

Smart Irrigation System for Medicinal Plant Cultivation: Integrated Disease Identification, Moisturization, and Temperature Monitoring for Drug-Bearing Crops

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Abstract— In this project, the smart irrigation system is proposed, which is a device based on Raspberry Pi and IoT technologies that is used to optimize the schedule of irrigation and crop diseases. This system combines the sensors, cameras and weather prediction to give real-time insights and make irrigation decision automated. The project shows the application of appropriate soil moisture meters that assists to alleviate the agony of construction monitor and record of the variation in soil moisture. Moisture sensor and temperature sensor are controlled and analyzed using the Arduino Mega micro controller with Light-Depended Resistor sensor, moisture sensor, temperature sensor and the temperature. The soil itself, over some period of time gives information, which pertains to the moisture condition of the soil. The Sensor received data will be collected and processed on the Arduino Mega. The water will supply when a limit level of water content of the soil is met. This is necessary because water should be supplied to the plant at a specific time to have a good yield. Farmers can use this project extensively since the traditional or manual irrigation system can be eradicated.

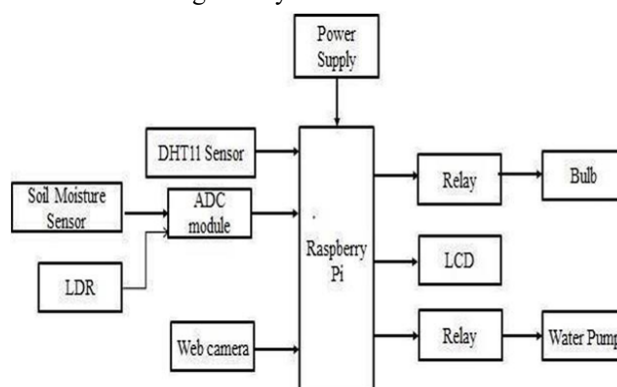
Keywords— Crop Disease identification, Moisturization, Temperature Monitoring, Iot Sensors, Machine learning.

How to cite this article: Reddy MRP, Kiran K, Raghu K, Sunny Dayal P, Srilatha G, Sarma SS. Smart Irrigation System for Medicinal Plant Cultivation: Integrated Disease Identification, Moisturization, and Temperature Monitoring for Drug-Bearing Crops. *Int J Drug Deliv Technol.* 2026;16(35s):62-67. DOI: 10.25258/ijddt.16.35s.9

I. INTRODUCTION

Large agribusiness companies such as Cargill to small organic farmers, growers everywhere in the world are utilizing the Internet of Things to curb their water and fertilizer usage, waste and enhance quality or yield of what they produce. The examples include the microclimatic tracking of cropland, the intensive monitoring of temperature shifts and humidity variations during the shifting of perishable goods between the field and the warehouse to the store to gain more time on the shelf and reduce waste. Tech providers assist them with the help of such tools as drone imagery and soil sensors, which monitor real-time conditions. The Nature Conservancy believes that this type of precision agriculture would help farmers reduce water usage by up to 40 percent and fertilizer usage by up to 40 percent without decreasing yields. This industry will be more sustainable and competitive through enhancement of irrigation efficiency of the agricultural sector. In addition, proper irrigation cannot be done in dry areas where the rainfall is not adequately received. Therefore through such irrigation system through checking the moisture content of soil can sustain the water demand required by the field. Water and time are the considerations of importance to save time and energy of the farmers. As it is, they have to wait until field is watered. This limits them to carry out other activities. This

concept does not just apply to farmers but watering the plants. In our current times, the farmers are irrigating their farms after every set period of time. The methods they employ will burn more water through the formation of water logging and leads to wasting of water. The stress of manual Labour will be totally removed with this system that we designed. It has been tested on two types of soils and will only work in the dry condition of soil. The main component of the system is the raspberry pi and the interface between the raspberry pi and webcam is provided through Wi-Fi Module. Automation is carried out with the help of Python programming language. The system is a network comprising of wireless sensors and a wireless base station that can be utilized in supplying the sensors information to automate the irrigation system.



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Fig 1 Block Diagram

II. LITERATURE REVIEW

The worldwide trend of switching to precision agriculture has given rise to the desire to consider smart irrigation systems based on IoT, AI, and sensor networks. These are designed at ensuring water use is optimized, environmental status is monitored, and early detection of crop diseases, which eventually enhance crop yield and sustainability. This literature review addresses the recent developments and studies on smart irrigation system with respect to three main areas which comprise crop disease detection, temperature and soil moisture sensing. The simplest smart irrigation system based on soil moisture sensors and an Arduino-based automation. The system sprinkles the fields when there is a need to save on water usage without the need to manually handle it [1]. An irrigation system based on a wireless sensor which monitored soil moisture in real-time, and activated drip irrigation systems when they reached set thresholds. They found that their results were a 30 to 40 percent decrease in water use [2].

Extended the strategy by connecting data analytics on the cloud with IoT sensors. Their system was able to give real time control and prediction of how best to irrigate depending on the soil conditions and the weather conditions [3]. A system that examined the temperature and humidity values and compared them with the soil data to make smarter irrigation choices via the use of fuzzy logic. They stated that they had better crop health and reduced wastage of water [4].

Convolutional Neural Networks (CNNs) to determine the disease of the plants through leaf images. Their model was quite accurate in the identification of diseases in a number of crops including leaf spot, rust, and bacterial blight [5]. A massive amount of data of more than 50,000 leaf images and trained systems of deep learning to identify 26 different plant diseases with over 90 percent accuracy. They focused on the possibility of implementing mobile-based applications on farmers in their work[6].

The detailed analysis of the image-based disease detection methods and emphasized the main difficulties, the light variation, overlapping leaves and similarity of visual symptoms in different diseases [7].

Various sources of water can be used and incorporated in various irrigation systems. The primary aim is, however, to bring water into the whole field making sure that every one of the plant gets sufficient water. The supply to the crops shall be done through the modern irrigation systems. The contemporary practices are effective in minimizing the wasted water, unleashing the given quantity of water and energy conserved and controlling the irrigation stage efficiently. The water usage needs to be enhanced by monitoring certain factors that affect the development and growth of plants. We used to monitor the plant health, soil moisturization contextually. The IOT, AI and cloud computing is significant in augmenting the

land productivity. Appropriate decisions are to be made with the usage of such technologies as crop and soil monitoring systems. We will have to apply this smart irrigation in order to improve quality of crops and identify disease in plants. The sensors and IOT devices provide an opportunity to monitor the plant in this smart irrigation. This intelligent irrigation will lead to increase in crop production and the use of pesticides in the field being reduced.

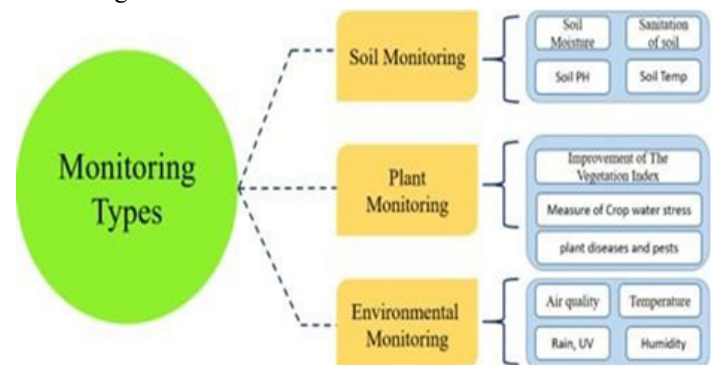


Fig 2 Monitoring Types

The basic building blocks, or building blocks, of any system that give it its functionality, effectiveness and reliability are. All of them, be it a hardware or software, play an imperative role in the attainment of the targeted objectives in general. Scalability is improved through the proper choice and integration of components, which cut the expenditures and lead to improved performance. Their contribution contributes to optimization of the system design and also the efficiency of proper problem solving. Therefore, the success and success of any technical solution largely hinge on components.

The Raspberry Pi 4 represents a single board computer of the Raspberry Pi Foundation. It has a quad-core cortex- A72 processor and is available in 2GB, 4GB or 8GB RAM, which is much faster than its predecessors. The board has two micro-HDMI ports, and it can be used to run two 4k screens. It is equipped with USB 3.0 port that are faster to transfer data and Gigabit Ethernet that provides fast networking. 802.11ac Wi-Fi and Bluetooth 5.0 are installed by default so that they can be used wirelessly. It is also compatible with Raspberry Pi OS and other Linux platforms, and thus it is ideal in code writing, IoT, and DIY. It has 40 pin gpio head, which is used to interface with sensors and external devices. The Pi 4 has a 5 V USB-C power supply, which offers a more efficient power supply. It is employed very widely in home automation, media centers and learning programming. Its low cost and versatility make it popular among students, hobbyists as well as professionals.

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Fig 3 Raspberry PI Module

Raspberry Pi Camera Module is an official product that serves to capture pictures and videos. The module is connected with Raspberry Pi using CSI (Camera Serial Interface) port to transfer more data in high speed. The present generation, Camera Module 3 has IMX708 sensor which has 12MP sensor, autofocus and HDR. Other older ones, like the Camera Module 2, use an IMX219 8MP sensor with fixed focus. Still photography, recording and streaming can be done with the camera. Raspberry Pi OS can be used to program the camera using lib camera or Pi camera library. It is able to record a 1080p, 720p as well 480p video. It is used in computer vision, surveillance systems, and works that use artificial intelligence. The module is small, lightweight, and with power source being provided by the Raspberry Pi directly. The camera is widely used in the field of DIY, robotics, and automation.



Fig 4 Camera Module

DHT sensor is among the frequently used digital sensors that are used in monitoring the humidity and temperature. It is of two broad types, DHT11 (decreased accuracy, reduced range) and DHT22 (increased accuracy, increased range). It consists of capacitive humidity sensor and a thermistor that measures temperature. It is digitally controlled over single-wire using the microcontrollers Raspberry Pi and Arduino. It operates on 3.3V to 5V and has low power consumption and can be used in embedded systems. Periodic update is provided by data output that is updated every 1-2 seconds. On the data pin, a pull-up resistor (4.7k to 10k) should be added to have a stable communication. It operates in application on weather stations, indoor climate monitoring as well as IoTs. It requires special library like Adafruit DHT to process the data in the best way. It is very cheap and simple, and is popular with electronics hobbyists and professionals.

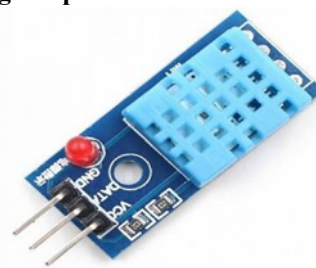


Fig 5 DHT Sensor

To determine the amount of water in the soil, a soil moisture sensor is applied to monitor irrigation and take care of plants. It works by sensing the variation in the soil resistance as per the moisture content. The sensor contains two electrodes in the form of probes that conduct through the soil carrying a small electrical current. Wet soil is less resistant compared to dry soil, and the sensor is therefore able to estimate the level of moisture in the soil. Other higher-tech sensors employ capacitive sensing to have more precise readings without corrosion. The sensor produces analog or digital signals, which combines with Arduino, Raspberry, and other microcontrollers. Relay module can be used to set a limit to which automatic irrigation systems can be activated. It also uses 3.3V to 5V which is energy efficient. The sensor has many applications in smart farming, automation of greenhouses, and the IoT. It is easy to install and only needs to be properly calibrated to give the correct readings. Electrode corrosion may lead to shortening of the lifespan of traditional resistive sensors. Capacitive soil moisture sensors are better in long-term projects to enhance durability. The sensor is used to conserve water by making sure that plants get the required amount of water to minimize wastage.

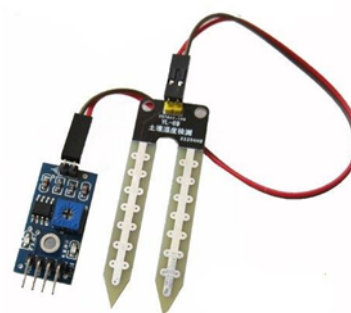


Fig.6 Soil Moisturization Sensor

III. METHODOLOGY

Smart irrigation system that involves crop disease identification, soil moisture measurement, and temperature measurement procedure consists of a number of steps. The initial action plan is to deploy the devices such as soil moisture sensors, DHT sensors (to measure temperature and humidity), and camera modules (to detect diseases) to the field. The soil moisture sensor is applied to measure the water concentration in the soil to offer optimum irrigation. DHT sensor measures temperature and humidity to help in climate control of plants.

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An AI-powered image processing camera module is used to identify plant diseases generated by their leaf color, texture and spots. The sensor data is sent to a microcontroller or Raspberry Pi which takes the data and forwards it to a cloud-based platform to monitor it remotely. The machine learning developed is used to process disease symptoms and provide notifications to farmers via mobile applications. An automatic irrigation system is also set so that the required water is supplied without over or under watering depending on the level of moisture in the soil. The connection of real-time data transmission is offered over wireless communication (Wi-Fi, LoRa, or GSM). A solar-powered system can be added which is energy efficient. Data analytics are relevant to weather forecasting and scheduling. The system helps in remote monitoring and reduces labor as well as enhancing crop health. The long-term farm management is supported with historical data. The use of IoT and AI will ensure precision agriculture that leads to high crop yield and sustainability.

IV. RESULTS

The ultimate results of the smart irrigation system of detecting crop diseases, temperature, and moistening soil have amazing improvements in plant and farming efficiency. The system is able to detect crop diseases by using image recognition through AI based on the raspberry pi camera module and identifying the signs of change in the colour of the leaf, spots and some changes in texture with very high accuracy.

The sensor can detect the temperature and moisture and prevent the weather conditions, which farmers can achieve with the help of the DHT sensor. The water sensor of the soil also gives sufficient water supply without over-irrigation and under-irrigation issues. The system is instant with the crops being watered only as needed thereby conserving the water resources. With the IoT technology in place within the system, it is possible to monitor remotely through real-time notification on the mobile applications. The system conserves labor expenditure and manual work thereby enhancing efficiency and productivity. Data analysis will help predict the weather and improve plans to irrigate the land.



Fig 7 Common rust



Fig 8 Gray leaf spot



Fig 9 Healthy leaf



Fig 10 Corn blight

The wireless communication system offers flawless data transfer which increases the credibility of the system. The system has shown to increase crop yield due to increased control of diseases and controlled irrigation. The system is energy efficient with a solar-powered design that is eco-friendly. The historical data can be stored, which supports long-term decision-making and planning of farms. The farmers would suffer minimal loss due to diseases and water wastage and this leads to high profitability. In most cases, the smart irrigation system greatly enhances precision farming, sustainability and food security.

Table 1 Disease Detection Performance

| Disease Class | Precision | Recall | F1-Score | Accuracy |
|----------------|-----------|--------|----------|----------|
| Common Rust | 94.2% | 93.8% | 94.0% | — |
| Gray Leaf Spot | 91.5% | 90.7% | 91.1% | — |
| Corn Blight | 92.8% | 93.1% | 92.9% | — |
| Healthy Leaf | 97.3% | 96.9% | 97.1% | — |

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| | | | | |
|----------------|---|---|---|--------------|
| Overall | — | — | — | 93.5% |
|----------------|---|---|---|--------------|

Disease detection accuracy
AI model performance per crop disease class (Raspberry Pi camera + CNN)

■ Precision ■ Recall ■ F1-Score

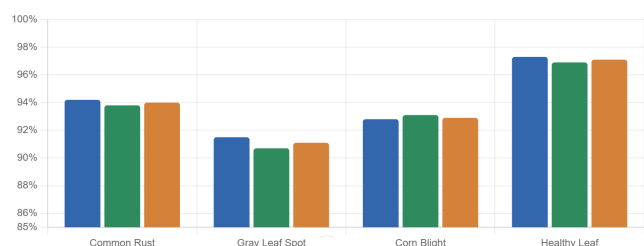


Figure 11 Disease detection accuracy

Soil moisture sensor readings over time
7-day monitoring — irrigation triggered below 30% threshold

■ Soil moisture (%) ■ Trigger threshold (30%)

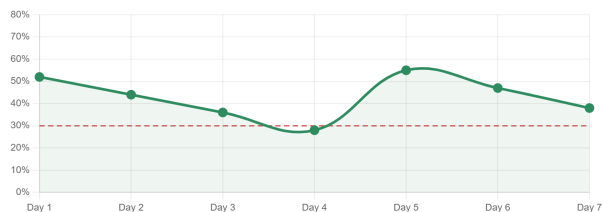


Figure 12 Soil moisture sensor readings over time

Temperature & humidity monitoring (DHT22)

24-hour environmental readings — dual axis

■ Temperature (°C) ■ Humidity (%)

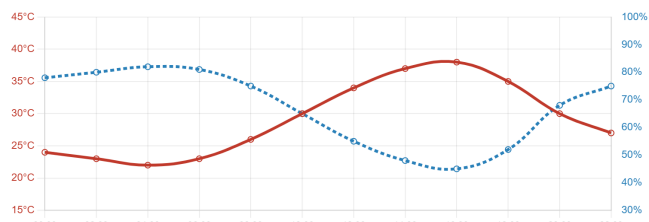


Figure 13 Temperature & humidity monitoring (DHT22)

Water consumption comparison

Average daily water usage per plant (litres/day)

■ Water used (L/day/plant)

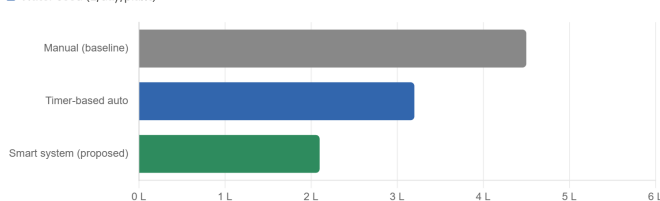


Figure 14 Water consumption comparison

Table 2 Water Savings Comparison

| Irrigation Method | Water Used (L/day/plant) | Reduction vs. Manual |
|------------------------------|--------------------------|----------------------|
| Manual (Baseline) | 4.5 | — |
| Timer-based automatic | 3.2 | 28.9% |
| Proposed Smart System | 2.1 | 53.3% |

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