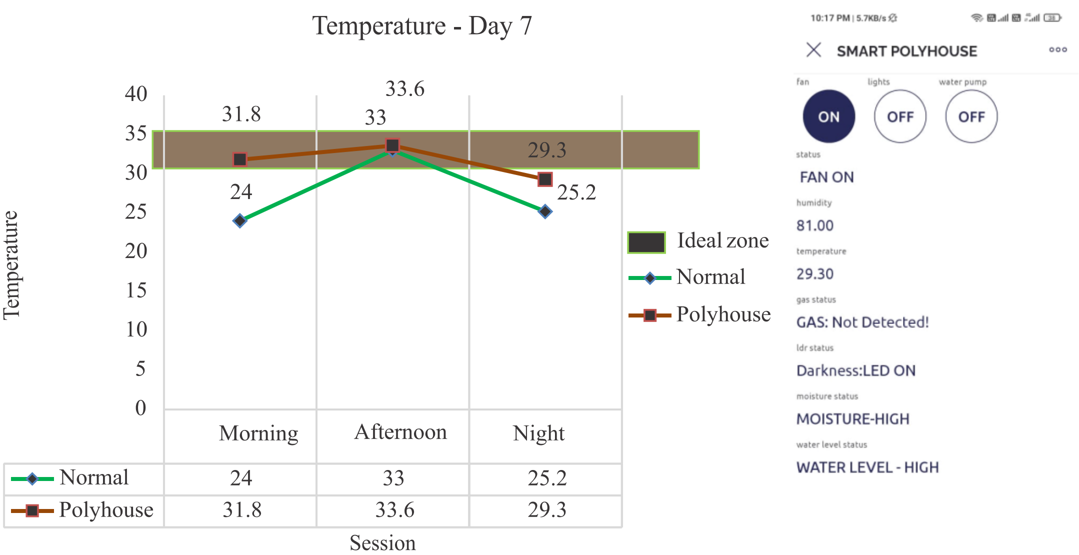

Figure9: Variation of Temperature in Open field (Normal) and Polyhouse for Day 7

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After 7 days of continues monitoring and maintaining the favorable conditions inside the polyhouse significant growth of crop was observed and no damage was reported to the polyhouse or electrical components inside.

The structure was placed outside in open to get abundant sunlight, it experienced severe heat and rainfall but the system was robust and handled the nature effects without taking any significant damage.

The polythene sheet covering the structurer from top was a bit effected due to continuous use for monitoring and inspection of crop. All the actuator units worked properly and provided desirable outcomes.

Due to excess heat outside, polyhouse experienced excess heating which was controlled by exhaust fan and covering the structure with the jute bag to cool down the electrical components as well.

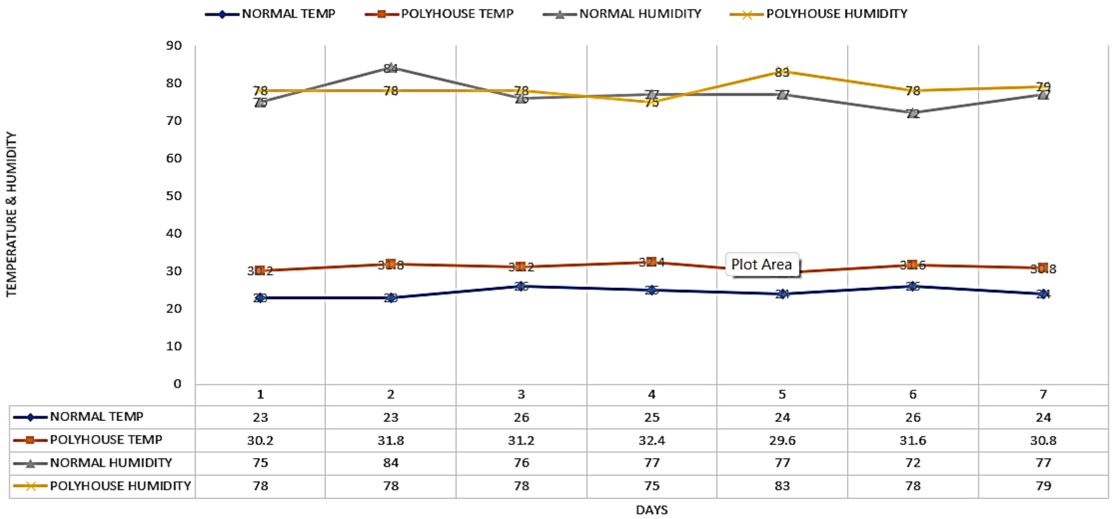
For the constructed model 2 exhaust fans are required to control the temperature as one fan is not very effective for the model, and it was required to unfold the plastic covering to regulate the temperature sometimes.

Figure 11 presents the temperature and humidity changes over seven days in the morning session, comparing conditions in both an open field (normal) and a polyhouse. It's evident that throughout these seven days, the polyhouse consistently achieved the ideal temperature and humidity levels necessary for the crop's development during the morning session, distinguishing it from the conditions observed in the open field.

Figure 12 compares the conditions in an open field (normal) with a polyhouse, showing the temperature and humidity fluctuations over time during the afternoon session. Compared to the conditions seen in the open field, the polyhouse constantly maintained the ideal temperature and humidity levels required for the crop's development during this time.

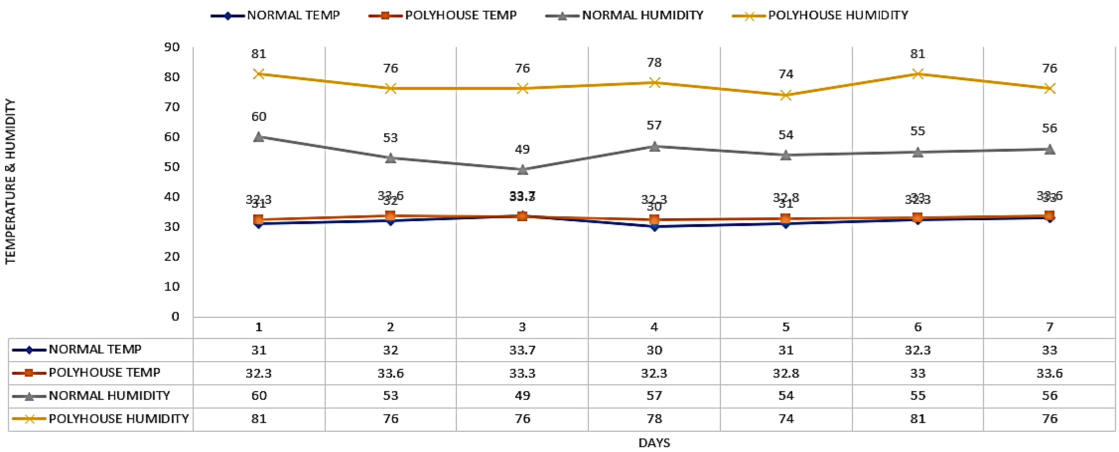
Figure 13 compares the conditions in an open field (normal) with a polyhouse, showing the variations in temperature and humidity over the night session. Notably, in contrast to the conditions seen in the open field during the night session, the polyhouse constantly maintained the appropriate temperature and humidity levels necessary for the crop's growth.

Figure 10. Progress of the Crops after 7 days.



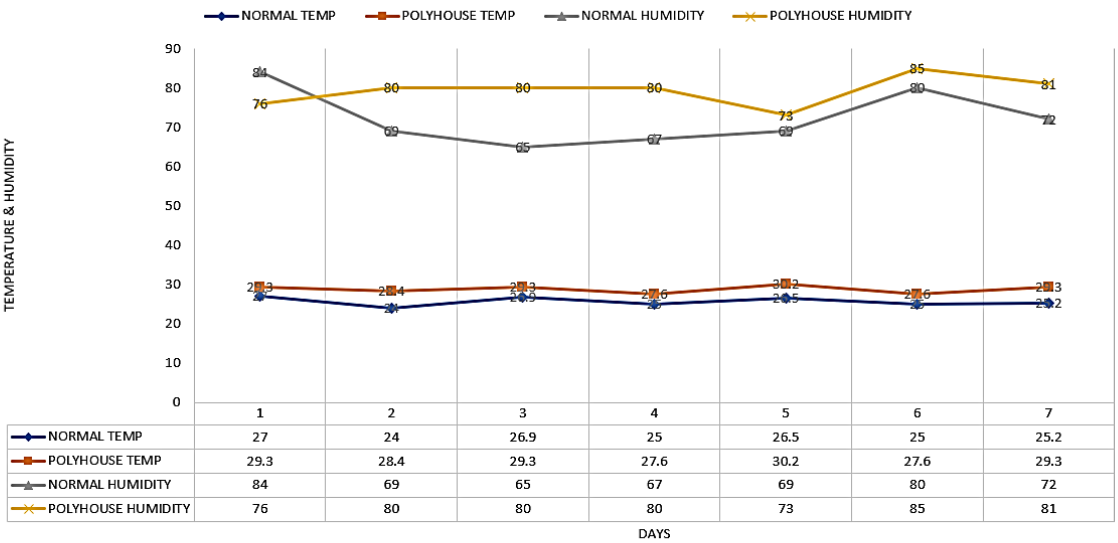
	1	2	3	4	5	6	7
NORMAL TEMP	23	23	26	25	24	26	24
POLYHOUSE TEMP	30.2	31.8	31.2	32.4	29.6	31.6	30.8
NORMAL HUMIDITY	75	84	76	77	77	72	77
POLYHOUSE HUMIDITY	78	78	78	75	83	78	79

Figure 11. Variation of Temperature and Humidity with Days in Open field (Normal) and Polyhouse in Morning Session.



	1	2	3	4	5	6	7
NORMAL TEMP	31	32	33.7	30	31	32.3	33
POLYHOUSE TEMP	32.3	33.6	33.3	32.3	32.8	33	33.6
NORMAL HUMIDITY	60	53	49	57	54	55	56
POLYHOUSE HUMIDITY	81	76	76	78	74	81	76

Figure 12. Variation of Temperature and Humidity with Days in Open field (Normal) and Polyhouse in Afternoon Session.



	1	2	3	4	5	6	7
NORMAL TEMP	27	24	26.9	25	26.5	25	25.2
POLYHOUSE TEMP	29.3	28.4	29.3	27.6	30.2	27.6	29.3
NORMAL HUMIDITY	84	69	65	67	69	80	72
POLYHOUSE HUMIDITY	76	80	80	80	73	85	81

Figure 13. Variation of Temperature and Humidity with Days in Open field (Normal) and Polyhouse in Night Session.

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CONCLUSION

As a result of IoT deployment in smart polyhouses, traditional farming methods have undergone a revolution that has improved sustainability, production, and efficiency. These smart polyhouses can efficiently monitor and adjust a variety of environmental parameters in real-time, including temperature, humidity, light intensity, and soil moisture, by integrating sensors, actuators, and connection devices. By automating modifications depending on predetermined parameters, this technology enables farmers to maximize crop growth conditions, minimize resource waste, and reduce crop failure. Additionally, the information gathered from these sensors can offer insightful information for well-informed judgments on crop management, irrigation, and pest control. IoT technologies also enable remote management and monitoring, giving farmers access to real-time information and system control from any location via smartphones or other connected devices, thereby increasing operational efficiency. By consuming less electricity, water, fertilizer, and other resources, smart polyhouses additionally improve sustainability.They closely monitor plant health and precisely control environmental factors, which decreases resource waste and the environmental effects of conventional farming methods and ultimately encourages the development of a more environmentally friendly and sustainable agricultural system.

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