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Development and integration of soil moisture and soil sensor based system for real time monitoring of soil moisture and soil nutrient

Madhukar Patel, Narendra Agrawal, Dhiraj Khalkho and MP Tripathi

Abstract

An important sector of India's economy is agriculture. Due to poor crop yields, a labour shortage, high labour costs, a lack of knowledge about modern farming practices, excessive use of chemical fertilizers and pesticides, and other physical factors, farmers are facing numerous challenges, and the percentage of agricultural practices has been rapidly declining over the past few years. Farmers must be aware of the quantity of soil nutrients existing in their soil in order to control the misuse of chemical fertilizers. Most farmers don't show any interest in carrying soil samples to testing facilities and waiting for the results, which is the usual method for determining the amount of soil nutrients. The creation of an integrated sensor for accurate monitoring of soil moisture and soil nutrient status without hauling soil samples was the main goal of this research. In this method, farmers can check their soil's nutrient value remotely and get the result in a few minutes. By which they can apply fertigation where it is needed and also maintain a strategic distance from over fertilization of the crops. This would make it possible for farmers to efficiently monitor and manage the applications of water and nutrients in the field. This prevents the overuse of chemical fertilizers and ecological misbalance. Crop yield will be improved without degrading the soil.

Keywords: Soil moisture sensor, soil nutrient sensor, automated fertigation system

Introduction

In India, the climatic conditions are isotropic, and farmers are unable to fully utilize their agrarian assets. The generation of credit depends on the interaction between soil and plant properties. Maximization of crop generation is reflected by the organic, physical, and chemical conditions of the soil (soil nutrients). Water, is limited natural resource, is fundamental to life, food security, livelihood, and sustainable development. 70% consumes the freshwater resources globally (Goodwin and O'Connell, 2008; Dowgert, 2010) [3, 2]. Farmers currently use surface irrigation to regularly physically irrigate their fields. Despite being widely used, the technique has low irrigation efficiency, which causes over- or under-irrigation and lower crop growth and yields. (Adamala *et al*., 2014) [1]. To improve water production and resource conservation, it is imperative to modernise agricultural practises. Sensor-based automation irrigation systems have the potential to improve water use efficiency by maintaining a constant soil moisture regime in the crop root zone, thus solving problems associated with manual irrigation (Perea *et al*., 2013) [7]. Sensor systems also help farmers know about their soil remotely. The amount of NPK is dependent on trim sort and plant development status. The amount of fertilizer to be utilized can be determined in a few minutes. Since macronutrients affect crop yield, the amount of NPK should be kept stable. The amount of these nutrients should neither exceed nor decrease, so that the farmers can attain profit without degrading the soil and environment.

Traditional methods take a lot of time for inspection, investigation, and analyzing the condition of the soil. In order to boost agricultural production profitability, improve crop quality, and protect the environment, precision farming entails the careful use of farming inputs. The decision-making process requires knowledge of the variability of several soil properties in a field. (Marvin E. Jensen and Richard G. Allen, 2016) [5]. Various soil sensors make it simple to map the chemical and physical characteristics of soil. It is essential for the efficient transfer of minerals and other nutrients through the crops, as well as for photosynthesis, respiration, and transpiration (Joachim *et al*., 2013). If the soil's moisture content is optimal for their growth, crops can quickly absorb soil water.

It is essential as a medium for the provision of nutrients to growing crops because soil water dissolves salts and creates the soil solution. Numerous soil sensors can quickly map the chemical and physical characteristics of soil. One of the most crucial factors affecting crop productivity is soil moisture. It is essential for effective photosynthesis, respiration, transpiration, and the movement of nutrients and minerals through the crops (Joachim *et al*., 2013) [4]. Crops may quickly absorb soil water if the soil's moisture level is ideal for their growth. The soil solution, which is formed when salts are dissolved in water in the soil, is essential as a delivery system for nutrients to growing crops.

Therefore, the irrigation system may be automated with the help of sensors that can continually monitor and measure the available soil nutrient content as well as the level of soil moisture in real-time. This will allow the field to be fertigated at the appropriate moment. A low-cost, modified soil moisture sensor-based automated system has been developed by the Department of Soil and Water Engineering at Swami Vivekanand College of Agricultural Engineering and Technology and the Research Station at Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh (Singh, 2020) [8]. The system has since been integrated with a soil nutrient sensor to make it more user-friendly for better handling in the field. Since then, the device has been upgraded with a soil nutrient sensor to improve use and field handling.

Materials and Methods

In the Soil and Water Engineering Department, along with the all India Coordinated Research Project on Irrigation Water Management, Raipur Center. Low-cost soil moisture and nutrient sensor-based automated drip irrigation systems were developed and integrated.

Agro–Climatic Condition

Raipur comes under the sub-humid, dry agro-climatic zone. It receives rainfall of around 1150 mm from the southwest monsoon each year, roughly 80–85% of which falls between the third week of June and mid-September, and the remaining amount between October and February. The warmest month of the year is often May, while the coldest is typically December. The pattern of rainfall has changed dramatically year over year during the last few decades, especially from June to September. The minimum and maximum temperatures are, respectively, between 18 and 23.1 °C and 30 and 39.8 °C.

Soil Analysis

The experimental field's soil investigation revealed that the field had a sandy-clay texture, with field capacity and bulk densities as 31% and 1.31 g/cc, respectively. Before planting during in the study, a composite of soil samples and aggregates from different locations of the field was taken from a depth of 30 cm and examined for some of the tests, such as texture and structure of the soil, field capacity, particle size distribution, bulk density, and pH. The details of the chemical and physical properties of the soil at the experimental site are shown in Table 1. An integrated soil moisture and soil nutrient sensor-based automated drip fertigation system was framed and developed in such a manner that it will provide irrigation water and nutrients to the crops in response to soil moisture and nutrient depletion.

Table 1: Physical & Chemical properties of soil

Particulars	Unit	Value
1. Sands	Percent	19.05
2. Silt	Percent	36.22
3. Clay	Percent	44.75
4. Textural Class	Clay loam (*Alfisols*)	
5. Field capacity	Percent	28.6
6. Permanent wilting point	Percent	10.74
7. Bulk density	(gm cm^{-3})	1.44
8. Basic infiltration rate	cm hr^{-1}	0.59
9. Hydraulic Conductivity	cm hr^{-1}	2.52

Particulars	Unit	Value
1. Organic carbon	Percent	0.29
2. pH (1:25) soil: water		6.20
3. Electrical Conductivity (EC)	ds m^{-1} at 25°C	0.05
4. Available N	(kg ha^{-1})	188.10
5. Available P	(kg ha^{-1})	10.00
6. Available K	(kg ha^{-1})	515.20

The design of the automation unit was an essential step to conserve the exploitation of the precious irrigation water and nutrients. The developed automated system was calibrated to provide three levels of moisture settings in the field. The system was designed to operate between 100% and 80% of ASM, 90% and 70% of ASM, and eventually, 80-60% of ASM. The varying soil The design of the automation unit was an essential step to conserve the exploitation of the precious irrigation water and nutrients. The developed automated system was calibrated to provide three levels of moisture settings in the field. The system was designed to operate between 100% and 80% of ASM, 90% and 70% of ASM, and eventually 80–60% of ASM. The varying soil moisture status levels represent the farmer's access to irrigation water. Farmers can operate in the 100–80% moisture range when there is enough irrigation water available, in the 90–70% moisture range when there is sufficient irrigation water available, and in the 80–60% moisture range when there is insufficient irrigation water available. To ensure the rejuvenation of soil moisture, the developed automated system was calibrated and tested along with a soil moisture sensor and soil nutrients at various levels of moisture content.

This was done by automatically turning on the drip irrigation system when the requirement is met and automatically turning it off when it is no longer needed. Moisture status levels represent the farmer's access to irrigation water. Farmers can operate in the 100–80% moisture range when there is enough irrigation water available, in the 90–70% moisture range when there is sufficient irrigation water available, and in the 80–60% moisture range when there is insufficient irrigation water available. To ensure the rejuvenation of soil moisture, the developed automated system was calibrated and tested along with a soil moisture sensor and soil nutrients at various levels of moisture content. This was done by automatically turning on the drip irrigation system when the requirement is met and automatically turning it off when it is no longer needed.

Components of integrated Sensor System

Soil moisture sensors measure the soil's VMC, or volumetric moisture content. The experiment's soil moisture sensors were calibrated and put to the test for automatic irrigation scheduling based on soil moisture content. The automated system is easy to operate and has a straightforward design. The soil moisture sensor, 3.5-inch LCD (liquid crystal display), sensor connection cables, microcontroller Atmega 328, relay module, contactor, and small circuit breaker are some of the parts that make up sensor-based automated irrigation systems (MCB).

Soil Moisture Sensor

Five different soil sensors were used in this project's trial. The sensors give a digital signal to the microcontroller depending on changes in the soil's moisture content and electrical resistance (Fig. 2). The sensor operates according to the electrical resistivity theory. When measuring the moisture content of the soil, resistive soil moisture sensors use a link between electrical resistance and water content. The main sensor and the control board are the two components of the soil moisture sensor. The sensor portion of the device consists of two conducting probes that measure the volumetric moisture content (VMC) of the soil, while the control board is made up of the voltage comparator LM393 IC. Other important parts, like LEDs, connections, resistors, and a potentiometer to change the sensor's sensitivity, are also included. The microcontroller board was connected to the soil moisture sensor's analogue output. This produces a number between 0 and 1023 by utilising the analogue value from the soil moisture sensor and calibrating it to the moisture content measured in percentage in the range of 0-100.

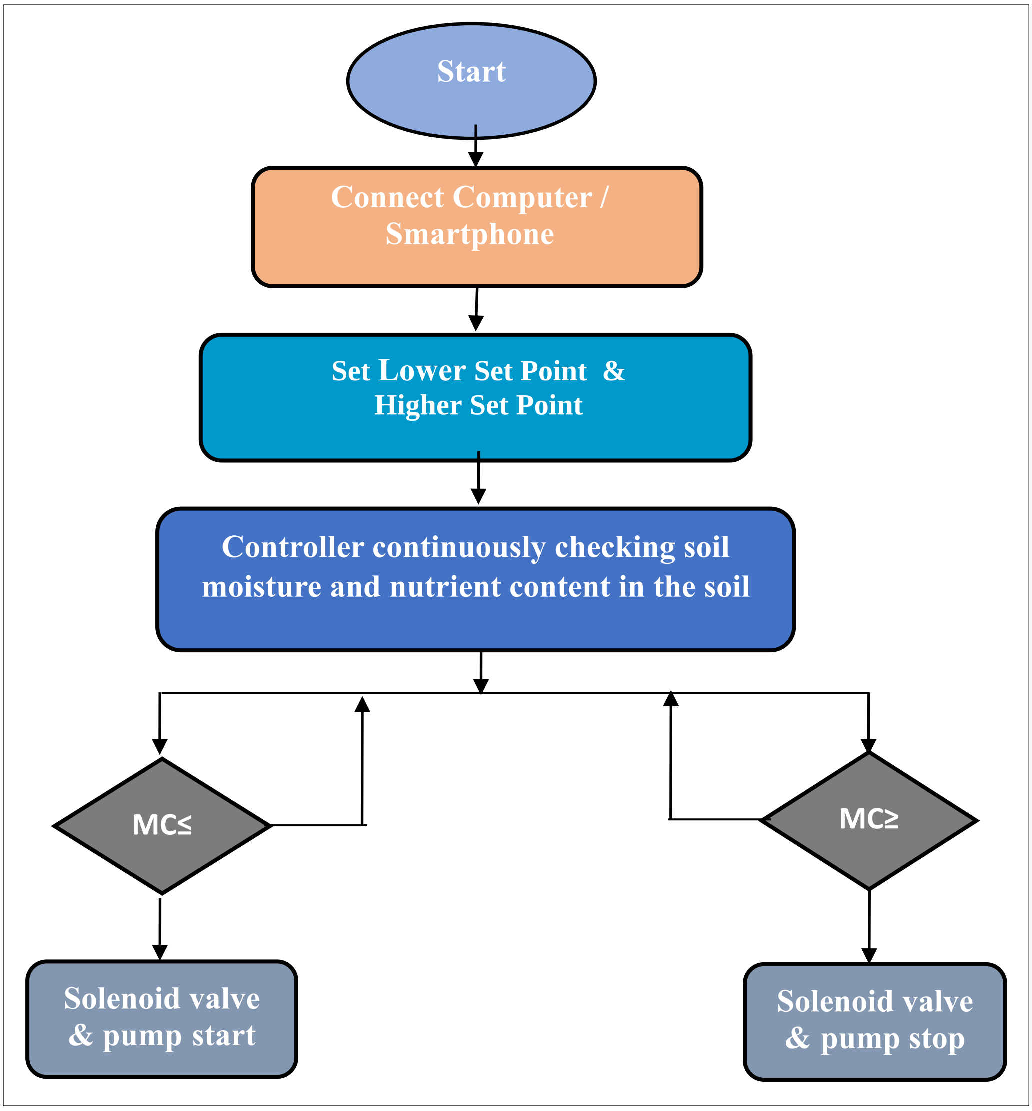

Fig 1: Flow-chart for the operation of integrated drip automation system

Soil NPK Sensor

Basically, the Soil Nitrogen, Phosphorus, and Potassium 3 in 1 Fertility Sensor is used for detecting the content of nitrogen, phosphorus, and potassium in the soil. This soil NPK sensor is considered to have the highest precision, accuracy up to ±2%, fast speed measurement, and increased stability. The resolution of this soil NPK sensor (Fig. 3) is up to 1 mg kg-1 or 1 mg l-1. This is an easy-to-carry sensor and can even be used by non-professionals, by inserting these stainless-steel rods into the soil and reading the soil nutrient content.

Arduino Micro–controller Board

The Soil Nitrogen, Phosphorous, and Potassium 3-in-1 Fertility Sensor is essentially used to measure the levels of nitrogen, phosphorus, and potassium in the soil. This soil NPK sensor is regarded as having the highest precision, accuracy, and stability, with an accuracy of up to ±2%. By inserting these stainless-steel rods into the soil and reading the soil nutrient level, the Soil NPK Sensor (Fig. 3) can be used by non-professionals and has a resolution of up to 1 mg kg-1 or 1 mg/l.

Based on practical or simple-to-use hardware and software, Arduino is an open-source electronics platform based on easy-to-use hardware and software. It's intended for anyone making interactive projects. Arduino senses the environment by receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators. The actual Arduino board is programmed with computer code using the IDE.

Miniature Circuit Breaker (MCB)

An electromagnetic device called an MCB (Fig. 5) supports an entirely molded insulating material. Its main job is to turn the circuit on and off. When there are overloads or short circuits, it is used to shut off the circuit. When the circuit's current exceeds a certain threshold, it automatically opens the circuit to which it was connected. Like other switches, it may be manually switched on or off as needed.

Relay Module

An electrically powered Relay module device contains High-voltage, high-current loads including AC loads, motors, lights, and solenoids were regulated by it. A single-channel (5 volt) microcontroller module was intended to be used with it. Three high-voltage terminals NC, C, and NO connect the system component that has to be controlled to the electric pump. Three low-voltage pins on the other side—Ground, voltage common collector (VCC), and Signal—were connected to the microcontroller board.

LCD Unit

The sensors' detected moisture level was shown on a 3.5-inch liquid crystal display device. The LCD shows the total amount of moisture and nutrients as well as the total amount of moisture captured by each sensor individually (Fig. 7). Additionally, the status of the pump's operation is shown.

Fig 2: Resistive type soil moisture sensor

Fig 3: Soil NPK Sensor

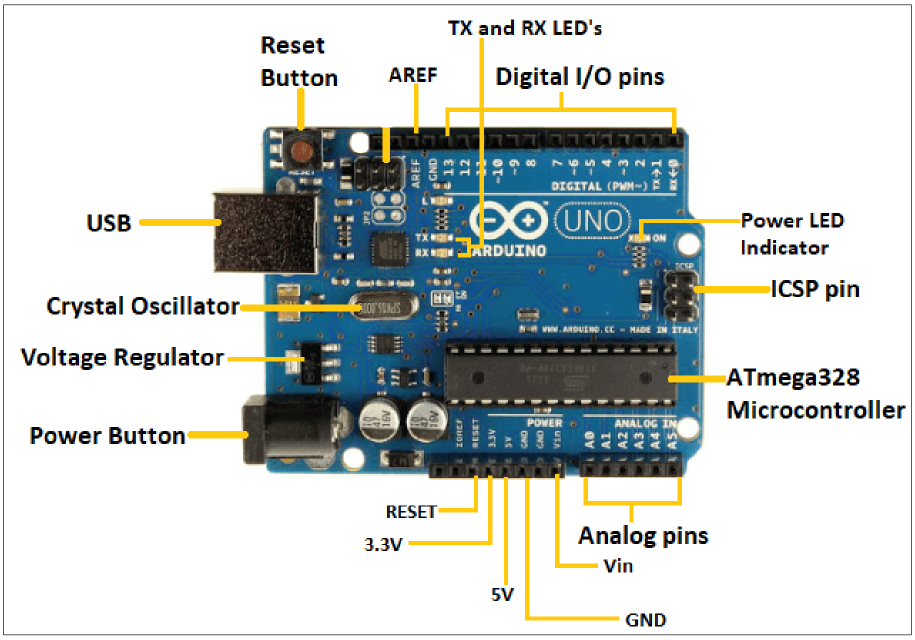

Fig 4: Arduino Micro–controller Board

Fig 5: Miniature Circuit Breaker

Fig 6: Relay Module

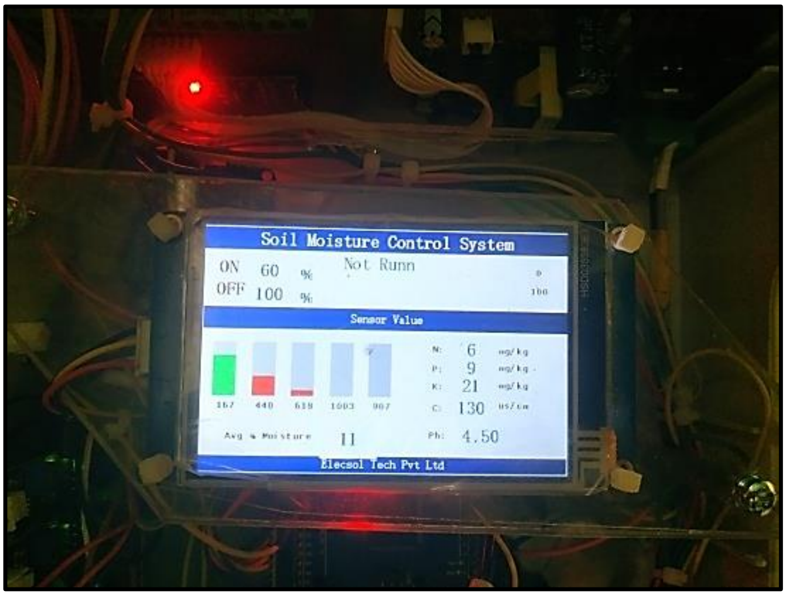

Fig 7: LCD Display

Results and Discussion

Depending on the depth at which the roots were growing, a soil moisture sensor made up of probes was put into the soil at various depths. The microprocessor unit reads analogue input data from the soil moisture sensor probe and translates it into digital output in the form of moisture content. The analogue output from the soil moisture sensor probe ranges from 0.06 volts to 5 volts. With the aid of several soil moisture measurements made using a soil moisture meter and the gravimetric method, the soil moisture sensor was calibrated. The microcontroller board is the brain of the entire system. To set or modify any logical programmed on the motherboard, this LCD serves as a Human Machine Interface (HMI). The microcontroller's ground analogue input pin was linked to the relay's ground terminal, and the board's 5V analogue input terminal was connected to the 5V VCC supply. The pump was attached to the high-voltage terminal. Between the relay module and the pump, an MCB and a contractor were connected to protect against short circuits and overloads.

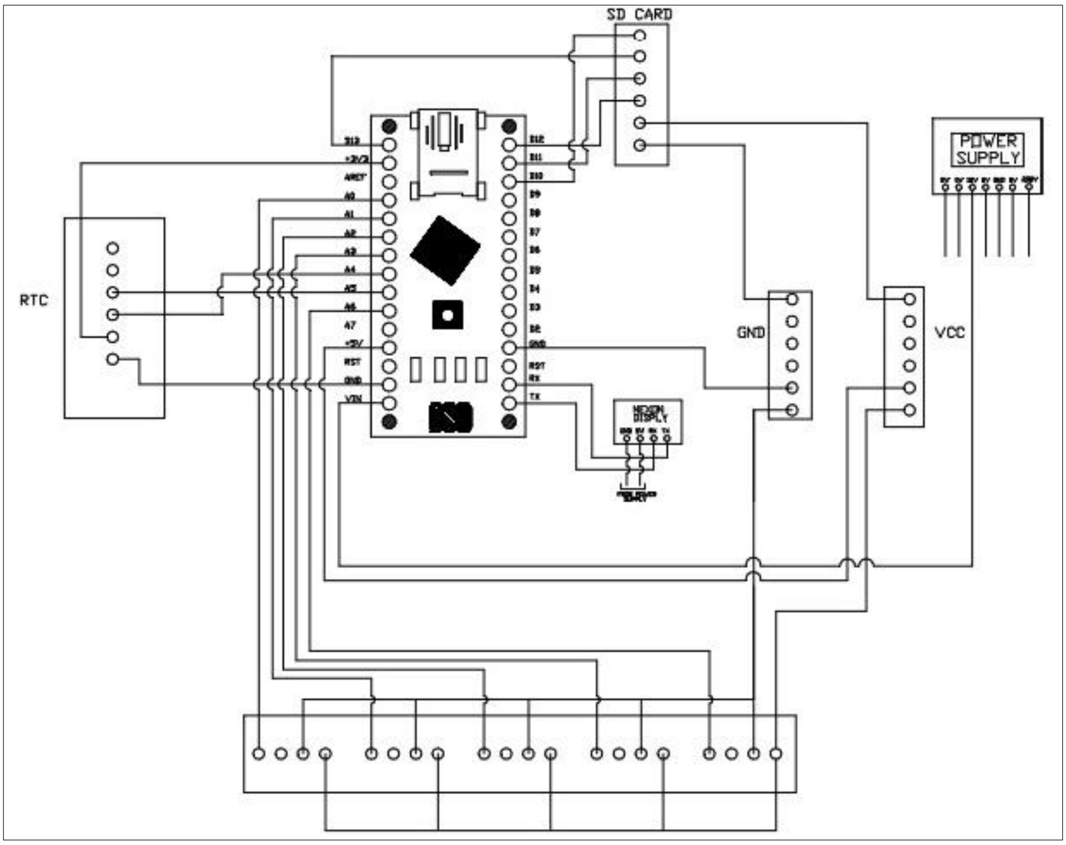

Fig 8: Circuit of system connection

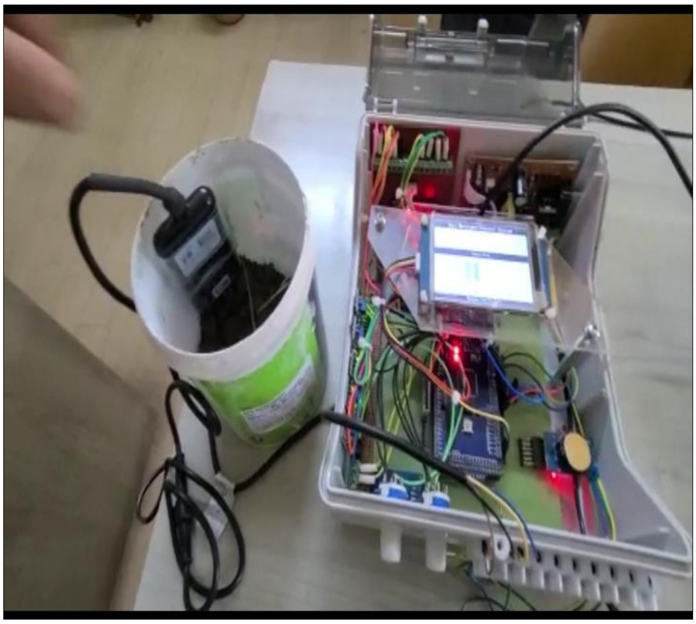

Fig 9: Integrated Soil Moisture and Soil NPK sensor system

Conclusions

It was decided to redesign the entire sensor system to make it light, compact, and user-friendly (Fig. 9) because the previously created system was too cumbersome and large. To take into consideration the farmer's varying access to irrigation water, the sensor system was further modified. The integrated soil moisture and nutrient sensor system was effective and was saving labourers' time as well as important water and nutrients. utilizing three different moisture range settings, such as 100-80%, 90-7%, and 80-60% of the soil's usable moisture content, the integrated soil moisture and nutrient sensor system was properly calibrated for the drip irrigation system. According to the study, the automated irrigation system supplied the crop with the irrigation water it required by turning the irrigation pump "ON" when soil moisture dropped below 90% of the field's capacity and switching it "OFF" when soil moisture exceeded 100% of the field's capacity. The calibrated and validated integrated soil moisture and soil nutrient sensor system was utilised to monitor soil moisture content in real-time.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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