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Design of an Automated Fertilizer Intimation Framework using IoT for Tomato Cultivation

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KEYWORDS

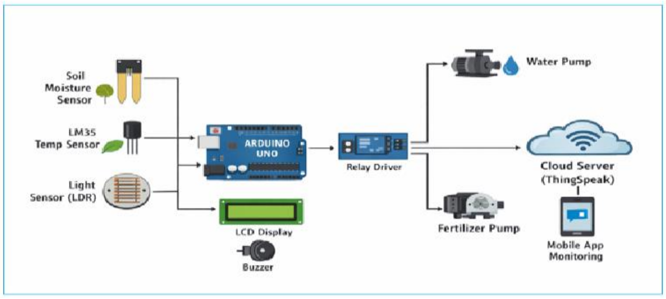
IoT, Tomato Cultivation, Automated Irrigation, Fertilizer Intimation, Smart Farming.

ABSTRACT

Climate change and widespread deforestation have adversely impacted agricultural productivity in India, highlighting the need for smart and resource-efficient farming solutions. Tomato cultivation demands regular irrigation and accurate fertilizer application; however, it is often adversely affected by manual farming practices, insufficient availability of timely labour, and the increasing cost of agricultural wages. To overcome these challenges, this work presents a cost-effective IoT driven fertilizer intimation and irrigation system designed specifically for tomato farming.

The proposed system enables automated watering and nutrient delivery through an app-based monitoring and control platform. Water is supplied to a mixing tank via a controlled valve, while peristaltic pumps accurately dose the required quantity of fertilizer. After proper mixing, the nutrient solution is delivered to the tomato growing medium using gravity flow, ensuring uniform distribution with minimal energy consumption. The system provides timely notifications and reduces the need for continuous human intervention. Overall, the developed solution improves irrigation efficiency, optimizes fertilizer usage, and supports sustainable and climate-resilient tomato cultivation through affordable smart agricultural technology.

GRAPHICAL ABSTRACT



1. INTRODUCTION

Agriculture remains one of the primary sources of livelihood in India and plays a vital role in ensuring food security for its rapidly growing population. With increasing population pressure and changing climatic conditions, improving agricultural productivity has become a critical necessity. Tomato cultivation, an important horticultural activity, requires precise management of irrigation and nutrient supply to maintain soil health and crop yield. However, traditional farming practices largely depend on manual monitoring, which often leads to inefficient water usage and improper fertilizer application.

Recent advancements in the Internet of Things have enabled the development of smart agricultural systems that enhance crop monitoring and resource optimization. IoT based farming integrates sensors to measure parameters such as soil moisture, temperature, and humidity, allowing farmers to monitor field conditions remotely[1&4]. These technologies significantly improve efficiency compared to conventional methods by enabling automated decision-making.

This project focuses on the development of a low cost IoT driven fertilizer intimation and irrigation system for tomato cultivation. The system monitors soil and environmental conditions and automates water and nutrient delivery through an app-based interface. By ensuring timely irrigation and accurate fertilizer application, the proposed system reduces manual effort, prevents crop stress, and supports sustainable tomato farming practices.

2. LITERATURE REVIEW

IoT based smart agriculture systems have been widely studied for improving irrigation efficiency and crop monitoring. Previous research has shown that integrating sensors for soil moisture, temperature and humidity with wireless communication enables automated irrigation and remote field monitoring through mobile or web applications. Such systems help maintain optimal soil conditions while reducing water consumption and manual labour.

Traditional farming methods depend on manual observation of crop and soil parameters, which is often inaccurate and inefficient. To address this, researchers have introduced wireless sensor networks and cloud-based platforms for real-time data collection, storage, and analysis. These technologies allow farmers to access field information remotely and make timely decisions.

Recent studies have also emphasized the importance of nutrient management in agriculture. While several soil nutrient monitoring systems exist, many rely on costly equipment or lack real time IoT integration. This highlights the need for low cost, IoT enabled solutions that combine irrigation automation with fertilizer management. The proposed system builds on these studies by providing an affordable and automated fertilizer intimation and irrigation solution for smart tomato cultivation.

3. DESIGN OF HARDWARE

This section describes the hardware components used in the proposed IoT-based fertilizer intimation and irrigation system for tomato cultivation. The hardware design focuses on reliability, low cost, and ease of integration to support automated monitoring and control of irrigation and nutrient delivery. The main control unit coordinates sensor data acquisition, decision making, and communication with external devices.

Arduino Uno

The Arduino Uno serves as the central processing unit of the system. It is built around the ATmega328P microcontroller and provides sufficient digital and analog input/output pins to interface with sensors, actuators, and communication modules. The board includes multiple digital I/O pins, analog input channels, and pulse-width modulation (PWM) outputs, making it suitable for controlling pumps, valves, and other peripheral devices.

The Arduino Uno operates at a clock frequency of 16 MHz and can be powered through a USB connection or an external power supply, allowing flexible deployment in agricultural environments. It's on board USB to serial interface enables easy programming and data communication. Due to its stability, low power consumption, and wide community support, the Arduino Uno is an effective choice for implementing automated irrigation and fertilizer intimation systems in smart tomato farming applications.

Fig.1 Arduino Uno

Power Supply

A reliable power supply is essential for the continuous operation of the proposed IoT-based fertilizer intimation and irrigation system. The power unit is designed to convert high-voltage AC mains electricity into a stable low-voltage DC supply suitable for microcontrollers, sensors, and control devices used in the system. To ensure safe and efficient functioning, the power supply provides regulated output voltages that remain constant despite fluctuations in input voltage or variations in load conditions.

The power supply module typically consists of a step-down transformer, rectifier, filter, and voltage regulator. The transformer reduces the AC mains voltage to a lower level, which is then converted into DC using a rectification process. Filtering components are used to minimize voltage ripples, and a voltage regulator maintains a steady DC output required for reliable system performance. This regulated DC power ensures uninterrupted operation of the Arduino-based control unit, sensors, and pumps, there by supporting accurate monitoring and automated irrigation and fertilizer delivery in smart tomato cultivation.

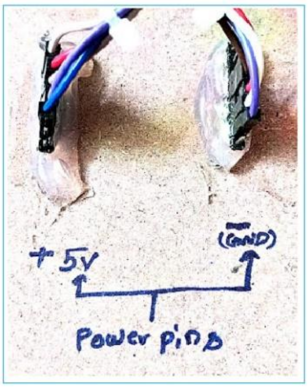


Fig.2 Power supply pins

LCD Display

A low-cost 16×2 LCD module is used to display real-time system information in the proposed IoT-based fertilizer intimation system. The display shows important parameters such as soil moisture, temperature, and system status. It is easy to interface with the microcontroller and consumes minimal power. Features like backlight support and clear alphanumeric output ensure good visibility under various field conditions, making it suitable for smart tomato cultivation.

Fig.3 LCD display

Buzzer

A buzzer is used in the system to provide audible alerts for important events such as irrigation or fertilizer application status. Since microcontroller pins cannot supply sufficient current to directly drive the buzzer, a driver circuit using a transistor is employed. This arrangement allows the buzzer to operate safely while protecting the microcontroller. The buzzer enhances user awareness by providing immediate audio indication during system operation in the IoT-based smart tomato cultivation setup.

Temperature Sensor (DHT11)

Temperature is an important parameter for tomato cultivation, as it influences plant growth and nutrient absorption. In this project, the DHT11 temperature sensor is used to continuously measure the ambient temperature and send the readings to the microcontroller. The sensor produces an analog voltage output that is directly proportional to the temperature in degrees Celsius.

The DHT11 is a precision integrated-circuit temperature sensor that does not require external calibration. Its output increases linearly with temperature, providing accurate readings within a wide range. Due to its reliability and ease of use, the DHT11 is suitable for continuous monitoring in the automated irrigation and fertilizer management system, ensuring optimal environmental conditions for tomato growth.

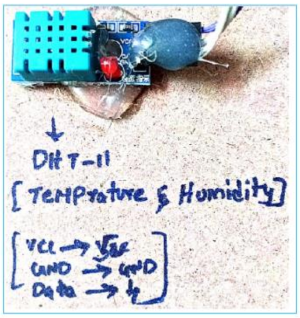


Fig.4 Temperature sensor

ESP32 Wi-Fi Module

The ESP32 module is used to provide wireless connectivity for the proposed smart tomato cultivation system. It enables the microcontroller to connect to a Wi-Fi network and transmit sensor data to an online platform. This allows farmers to monitor soil and environmental conditions remotely through a mobile app or web interface.

ESP32 is a cost-effective Wi-Fi-enabled microcontroller module that supports the TCP/IP protocol, making it suitable for IoT applications. It can be easily programmed and integrated with the Arduino platform, enabling real-time data transmission and remote control of irrigation and fertilizer processes. Its low power consumption and compact design make it ideal for agricultural environments where continuous monitoring is required.

Fig.5 Wi-Fi module

Soil Moisture Sensor

Soil moisture sensors are used to determine the amount of water present in the soil, which is essential for maintaining optimal conditions for tomato growth. These sensors estimate moisture by measuring changes in soil properties such as electrical resistance or capacitance. The sensor outputs a voltage signal that is proportional to the soil's water content, which is then read by the microcontroller.

Accurate moisture measurement helps the system decide when irrigation is required and prevents both under-watering and over-watering. Since soil type and temperature can influence readings, calibration may be needed for precise results. In the proposed IoT based system, the soil moisture sensor plays a key role in automating irrigation and ensuring that the tomato plants receive the right amount of water at the right time.

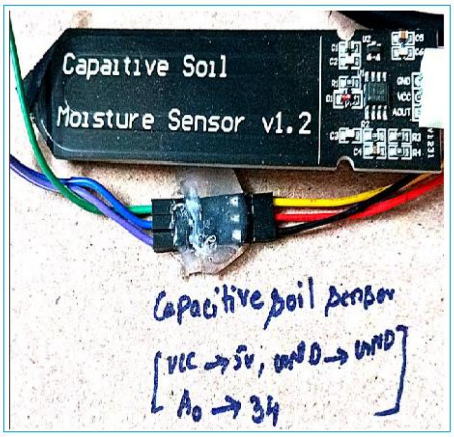


Fig.6 Soil sensor

Light Dependent Resistor

A Light Dependent Resistor (LDR) is a sensor that changes its resistance based on the amount of light it receives. When the light intensity increases, the resistance of the LDR decreases, and when the light decreases, the resistance increases. This property allows the LDR to be used for monitoring ambient light levels in the agricultural environment.

In the proposed smart tomato cultivation system, the LDR helps track sunlight conditions, which influence plant growth and photosynthesis. The microcontroller reads the LDR output and can provide alerts or adjust system behaviour based on the detected light level. The LDR is commonly used in low cost IoT projects due to its simplicity and easy interfacing with microcontrollers.

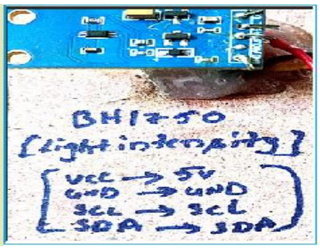


Fig.7 Light sensor

4. SYSTEM DESCRIPTION

This work explains the working principle and circuit design of the proposed system. The operation is illustrated using a block diagram, showing how sensors, controller, and actuators work together to automate irrigation and fertilizer delivery for tomato cultivation.

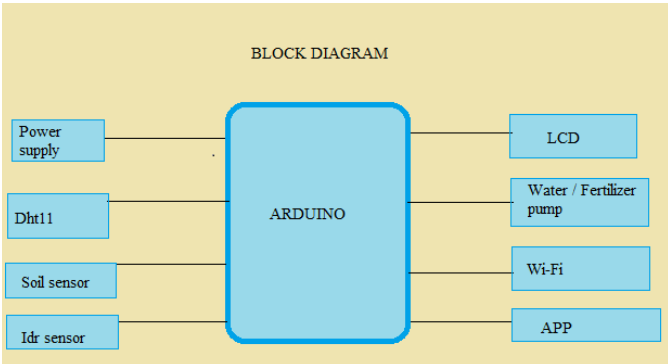


Fig. 8 Block diagram

Software Requirements

Arduino and

Embedded c language

A. Working

The system continuously monitors soil moisture and temperature to control irrigation and fertilizer delivery for tomato plants. Sensor readings are sent to the microcontroller, which processes the data and triggers the water pump and fertilizer dosing system when required. When soil moisture falls below the set threshold, the relay activates the pump, allowing water and nutrient solution to flow to the plants. Once the desired moisture level is reached, the pump turns off automatically.

The collected data is transmitted through Wi-Fi to an IoT platform, enabling remote monitoring via a mobile application. This approach reduces manual effort, conserves water, and ensures timely fertilization. The system also provides alerts through the app, helping farmers to manage tomato cultivation efficiently and effectively.

5. CONCLUSION

The proposed IoT-based system offers an effective solution for smart tomato cultivation by automating irrigation and fertilizer application. By continuously monitoring soil moisture and temperature, the system ensures that water and nutrients are supplied only when needed, reducing wastage and improving crop health. Remote monitoring through a mobile app provides farmers with real-time updates and control, minimizing manual effort and supporting efficient farming practices. Overall, the system contributes to sustainable agriculture by enhancing resource management and enabling better crop productivity in a cost-effective manner.

Future Scope

The project can be further enhanced by adding more features to improve usability and performance:

- Integrating a camera module to capture crop images and store them in a database for growth tracking and disease detection.
- Incorporating GPS functionality to provide precise field location and local weather updates.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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