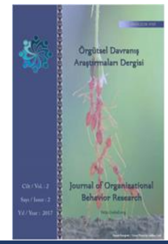
Örgütsel Davranış Araştırmaları Dergisi
Journal Of Organizational Behavior Research
Cilt / Vol.: 7, Sayı / Is.: S, Yıl/Year: 2022, Kod/ID: 22S0-868
2528-9705



Evaluating the quantitative and qualitative characteristics of fruits on the smart farms using the Internet of Things

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ABSTRACT

The Internet of Things is a huge network of interrelated objects and people connected to the Internet. Over the past few years, IoT science has gained great influence and importance in the agricultural sector. One of the important sub-fields of this science is monitoring and control of greenhouses, farms, and fisheries. To be more specific, the monitoring process in agriculture observes the proper operation of systems and the realization of agricultural production. In this study, a monitoring system based on wireless sensor network (WSNs) technology has been developed to monitor the environmental conditions of the greenhouse using the NRF24L01 + module and the Arduino board. The connection between the sensor node and the base station is established by the NRF24L01 + module, and subsequently, the information collected by the sensor node is transferred to the base station. The collected data is transferred from the base station to an Internet database and stored. The user can access the desired information using a mobile phone or browsing web pages through a browser. Comparing the qualitative and quantitative characteristics of the products produced in the proposed system compared to the traditional greenhouse proves the improvement of the performance of the proposed system.

Keywords: *IoT, smart farm, quantitative and qualitative characteristics of fruit, the sensor node*

INTRODUCTION

The core of the Internet of Things is data. To optimize farming processes, embedded IoT devices must collect and process data in a repetitive cycle so that farmers can respond quickly to emerging issues and changing environmental conditions. Precision agriculture is a new concept for IoT-based approaches with more precise control over farming processes. In simplest terms, plants and animals receive the treatment they need well enough. The biggest difference with traditional approaches is that in precision agriculture, separate decisions are made per square meter or even per plant/animal (rather than a farm). By accurately measuring changes in a field, farmers can increase the effectiveness of pesticides and chemical fertilizers and use them selectively and optimally.

Wireless sensor networks have a variety of applications in smart farms, such as measuring and monitoring soil properties, including soil moisture, soil temperature, soil pH level, and properties such as temperature, wind speed, and rainfall. The information generated by the sensors can be sent to farmers in the form of packets via the Internet, and necessary measures such as irrigation or fertilization can be done (Kodali et al., 2014).

Over the past few years, much research has been done on IoT applications in agriculture. Creating the right environmental conditions is critical for the ideal growth of plants, crop growth, and the optimal use of water and other resources. For example, using Arduino Mega, Sambasivam et al. (2018) analyzed atmospheric conditions such as soil moisture, humidity, and temperature in an indoor environment. By using greenhouse automation, productivity can be increased to some extent. Also, Tanmay Baranwal et al. (2016) designed an IoT-based device that analyzes sensed information and sends it to the user. This device can be monitored remotely and used in agricultural fields and refrigerators for security purposes.

In Chaudhary et al. (2011), the use of a programmable system on chip (PSoC) technology as part of a wireless sensor network (WSN) to monitor and control various greenhouse parameters has been proposed. Aung et al. (2019) introduced the smart greenhouse system as a convenient way to extract information from the greenhouse. IoT provides a report of all work done and updated information and the current state of the greenhouse from anywhere and anytime. The information the greenhouse owner receives is limited, but accessing such information is immediate. In (Jorda et al., 2019), an experimental prototype of an IoT-based micro-farm is designed using a wick system as a planting method. The results of this study allow urban farmers to remotely monitor their farms.

Manishkumar et al. (2018) discuss using the cloud-based Internet of Things in agriculture. Precision agriculture promptly provides adequate resources, including water, light, pesticides, etc.

Based on a more accurate and cost-effective resource approach, smart agriculture has the potential to provide better and more sustainable agricultural products. The new farms are fulfilling the eternal dream of mankind and feeding our growing population, estimated to reach 9.6 billion by 2050. Accordingly, this study aims to evaluate the quantitative and qualitative characteristics of fruits in the smart farm using the Internet of Things platform.

Proposed method

The proposed method has been experimentally implemented in a designed greenhouse with a length of 3 meters and a width of 2 meters. The sensor node and base station start working simultaneously in this method. A radio network is then established using the RF24L01 + module, and the base station is connected to a wireless Internet modem. In the next step, the data request is sent to the sensor node because the base station does not yet have the sensor information. After receiving the request from the base station, the sensor node sends the information to the base station. At the same time, the sensor compares the information with the threshold and, if necessary, controls the relevant relays. Immediately after receiving the data, the base station creates an HTML page, displays the information, and sends the information to the database.

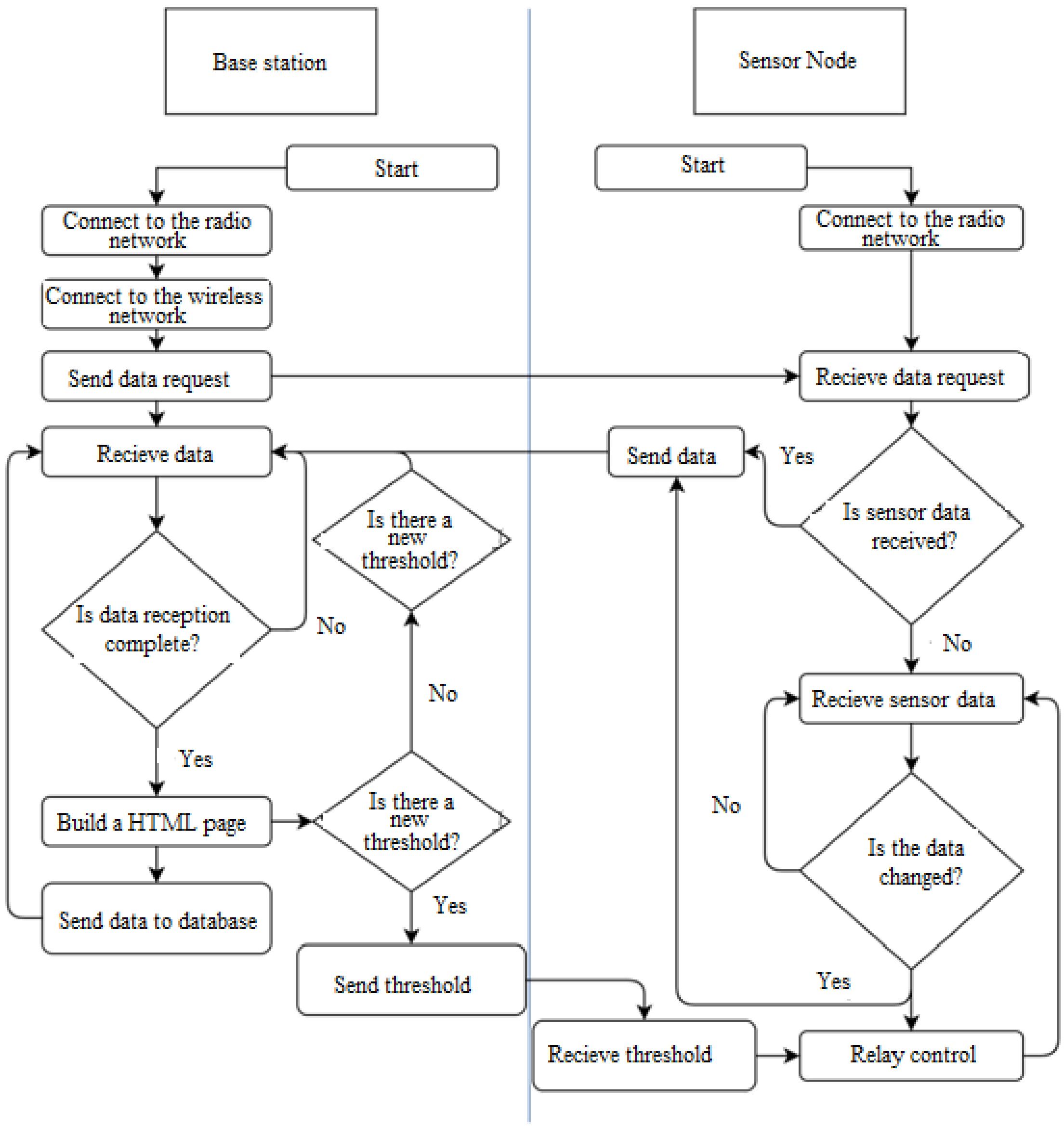


Figure 1: Flowchart of the proposed method

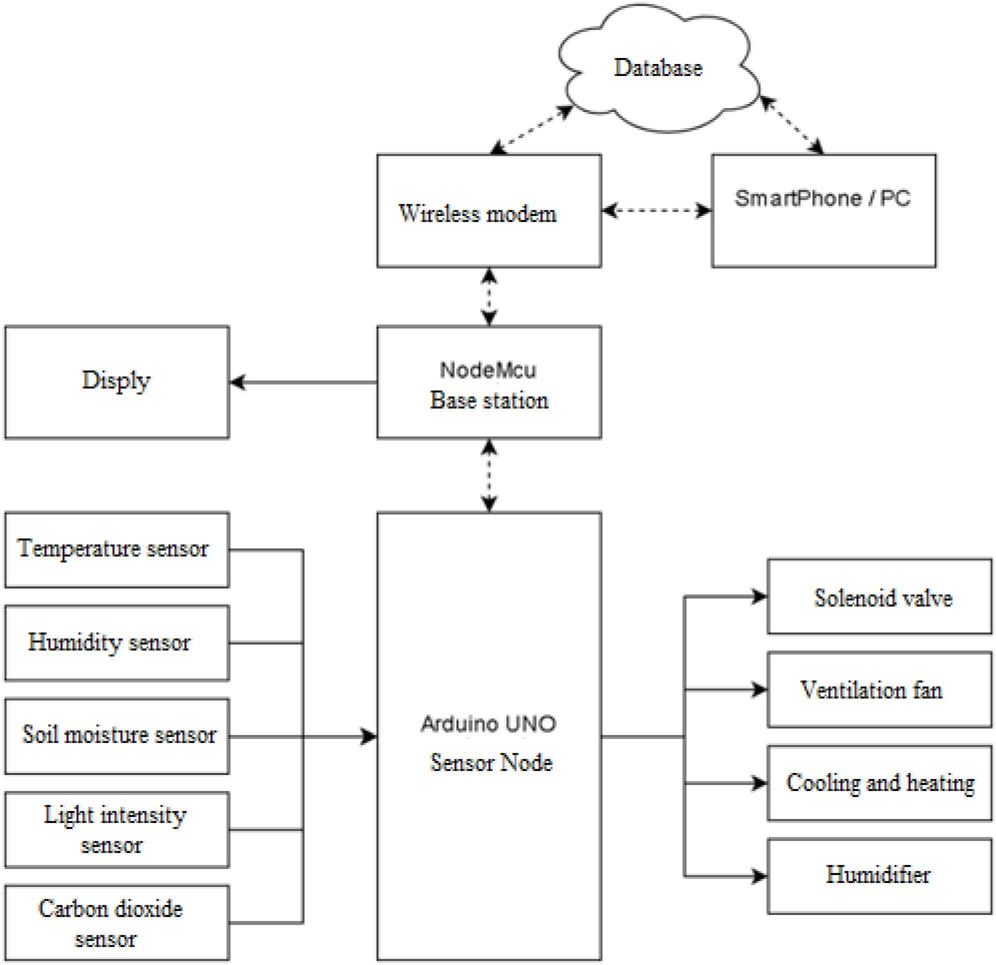


Figure 2: Proposed system components

1. Sensor node hardware

Arduino Uno is one of the most well-known and popular microcontroller boards developed by Arduino. The Arduino Uno allows most communication methods with different modules and carries a reasonable number of pins. Its board also provides enough processing speed and memory to perform many simple calculations. In the figure below, you can see the Arduino Uno board. As shown in the figure, the Arduino Uno board communicates wirelessly between the sensors and the base station. The sensors and a wireless transmission module are connected to the Arduino. A wireless transmission module is also connected to the base station. Putting results together, the sensors and the base station communicate wirelessly and exchange data.

Figure 3: Arduino UNO board

The NodeMCU module is a development board specifically used in the Internet of Things. This module has an open-source, programmable FIRMWARE running on the ESP8266 WiFi chip used to control objects.

Figure 4: NodeMcu module in combination with CH340G chip

The DHT11 temperature and humidity sensor are low-cost for measuring air temperature and humidity. The small size of this sensor, low power consumption, and signal transmission over a distance of more than 20 meters has made it one of the best options for use in various projects.

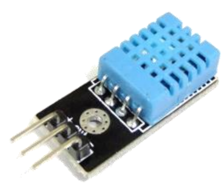


Figure 5: DHT11 temperature and humidity sensor module

Measuring soil moisture is critical in agricultural applications. We need a soil moisture sensor to supply water in a timely and correct manner leading to the production of quality products.

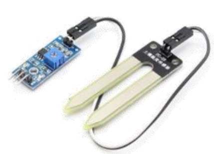


Figure 6: YL-69 soil moisture sensor module

The TSL2561 light sensor is a sophisticated sensor capable of detecting a wide range of visible light.

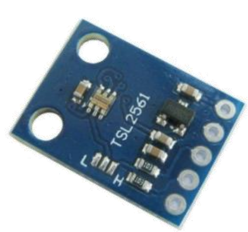


Figure 7: TSL2561 light sensor module

The MQ-135 sensor is an air quality sensor that detects smoke, alcohol, gasoline, and carbon dioxide in the air. The heater of this sensor uses voltage V5.

Figure 8: MQ135 air quality sensor module

The NRF24L01 + module utilizes 2.4 GHz radio waves to communicate with various devices up to a maximum distance of 100 meters.

Figure 9: NRF24L01 + wireless transmitter and receiver module

This project uses the NRF24L01 + module to communicate wirelessly between nodes and the base station. The NRF24L01 + modules are connected separately to the base station (NodeMcu) and the Arduino board. The two modules then exchange data.

Figure 10: Dual channel relay module

This project uses a two-channel relay to control the water pump, humidifier, air conditioner, and ventilation.

One of the important features of LCD monitors is the number of characters that can be displayed. For example, the 2 × 16 model means the LCD screen has four columns and four rows.

Figure 11: Character LCD with dimensions of 16 × 2

This display is used to display base station information.
In this project, the following parts have been used to set up the base station:

- NodeMcu control board - CH340G
- Character LCD with dimensions of 16 × 2
- Transmitter and receiver module + NRF24L01
- Micro USB cable
- Adapter 5V 1A
- Jump wire

The above parts are connected as follows.

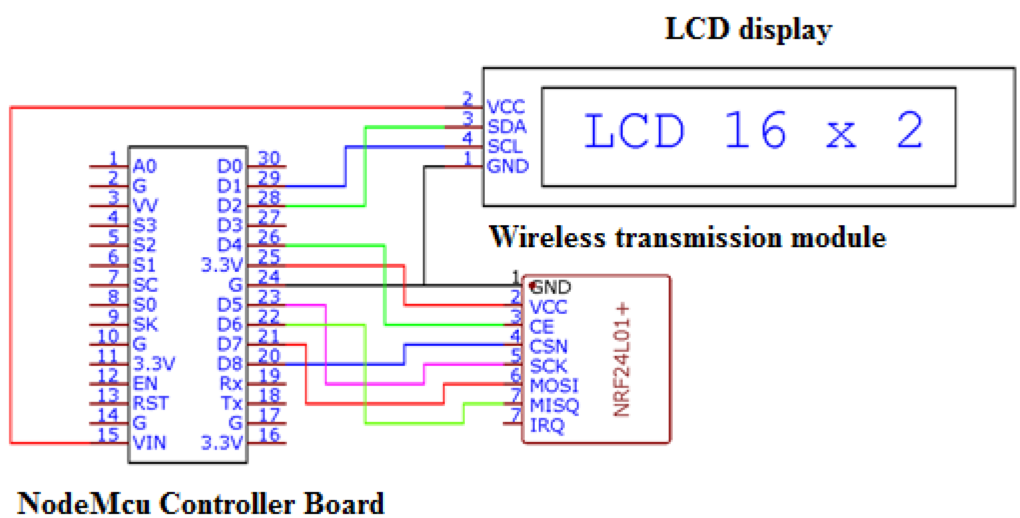


Figure 12: Base station (master) circuit schematic

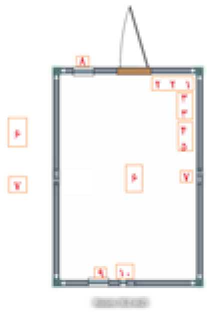
After communicating between the NodeMcu board, the NRF24L01 + transfer module, and the LCD, a Google Sheet must be created over the Internet to store the data received from the sensors. After creating the desired file, we load the script code using the Google Script Editor tool. These codes load the data sent from the base station into the file. This system also can display stored data in the form of plots.

Smart greenhouse scenarios

One of the definable scenarios for environmental parameters is as follows: "The temperature or humidity of the greenhouse environment is high or low." By installing temperature and humidity sensors in different parts of the greenhouse, it is possible to control the heating, cooling, and air conditioning equipment in proportion to the ambient temperature and humidity. Also, in critical situations, the necessary warnings are sent to the farmer to reduce the quality loss or even the loss of crops. Another scenario is reduced soil moisture and thirsty plants. Soil moisture sensors located in different parts of the greenhouse monitor the irrigation conditions of plants. If the farmer does not have access to the greenhouse, using the remote control scenario, the conditions for controlling the greenhouse equipment and remote monitoring are provided for the farmer. Also, using wireless modules, sensor information can be stored on the Internet, and changes in environmental parameters can be observed on plots.

Localization of sensors in the greenhouse

The location of the sensors in the greenhouse is determined based on the scenarios defined in the previous section. Figure (3-15) shows the proposed greenhouse map as well as the location of the sensors with a focus on facilitating agriculture and implementing various scenarios.



1. Arduino
2. Relay
3. Solenoid valve
4. Light sensor
5. Carbon dioxide sensor
6. Temperature and humidity sensor
7. Soil moisture sensor
8. Ventilation fan (input)
9. Ventilation fan (output)
10. Cooling and heating equipment

Figure 13: Proposed map of the greenhouse and location of the sensors

The length, width, and height of the proposed greenhouse are 3, 2, and 2.5 meters, respectively. The sensors are located in specific sections according to their application. The temperature and humidity sensor is placed at the height of 2 meters in the center of the greenhouse to sense the temperature and humidity of the greenhouse. The soil moisture sensor is located at the farthest point from the central irrigation system to record the lowest amount of soil moisture. The following figure shows the implementation circuit of these sensors.

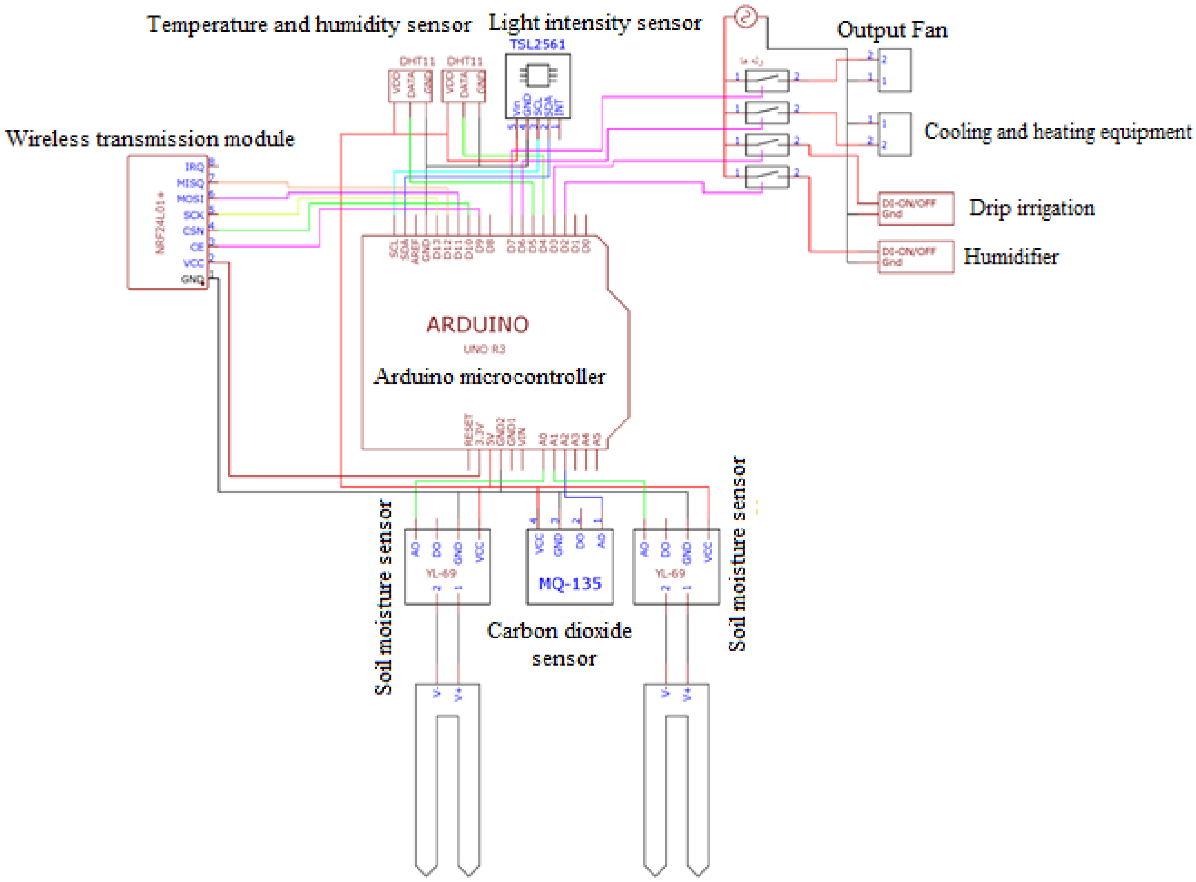


Figure 14: Sensor node (slave) circuit schematic

Software implementation

Designing and implementing an HTML application interface for displaying data stored in Google Sheets is desirable. This user interface interacts directly with the base station. The interface is designed using HTML and displays sensor update information on web pages. The information plots stored in Google Sheets are also displayed as 24-hour charts.

1. Real-time display of sensor information. This part displays the information of temperature and humidity sensors, soil moisture, carbon dioxide, and light intensity in an instant and is updated automatically.
2. Defining the threshold of the parameters. This part defines the desired limitations, such as maximum temperature, air humidity, and soil moisture. Clicking the "Submit" button sends the information to the sensor station through the base station.
3. Greenhouse 24-hour plots. The sensor information is sent to the Google Sheets platform every 1 hour. Using the plot tool, we show the sensor information diagrammatically.
4. Outside the greenhouse, 24-hour plots.
5. The URL of the web page that is defined locally.

In this study, a string variable in the Arduino programming language is used to display the user interface, which contains the HTML file of the user interface. The GET method gets the settings, sending the desired parameters to the base station via URL.

The NodeMcu wireless controller board is used to create the server. This board is connected to the wireless modem using the ESP8266WiFi.h library and the definition of SSID and password, then displays the information received from the sensors through the ESP8266WebServer.h library using the class “send” (TEXT/HTML). It also receives the HTML file class as a parameter and sends it to the server.

Subsequently, to store information in the Google Sheets platform, we use the HTTPSRedirect.h library and the class “connect” (host, HTTPS Port) to connect to the above system and use the unique spreadsheet code created to access the data storage location and send the desired parameters via URL. Finally, the information is checked and stored using a script written for the file.

The Chart tool displays the sensor information plot on the Google Sheets platform, and the above plot is inserted into the HTML file with the <iframe> tag using the Publish Chart option.

Results

The table below shows a significant increase in the fruit mean length in EDU of the proposed method compared to the traditional method. The values obtained in Sweet million do not differ significantly. In other types, the fruit length in the traditional method is not significantly different from the proposed method, and no special trend is observed.

Table 1: Fruit mean length (mm) in five types of greenhouse tomatoes

Method	Guiza	EDU	M09	Golden cherry	Sweet million
Traditional	56	54	60	30	22
Smart	67	75	67	34	23

According to the values in the table below, the fruit mean diameter of all types (except EDU) has not increased significantly. The diameter of the fruit is not affected by different methods.

Table 2: Fruit mean diameter (mm) in five types of greenhouse tomatoes

Method	Guiza	EDU	M09	Golden cherry	Sweet million
Traditional	52	50	51	20	24
Smart	52	54	51	20	24

According to the table below, the mean weight of fruit in EDU produced based on the proposed method compared to the traditional method shows a significant increase. In Guiza, the amount obtained from the proposed method compared to the traditional greenhouse method shows a significant increase. In other types, there is no significant difference between the methods.

Table 3: Fruit mean weight (g) in five types of greenhouse tomatoes

Method	Guiza	EDU	M09	Golden cherry	Sweet million
Traditional	119	97	141	8	7
Smart	156	148	148	10	9

According to the results in the table below, the mean plant yield (total harvest from the first five clusters) in Sweet million and Guiza is not significantly different. In Golden cherry, the performance of the proposed method has improved 1.7 times. Also, the results of the proposed method in M09 and EDU show a significant increase of 1.8 and 1.3 times compared to the traditional method.

Table 4: Mean plant yield (kg) in five types of greenhouse tomatoes

Method	Guiza	EDU	M09	Golden cherry	Sweet million
Traditional	13.23	11.24	7.49	4.93	3.38
Smart	13.39	14.69	13.98	8.55	3.72

Conclusion

Understanding environmental factors and using smart tools can effectively create an ideal environment for growing plants and agriculture. Given the growing population of the world, it is vital to provide solutions to address food shortages. The proposed solutions should help farmers minimize the manpower and resources needed and increase the quality of products. One of the ways to increase the quality and quantity of products is the optimal use of water and fertilizer resources. This study assessed the needs and problems of farmers and used special hardware and software to implement smart greenhouses and meet the relevant needs.

The results showed that the proposed system could grow five types of tomatoes. Regarding qualitative parameters, the fruit length of EDU in the proposed method has increased 1.38 times compared to the traditional method. No significant difference was observed in the fruit diameter parameter in the cultivated varieties. The fruit weight of EDU in the proposed method has increased 1.52 times compared to the traditional method. Also, the weight of Guiza in the proposed method has increased 1.31 times compared to the traditional method. The mean total plant yield in M09, EDU, and Golden cherry types increased 1.8, 1.3, and 1.7 times, respectively. We recommend using a servo motor and moving canopy on sunny days for better temperature control. Using a gas solenoid valve to control the temperature in winter is also desirable instead of heating equipment. On the other hand, pH sensors can measure the salinity of the soil as well as the number of elements needed. Finally, the farmer is informed about the current condition of the greenhouse by sending short messages and emails.

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