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Research Article

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Evaluation of Smart Greenhouse Monitoring System using Raspberry-Pi Microprocessor for Tomato Production

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Abstract

To provide fresh and highly nutritive food, automated greenhouses and smart farming systems had proved to be helpful for growing world population. The smart greenhouse monitoring system not only helpful in exploiting the production but also helpful to bridge up the quality of the tomato produce. The current study was designed to explore the potential use of a smart greenhouse monitoring system using Raspberry-Pi microprocessor. Two tomato varieties (Roma and cherry tomato) were grown in smart and greenhouse system to compare the agronomic and quality parameters. Temperature and humidity were set according to the production technology of tomato using automation system. The smart greenhouse monitoring system worked better in maintaining the microclimate inside the greenhouse with a difference of about 5-6 ℃ temperature and 20-30% humidity higher than the conventional greenhouse. The results predicted a progressive increase in agronomic parameter with a difference of 10-15% in plant height, number of leaves, number of fruits and weight of fruit as compared with growth parameters in conventional greenhouse. Similarly the quality parameters were effective with maximum size of fruit in Roma variety that was 75 mm as compared to fruit size 65 mm (Roma) in conventional farming. The over average yield of tomato per plant (5.5 kg/plant) in Roma variety was also recorded in smart greenhouse that was significantly increased as compared with conventional greenhouse. The results predicted that the yield of tomato was positively affected using smart greenhouse monitoring system and consequently, the smart technologies could be used for the potential crop production and monitoring of cultivation activities.

Keywords: *Automation, Microcontroller, Raspberry-Pi, Smart greenhouse*

Introduction

In the era of rising smart technologies, smart greenhouse monitoring systems play a key role in reducing the human involvement and efforts in agriculture. To meet the requirements of fresh, quality and increasing demands of food for daily consumption these smart greenhouse technologies have accelerated the conventional farming and support to produce quality food in economical means (Singh *et al.*, 2016). According to Folnovic (2011) due to population growth, urbanization, industrialization, climatic changes and environmental pollution, the agriculture lands around the globe are continuously decreasing that may poses challenges for food security in nearby future. This rapid change and decreasing agriculture lands are demanding new smart approaches to ensure food security. Microclimates or greenhouse agriculture may considered an alternative to combat the food challenges by maintaining local environmental conditions for cropping all around the year (Rayhana *et al.*, 2020). However, conventional greenhouse has many limitations for effectual process and its supervision. Therefore smart technologies like Internet of Things (IoT), using sensors, artificial intelligence devices, smart surveillance and monitoring systems play a role to combat the key challenges in conventional greenhouse farming like controlling the local climate of greenhouse, monitoring the crop growth parameters and fixing the crop harvest time (Rayhana *et al.*, 2020).

Smart greenhouse automation systems should maintain microclimate using setpoints and protect plants from rapid changes in micro-climate to automate the parameters like temperature, humidity, photoperiod using sensors based technologies. An example is the Internet of Thing (IoT) to maintain temperature and humidity using the automated mist cooling protocol (Chaudhary *et al.*, 2019; Hafiz *et al.*, 2020). These modern information technology based developments help to overcome difficulties maintaining microclimatic conditions and reduce the labor used in conventional greenhouses (Sidik *et al.*, 2015). A precision agriculture monitoring system (PAMS) was developed by using wireless sensor network (WSN) to monitor microclimate parameters like humidity, temperature, photoperiod, and electrical conductivity (EC) and Raspberry-Pi microcontroller as server but not tested the sensor system on a large area (Flores *et al.*, 2016). These sensor technologies have been accepted by the farmers for better production and quality of crop but still challenges needs to address the proper implementation of WSN system for smart agriculture (Ojha *et al.*, 2015).

So the current study was designed to compare the agronomic as well as quality parameters in conventional and smart greenhouse monitoring system to celebrate the limitations in precision agriculture for enabling the real-time monitoring and controlling of microclimate in smart greenhouse.

Materials and Methods

Smart greenhouse microprocessor: The current research was done from February to April 2022 in a built in small smart greenhouse designed with the installation of Raspberry-Pi microprocessor to control temperature and humidity using sensors to evaluate the impact on agronomic and quality traits of tomato. The data set in the microprocessor for tomato growth was 24-28 ℃ with humidity above 75% for first 30-35 days to check the impact on vegetative growth then the temperature was lowered to 20 ℃ with humidity below 60% for 15-20 days to initiate the reproductive phase and again the temperature and humidity was raised to 24-28 ℃ for the change of color of tomato fruit. The data was accessed on a digital receiver after every 10 days interval. Two different varieties Roma and cherry tomato was used to check the impact of the study. The seedlings were transplanted in plastic pots containing sterilized sandy loamy soil and proper fertilization and irrigation requirements were maintained. A set of 10 replications of each variety was done to take the average.

Conventional greenhouse trail: Well drained sterilized sandy loamy soil was used for the transplantation of tomato seedlings with fertilization and irrigation requirements were properly maintained by placing the pots in a conventional greenhouse. Ten seedlings of each variety were used in individual pot. After every 10 ten days interval the data of agronomic parameters and then quality parameters were taken to compare the impact on growth traits and quality of tomato produce with smart greenhouse monitoring system.

Sensors used: In smart greenhouse selective sensors continuously recorded data that were set with an application to transmit the signals to display on a digital receiver (Figure 1) these sensors were;

1. Humidity sensor to monitor the level of humidity inside the greenhouse (Figure 2a);
2. Temperature sensors monitoring inside temperature to maintain microclimate (Figure 2b);
3. Timer to automatically change the settings of the temperature and humidity sensor to maintain the microclimate conditions; and the setpoints for recording the data of microclimate and the control of equipment was 15 min interval.

Results

The data collected with smart automation system in greenhouse microclimate was carried out every 10 minute and was displayed on digital receiver and recorded. After 25-30 days the agronomic parameters were studied both in conventional and smart green house and was found promising results in smart greenhouse system. There was found 10-15% effective results in smart greenhouse system rather than conventional greenhouse system. The average plant height recorded in smart greenhouse was 110 cm and 115cm in Cheery and Roma variety respectively (Figure 3) while 95 cm and 105 cm in conventional greenhouse (Figure 4). Similarly, after 30 days no of leaves were counted and found 50 and 60 leaves of Cherry and Roma respectively that was more in number than plants in conventional green house. Furthermore the number of flowers were also recorded and found on an average 120 and 130 flowers per plant on Cherry and Roma respectively (Figure 3) in smart greenhouse that were more in number than conventional green house (100 and 105 on Cherry and Roma respectively) (Figure 4). Also the number of fruits and the weight of fruit was also recorded and found progressive results in smart greenhouse system than conventional greenhouse system.

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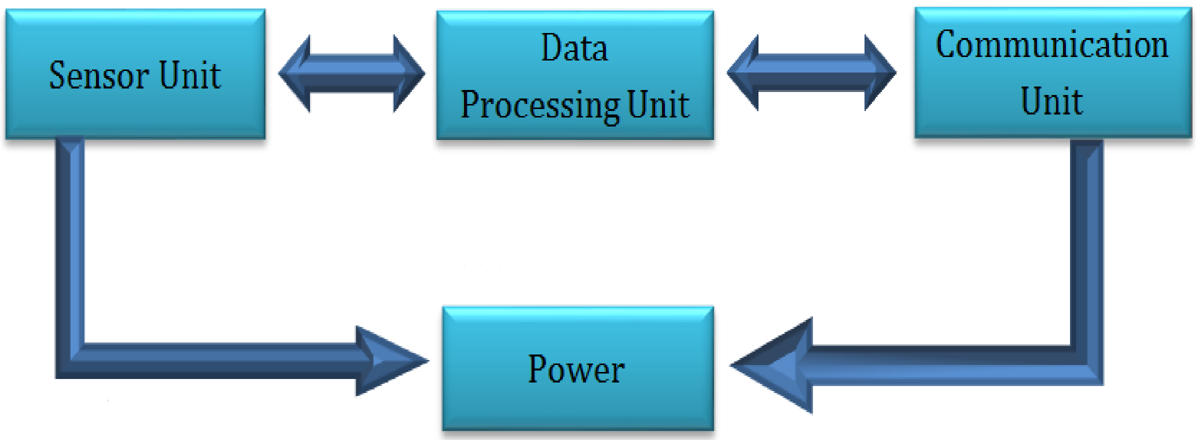

Figure 1. A block diagram of a sensor node used.

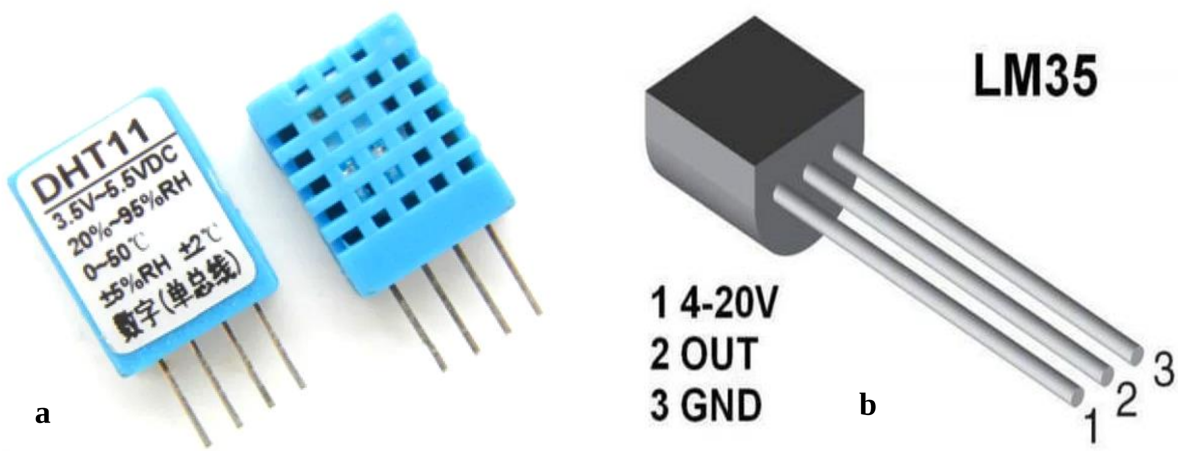

Figure 2 a. DHT11 Humidity sensor; b. LM35 Temperature sensor used in the study.

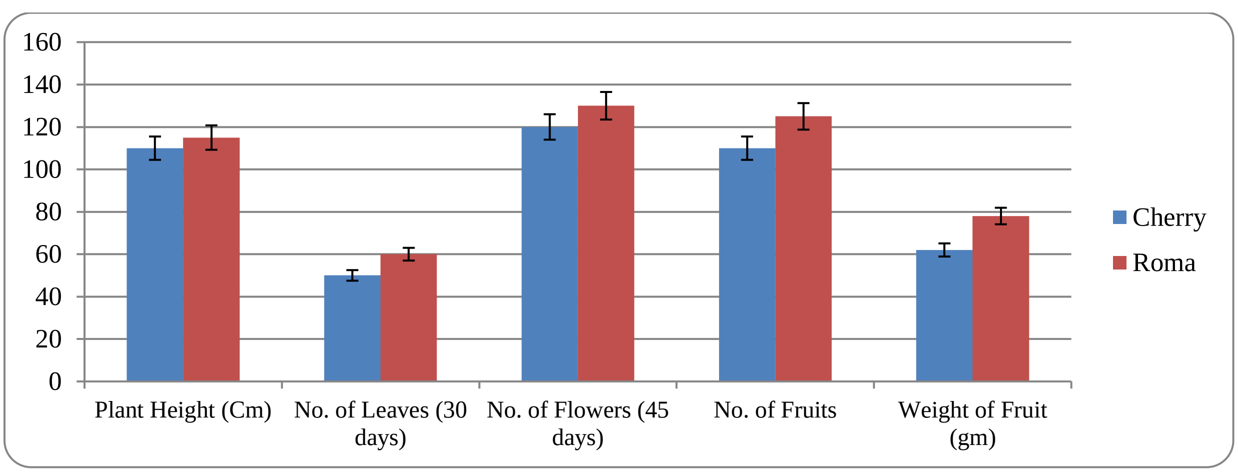

Figure 3. Average of different agronomic parameters on tomato plant studied in smart greenhouse monitoring system.

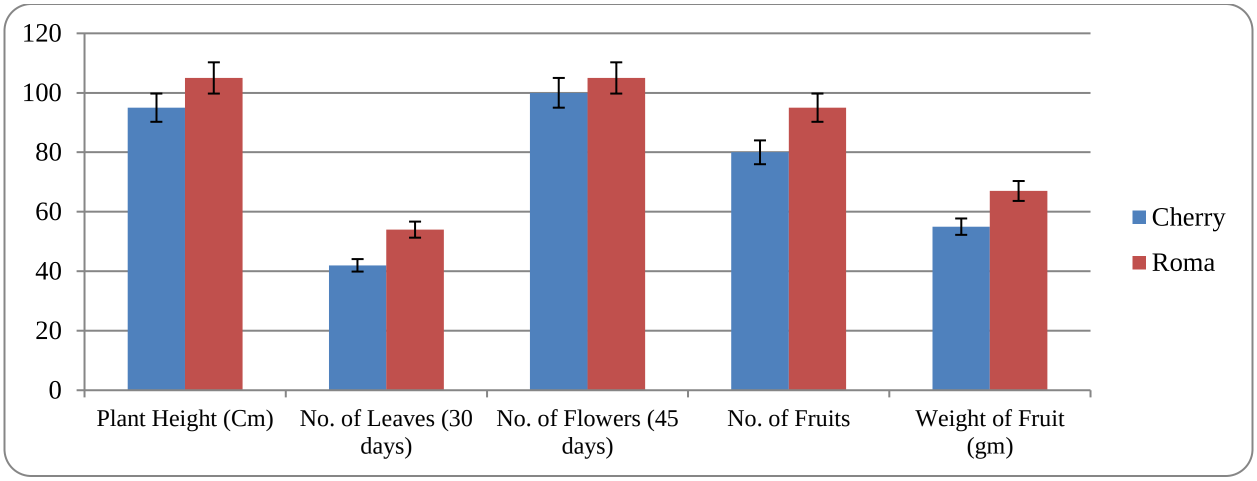

Figure 4. Average of different agronomic parameters on tomato plant studied in Conventional greenhouse.

Similarly the quality parameters were studied and it was found that the shape of fruit was uniform and symmetrical and the color of the fruit was orange to red in smart greenhouse system while pale yellow to red color was observed with irregular fruit shape in conventional farming (Table 1). The color setting and size of fruit on average fruits were found uniform on at once in the smart greenhouse monitoring system. Also, the size of fruit was measured and found maximum 75mm on Roma variety in smart green house while 65 mm was measured in conventional greenhouse (Table 1).

Also the yield of tomato fruit was recorded for both the varieties and found that the average maximum yield of tomato per plant was recorded from Roma variety (5.5 kg/plant) grown in smart greenhouse (Figure 5) while on average 4kg/plant yield was recorded on the same variety in conventional greenhouse (Figure 6). The yield of cherry tomato was also found more in smart greenhouse than the yield of same variety in conventional green house.

Table 1. Comparison of quality parameters of tomato in smart and conventional greenhouse.

Parameters	Smart greenhouse		Conventional greenhouse	
	Cherry	Roma	Cherry	Roma
Fruit Color	orange to red	Red	Pale yellow to red	Light Red to red
Size of Fruit (mm)	35	75	30	65
Shape of Fruit (mm)	oblong (grape shaped)	egg or pear shaped	oblong (irregular)	Pear shaped (not uniform)

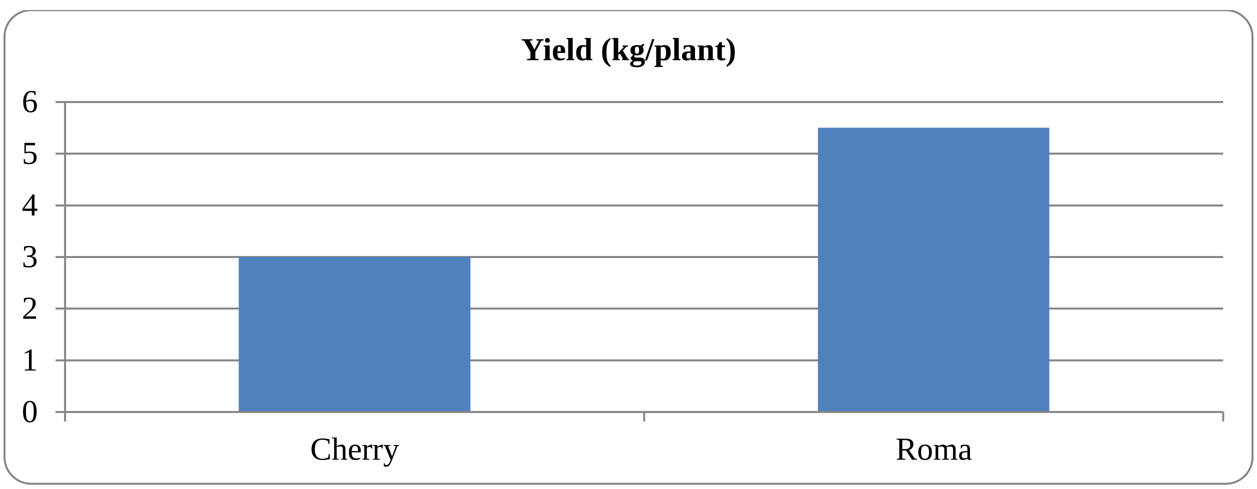

Figure 5. Average yield of tomato plant recorded in smart greenhouse.

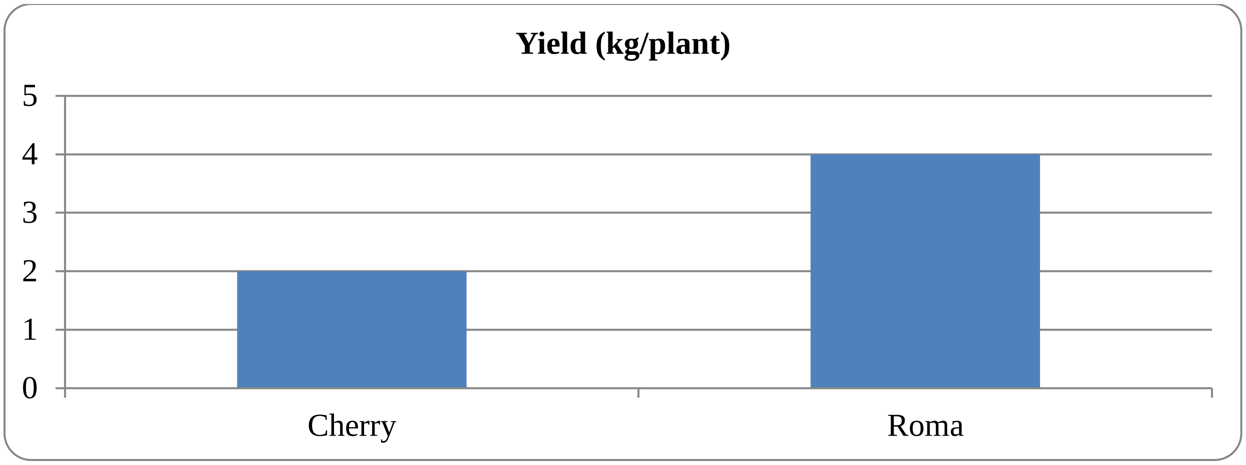

Figure 6. Average yield of tomato plant recorded in conventional greenhouse.

Surveillance of disease and insect data was also recorded regularly on an interval of 10 days and it was found a few discoloration signs on the leaves of tomato plants grown in smart greenhouse but not a clear symptom of disease and insect/pest was found in smart greenhouse. While in conventional greenhouse on the basis of symptomology the prevalence of late blight of tomato and bacterial spot of tomato was found on both the verities, similarly the pest (aphid, leaf miners and moths) were found on both the varieties (Table 2).

The comparison of temperature was done on the basis of data recorded in the smart greenhouse system and conventional greenhouse. The impact of temperature found proportional with the yield and quality parameters in the smart green house as the temperature was set and found uniform throughout the growing period of tomato crop then a bit lowered on flowering stage and again optimum at fruit ripening stage while in conventional greenhouse the temperature was raised and not found uniform throughout the growing period of tomato crop (Figure 7).

Table 2: Comparison of disease parameters of tomato in smart and conventional greenhouse.

Parameters	Smart greenhouse		Conventional greenhouse	
	Cherry	Roma	Cherry	Roma
Diseases	No	No	Late blight Bacterial spot	Late blight Bacterial spot
Insects	No	No	Aphid Leafminers Moths	Aphid Leafminers Moths

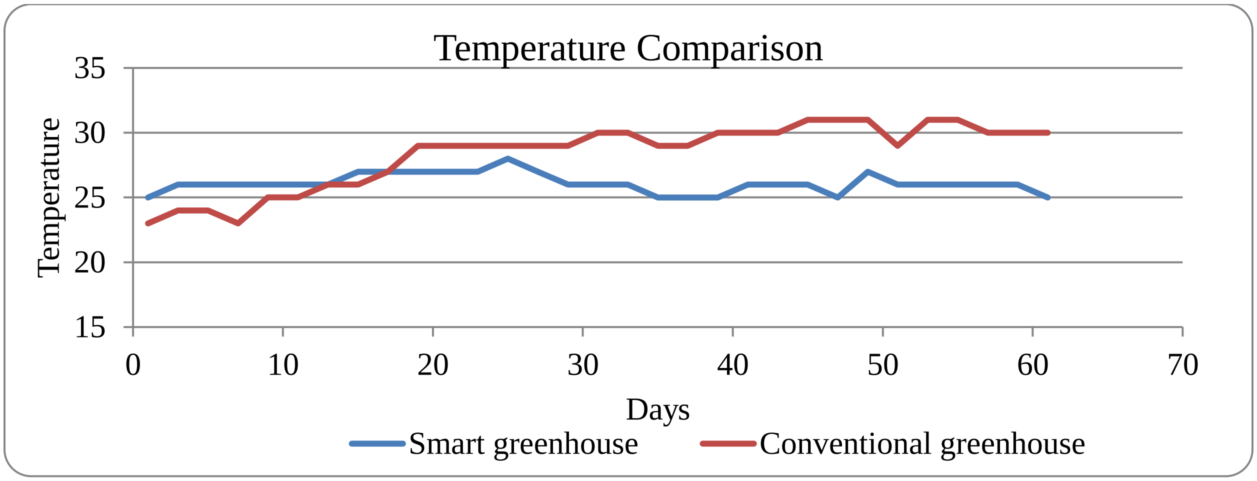

Figure 7. Comparison between smart greenhouse and conventional greenhouse temperature during crop growth.

Discussion

In greenhouse production of tomato, different traits were focused including the color of tomato considered the most important as a market factor for the demand of customers. But the color of tomato varies in the field and in conventional greenhouses due the temperature effects during harvesting and storage (Wasson *et al.*, 2017), it is a big challenge to achieve an even and attractive fruit color of tomato after harvesting and shipping (Wasson *et al.*, 2017). Therefore, the temperature control during fruit setting and maturity is an important factor for tomato production and to minimize the risk of pests and diseases of tomato especially early and late light of tomato in smart greenhouse technologies (Bannister *et al.*, 2008; Bashir *et al.*, 2020; Hyder *et al.*, 2018; Kirci *et al.*, 2022).

The study reported by Vermeulen *et al.* (2007) that the sensors directly collect data from the sampled plants in the greenhouses including monitoring of the whole crop in the greenhouse as microclimatic conditions and also individually single plant weight using weighing gutters and crop load cells. The data collected were potentially used by the algorithmic formulas for the calculation of correlations under different parameters in the microclimate. In advance sensors fixed in the xylem and phloem was allowed to monitor the fluid transport for determining the internal temperature and irrigation strategies under heat and drought stress conditions (Hemming *et al.*, 2020).

The principal goal of the smart greenhouse system was to uplift the economic impact viz. net profit using sensors and artificial intelligence by controlling the microclimate of greenhouse. To operate the individual climate with specific operation using artificial intelligence techniques different teams of artificial intelligence and horticulture background people were defined to develop intelligence algorithms using specific sensors to set the microclimate for crop growth parameters and found it was possible to implement the smart technologies in greenhouses for better economic impacts on the farming communities (Hemming *et al.*, 2020).

A similar study was reported by Saha *et al.* (2017) that Atmega328 microcontroller was used with Arduino, sensors and actuators to check the efficiency and reliability of the a smart greenhouse system and found higher efficiency and reliability than conventional greenhouses. Similar results were also in our current study that human errors that can be in conventional greenhouses were less in automated smart greenhouses monitoring system. Similar study was conducted by Singh *et al.* (2016) that a remote-controlled greenhouse was developed and was controlled using microcontrollers with specific parameters showed efficient results.

Similar studies were also reported by Azaza *et al.* (2016), that a microcontroller model similar to be used in the current study was developed and used on a larger scale and observed 33% less water used in the same cropping pattern in a conventional greenhouse. The results of current study was similar with the results reported by results Sari *et al.* (2018) used an Arduino uno microcontroller along with sensors, fans, LED bulbs and water pump. During the study it was found that the temperature sensor (DHT11) module had on an average 2.64% error value that was close to the error margin specified in the specifications of the sensor.

Smart machine learning or artificial intelligence is an approach to collect and process the sensing data to make predictions and correlation between the variables to provide smart solutions in automated greenhouse monitoring systems. The smart technologies were already used to develop automation controlled irrigation systems, also used to identify and predict models of plant diseases management (Channe *et al.*, 2015; Dubey *et al.*, 2013; Liu *et al.*, 2017).

In present study, a smart greenhouse monitoring system that was controlled with an Android application was used to automate the variables (temperature and humidity) with specific time periods in a smart greenhouse to check the physiological and quality parameters of two varieties of tomato and found significantly effective results.

Conclusions

The current study results should be considered a prototype and is a way forward to develop commercial scale smart greenhouse systems. This should be a tool for food security by increasing quality agricultural production on commercial scale. Specific parameters should be adopted using sensors and artificial intelligence in smart greenhouses not only enhances the quality and production of agriculture commodities but also minimize the labor requirements that ultimately minimize the chance of pest and disease in the greenhouses.

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