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# Studies on Smart Irrigation System Using IoT Approaches

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## ABSTRACT

Drip irrigation is widely acknowledged for its cost-effectiveness and efficiency in contrast to traditional methods that rely heavily on human oversight. This research paper underscores the potential to enhance water utilization efficiency while maintaining optimal yields through the implementation of sound water management strategies and the integration of cutting-edge technologies. The study introduces an automated irrigation control system designed to autonomously supply adequate water to crops across all agricultural seasons. This system is intended to create an automated irrigation mechanism which turns the pumping motor ON and OFF on detecting the moisture content of the earth. Utilizing inexpensive sensors and straightforward circuitry renders this project a cost-effective solution, making it accessible even to economically disadvantaged farmers. The designed system was tested on tomato crop. Plant height of tomato crop controlled by an automatic drip irrigation circuit for automatic watering was slightly higher than those manually irrigated. The use of automatic irrigation technology improved crop yields and quality in tomato crop due to timely supply of water. Tailored for regions facing water scarcity and necessitating judicious water use, this research offers significant advantages.

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## INTRODUCTION

The global decline in water resources is a well-acknowledged phenomenon, while the escalating demands for fresh water, driven by rapid urbanization, population growth, and the expansion of industries and agriculture, pose significant challenges. In countries where agriculture is a primary focus, water is predominantly utilized for irrigation, and any disruption in water supply can adversely impact production rates. Effective water management is crucial for the proper functioning of irrigated agricultural cropping systems (Jha *et al.,* 2019 and Khan *et al.,* 2021). Enhancing water usage efficiency without compromising yields is achievable through the implementation of advanced water management strategies and up-to-date technologies. There is an urgent necessity for agriculturally oriented nations to adopt more efficient agricultural technologies to ensure optimal management of water resources (Tantalaki *et al.,* 2019, Elijah *et al.,* 2018, Weersink *et al.,* 2018, Al Nahian *et al.,* 2021).

Irrigated agriculture stands as the largest consumer of water globally, frequently contending with the industrial and urban sectors for resources. In semi-arid regions characterized by scant and irregular rainfall, supplemental irrigation becomes indispensable to boost crop production and overall productivity. A key focus is on improving the water productivity (WP) of various crops, representing a significant initiative to conserve water in the agricultural sector. Achieving a balance between water supply and demand is paramount for enhancing productivity and ensuring sustainability in irrigated environments. Additionally, a thorough understanding of crop-water requirements is essential for the effective management and planning of water resources, aiming to enhance overall water productivity (Andric *et al.,* 2020, Fan *et al.,* 2018 and Hatfield *et al.,* 2019).

The primary challenge in India for ensuring sustainable food production lies in effective water management in agriculture. The increasing demand for water in arid and semi-arid regions is expected to lead to a decline in the availability of irrigation water in the coming years. Consequently, it is crucial to develop technologies that enable the judicious use of available water resources in agriculture, safeguarding the country's future food security. Projections indicate that by 2050, approximately 22% of the geographic area and 17% of the population in India will face absolute water scarcity. The per capita water availability, which stood at about 1704 cubic meters in 2010, is anticipated to decrease to 1235 cubic meters by 2050 (Elbasiouny *et al.,* 2020 and Sharma *et al.,* 2022).

Irrigation is typically a labour-intensive task, demanding a substantial workforce to be completed within a reasonable timeframe. Traditionally, all the necessary steps were carried out manually by humans. Presently, certain systems leverage technology to decrease the workforce or time needed for irrigation (Upadhyaya *et al.,* 2022). However, these systems often exhibit limited control, leading to the inefficient use of

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resources, particularly water. Excessive water usage poses a challenge for every country striving to meet the demand for fresh food while simultaneously reducing agricultural water consumption on farms.

Drip irrigation stands out as the most advanced and effective among various irrigation techniques. In this system, water is delivered to the crops in minute, controlled drops through a network of narrow plastic pipes equipped with outlets known as emitters or drippers. Commonly referred to as trickle irrigation, this method differs from surface or sprinkler irrigation by not saturating the entire soil profile; instead, it targets the specific soil area where plant roots are present. Essentially, drip irrigation ensures the direct and precise supply of water and nutrients to the roots of each plant, promoting optimal growth and development by delivering the right amount at the right time.

Over the past decade, some systems have aimed to decrease agricultural water consumption, but they come with certain constraints. These existing systems lack the capability to analyze soil properties before watering, leading to uneven water distribution in the soil and subsequently lower yields. Additionally, these systems require substantial human intervention and are time-consuming. Consequently, there is a pressing need to shift focus towards modern technology to address these challenges and enhance irrigation management (Gloria *et al.,* 2020 and Liang *et al.,* 2020). In response, we have introduced an automatic irrigation system as a proposed solution. The aim of this system is to create automated drip irrigation systems that align with the specific daily requirements of the crop based on a single climate criterion. Sensors positioned in the soil near the plant roots will detect moisture and temperature levels. These sensors will send the collected data to a server, where it will be compared against pre-established values. Based on the threshold values, the system will autonomously initiate the necessary actions. Calculating soil moisture is crucial for plant growth, and this system ensures that water levels in the soil are in harmony with the plant's needs. The automated drip irrigation system offers significant advantages, primarily in the conservation of a substantial amount of water and the reduction of accidents that may occur during night time watering. This system automatically irrigates all manually irrigated lands (Barkunan *et al.,* 2019, Sayed *et al.,* 2021). In contrast to the previous method where farmers had to consistently monitor the fields for signs of dryness, this system minimizes the time required for field surveillance. The need for manpower is significantly decreased, and the system can operate efficiently even when the owner is temporarily unavailable, ensuring proper irrigation in their absence. Additionally, water wastage during traversal is eliminated.

## MATERIALS AND METHODS

The objective of the research was to develop an accurate and economically viable electronic circuit for the automatic irrigation of crops. The experimentation occurred within a polyhouse situated at Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K) in Shalimar, Srinagar, spanning from May to July. Positioned at latitude 34.14° N and longitude 74.87° E, SKUAST-K is situated at an elevation ranging from 1550 to 2500 meters above mean sea level (MSL).

The experimental site has a temperate climate characterized by relatively mild summers, moderate rainfall during the rainy season, and intense winters.

### Automatic Drip Irrigation Circuit

The automatic drip irrigation system effectively tackles various challenges associated with agriculture and irrigation. It adeptly manages water and electricity resources, thereby contributing to increased agricultural productivity while minimizing water usage. Additionally, it diminishes the necessity for manual involvement in irrigation tasks. These features collectively position the automated system as a sustainable solution for improving agricultural and irrigation efficiency (Sharma *et al.,* 2021).

The key components of the automatic drip irrigation circuit include transistors, relays, soil moisture sensors, batteries, diodes, resistors, LEDs, and a motor (figure 1). The sensor circuit gauges soil conditions by measuring soil voltage and comparing it with a reference voltage. A TIP31C transistor is employed to drive the relay, with the DC motor connected between the normally-open (N/O) pin and the pole of the relay. If the soil is dry, indicating that the ground voltage exceeds the reference voltage, the transistor conducts, triggering the relay. This activation happens as the pole pin makes contact with the N/O pin. As a result, the motor is energized with power supplied by the battery. Conversely, when the soil is moist, indicating that the soil voltage is lower than the reference voltage, the transistor fails to activate the relay. Consequently, the motor switches off.

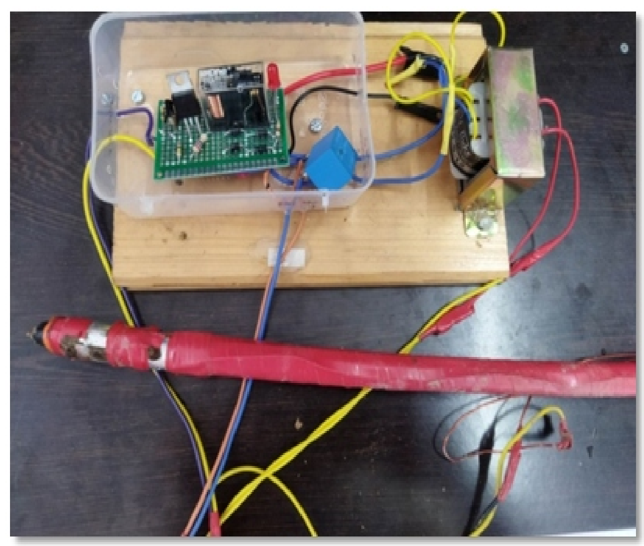

**Fig. 1:** A circuit consisting of various components to automate drip irrigation system Components of Automatic Drip Irrigation System

### *Relay*

A relay (fig. 2) is an electrically operated switch and uses an electromagnet to operate a switching mechanism mechanically. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. The specifications of the relay used are described in Table 1.

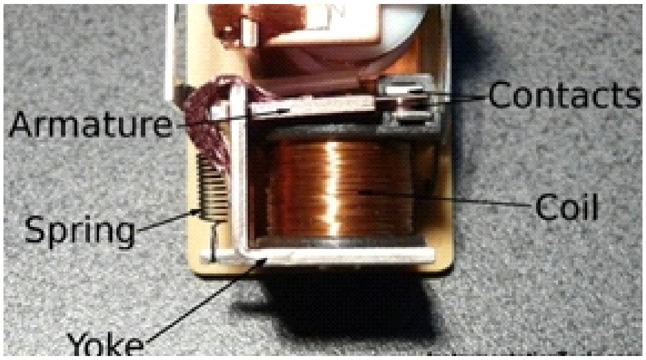


**Fig. 2:** Relay

**Table 1:** Specifications of Relay

| Specifications | HE JQC3FC(5 Pin relay) | LM 12-L-DC 12 V-T (8 pin relay) |
|---|---|---|
| Brand | HE | LeOne |
| Voltage | 24V DC | 30V DC |
| Current | 7 Amp | 5 Amp |
| Contact form | SPDT | DPDT |
| No. of poles | Single pole | Double pole |

***Light Emitting Diode (LED)***

A light-emitting diode (LED) is a two-lead semiconductor light source (fig. 3). It is a pn junction diode that emits light when activated. When a suitable voltage is applied to the leads, electrons are able to recombine with electron holes within the device, releasing energy in the form of photons. This effect is called electro luminescence, and the colour of light (corresponding to the energy of the photon) is determined by the energy band gap of the semiconductor. LEDs are typically small (less than 1 mm) and integrated

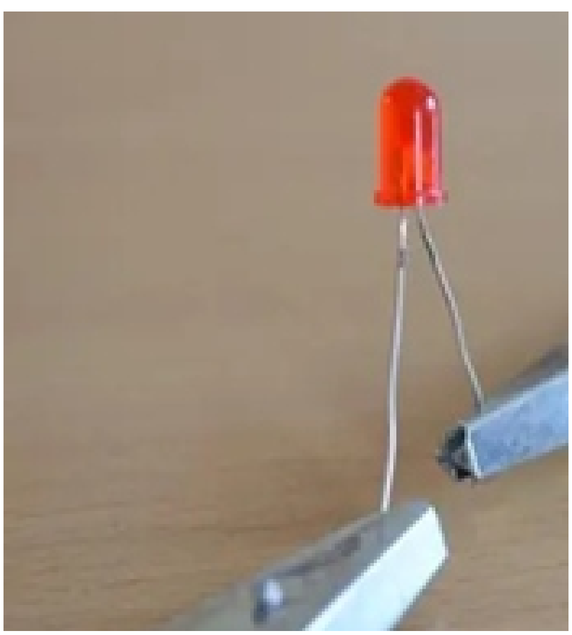

**Fig. 3**: Light Emitting Diode (LED)

**Table 2:** Specifications of LED

| | |
|---|---|
| Model | RC801-01 |
| Typical forward voltage | 3.6V |
| Rated forward current | 150 mA |
| LED colour | Red |
| Style | Round 8mm |
| Power dissipation | 0.5 W |
| Peak pulsed current | 200 mA |
| Intensity | 50000 mcd |
| Colour frequency | 650 nm |

***Resistors***

A resistor (fig. 4) is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. The specifications of the relay used are described in Table 3.

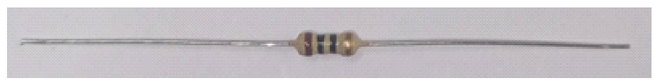

**Fig. 4**: A 10Ω resistor

**Table 3:** Specifications of Resistor

| | |
|---|---|
| Product Name | Resistor |
| Resistor type | Carbon film |
| Rated power | 1/4W |
| Resistance value | 100 ohm |
| Tolerance | A+-5% |
| Withstand voltage | 250V |
| Body Size | 5 x 2mm/0.2" x 0.08" (L*D) |
| Lead size (each end) | 20 x 0.4mm / 0.8" x 0.016" (L*D) |
| Total length | 45mm |
| Weight | 10g |

***Diode (IN40007)***

In electronics, a diode (fig. 5) is a two-terminal electronic component that conducts primarily in one direction (asymmetric conductance), it has low (ideally zero) resistance to the flow of current in one direction, and high (ideally infinite) resistance in the other. A semiconductor diode is a crystalline piece of semiconductor material with a p-n junction connected to two electrical terminals. The specifications of the relay used are described in Table 4.

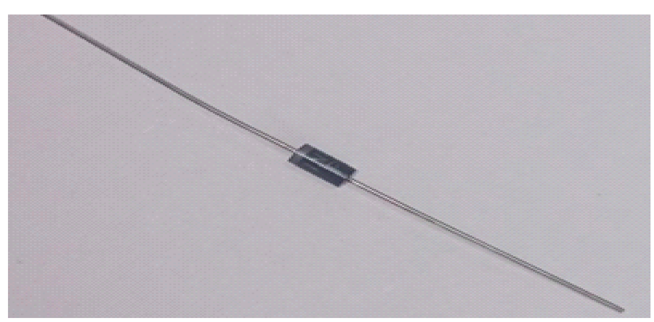

**Fig. 5**: An IN40007 Diode

**Table 4:** Specifications of Diode

| | |
|---|---|
| Brand name | PFS |
| Diode type | Silicon rectifier general usage diode |
| Maximum power dissipate | 3W |
| Maximum recurrent peak reverse voltage | 1000V |
| Maximum RMS Voltage | 700V |
| Max DC blocking voltage | 1000V |
| Average forward current | 1.0A |
| Peak forward surge current | 30A |
| Maximum instantaneous forward voltage | 1.0V |
| Maximum DC Reverse Current at rated DC blocking voltage | 5.0µA @ 25°C |
| Typical junction capacitance | 15Pf |
| Typical reverse recovery time | 2.0µs |
| Operating temperature | -55°C ~ 150°C |

***DC Motor***

A DC motor (fig. 6) is any of a class of rotary electrical machines that converts direct current electrical energy into mechanical energy. The most common types rely on the forces produced by magnetic fields. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic; to periodically change the direction of current flow in part of the motor. The specifications of the DC motor used are described in Table 5.

**Fig. 6**: Crompton Mini Marvel II DC Motor

**Table 5:** Specifications of DC Motor

| | |
|---|---|
| Model | MINI MARVEL II |
| Brand | Crompton |
| Size | 25*25mm |
| Motor horsepower | 0.37kW(0.50hp) |
| Head range | 6-24m |
| Material | Cast Iron |
| Power Source | Electric |
| Motor Phase | Single Phase |
| Frequency | 50 Hz |
| Voltage | 220V |
| Country of origin | Made in India |
| No. of stages | 1 |
| Discharge range | 600-2600 LPH |
| Warranty | 18 Months |

***Transistors***

A transistor is a device that regulates current or voltage flow and acts as a switch or gate for electronic signals. Two transistors have been used in the circuit namely TIP31C and RADCOM (fig. 7). The specifications of the transistors used are described in Table 6 and 7.

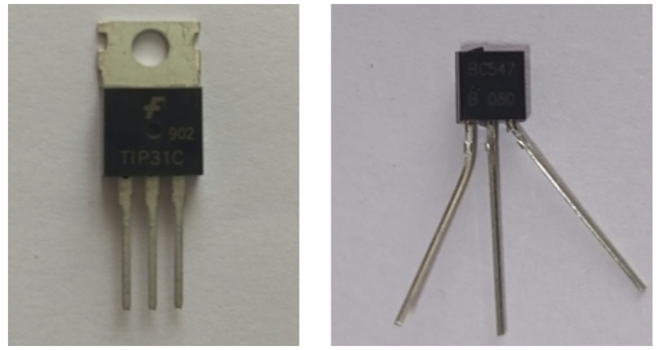


**Fig. 7**: TIP31C and RADCOM

**Table 6:** Specifications of TIP31C transistor

| | |
|---|---|
| Power transistor | Medium |
| Maximum voltage across collector and emitter of transistor | 100V |
| Maximum current allowed through transistor collector | 3 A DC |
| Maximum voltage across base and emitter of transistor | 5V |
| Maximum current allowed through transistor base | 1A DC |
| Maximum voltage across collector and base of transistor | 100V |
| Maximum operating temperature | 150º C |

**Table 7:** Specifications of RADCOM transistor

| | |
|---|---|
| DC Current Gain (hFE) | 800 max |
| Continuous collector current (Ic) | 100 mA |
| Emitter base voltage(VBE) | 6V |
| Base current (IB) | 5mA max |

***Transformer (12-0-12)***

A transformer (fig. 8) is a device that transfers electric energy from one alternating current circuit to one or more other circuits, either increasing (stepping up) or reducing (stepping down) the voltage. The specifications of the transformer used are described in Table 8.

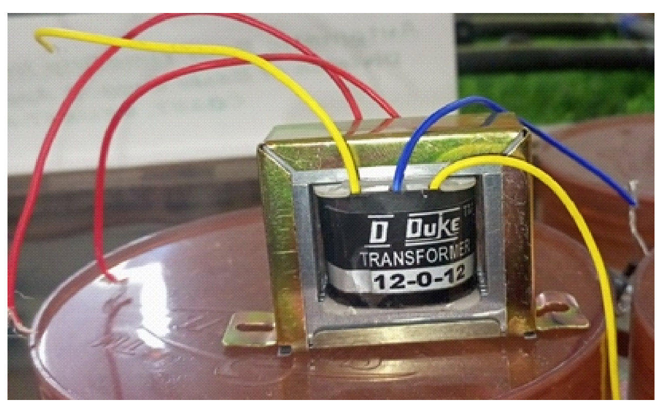


**Fig. 8**: 12-0-12 transformer

**Table 8:** Specifications of 12-0-12 transformer

| | |
|---|---|
| Input voltage | 240 V |
| Output voltage | 12V, 24V |
| Current(Ampere) | 2A |
| Frequency (Hertz) | 50 |
| Material | Copper, Aluminium |

*Soil Moisture Sensor*

The soil moisture sensor (fig. 9) is a sensor connected to an irrigation system controller that measures soil moisture content in the active root zone before each scheduled irrigation event and bypasses the cycle if soil moisture is above a user defined set point.

**Fig. 9**: Self made Soil moisture sensor

*Soil Moisture Meter*

The moisture level of soil was analysed by using leutron professional soil moisture meter (PMS-714). The measurement range of this moisture meter is 0%-50% moisture content and having a resolution of 0.1%. The length of meter body is 172 mm (17.2 cm), Probe body is 200mm (20 cm) having a diameter of 10mm (1 cm). The moisture content was displayed by the meter body in terms of percentage (fig. 9) . The specifications of the soil moisture meter used are described in Table 9.

**Table 9:** Specifications of PMS-714

| | |
|---|---|
| Display | LCD size: 28mmX19mm |
| Measurement Range | 0% to 50% moisture content on soil |
| Resolution | 0.1% |
| Accuracy | ± (5 % F.S+ 5d) @ 23± 5%, F.S: full scale. |
| Data Hold | Freeze the display reading |
| Sampling Time | Approx. 0.8 second |
| Operating temperature | 0-50?C |
| Operating Humidity | Less than 80% RH |
| Power Supply | DC 1.5 V battery |
| Current | DC 12 mA |
| Weight | 267 g/ 0.58 LB @ Battery is included |

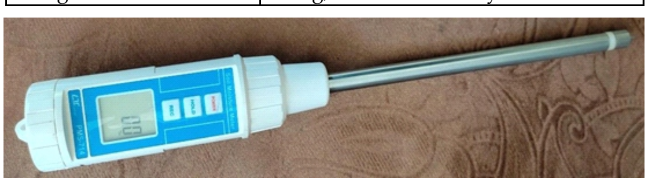

**Fig. 10**: Leutron professional soil moisture meter (PMS-714)

**Working**

The transistor's base is connected to a 100k ohm resistor, while the emitter is linked to a 200-ohm resistor. A bridge circuit, comprising four diodes, connects one end to the 100k ohm resistor and the other to the soil moisture sensor. To control the relay connected to the motor, a transistor is employed. The relay coil's one terminal receives a 24 V DC supply, with the other end connected to the transistor's collector. The relay's contacts are linked to both the motor and the AC supply. An LED is connected between the DC supply and the collector, indicating motor operation.

The soil moisture sensor, placed in the soil close to the roots within the root zone of the plants, measures soil conductivity. This sensor is pivotal for turning the pumping motor on or off based on the detected soil moisture content. Before installing the automatic drip irrigation circuit in the polyhouse, the water source, in this case, a tank, is filled, and the motor is connected to the water source via pipes. Subsequently, the automatic drip irrigation circuit is installed, and the motor is connected to it. Upon providing power to the circuit, irrigation commences.

The soil moisture sensor, placed near the plant roots, acts as a resistor with variable resistance dependent on soil moisture content. This resistance is inversely proportional to soil moisture: Higher soil moisture results in better conductivity and lower resistance & Lower soil moisture leads to poor conductivity and higher resistance.

The sensor generates an output voltage based on the resistance, allowing for the determination of moisture levels. The soil moisture sensor regulates the pumping motor, switching it on or off in response to soil moisture content. Once the crop is adequately irrigated, reaching the root zone, the motor turns off. During this period, the motor stays operational, ensuring uninterrupted irrigation.

## RESULTS AND DISCUSSION

The monitoring of the soil water available with time was done by Leutron Professional Soil moisture meter (PMS-714). The moisture meter was installed in the soil and moisture content was recorded at two depths, first at 10 cm depth and second at 20 cm depth under both dry and wet conditions.

**Soil Moisture Measurements**

The sensor was placed in the soil under dry conditions and embedded up to a fair depth of the soil. In dry condition, as there was no conduction path between the two copper leads the sensor gave a high resistance value (nearly 700 kΩ). With

**Table 10:** Moisture content at different depths

| S. No. | Moisture Content in % | | | |
|---|---|---|---|---|
| | Dry Condition | | Wet Condition | |
| | At 10 cm height | At 20 cm height | At 10 cm height | At 20 cm height |
| 01 | 7.4 | 14.7 | 14.1 | 19.0 |
| 02 | 7.9 | 15.8 | 18.8 | 19.5 |
| 04 | 7.7 | 15.1 | 18.2 | 19.0 |
| 05 | 8.2 | 15.0 | 16.7 | 18.6 |
| 06 | 7.6 | 14.6 | 16.8 | 18.8 |
| 07 | 7.5 | 14.8 | 18.5 | 18.9 |
| 08 | 7.4 | 14.8 | 18.4 | 18.6 |
| 09 | 7.7 | 15.2 | 19.8 | 19.9 |
| 10 | 8.1 | 15.3 | 19.7 | 20.6 |
| 11 | 8.3 | 15.9 | 17.6 | 19.3 |

the increase in water content beyond the optimum level, there was a drastic increase in the conductivity of the soil and the sensor resistance was further decreased to around 50kΩ.

The soil moisture readings obtained using leutron professional soil moisture meter is given in the table 10.

**Variation of Soil moisture**

Fig. 11 & 12) show moisture content measured at different soil depths, at different moisture contents and at different times using leutron Professional soil moisture meter and it has been seen that the readings obtained at fully wet conditions are varying in similar manner w.r.t full dry conditions.

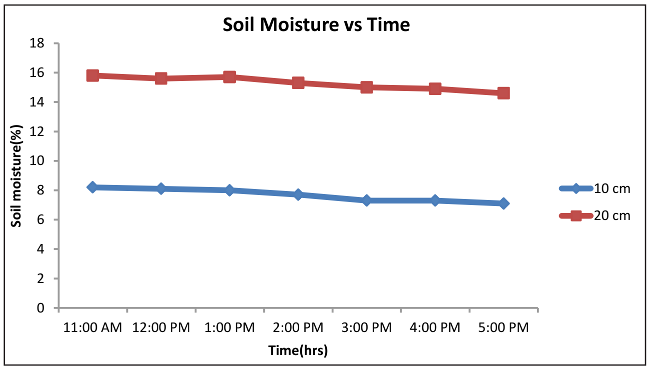


**Fig. 11**: Variation of soil moisture content with time under fully dry conditions

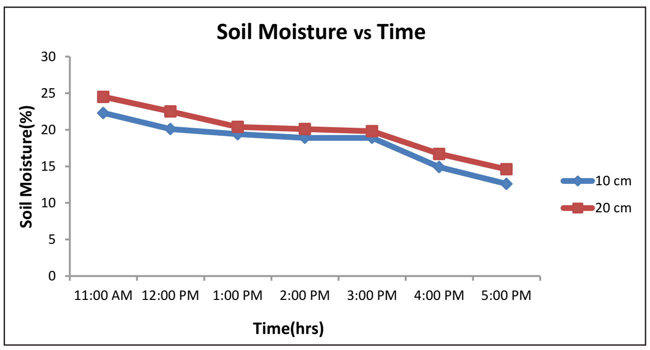


**Fig. 12**: Variation of soil moisture content with time under fully wet

**Temperature and humidity variation inside polyhouse**

The figures 13 and 14 show the temperature variations and the relative humidity values in the polyhouse.

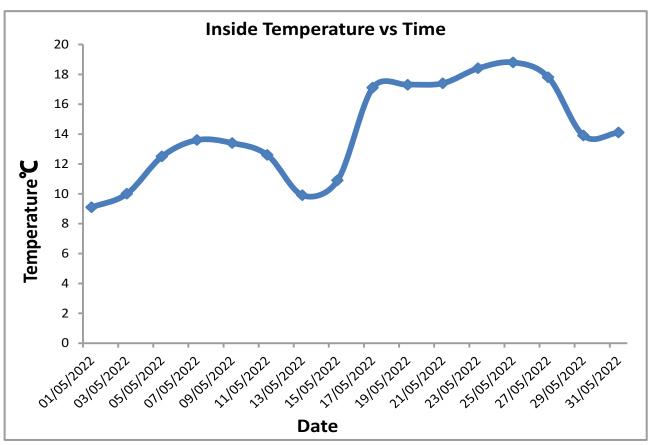


**Fig. 13**: Temperature variation inside polyhouse during the month of May 2022

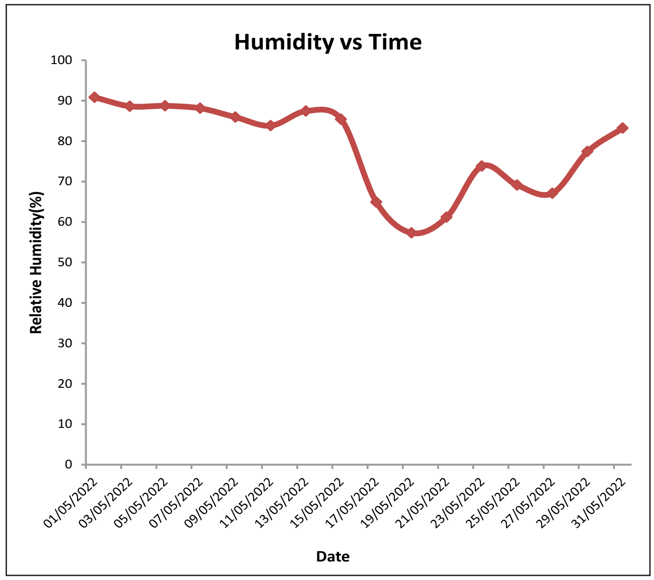


**Fig. 14**: Relative humidity values in polyhouse during the month of May 2022

**Effect of Automatic Irrigation on Crop Parameters**

*Effect on Plant Height*

Plant heights of tomato crop controlled by an automatic drip irrigation circuit for automatic watering were slightly higher than those manually irrigated.

*Effect on Plant Photosynthesis*

The photosynthesis is the process by which plants make their food (biomass) that will be used for growth and economically increases yield. The rates of photosynthesis were determined in both manually and automatically irrigated plants in order to relate the biomass accumulation expressed as dry weight to the photosynthesis rates. The results showed that photosynthesis rates declined earlier (1000 μmol quanta) in manually irrigated plants.

*Effect on crop yield*

The use of automatic irrigation technology improves crop yields and quality due to timely supply of water.

**Table 11:** Price description of circuit components and other accessories

| S. No. | Component | No. | Price |
|---|---|---|---|
| 1 | Transformer | 1 | 200 |
| 2 | Relay | 2 | 50 |
| 3 | Transistor | 2 | 50 |
| 4 | Resistors | 4 | 2 |
| 5 | Diode | 4 | 8 |
| 6 | LED | 1 | 5 |
| 7 | Electric wiring | 6(mtr) | 50 |
| 8 | General PCB | 1 | 10 |
| 9 | Motor accessories | 5 | 645 |
| | | | **Total= 1020** |

**Cost Analysis**

The total cost incurred for the design and development of the automatic drip irrigation circuit along with motor accessories is Rs. 1020. Thus, the developed system is a low cost system. The price description of circuit components and other accessories is presented in table 11.

## CONCLUSION

This research is intended to create an automated irrigation mechanism which turns the pumping motor ON/OFF on detecting the moisture content of soil. In order to enhance the irrigation scheduling techniques in farmer's field, an automatic drip irrigation system circuit was installed in such a manner in order to effectively irrigate the crops. Using an automatic drip irrigation system reduces the farmer's presence for irrigation which is a major part of the practice of farming and optimises the usage of water. The proposed circuit eliminates the manual switching mechanism used by the farmers. The use of this system will be able to contribute to the socio- economic development of the nation. It is a fast response and a user-friendly system. The accurate measurement and watering improve yield obtained because of the effective and timely irrigation. This can be an industrial revolution for the methods of farming irrigation.

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