AN IOT BASED DRIP IRRIGATION SYSTEM FOR VERTICAL FARMING IN RAINSHELTER

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TAVANUR-679 573, MALAPPURAM

KERALA, INDIA

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PROJECT REPORT

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

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2023

DECLARATION

We hereby declare that this project entitled "**AN IOT BASED DRIP IRRIGATION SYSTEM FOR VERTICAL FARMING IN RAINSHELTER**" is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of another university or society.

Place: Tavanur

Date:

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CERTIFICATE

Certified that the project entitled **“AN IOT BASED DRIP IRRIGATION SYSTEM FOR VERTICAL FARMING IN RAINSHELTER”** is record of project work done jointly by **Adithya S, Aleena A.N.S, Sona K, Vishnupriya R** under my guidance and supervision and that it has not previously formed on the basis for the award of any degree, diploma, fellowship or associateship to them.

Place: Tavanur

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DEDICATED TO OUR PROFESSION

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SYMBOLS AND ABBREVATIONS

&	:- And
°	:- Degree
’	:- Minute
”	:- Seconds
%	:- Percentage
β	:- Beta
A	:- Ampere
AC	:- Alternating current
ADC	:- Analog to digital converter
cm	:- Centimetre
CWRDM	:- Centre for Water Resource Development & Management
db	:- Decibel
DC	:- Direct current
E	:- East
EC	:- Electrical conductivity
E.g.	:- Example
ESP	:- Espressif systems
et al	:- And others
etc	:- Etcetera
Eu	:- Emission uniformity
g	:- Gram
GDP	:- Gross Domestic Product
GI	: - Galvanized iron
GPIO	:- General purpose input & output
ha	:- Hectare
i.e.	:- That is

IOT	:- Internet-of-thing
i/o	:- input
kg	:- Kilogram
KB	:- Kilobytes
L	:- Litre
LED	:- Light emitting diode
LCD	:- Liquid display crystal
lph	:- Litre per hour
m	:- Metre
mm	:- Millimetre
MB	:- Megabytes
MCU	:- Micro controller unit
MHz	:- Mega hertz
N	:- North
Nos	:- Numbers
PFDC	:- Precision Farming Development Centre
pH	:- Pouvoir hydrogen
PVC	:- Poly vinyl chloride
RDI	:- Regulated deficit irrigation
SoC	:- System of chip
SPI	:- Serial peripheral interface
UART	:- Universal Asynchronous receiver transmitter
UV	:- Ultra violet
V	:- Volt
Viz	:- Videlicet
W	:- Watts

INTRODUCTION

CHAPTER 1

INTRODUCTION

Agriculture is an art and science that prudent endeavour to reshape a part of Earth's crust through cultivation of plants and other crops for sustenance or other necessities for human being and economic gain. It is derived from the Latin word ‘ager and cultura’ which means ‘field and cultivation’ respectively. Indian agriculture sector accounts for 18 per cent of India's gross domestic product (GDP) and provides employment to 50% of the countries workforce. India is the world's largest producer of pulses, rice, wheat, spices and spice products. Modern agriculture is an evolving approach with innovations in farming practices that helps in increasing agricultural efficiency and reduce the loss of natural resources. These techniques in India promote sustainable agriculture, improves the fertility of the soil, decrease the effect on the ecosystem, and have modern storage methods that reduce wastage of food grains.

Traditional irrigation is a method of watering crops and plants that has been used for thousands of years. It involves the use of surface water sources such as rivers, lakes, and wells to irrigate farmland, which includes furrow irrigation, flood irrigation, and border irrigation. In furrow irrigation, water is delivered to the field through furrows or trenches between crop rows. In flood irrigation, water is applied to the field in a continuous flow. Water is applied to the field in a series of parallel strips in border irrigation. One of the main drawbacks of traditional irrigation methods is their inefficiency. Traditional irrigation systems are often characterized by high water losses due to evaporation, deep percolation, and runoff. It can also lead to soil erosion and degradation. Excessive irrigation can lead to water logging and soil salinization, which can negatively impact crop productivity. Furthermore, traditional methods are labour-intensive and require significant amounts of time and effort to maintain.

Modern irrigation systems, is one of the milestone applications in agricultural sector, has contributed to improving agricultural production. These systems have the ability to rationalize water consumption. The importance of modern irrigation systems lies in reducing the agricultural problems facing many farmers in the world, such as the problems of saturation, salinization, and leaching, furthermore it assists in improving the productivity of crops. Therefore, the utmost importance for any irrigation system of any kind is the optimal use of water. The issue of conserving water is more sensitive than it seems, but all we can do is contribute to the responsible use of this resource and benefit from it. In our modern age we suffer from the problem of water scarcity, and many irrigation systems have been devised for this task, not only to rationalize water but also to make things easier for us to take care of our crops and farms. Sprinkler and drip irrigations are best patterns suited for modern irrigation system in agriculture.

Drip irrigation or trickle irrigation is a type of micro-irrigation system that has the potential to save water and nutrients by allowing water to drip slowly to the roots of plants, either from above the soil surface or buried below the surface. The goal is to place water directly into the root zone and minimize evaporation. Drip irrigation systems distribute water through a network of valves, pipes, tubing, and emitters. Depending on how well designed, installed, maintained, and operated it is, a drip irrigation system can be more efficient than other types of irrigation systems, such as surface irrigation or sprinkler irrigation.

Soil media, which is used to grow plants in a container or a controlled environment provides plants with nutrients, water, and air, and it supports the plant's roots as it grows. It can be made from a variety of materials, including soil, peat moss, vermiculite, perlite, coconut coir, and various other organic and inorganic materials. The choice of soil media depends on the needs of the plants being grown, as well as the environmental conditions in which they are grown. In addition to providing nutrients, water, and air to plants, soil media can also affect other aspects of plant growth, such as p^H levels, salinity, and drainage. Different types of soil media can have different properties and characteristics that affect plant growth, such as water-holding capacity, porosity, and nutrient content. Soil media can be used for a variety of applications, including indoor and outdoor gardening, hydroponics, and container gardening.

A rain shelter is a structure designed to protect crops from the negative effects of rain and other weather conditions. They are naturally ventilated and are similar to green houses, made using GI pipes or wooden or bamboo poles with roofs made up of transparent UV-stabilised low density polyethylene film. It can be permanent structures made of materials such as metal, plastic, or wood, or can be temporary structures made of materials such as PVC pipe and plastic sheeting. They can also be used in small-scale farming to protect crops from heavy rainfall or other extreme weather events. This can help to prevent soil erosion, reduce the risk of disease and pest infestations, and protect the plants from damage caused by heavy rainfall, hail, or high winds and helps in promoting crop growth, and in achieving stable production of high-quality vegetables. It can also be used to control the amount of sunlight and temperature that the crops are exposed to, which can be useful for testing the effect of different environmental conditions on crop growth and yield.

Vertical farming is a relatively new method of cultivation that involves the use of vertically stacked layers of plants. The advantage of vertical farming is that it utilizes the vertical space, when the land area available is less. It is a form of urban agriculture that can be practiced in small spaces, making it particularly suitable for densely populated cities where land is scarce. It often incorporates controlled-environment agriculture, which aims to optimize plant growth, and soilless farming techniques such as hydroponics, aquaponics, and aeroponics.

The modern concept of vertical farming was proposed by Dickson Despommier, professor of Public and Environmental Health at Columbia University. The main advantage of utilizing vertical farming technologies is the increased crop yield that comes with a smaller unit area of land requirement. Another sought-after advantage is the increased ability to cultivate a larger variety of crops at once because crops do not share the same plots of land while growing. Additionally, crops are resistant to weather disruptions because of their placement indoors, meaning fewer crops are lost to extreme or unexpected weather occurrences. Because of its limited land usage, vertical farming is less disruptive to the native plants and animals, leading to further conservation of the local flora and fauna.

Automation of drip system refers to operation of the system with no or minimum manual interventions. Irrigation automation is practiced in large areas where it is divided into small irrigation blocks and these segments are irrigated in sequence to match the flow available from the water source. The use of wireless sensor networks, IoTs, and communication technology for the automation of irrigation is an entirely new and futuristic field of research for development. It eliminates the manual opening and closing of valves. It starts and stops pump exactly as and when required thus optimizing the energy requirement. Irrigation system can be started at any desired time. There are two types of automation: Semi-automatic and fully automatic systems.

Semi-automatic systems require manual attention at each irrigation and are usually simpler and less costly than the fully automatic systems. Most semi-automated systems use mechanical or electronic timers to activate control structures at predetermined times. The irrigator usually determines when to begin irrigation and its duration and manually resets or returns the devices to their original positions or moves them from one location to another before the next irrigation. Such systems require communication between the controller and system components located in the field.

Fully automatic systems normally operate without operator attention except for periodic inspections and routine maintenance. The irrigator may determine when and how long to irrigate and turn water into the system or start programmed controllers to initiate the automated functions. Fully automatic systems may use soil moisture sensors, such as tensiometers or electrical resistance blocks to activate electrical controls when soil water is depleted to predetermined levels. Irrigation duration may be controlled by programmed timers, soil moisture sensors or surface water sensors. Fully automatic systems require a water supply available on demand such as from wells or farm reservoirs. Most farm systems however do not have the flexibility required for complete automation.

Automatic systems in fully automated systems, the human factor is eliminated and replaced by a computer specifically programmed to react appropriately to any changes in the parameters monitored by sensors. The automatic functions are activated by feedback from field units and corrections in the flow parameters by control of devices in the irrigation system until the desired performance level is attained.

This study was undertaken to develop an IoT based automated irrigation system for the vertical farming structure developed for carrying out vertical farming inside the rain shelter.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

2.1 RAIN SHELTER

Foale *et al.* (1985) postulated that a shelter must have a shape that minimizes horizontal and vertical wind loads while maintaining strength and excluding driving rain. Various types of mechanism to move the shelter are discussed and the features of a reliable controller are identified. As rain shelters are necessarily constructed in sites that are highly exposed to the elements they may be damaged by extreme winds and, where thunderstorms are frequent and intense, by lightning-induced pulses affecting the control circuitry. The designs recommended herein embody a high degree of reliability in operation and provide prompt warning of failure.

Legg *et al*. (1978) researched on two rain shelters, each covering an area of 210 m^2, which had been built at Rothamsted for use in tillage experiments and drought experiments. Each shelter automatically moves over the experimental area when rain starts, and moves away when rain stops; thus, all rain is kept off, but other aspects of the microclimate are little affected. Small experimental plots were used, and, except in the 0·5 m strips at the plot edges, the height and yield of a barley crop were uniform. Irrigation water to some plots was labelled with tritium; when applied to very dry plots, a measurable proportion of this water moved laterally by more than 1·0 m. However, the total quantity of water transferring between adjacent plots was not large enough to inconvenience the tillage or drought experiments.

2.2 VERTICAL FARMING

Despommier (2011) explores the potential of vertical farming as a solution to the challenges of feeding a growing world population in the 21^{st} century. Vertical farming offers the opportunity to rework the resources required for food production thereby reducing the demand pressure on land for agricultural activities. Vertical farming has a number of advantages over traditional farming including y ear-round production, reduced water use, no need for fossil fuels to harvest etc. The shift in farming approaches supports the probability of defining new usage of farmlands for multiple ecological functions that would be beneficial for environment and humanity. Regardless of location, vertical farming concept can be adapted to urban areas.

Al-Kodmany (2018) discusses the emerging need for vertical farms by examining issues related to food security, urban population growth, farmland shortages, “food miles”, and associated greenhouse gas emissions. He examines urban agriculture as a solution to these problems by merging food production and consumption in one place, with the vertical farm being suitable for urban areas where available land is limited and expensive. Recent advances in greenhouse technologies such as hydroponics, aeroponics, and aquaponics have provided a promising future to the vertical farm concept. He also speculates about the consequences, advantages, and disadvantages of the vertical farm’s implementation. These high-tech systems represent a paradigm shift in farming and food production and offer suitable and efficient methods for city farming by minimizing maintenance and maximizing yield.

Beacham *et al.* (2019) studied the main categories of vertical farming in order to help clarify this emerging but sometimes confusing area of agriculture and discusses how scientific investigations of the potential of vertical farming is currently lacking and will be required to help determine its feasibility as a method to assist meaningfully in global food production. Pressure on agricultural land from a rising population is necessitating the maximization of food production per unit area of cultivation. Attention is increasingly turning to Vertical Farming approaches in an attempt to provide a greater crop yield per square meter of land. However, this term has been used to cover a broad range of approaches, from personal- or community-scale vegetable and herb growing to vast skyscrapers for commercial production of a wide range of crops.

Kalantari *et al.* (2017) review the major opportunities and challenges of vertical farming, uses the framework of sustainability to examine the role of it in prospective food provision in cities. They also explain about the details of most effective vertical farming in around the world in different countries by evaluating the feasibility of vertical farming for various climate/ geographical areas by their type and technologies. Vertical Farming can be potentially beneficial in increasing food production, maintaining high quality and safety and contributing to sustainable urban farming.

Mir *et al.* (2022) covers the basics of the possible outcomes, benefits, and drawbacks of implementing a vertical farm. The vertical farm idea seems to have a bright future with recent technologies like hydroponics, aeroponics, and aquaponics. High-tech systems bring a change in farming and food production and are ideal for city farming because they minimise maintenance and maximise yield. These techniques as well as project prototypes could pave the way for a vertical farm to become a reality. During pandemics like COVID-19, vertical farming has emerged as a viable option for producing a wide variety of food crops to meet the nutritional needs of the growing global population.

2.3 SOIL MEDIA

Shrivastava and Rao (2002) examined the effectiveness of open and filled trenches for screening Rayleigh waves due to impulse loads for 3D problems. The effects of the geometric parameters of trench reducing ground displacements were studied in detail. The computational scheme involves the use of finite element method to discretize a large computational domain and the resulting integration dynamic equilibrium equations are integrated to get the response using Newmark's β method. Effectiveness of vertical trenches for vibration isolation of machine foundation and impulsive loads has been investigated by 3D FEM. Both, horizontal and vertical loadings have been considered. The effect of geometric parameters (viz. length, depth, etc.) has been studied.

Han and Sabin (2005) studied the dynamic impedances of a radially inhomogeneous viscoelastic soil layer based on a new boundary zone model with a nonreflective boundary. A parabolic variation of the medium properties is assumed, so that the boundary zone has properties smoothly approaching those of the outer zone to alleviate wave reflections from the interface between the two media. The researchers examined the excited soil layers vertically, torsionally and radially and the results were evaluated over a wide range of the parameters involved and compared with those obtained for a homogeneous layer, as well as compared with

Novak and Veletsos's solutions. Since this boundary-zone model includes mass and a nonreflective boundary, the impedances (soil stiffness and damping) presented in this paper are considered to be more suitable to practical applications.

González *et al.* (2015) aimed to calibrate and validate the HYDRUS-1D software package to model soil water dynamics in maize grown under a shelter, while considering various treatments of full and deficit irrigation. The study also compared water balance results of HYDRUS-1D and SIM Dual Kc, taking into account that the former computes results soil layer by soil layer, while the latter calculates for the entire soil profile without distinguishing between soil layers and helped to contribute for improving the background information of the web-based IRRIGA system used to support Brazilian farmers irrigation scheduling decisions. For the study, the field experiment was conducted at the experimental field site of the Agricultural Engineering Department, Federal University of Santa Maria (UFSM), Rio Grande do Sul State, Brazil and the HYDRUS-1D model successfully simulated the temporal variability of soil water dynamics in treatments irrigated with full and deficit irrigation.

2.4 DRIP IRRIGATION

Drip irrigation system is the method of applying uniform and precise amount of water directly to the root zone of the plants as per the requirement, through emitters at frequent intervals over a long period of time, via a low-pressure pipe network comprising of mains, sub mains & laterals. Various software’s were available for design and development of drip irrigation system (Reddy *et al.,* 2017*).* Drip irrigation provides an efficient method of fertilizer delivery and allows precise timing and uniform distribution of applied nutrients. Fertilizer application through drip irrigation (fertigation) can reduce fertilizer usage and minimize groundwater pollution due to fertilizer leaching from excessive irrigation. Fertigation events can be scheduled as often as irrigation, up to several times per season (Badr and El-Yazied, 2007).

Kumar *et al.* (2005) investigated a study related on effect of drip irrigation system on yield, quality and economic return of guava production in saline soil having pH 8.18 and EC 0.95 mmhos cm^{-1}. Guava has been planted at 5×5m and 6×6m in square system. Plants were irrigated with canal water using drip and flood irrigation systems. The results revealed that the drip irrigated guava plants started bearing at 3rd year of planting, whereas flood irrigated plants after fourth year of planting. The guava plants planted at 5 x 5 m had higher irrigation production efficiency than 6 x 6 m. Fruit weight and TSS and total sugars and vitamin C contents were superior in fruits obtained from drip-irrigated plants as compared to flood-irrigated ones.

Water is very precious to all the humans and as well as to the plants, trees. The major amount of fresh water is utilized by the agricultural industry for irrigation. By using drip irrigation, the water will be maintained at the constant level i.e., the water will reach the roots by going drop by drop. This is very important because this can only ensure the survival of the plants. Water can be applied at a single point on the land surface through devices called emitters or as a line source from either closely spaced emitters or tubes with continuous or equally spaced openings that discharge water a drop at a time. If the field is irrigated heavily with water, there are chances that the plant may die because of excessive irrigation. The water could also wash them away during irrigation if very strong force of water is released at the same time. On the other hand, if there is insufficient water, then also there are chances that the plants may die due to lack of water. So, it is very important for the farmer to maintain the content on the field (Prathyusha and Suman, 2012).

Swamy *et al.* (2013) conducted a study on microcontroller-based drip irrigation system. He suggested that use of proper method of irrigation is important and it is well known that irrigation by drip is very economical and efficient. In the conventional drip irrigation system, the farmer has to keep watch on irrigation timetable, which is different for different crops. The project makes the irrigation automated. With the use of low-cost sensors and the simple circuitry makes their project a low-cost product, which can be bought even by a poor farmer. Their project is best suited for places where water is scares and has to be used in limited quantity. Also, third world countries can afford this simple and low-cost solution for irrigation and obtain good yield on crops.

Mistry *et al.* (2017) experimented a study to analyse the hydraulic performance drip irrigation system on emitter discharge, coefficient of variation and emission uniformity, statistical uniformity coefficient, variation of emitter flow, emitter flow uniformity and absolute uniformity. The experiment was conducted to collect discharge rate at nine different pressures i.e., 0.3, 0.4, 0.5, 0.6, 0.7, 0.9, 1.0, 1.1 and 1.2 kg/cm2 to assess the hydraulic performance of drip irrigation system. Emission uniformity (Eu) of the system decides the uniformity distribution of discharge by each emitter or uniformity distribution of water to each crop. Result shows that the discharge flow rate of emitter is increased when the increase of the pressure and the coefficient of variation is increased when the pressure is decreased means the pressure directly affected the discharge rate of emitter.

The water requirements for irrigation have been very demanding nowadays. There is a requirement for a wise irrigation system which will save a good amount of water. In the world, water and food are two of the most important resource, which makes agriculture crucial to mankind. With advancing technology growth in the agriculture sector, the internet-of-thing (IOT) technology provides a solution much simpler and faster for drip irrigation. A microcontroller along with a node MCU is used for sending the data in the cloud in the server. A web-based application is also developed so that the user can take appropriate action accordingly for drip irrigations. This web application accurately controls the water level by employing a soil moisture sensor and microcontroller system in the gardens. This is realized by integrating the sensors within the developed prototype to observe the soil moisture level, humidity, and temperature conditions where these data send through the microcontroller and node MCU for the requirement of water to the plants. Crop health can be monitored and controlled through mobile and desktop computers and provides a solution for smart farming, agricultural fields, Lawns, gardening, etc. (Jain *et al.*, 2020).

Menon (2021) gives an idea about remote monitoring of drip irrigation with microcircuits and sensors which was to develop an engineering solution to help reduce the difficulties with drip irrigation and to aid farmers with water conservation. Compared to traditional methods, drip irrigation can save over one million gallons of water per acre per year. The main issue highlighted during the study was that the drip lines are located underground and not visible, as farms are located several miles away from the irrigation system. Due to this distance, it is difficult for farmers to monitor if the crop is irrigated as scheduled. This paper shares the development and testing of a prototype that utilized a pressure transducer integrated to a microcontroller to upload information to the cloud and display it through a web portal on a farmer’s smartphone. Observations over multiple weeks showed the capability of the system to remotely sense and transmit the operation of drip irrigation. In addition, the simulations showed a system capable of detecting pipe bursts and clogs. Through field observation, the design was modified to be more robust against rodent damage. Overall, this solution eliminated a major hurdle in detecting the functionality of buried irrigation systems by displaying the information remotely at a reasonable cost.

Drip irrigation is a modern, advanced, high-tech and environmental technology, which providing right scientific support, enables to get high yields and economic benefits with minimum consequences for the environment. The cultivation of high-productivity hybrids of vegetables and fruit when using modern technology of drip irrigation provides high yields and standard quality of production, that is the crop production is transformed into a stable profitable business. At the same time, applying modern methods of evaluation of the feasibility of investment will increase the validity of management decisions as to the selection of crops and their combinations and will facilitate investment attraction (Nadia *et al., 202*0)

Palvan *et al.* (2023) developed an automated control system of drip irrigation. The system is automated through integration, which allows controlling the entire irrigation process through a control device with controllers, shows the main elements of the drip irrigation system that carry out complete controlling and the procedure for moistening the soil and fertilizing, presents a functional diagram of the automated system for regulating soil moisture, as well as pressure in the pipeline. Mathematical modelling of water consumption of crops under drip and combined irrigation is considered, the influencing factors that require regulation, which will ensure the management of plant development. The complexity of the simulated system "Plant-moisture-soil-atmosphere-solar radiation" and its subsystems are explained by a large number of interrelated factors of various nature and requires the construction of numerical schemes, computer simulation using various computer programs.

2.5 Automation

In automated irrigation system, soil moisture content is automatically measured every few seconds using moisture sensors. If the moisture in the soil falls below a minimum threshold for the agricultural crop in the land, the system sends a wireless message to the valves in the irrigation pipelines, including the valve controlling access to the main water source, causing the power supply to the valves to be altered, opening them and allowing water to flow into the land for crop irrigation. Soil moisture is continuously measured throughout the entire irrigation process. When the moisture level in the soil rises above a maximum threshold for the crop, the system sends another wireless message to the valves in the irrigation pipelines, altering the power supply to the valves to shut them and cease land irrigation. This automated irrigation system can also be used to upgrade existing drip irrigation systems, surface irrigation systems, and sprinkler irrigation systems to enable them overcome all the limitations they inherently possess.

Shirgure (2012) stated that the research on automated irrigation in the Nagpur mandarin fruit yield was higher (30.91 tones/ha) with irrigation on alternate day 120 minutes three times, followed by irrigation scheduled with 90 minutes interval two times daily (30.11 tones/ha). Fruit weight (154.7 g), TSS (10.22 Brix) and juice percent (40.77%) was found with automatic irrigation at alternate day with 120 minute three times.

John *et al*. (2013) and Saavoss *et al*. (2016) demonstrated that more timely irrigation decisions through the use of sensor networks in rain shelters increased the yield and quality of snapdragon (cut flowers) by 30% depending on season and cultivar.

Hong and Hsieh (2016) compared conventional timer control and soil moisture control method with the integrated control strategy in wireless irrigation that consisted of microcontroller, weather sensor, soil sensor and blue tooth module and reported that test group had higher performance in plant height, leaf number, fresh weight and dry weight. Electricity and water usage also presents the ICS could save 90% of the electricity and water usage when compared to timer control method data for height of basil are mean ± SE of 23 plants.

Guery *et al*. (2016) developed an automated sensor-based control technology for strawberry. Soil moisture was monitored with loggers which are connected with sensors at 10 and 20 cm below the root zone depth. Sensor controlled irrigation was initiated when volumetric moisture content decreases below the set point 19% and reported that during the 15 weeks of the study (January 27-May 11, 2016), pulse-irrigation applied 7,618 m^3 ha^{-1} of irrigation water in 2-5 pulses per day, compared to3,141 m^3 ha^{-1} applied with sensor-based control (5 8.8 % less water).

Kumar (2017) conducted experiment to test the performance evaluation of indigenously developed automated system on vegetable crops under different methods of irrigation and reported that water productivity increased under automated drip irrigation system. The water saving range was 39.6 – 48.6% using automated drip irrigation over manual control check basin irrigation.

Liu and Xu (2018) studied automatic irrigation control for soilless culture of lettuce and found that the intelligent irrigation reduce the irrigation amount, drainage amount and increase the IWUE compared to the manual control irrigation, the IWUE of intelligent irrigation is 68.03% and 98.61% higher than manual control irrigation in spring and summer, respectively.

Sandra et al. (2019) conducted automatic irrigation experiments in plum tree and found that in 2017 and 2018, the treatments gave a higher yield than the C treatment. These differences were due to the higher number of fruits per tree in the RDI and A treatments, though the differences were only significant in 2017 between the C and A treatments. In 2018 although A showed some tendency towards higher productions, the differences with RDI did not become significant.

Jat and *et al*. (2019) studied on automation of micro-climate control through sensors and controllers under open-field and polyhouse culture, at irrigation levels of 80% or 100% of crop evapotranspiration in capsicum and reported that programmable logic controller-based automation system worked well for microclimate control leading to 93% and 53% higher yield and fruit weight, respectively in the polyhouse than open-field cultivation. The SPAD value increased with increase in plant growth up to 90 DAT in all treatments. At 90 DAT, maximum SPAD value (58.5) was in the polyhouse due to the 100% Etc. treatment.

Barkunan *et al*. (2019) proposes an automation of drip irrigation in which the Smartphone initially captures soil image, calculates its wetness level and transmits the data onto the microcontroller through GMS module intermittently. The microcontroller decides the irrigation and sends the status of the field to the farmer’s mobile phone. The system is tested for paddy field for over a period of three months. It is observed from the experimental setup, that it saves nearly 41.5% and 13% of water compared to the conventional flood and drip irrigation methods respectively.

MATERIALS & METHODS

CHAPTER 3

MATERIALS AND METHODS

This chapter includes materials used for the project and methodologies adopted for the study under the title "An IoT based Drip Irrigation for Vertical Farming in Rain shelter" conducted in Kelappaji College of Agricultural Engineering and Technology, Tavanur, Malappuram, Kerala.

3.1 STUDY AREA

Kelappaji College of Agricultural Engineering and Technology, the only Agricultural Engineering college in Kerala, is situated in southern banks of holy river, Bharathapuzha, at Tavanur in the Malappuram district and is named after the freedom fighter and social reformer Sri. K. Kelappan. This institution is part of the Kerala Agricultural University.

3.2 RAIN SHELTER

The experiment was conducted in the Rain shelter of Precision Farming Development Centre (PFDC), which is located in the instructional farm of KCAET. The study was carried out using Amaranthus during the month of February to May, 2023 in vertical farming structures under the rain shelter. The site is situated at 10°51'18''N latitude and 75°59'11'' E longitude at an altitude of 8.54 m above mean sea level (Gopika, 2020)

Rain shelter (20 m in length, 10 m in width and 4 m in height) is oriented in East-West direction. It is covered with 200-micron UV stabilized polyethylene film and the frame is made up of GI pipes. Type of rain shelter is gable shaped which consists of sufficient ventilation with a side wall, covered with 50 mesh net on all four sides at a height of 1m from ground and roof covering of 200-micron polythene with 85% light transmission.

Fig 3.1 Rain shelter

3.3 VERTICAL FARMING STRUCTURE

The Vertical farming structure has a base width of 210 cm and a height of 200 cm. The structure has two slanting faces of rectangular cross section having dimensions of 175 cm × 200 cm each which shown in fig 3.2. The platforms with 30 cm width & 50 cm height were constructed across the slanting face.

Fig 3.2 Vertical farming structure

3.4 COMPONENTS OF IOT BASED AUTOMATION SYSTEM

3.4.1 Pump

12 Volt water pump is a dc electric water pump motor that powered by a 12V direct current power supply. It uses centrifugal force that generated by high speed rotated impeller to booster, transfer, lift or circulate water. As a small water pump, 12V water pump is low in price, small in size, long working lifespan, so it's very popular with the market and users.

It is ideal for non-submersible pumps for a variety of liquid and air movement applications. As it provides enough pressure, used with nozzles to make the spray systems. Under the powered condition, the pump can suck water through the tube up to 2m and can pump water vertically up to 3m. This pump runs very quietly with a sound level under 30db while pumping the liquid. Whereas it is also capable of pumping air, but pumping air is quite noisy compared with the liquid. This mini aquarium pump also provides a filter inside as well as a suction cup. Pumps use mechanical energy to pressurize liquids and move them throughout systems. While they are critical to everyday processes, they also consume a lot of energy, which is why pump control and automation are such huge topics right now. Pump controllers will often accept both user commands or inputs from external sensors. These inputs can modulate pump speed or duty cycle automatically to achieve desired outputs for flow rates and pressures.

There are three layers of automation when it comes to managing and maintaining pumps: Monitoring, Controlling, and Automating. Pump monitoring involves supervising pump operation to identify performance issues. It does not include any form of control. Pump monitoring is crucial, as it gives your pump a voice to tell you when something is wrong. Operators can monitor pumps in person or remotely. Many workers will focus their monitoring efforts on pump power supplies or vibration. Though it is possible to monitor pump flow rates and discharge pressures.

Fig 3.3 12V Pump

Pump control is the actuation layer on top of monitoring. Again, it accounts for when we use digital controllers to change pump characteristics, i.e., speed and on/off state. Automation takes things a step further. Basic pump control requires someone to manually intervene to change a pump's parameters. Pump automation is when we incorporate external sensors or processes to change pump outputs automatically.

3.4.2 Liquid Crystal Display (LCD)

Fig 3.4 LCD display

It is one kind of electronic display module used in a wide range of applications in various circuits and devices.

Advantages: Inexpensive

Compact, thin & light

Low power consumption

Simply programmable

No limitations for displaying custom characters

A 16×2 LCD display is very basic module which is commonly used nowadays. A 16×2 LCD indicates that it can display 16 characters per line and there are 2 such lines. LCD consists of two registers: Command & Data. Command registers stores various commands given to display. Data register stores data to be displayed. Thee process of controlling display involves putting the data that form the image of what you want to display into the data registers, then putting instructions in the instruction register.

LCD consumes much less power than LED and gas display because they work on the principle of blocking light rather than emitting it where an LED emits light, the liquid crystals in an LCD produces an image using a backlight. A display is made up of millions of pixels. The quality of display commonly refers to the number of pixels.

3.4.3 I2C Module

It is very useful module to interface serial connection to parallel data, especially used for LCD displays etc. It is an easy-to-use display module, which makes display easier. A 16×2 I2C has a feature for blue blacklit display with 2 rows of 16 characters. Potentiometer on back to adjust display brightness and contrast.

The inter-integrated circuit provides a set of functions to configure the device's I2C module. The driver supports operation in both master and slave mode and provides functions to initialise the module, to send and receive data, to obtain status information, and to manage interrupts.

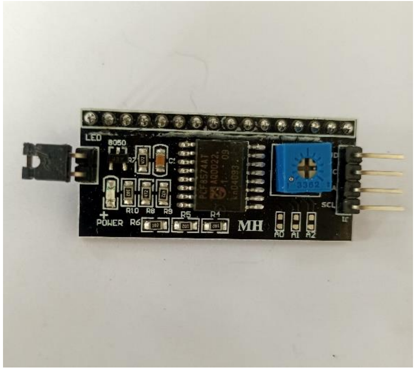


Fig 3.5 I2C Module

3.4.4 Relay module

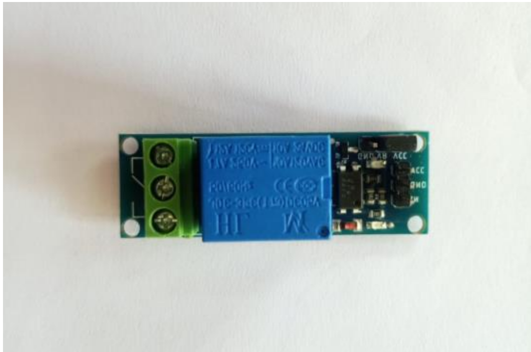


Fig 3.6 Relay Module

A power relay module is an electrical switch that is operated by an electromagnet. The electromagnet is activated by a separate low-power signal from a micro controller. When activated, the electromagnet pulls to either open or close an electrical circuit. A simple relay consists of wire coil wrapped around a soft iron core, or solenoid, an iron yoke that delivers a low reluctance path for magnetic flux, a movable iron armature and one or more sets of contacts. The movable armature is hinged to the yoke and linked to one or more set of the moving contacts. Held in place by a spring, the armature leaves a gap in the magnetic circuit when the relay is de-energized. While in this position, one of the two sets of contacts is closed while the other set remains open.

When electrical current is passed through a coil, it generates a magnetic field that in turn activates the armature. This movement of the movable contacts makes or breaks a connection with the fixed contact. When the relay is de-energized, the sets of contacts that were closed, open and breaks the connection and vice versa if the contacts were open. When switching off the current to the coil, the armature is returned, by force, to its relaxed position. This force is usually provided by a spring, but gravity can also be used in certain applications.

3.4.5. 12 V DC supply adapter

A 12 V DC supply adapter is a device that converts AC (Alternating Current) power from a wall outlet into DC power with a constant voltage of 12 volts. This type of adapter is commonly used to power electronic devices that require a stable 12-volt DC power supply, such as routers, modems, LED lights, and other low-power devices.

The adapter typically consists of a transformer, rectifier, voltage regulator, and other electronic components that work together to convert the AC power to DC power with the desired voltage level. The adapter usually has a barrel-shaped plug on one end that can be inserted into the device's power jack, and a wall plug on the other end that can be connected to a power outlet. It can also be used in Battery backups of both internal and external models. This DC 12V adapter is usually compact in size and multi-protected against over-loading, over-current, over-heating and short circuit.

Fig 3.7 12V DC Adapter

3.4.6 Breadboard

A breadboard also known as protoboard is a type of solderless electronic circuit building. It is used to build an electronic circuit on a breadboard without any soldering. It is a white rectangular board with small embedded holes to insert electronic components. White plastic is the material that is used to create breadboards. The breadboards are available as per the specified point holes. For example, 400-point breadboard, 830-point breadboard, etc.

There are three parts in a breadboard: The top and bottom holes of a row in a breadboard are connected horizontally, and the centre part is connected vertically. It means a single horizontal line of a breadboard has the same connection. It is because the metal strip underneath the breadboard at the top and bottom are connected horizontally. Hence, it provides the same connection in a row. The two top and bottom parts of a breadboard are generally used for power connections. The vertical connection of the centre part means a single vertical line in a breadboard provides the same connection. It is useful when we need to connect the different components in series. There are two types of the breadboard, namely Solderless and solder breadboard.

3.4.6.1 Solderless breadboards**:** - It do not require any soldering after the electronic components are plugged in. The leads or ends of the components are inserted into the holes of a breadboard for its functioning.

3.4.6.2 Solder breadboard: - It is also a board that has a tiny hole embedded into it and can insert the terminal of the electronic components into the board. After the connection is rechecked, we can solder these components. The common difference between solder and Solderless breadboards is the reusability. Today, most of the breadboards are Solderless breadboards. We can directly plug in the electronic components and connect it with the external power supply.

The clips are often called tie points or contact points. The number of tie points is often given in the specification of the bread board. The spacing between the clips (lead pitch) is typically 0.1 in (2.54 mm). To use the bread board, the legs of components are placed in the holes. Each set of holes connected by a metal strip underneath forms a node. A node is a point in a circuit where two components are connected. Connections between different components are formed by 26 putting their legs in a common node. The long top and bottom row of holes are usually used for power supply connections. The rest of the circuit is built by placing components and connecting them together with jumper wires or solid conductor wires, for ease of use. Typically, the spring clips are rated for 1 ampere at 5 volts and 0.333 amperes at 15 volts (5 watts).

Terminal strips are the main areas, to hold most of the electronic components. In the middle of a terminal strip of a breadboard, one typically finds a notch running in parallel to the long side. The notch is to mark the centre line of the terminal strip. The clips on the right and left of the notch are each connected in a radial way; typically, five clips (i.e., beneath five holes) in a row on each side of the notch are electrically connected. The five clip columns on the left of the notch are often marked as A, B, C, D, and E, while the ones on the right are marked F, G, H, I and J.

Bus strips are to provide power to the electronic components. A bus strip usually contains two columns: one for ground and one for a supply voltage. However, some breadboards only provide a single-column power distributions bus strip on each long side. Typically, the column intended for a supply voltage is marked in red, while the column for ground is marked in blue or black. Some manufacturers connect all terminals in a column. This design provides a circuit designer with some more control and flexibility in designing the circuit. Bus strips typically run down one or both sides of a terminal strip or between terminal strips. On large breadboards additional bus strips can often be found on the top and bottom of terminal strips.

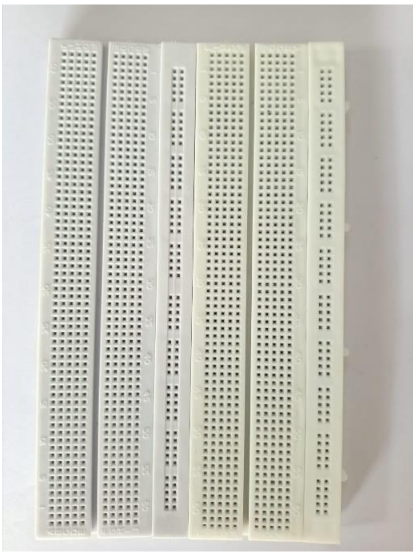
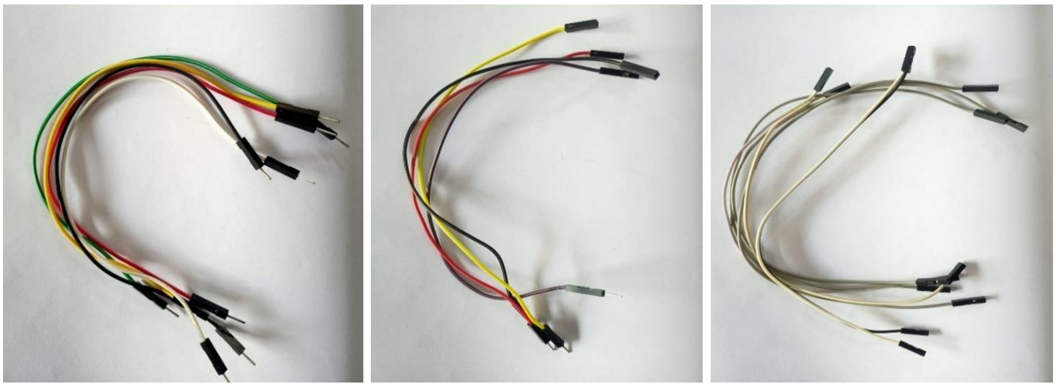


Fig 3.8 Bread board

3.4.7 Jumper wires

Jumper wires are simply wires that have connector pins at each end, allowing them to be used to connect two points to each other without soldering. Jumper wires are typically used with breadboards and other prototyping tools in order to make it easy to change a circuit as needed. Jumper wires come in three versions:

- Male-to-male jumper
- Male-to-female jumper
- Female-to-female jumper



(a) (b) (c)

Fig 3.9 (a) Male-to-male (b) Male-to-female (c) Female-to-female

Two types of head shapes: square head and round head.

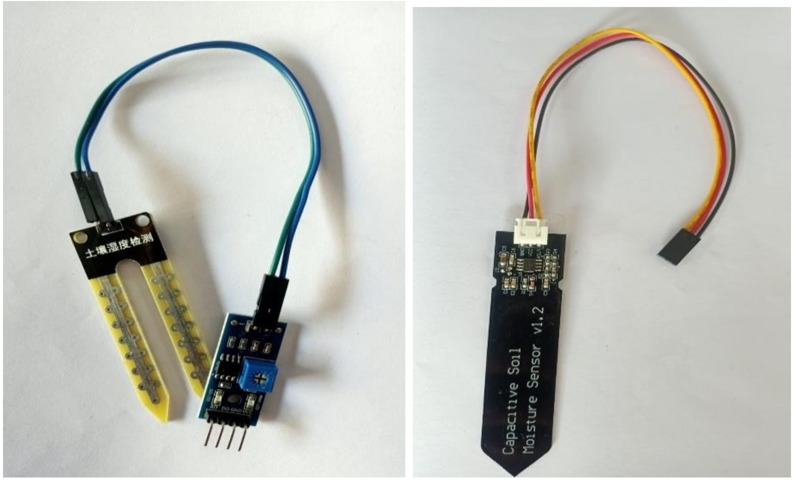
The difference between each is in the *endpoint* of the wire. Male ends have a pin protruding and can plug into things, while female ends do not but are also used for plugging. Moreover, a male connector is referred to as a plug and has a solid pin for centre conduction. Meanwhile, a female connector is referred to as a jack and has a centre conductor with a hole in it to accept the male pin. Male-to-male jumper wires are the most commonly used.

3.4.8 Soil moisture sensors

Soil moisture sensors are electronic devices that are used to measure the amount of moisture present in the soil. These sensors are essential for precision agriculture, as they allow farmers to monitor and manage the water content in the soil to optimize plant growth and reduce water waste. Soil moisture sensors are widely used in agriculture for irrigation management and crop monitoring.

There are mainly two type of soil moisture sensors, resistive soil moisture sensors and capacitive moisture sensors. A resistive soil moisture sensor works by using the relationship between the electrical resistance and water content to gauge the moisture level of the soil. A capacitive moisture sensor works by measuring the changes in capacitance caused by the changes in the dielectric. It does not measure moisture directly (pure water does not conduct electricity well), instead it measures the ions that are dissolved in the moisture. These ions and their concentration can be affected by a number of factors, for example adding fertilizer for instance will decrease the resistance of the soil.

Capacitive measuring basically measures the dielectric that is formed by the soil and the water is the most important factor that affects the dielectric. Capacitive measuring has some advantages, it not only avoids corrosion of the probe but also gives a better reading of the moisture content of the soil as opposed to using a resistive soil moisture sensor. Since the contacts (the plus plate and the minus plate of the capacitor) are not exposed to the soil, there is no corrosion of the sensor itself. In this project, we used capacitive soil moisture sensor for the experiment.



(a) **(b)**

Fig 3.10 (a) Resistive sensor (b) Capacitive sensor

3.4.9 Node MCU ESP 12E

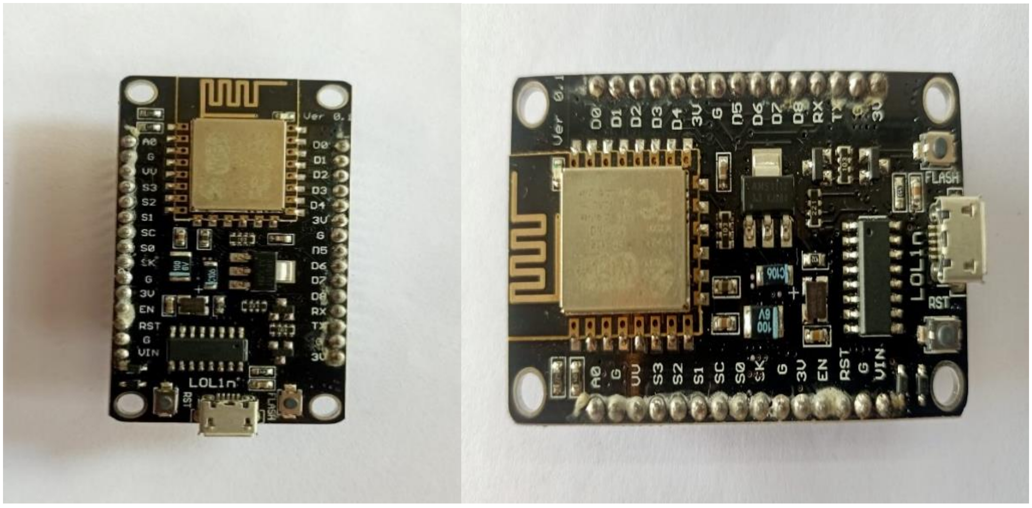


Fig 3.11 Node MCU ESP 12E

ESP-12E is a Wi-Fi Module based on ESP8266EX SoC, using the ESP-12E Module as the base board, the Node MCU team developed ESP8266 Node MCU ESP-12E. It's perfect for IoT applications, and other situations where wireless connectivity is required. This chip has a great deal in common with the Arduino – they're both micro controller-equipped prototyping boards which can be programmed using the Arduino IDE. There have been many different ESP modules over the years, each with their own advantages and drawbacks. There have been just two types of Node MCU boards, however: versions 0.9 and 1.0. The 0.9 version is blue and comes loaded with the ESP-12 chip, while the 1.0 is black, and comes with the ESP-12E (which stands for 'enhanced').

Table 3.1 Features of ESP8266 Node MCU ESP-12E

Microcontroller	ESP-8266 32-bit
Clock speed	80 MHz
USB converter	CP2102
USB connectors	Micro USB
Operating voltage	3.3 V
Flash memory	4 MB
Digital i/o	11
Analog inputs	1
Communicators	Serial, SPI. I2C and 1-Wire via software libraries
Wi-Fi	Built-in 802.11 b/g/n

The ESP8266 works with 3.3 volts rather than the 5 used on most Arduino units. To save space, there's no independent socket for a power supply; rather, the unit is powered via a micro-USB cable and provides 3.3 volts to other components via 3 pins evenly spaced around the edge of the unit. There are also 4 pins going to ground.

Important pins in NodeMCU

- ADC (Analog to digital converter) Channel (A0): -

To get the NodeMCU to read an analog voltage, like the one produced by a moisture sensor or a potentiometer, connect the signal to the ADC pin. This pin is connected to a device called an Analog to Digital Converter, which will turn that analog voltage into a digital value that your microcontroller can make sense of ADCs work by placing a row of comparators in series. If the voltage read is higher than a fixed voltage, a one will be output, while if it's lower, a zero will be output. On the ESP8266, the ADC is 10-bit, which means it have 10 zeros and ones for a total of 1024 possible values. This makes it possible to record precise changes in voltage.

- General purpose input & output (GPIO) Pins: -

The NodeMCU ESP8266-12E board has a large number of GPIO pins, which provides the ability to connect multiple sensors and actuators to the board. This makes the board highly expandable and capable of handling complex projects. These pins are highly flexible and can be programmed using various programming languages, such as C, C++, Python, and Lua. GPIO pins are used for interfacing with various sensors and actuators, such as temperature sensors, humidity sensors, motion sensors, LEDs, motors, etc. They can be programmed as input pins to read the sensor data or output pins to control the actuators.

Table 3.2 Pin number on Node MCU

Pin number on NodeMCU development kit	ESP8266 Internal GPIO Pin number
D0	GPIO16
D1	GPIO5
D2	GPIO4
D3	GPIO0
D4	GPIO2
D5	GPIO14
D6	GPIO12
D7	GPIO13
D8	GPIO15
D9/RX	GPIO3
D10/TX	GPIO1
D11/SD2	GPIO9
D12/SD3	GPIO10

All the GPIO pins except D0 have some other functions in NodeMCU. RX, TX, SD2, SD3 are not mostly used as GPIO, they are used for other internal process.

- SPI (serial peripheral interface) Pins

The SPI interface allows the NodeMCU to communicate with a wide variety of peripherals, such as sensors, displays, and other microcontrollers. It uses a master/slave architecture, where the NodeMCU acts as the master and the peripheral device acts as the slave. The SPI pins on NodeMCU ESP-12E include MOSI (Master Out Slave In), MISO (Master in Slave Out), SCK (Serial Clock), and SS (Slave Select). MOSI is used for transmitting data from the master to the slave, while MISO is used for transmitting data from the slave to the master. SCK provides the clock signal for synchronizing the communication between the master and the slave. SPI communication is faster than other serial communication protocols such as I2C and UART, and it can support higher data rates. This makes it ideal for applications that require high-speed data transfer, such as data logging, sensor data acquisition, and real-time control.

- I2C (Inter-Integrated Circuit) Pins

I2C (Inter-Integrated Circuit) is serial bus interface connection protocol. It is also called as TWI (two wire interface) since it uses only two wires for communication. Those two wires are SDA (serial data) and SCL (serial clock). SDA wire is used for data exchange in between master and slave device. SCL is used for the synchronous clock in between master and slave device. D1 (SCL) & D2 (SDA) are used for I2C communication.

- UART (Universal Asynchronous Receiver Transmitter) Pins

UART enables communication between the NodeMCU and other devices using a serial protocol. This makes it possible to exchange data with other devices in a variety of formats. It is also used for programming and debugging the NodeMCU, which allows for a serial connection between the microcontroller and a computer, which is used to upload code to the microcontroller or debug any issues that arise during programming.

3.4.10 WI-FI

Fig 3.12 Mercury 4G LTE Wi-fi

The Mercury 4G LTE Wi-Fi USB Dongle is a portable device that provides high-speed internet connectivity via 4G LTE technology. It is designed to work with any device that has a USB port and supports the use of a mobile broadband dongle.

The Mercury 4G LTE Dongle also comes with a built-in Wi-Fi hotspot feature, allowing to share the internet connection with other devices, such as smartphones, tablets, and laptops. The device is compact and easy to carry around, making it ideal for people who need to stay connected while on the move.

Insert a SIM card from a mobile network provider that supports 4G LTE to use the Mercury Dongle. Once the SIM card is inserted, plug the dongle into the USB port of a device like laptop and it will establish a connection to the internet. The dongle supports download speeds of up to 150 Mbps and upload speeds of up to 50 Mbps, making it suitable for streaming, browsing, and other internet-based activities. Availability and quality of the internet connection may vary depending on factors such as network coverage, signal strength, and network congestion.

Pros: -

- Enable you to access the Internet from anywhere.
- Are lightweight, portable and easy to carry.
- Can be used abroad.

- Are plug-and-play and so easy to use.
- Can be purchased for short-term use.
- Provide a secure connection to the 4G network, unlike Wi-Fi hotspots.

Cons: -

- Portable USB versions are increasingly hard to come by.
- You may find there are restrictions on daily downloads.
- For PAYG contracts you'll have to pay for the device upfront.

3.5 METHODOLOGY

3.5.1 Soil Media Preparation

Soil media preparation is a crucial step in agriculture, as it directly affects the growth and health of plants. Soil media is a mixture of various organic and inorganic components that provide the necessary nutrients, water, and support to plants for their proper growth and development. The primary purpose of soil media preparation is to create an ideal growing environment for plants that can help them thrive and produce healthy and high-quality yields. The process of soil media preparation involves selecting the appropriate components based on the type of plants being grown, climate conditions, and the desired soil characteristics. The components are then mixed in the right proportion to create a uniform and well-draining soil media.

For preparing soil media, soil, sand, dried and powdered cow dung & vermicompost was mixed in 1: ½:1: ½. This mixture will provide the necessary nutrients and soil structure suitable for young seedlings and are filled in grow bags where the seeds are sown.

Soil moisture constants are parameters used to describe the amount and availability of water in soil. There are several soil moisture constants that are commonly used, including:

- Field capacity: This is the amount of water that soil can hold against gravity, and is usually expressed as a percentage of the soil's dry weight. At field capacity, the soil is completely saturated with water and excess water has drained away.

- Wilting point: This is the point at which plants are no longer able to extract water from the soil. At this point, the soil is extremely dry and only retains water in the form of hygroscopic moisture.

- Permanent wilting point: This is the point at which plants are unable to recover even if water is added to the soil. At this point, the soil is so dry that the water is held too tightly by the soil particles to be extracted by plant roots.

- Available water capacity: This is the amount of water that can be extracted by plants between field capacity and the wilting point. It is an important parameter for irrigation management and crop growth.

- Saturation point: This is the point at which the soil is completely saturated with water, and any additional water will result in runoff or percolation.

Prepared soil sample was taken and send to Centre Water Resources Development & Management (CWRDM), Kozhikode for testing its field capacity and wilting point using Pressure plate apparatus. Resulting measurement thus we obtained was 23.47 as field capacity and 13.37 as wilting point.

Fig 3.13 Soil media preparation

3.5.2. Planting Method

Fig 3.14 Planting of seedlings

Crop was selected based on the characteristics such as height of the plant, vitality and resistance to pest and diseases. Amaranthus of CO-1 variety was selected for the study. Seedlings of about 15cm length were transplanted to the prepared soil media.

Table 3.3. Growth of Amaranthus by conventional method of irrigation

WEEK 1	Soil Media preparation and Planting	Mar 15- Mar 21
WEEK 2	Initial growth phase	Mar 22- Mar 28
WEEK 3	Maturation phase	Mar 29- Apr 4
WEEK 4	Examination and Harvesting	Apr 5- Apr 11

Table 3.4. Growth of Amaranthus by IoT based drip irrigation

WEEK 1	Soil Media preparation and Planting	Apr 27-Apr 30
WEEK 2	Installation of drip irrigation system and its automation	May 1- May 5
WEEK 3	Moisture analysis through Blynk	May 7- May 18
WEEK 4	Examination and Harvesting	May 19 – May 20

3.5.3. Installation of Drip Irrigation System

Irrigation was provided daily through drip irrigation system. By applying this system, adequate amount of water only supplied to the crop root zone which reduces wastage of water. Firstly, we collected water from source to 500l tank through PVC. From the mains water will be collected by the laterals. The water was applied to the crops using micro tubes fitted with emitters having discharge capacity of 4 lph. At the end of each line an end cap was provided for flushing the line. Materials required for providing irrigation are shown in table 3.3.

Fig 3.15 Drip Installation

Table 3.5 Materials used for Drip irrigation

Material	Quantity
Tank	1
PVC pipe (1.5 inch)	17 m
Laterals (16 mm)	18m
Microtube	9 m
Emitters (4 lph)	21 nos
T connector (16 mm) (1.5 inch)	1 4
Microtube connector	21 nos
Bend (16 mm) (1.5 inch)	6 3
End caps	10

3.5.4. Blynk 2.0

Blynk is an Internet of Things platform, which makes controlling hardware remotely and visualizing its data very easy. We can create your own interfaces using the free Blynk App. Every Wi-Fi, Bluetooth/BLE, Ethernet and Serial device is able to connect to the Blynk cloud or a locally running server.

3.5.4.1. Prerequisites

1. Arduino IDE (1.8.5 or newer)
2. Wi-Fi

3.5.4.2. Include ESP8266 Core to Arduino IDE

1) Goto 'Preferences' and enter the following URL to Additional Board Manager URLs

“http://arduino.esp8266.com/stable/package_esp8266com_index.json

2) Open the Boards Manager (*Tools* > *Board Menu*)

3) Search for "esp8266" and install the latest version

4) Select your board under *Tools* > *Board* and define Baud Rate etc.

3.5.4.3. Install Blynk libraries

1) Install the latest release of the Blynk libraries on GitHub

2) Unpack it

3) Move the libraries to *C:/User//Documents/Arduino/libraries*

3.5.4.4. Install Blynk App

1) Download the App for iOS or Android

Before creating your project, you have to create an account or sign in.

1. Click 'Create New Project'
2. Choose your device and connection type (NodeMCU, WiFi)
3. Receive and note down your 'Auth Token'
4. Open the 'Widget Box' ('+')
5. Add a button
6. Name it and select switch mode

```
#define BLYNK_TEMPLATE_ID "TMPL3TtkpF3Vt"
#define BLYNK_TEMPLATE_NAME "Plant watering
system"
#define BLYNK_AUTH_TOKEN
"jMIsSYixL9fbQxb4_WiNZsObZ5W8UFhm"
```

Fig 3.16 Firmware Configuration

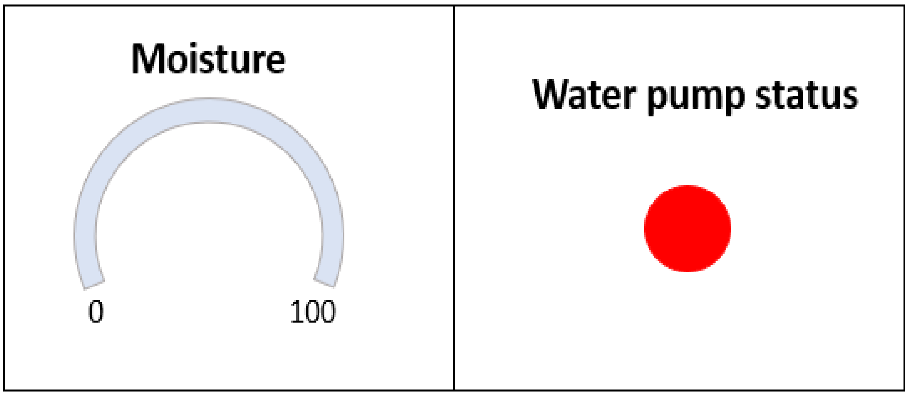


FIG 3.17 Selected widgets

3.5.4.5. Connecting Arduino to Blynk

1. Open the Arduino IDE
2. Go to Examples > Blynk > Boards WiFi and select your dev board
3. Enter your 'Auth Token' (char auth [])
4. Enter your WiFi credentials (char ssid[], char pass[])
5. Compile and Upload

3.5.5. Circuit description and programming

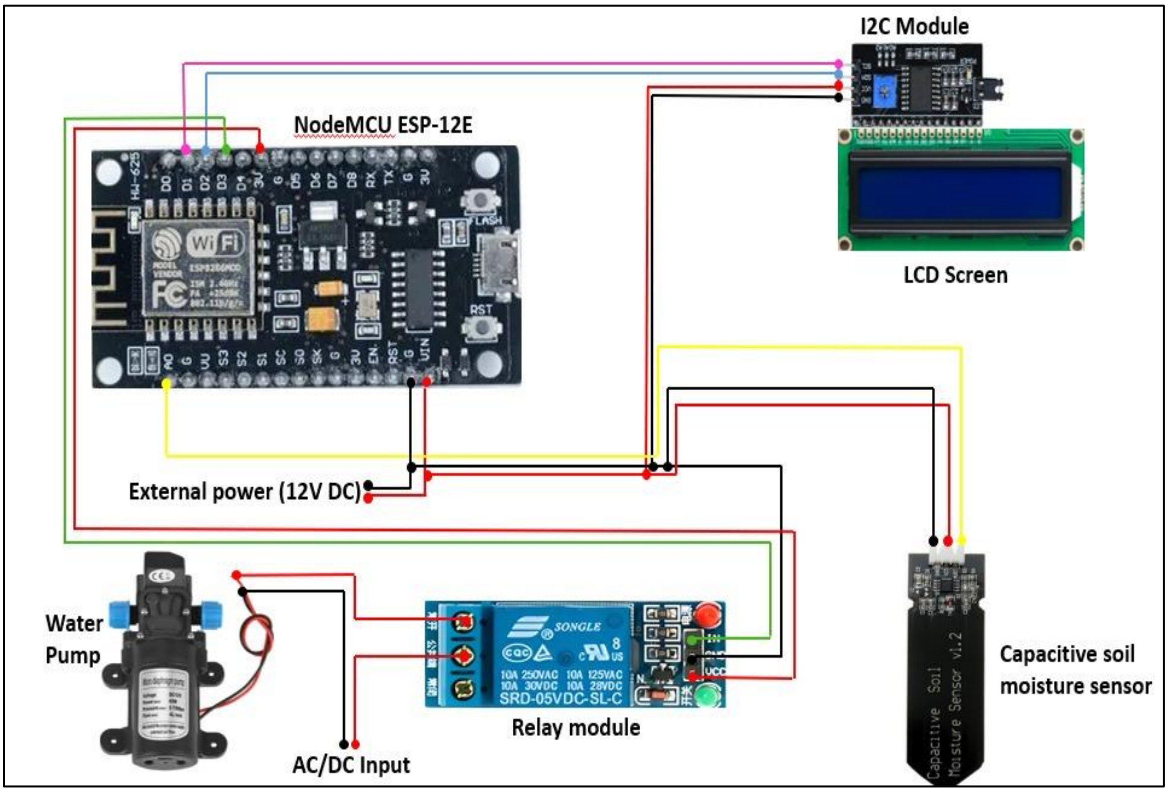


Fig 3.18 Circuit diagram

The circuit consists of certain components which are connected in a bread-board. The components are the following.

- Node MCU ESP-12 E
- I2C Module
- LCD Screen
- Capacitive soil moisture sensor
- Relay module
- External power (12 V DC)
- Water pump
- AC/DC input
- Jumper wires

The Node MCU ESP-12E is the basic component which operates at a voltage of 3.3V and contains certain digital i/o pins and Analog Input pins. The soil moisture sensor used here is of capacitive type consisting three pin headers which includes VCC, GND, and AO. The positive terminal VCC is connected to one of the power pin VIN, negative terminal GND to the negative pin(G) and the analog input 0 to the corresponding pin of node MCU. Similarly, the pins of other components are connected to the corresponding pins of micro controller as shown in the circuit.

3.5.6. Coding

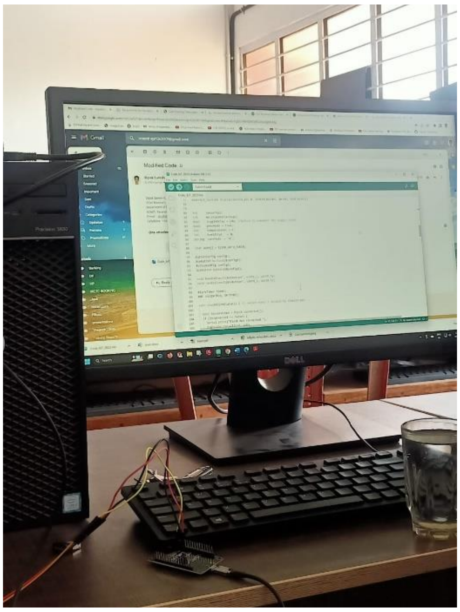


Fig 3.19 Programming

The code uploaded in the ESP 12-E for the working of circuit and operation of Blynk application are shown below:

```
#include <LiquidCrystal_I2C.h>

#define BLYNK_PRINT Serial

#include <ESP8266WiFi.h>

#include <BlynkSimpleEsp8266.h>

#define BLYNK_TEMPLATE_ID "TMPL3TtkpF3Vt"

#define BLYNK_TEMPLATE_NAME "Plant watering system"

#define BLYNK_AUTH_TOKEN "jMIsSYixL9fbQxb4_WiNZsObZ5W8UFhm"
```

```
//Initialize the LCD display
//LiquidCrystal_I2C lcd(0x27, 16, 2);
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
LiquidCrystal_I2C lcd(0x3F,16,2);
char auth[] = "jMIsSYixL9fbQxb4_WiNZsObZ5W8UFhm";//Enter your Auth token
char ssid[] = "Mercury_0822";//Enter your WIFI name
char pass[] = "1234567890";//Enter your WIFI password

BlynkTimer timer;
bool Relay = 0;

//Define component pins
#define sensor A0
#define waterPump D3

void setup() {
Serial.begin(9600);
pinMode(waterPump, OUTPUT);
digitalWrite(waterPump, HIGH);
lcd.begin();
lcd.backlight();

Blynk.begin(auth, ssid, pass, "blynk.cloud", 80);
```

```
lcd.setCursor(1, 0);
lcd.print("System Loading");
for (int a = 0; a <= 15; a++)
{
lcd.setCursor(a, 1);
lcd.print(".");
delay (500);
}
lcd.clear();

//Call the function
timer.setInterval(100L, soilMoistureSensor);
}

//Get the soil moisture values
void soilMoistureSensor() {
int value = analogRead(sensor);
value = map(value, 0, 1024, 0, 100);
value = (value - 100) * -1;

Blynk.virtualWrite(V0, value);
lcd.setCursor(0, 0);
lcd.print("Moisture :");
lcd.print(value);
lcd.print(" ");
```

```
if (value < 25)
{
digitalWrite(waterPump, LOW);
lcd.setCursor(0, 1);
lcd.print("Motor is ON ");
Blynk.virtualWrite(V1, HIGH);
}
Else
{
digitalWrite(waterPump, HIGH);
lcd.setCursor(0, 1);
lcd.print("Motor is OFF");
Blynk.virtualWrite(V1, LOW);
}
}
void loop() {
Blynk.run();//Run the Blynk library
timer.run();//Run the Blynk timer
}
```

3.5.6. Installation of Circuit in the Site

Installed circuit system in the site during 2nd phase of our project. Firstly, took current connection from nearby pump house through service wire extension. Installed our circuit set up at one side of vertical farming and dipped the sensor in a growbag. Wi-Fi modem is also provided.

Fig 3.20 Circuit installed in the site

3.5.7. Working of the Automation System

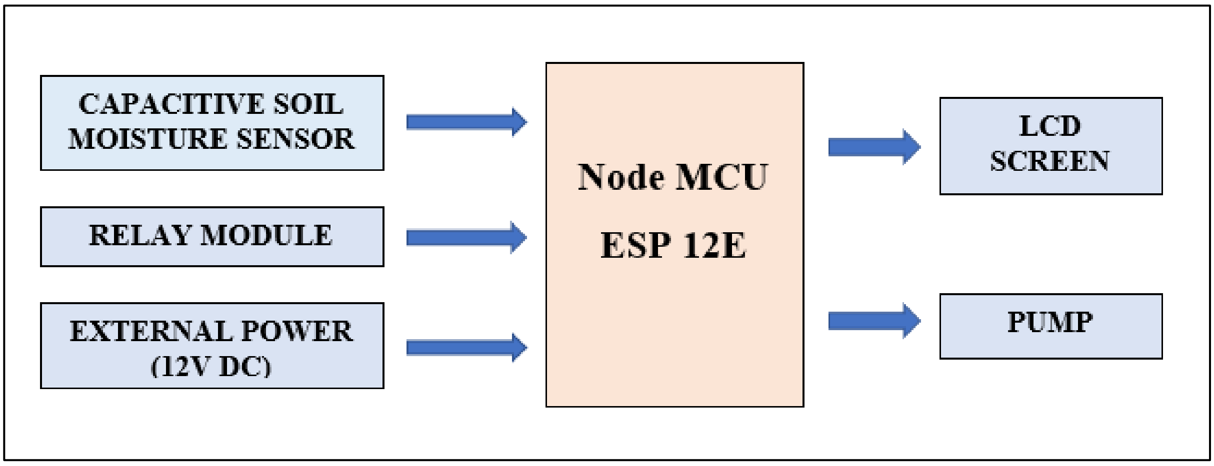


Fig 3.21 Connection diagram

The control strategy for individual parameters to be controlled as follows:

Considering the field capacity and permanent wilting point, the threshold limit of moisture content was set up in the ESP as 25%. When the moisture is below the threshold limit the pump starts working and the water from the tank is pumped to laterals and finally to the drippers and stops working when the value reaches 25%.

The moisture values are shown on the LCD screen and the Blynk application installed in the mobile phone connected using Wi-Fi modem. With the help of these data, variations in moisture content during each hour, day and week can be easily analyzed.

3.5.8. Monitoring of Automation through Blynk

The device named ‘Plant Watering System’ consists of a dashboard containing informations about the moisture sensed on hourly, daily, and weekly basis and the pump water status. It also depicts the moisture variations using charts enabling the user to understand the modulations over the period.

The timeline bar shows the online and offline status of the circuit connection, where it drafts the different timely responses of the electric supply system. Here, data of latest, last hour, half day, last day and last week are acquired.

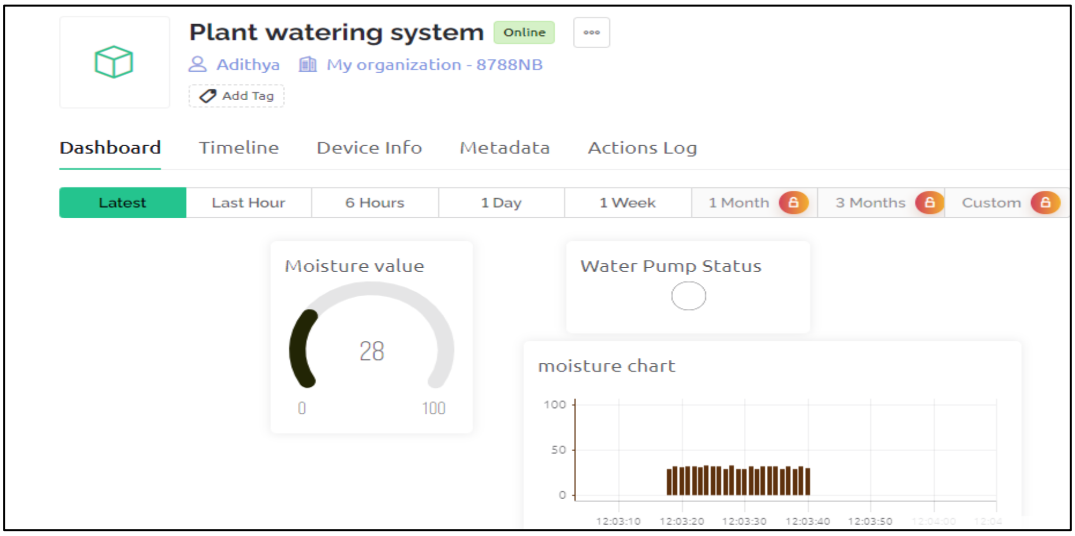


Fig 3.22 Dashboard view of blynk

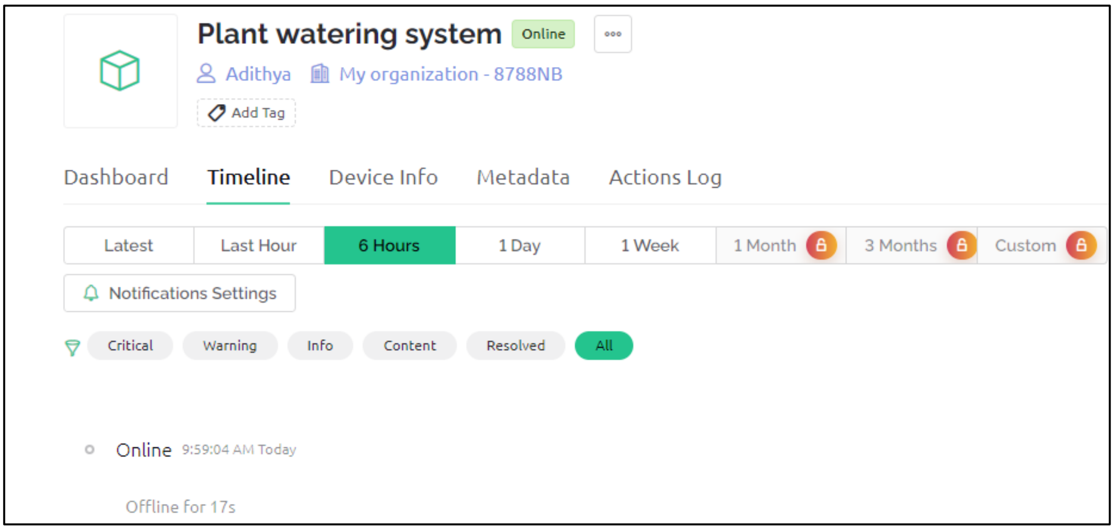


Fig 3.23 Timeline status of blynk

3.5.9. Bio-Metric Analysis of Amaranthus

Two plants each from crops cultivated using conventional and automatic method from vertical farming structure were tagged at random as observation plants. Bio-metric observations such as plant height, number of branches, width of leaf, weight of individual observation crop and the total yield was measured before each harvest. The collected data were tabulated and compared. The data collected are the following:

a. **Height of the plant (cm)**

Height of the randomly selected plants was measured from the surface of rooting media to the top of the plant before each harvest.

b. **Number of branches**

Number of branches in the tagged plants of each structure was measured before each harvest.

c. **Width of the leaf**

The longest distance between any two points on the blade edge perpendicular to the leaf length axis was measured before each harvest.

d. **Weight of the plant (grams)**

The weight of the individual plant immediately after its harvest was measured.

e. Total yield (grams)

The total weight of the plants after each harvest was recorded.

3.5.10. Harvesting of Amaranthus

Depending on variety and plant type, amaranthus can be harvested 20-45 days after planting or sowing when attained a height of 30-40 cm.

The crop under conventional method of irrigation was harvested on 11th April when it attained a height of minimum 50cm and the crop cultivated under automated condition was harvested on 20th May after attaining a height of minimum 70cm.

Fig 3.24 Harvesting of crops

RESULTS AND DISCUSSION

CHAPTER 4
RESULTS & DISCUSSION

The observations made during the study and the major results obtained are discussed in this chapter.

4.1 ANALYSIS OF IoT BASED SYSTEM

The working of drip irrigation using microcontrollers are analyzed using Blynk application. When the moisture decreases and falls down to 25, the water pump starts working and the moisture level increases to a certain value till the sensor senses a value greater than the threshold limit. The widgets added to the device in Blynk such as water pump status and moisture gauge shows the accurate values that is being shown in LCD screen in the circuit.

4.1.1. Moisture Analysis through Blynk

During the maturation period, the moisture being recorded was analysed through blynk application and it gives the accurate values throughout the crop period. The soil moisture was analysed from May 7 to May 18.

Thus, the moisture variations on daily and weekly basis are depicted below.

4.1.1.1. Moisture analysis on daily basis

On May 7, the initial moisture already present was 30 and it has been reduced to 24 within few hours. The automated system analysed the moisture content present in the soil through sensor and the pump starts operating, thus provided water through emitters. This increased moisture content to 28 and the system continued.

The moisture chart on blynk app and its graphical variation on May 7 is given below:

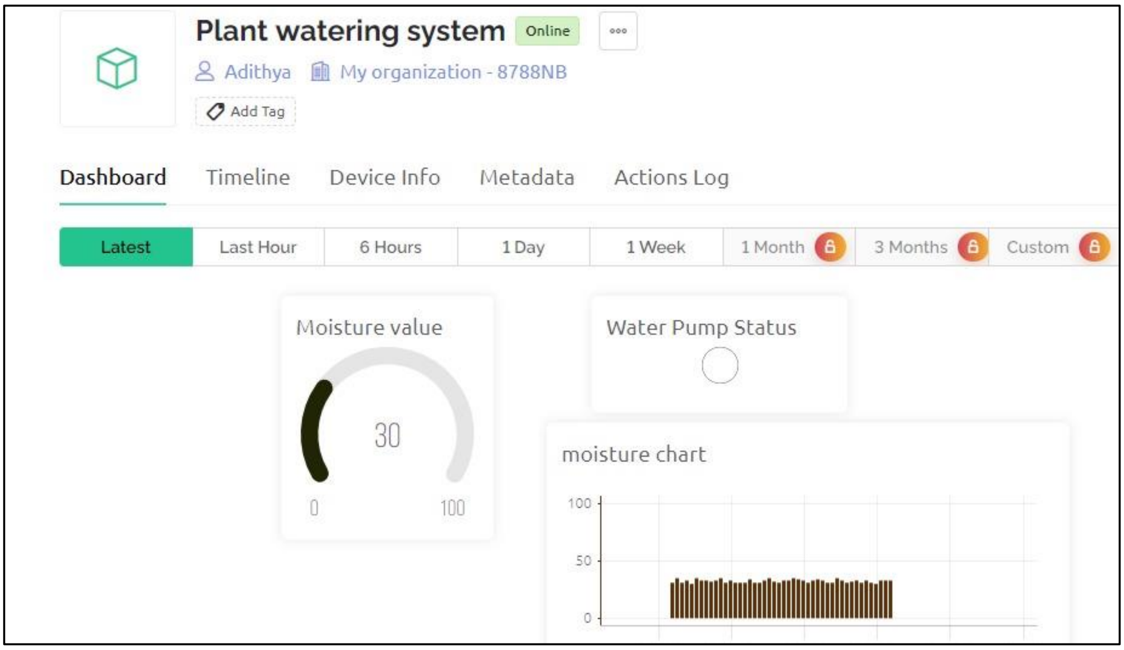


Fig 4.1 Initial moisture data from Blynk

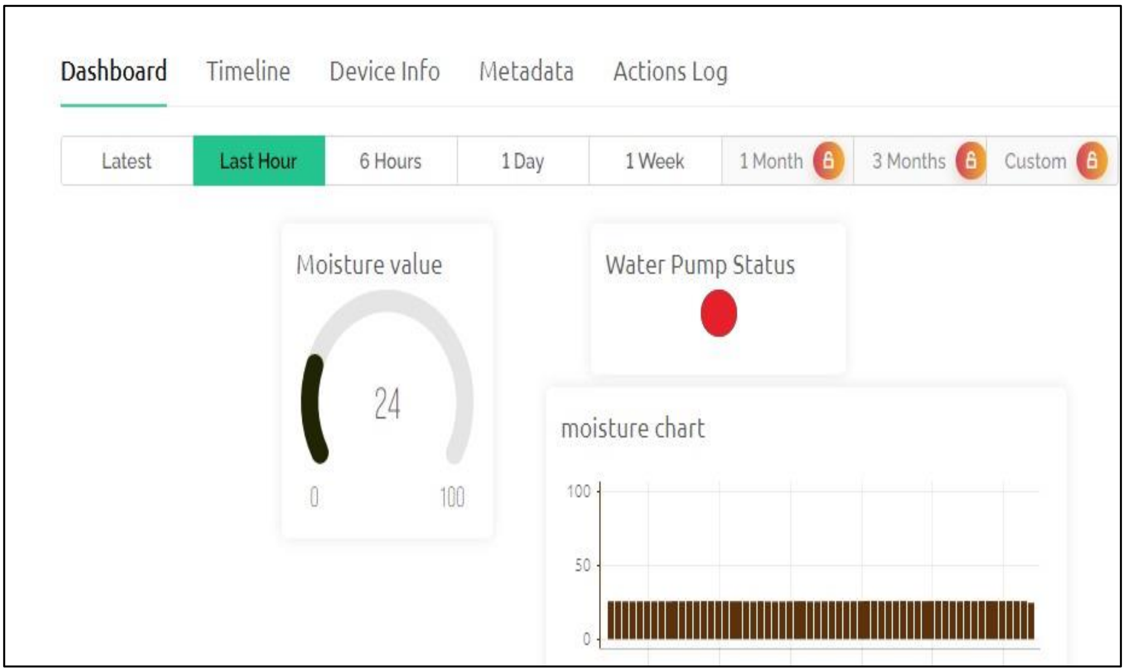


Fig 4.2 Pump status-ON detecting reduced moisture value

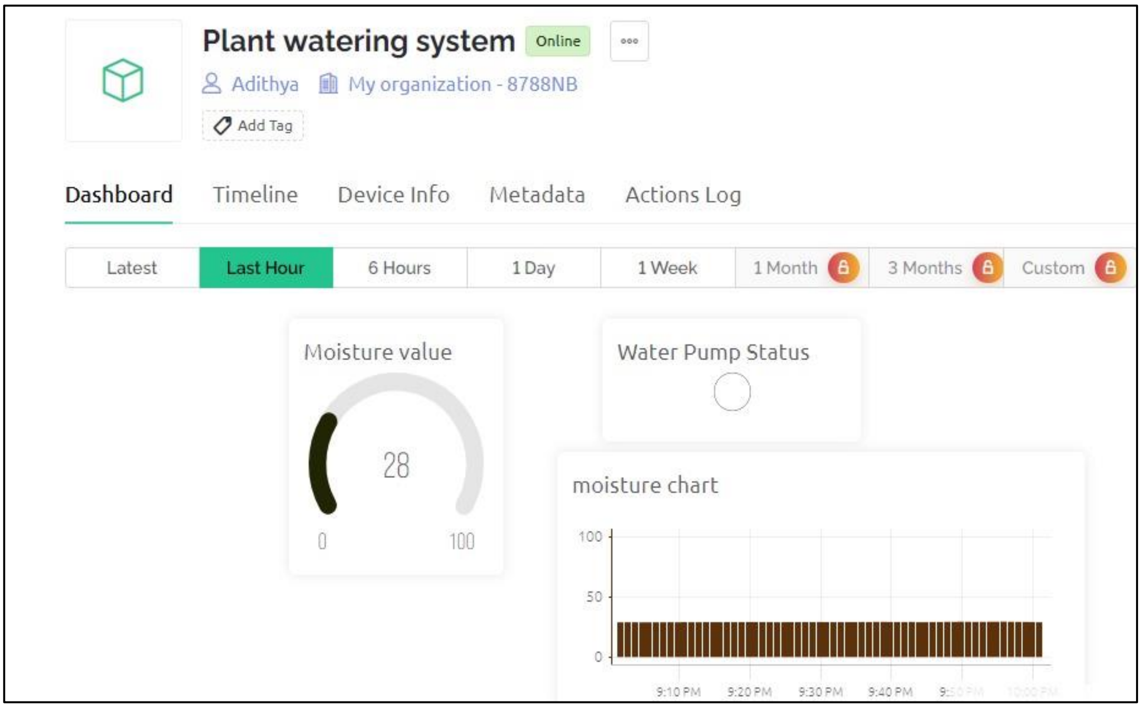


Fig 4.3 Final moisture level after pumping

4.1.1.2. Observations based on 12hour analysis of one day (may7)

Table 4.1 Moisture data for 12 hrs

Sl .NO	TIME	MOISTURE VALUE
1	8 AM TO 9 AM	30
2	9 AM TO 10 AM	24
3	10 AM TO 11 AM	28
4	11AM TO 12 PM	29
5	12 PM TO 1 PM	25
6	1 PM TO 2 PM	31
7	2 PM TO 3 PM	28
8	3 PM TO 4 PM	27

9	4 PM TO 5 PM	24
10	5 PM TO 6 PM	29
11	6 PM TO 7 PM	28
12	7 PM TO 8PM	26

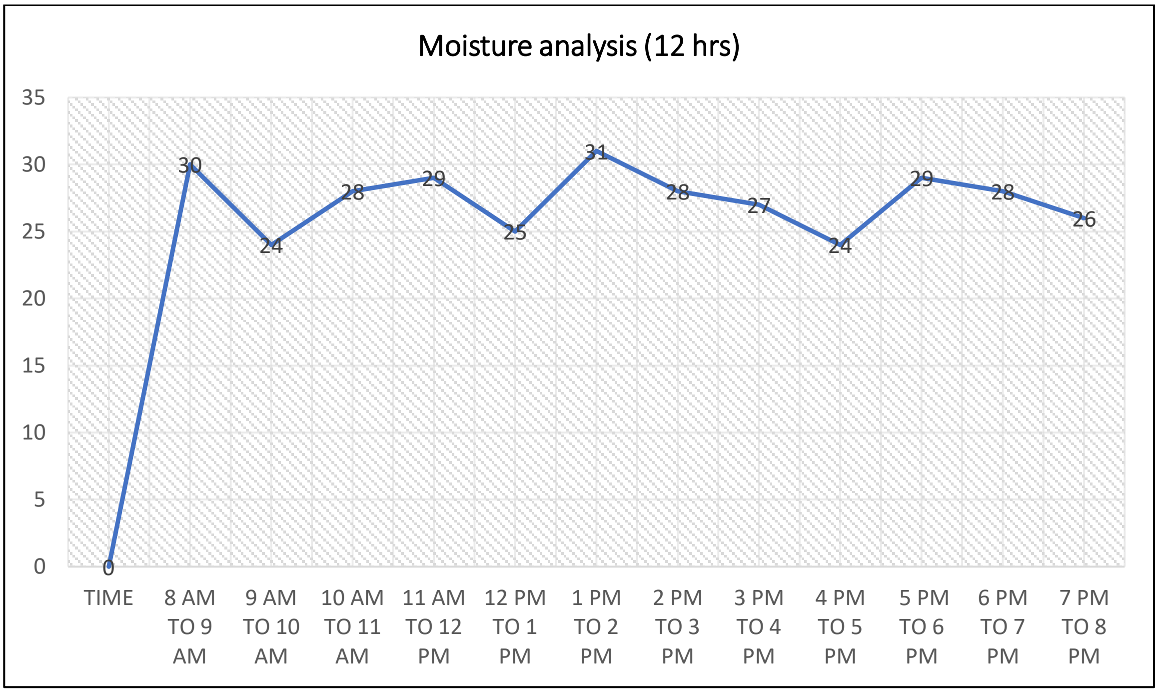


Fig 4.4 Moisture chart (12hrs)

4.1.1.3. Moisture analysis on weekly basis:

Moisture analysis for weekly basis from May 7 to May 13 was been recorded. There has been various fluctuations depending on its growth phase until it attain maturity. The procedure for analysis was same as that of daily basis.

The moisture chart on blynk app and its graphical variation from May 7 to May 13 is given below:

Table 4.2 Moisture data for one week

Day	Average moisture
May-07	28
May-08	31
May-09	29
May-10	30
May-11	27
May-12	30
May-13	29

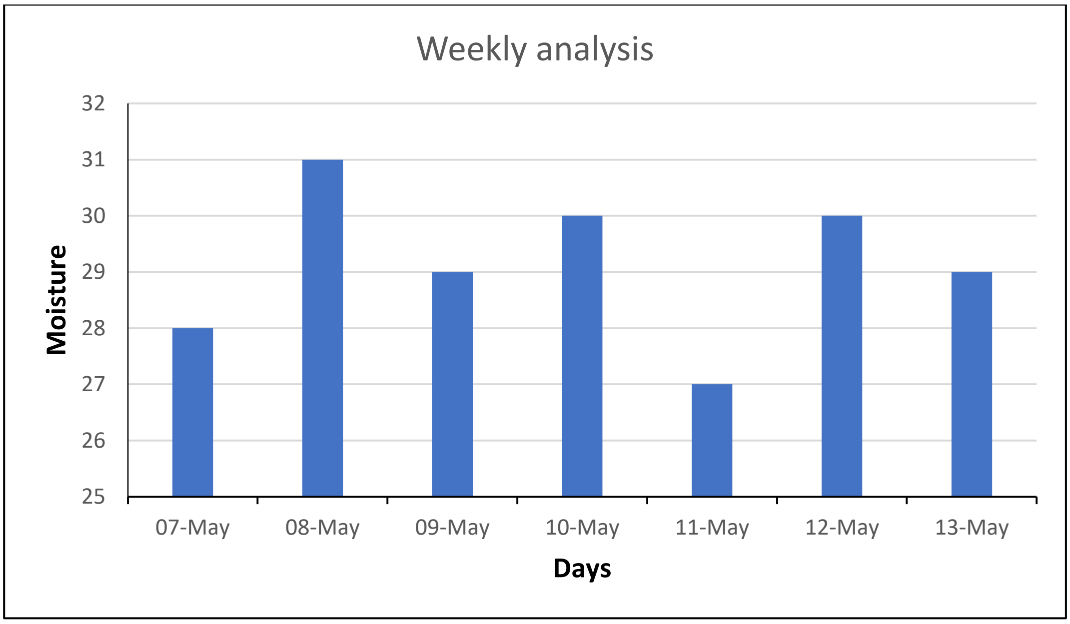


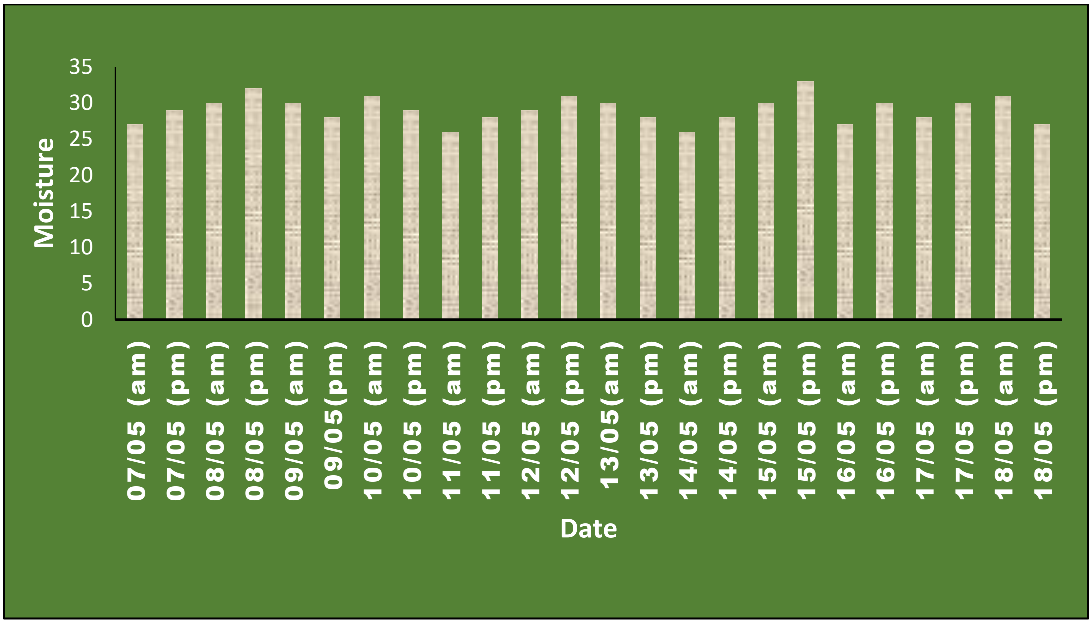
Fig 4.5 Moisture chart (1 week)

4.1.2 Overall Moisture Analysis

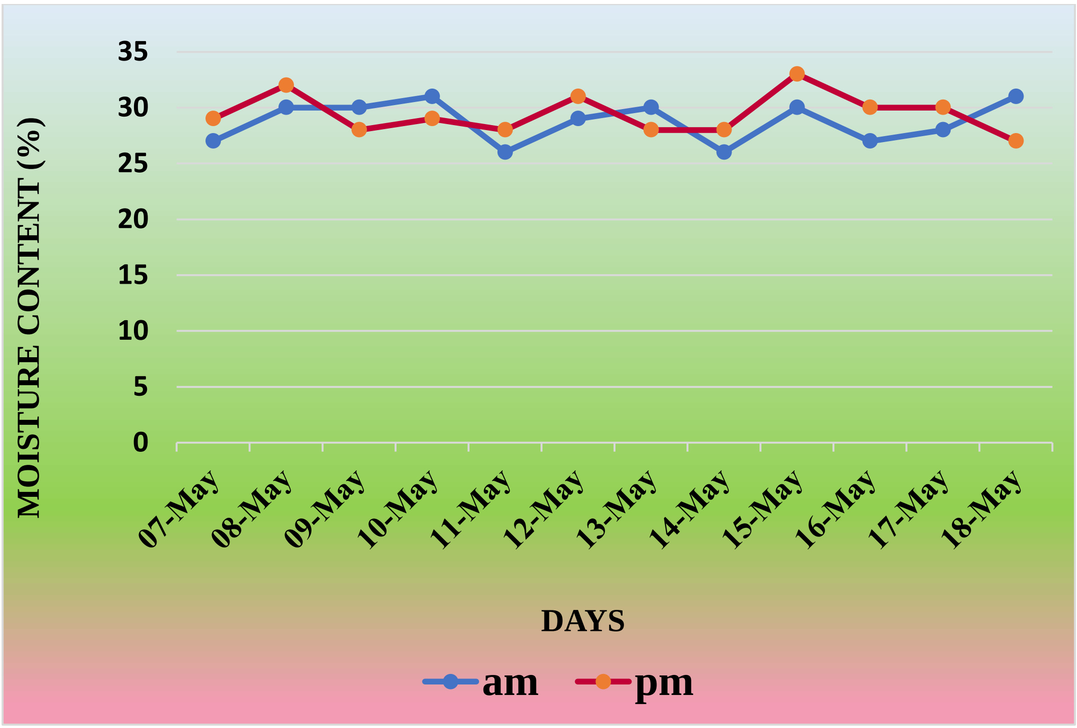
The moisture values were acquired from the blynk and has been recorded accurately using charts. This shows the fluctuations of moisture and the working of drip irrigation system throughout the monitoring period.

Table 4.3 Overall moisture values

Date	Time	
	am	pm
07/05	27	29
08/05	30	32
09/05	30	28
10/05	31	29
11/05	26	28
12/05	29	31
13/05	30	28
14/05	26	28
15/05	30	33
16/05	27	30
17/05	28	30
18/05	31	27



(a)



(b)

Fig 4.6 Overall moisture analysis charts (10 days)

4.2 COMPARISON WITH MOISTURE OBTAINED FROM OVEN DRYING METHOD

4.2.1. Oven drying method

The method is based on removing soil moisture by oven-drying a soil sample until the weight remains constant. The moisture content (%) is calculated from the sample weight before and after drying. The moist sample was kept in clean container. The mass of the soil and container with lid was determined. With the lid removed, the container was then placed in the oven and maintains the temperature of the oven between 105 °C-110 °C for about 16-24 hours. After drying the container was removed from the oven and allowed to cool. The lid was then replaced, and the mass of the container and the dry soil was found. The water content was calculated by the following equation:

$$\mathbf{W = (M_2 - M_3)/ (M_3 - M_1)}$$

Where,

M_1 = mass of container with lid

M_2 = mass of container with lid and wet soil

M_3 = mass of container with lid and dry soil.

4.2.1.1. Observed data

M_1 = 27.1 gm

M_2 = 110.65 gm

M_3 = 92.5 gm

W = (110.65 – 92.05) / (92.05 – 27.1)

= 28.63%

Thus, we obtained the moisture content of about 29% which is similar to the values observed from the moisture analysis charts.

4.3 STAGES OF GROWTH IN AUTOMATION METHOD

Fig 4.7 Initial and growing phases of amaranths

Fig 4.8 Elongation phase

Fig4.9 Matured stage before harvesting

4.4. BIO-METRIC OBSERVATIONS

The different bio-metric parameters of the tagged individual crops are noted and the changes in growth pattern are observed.

4.4.1 Observations of Crop under Automation System

Fig 4.10 Width of the crop **Fig 4.11 Height of the crop** **Fig 4.12 Total yield**

4.4.2 Biometric Comparison of Crops

Table 4.4 Biometric comparison of crops harvested using conventional method and IoT based drip irrigation (IoT)

Parameter	Using conventional method	Using IoT
Length of crop	50 – 60 cm	80 – 120 cm
Width of leaf	8 – 12 cm	14 – 18 cm
Weight of crop	3Kg	4Kg

4.5. COMPARISON OF CONVENTIONAL METHOD AND IOT BASED DRIP IRRIGATION

Table 4.5 Comparison of methods

CONVENTIONAL METHOD OF IRRIGATION	IOT BASED DRIP IRRIGATION
Minimum yield	Increased yield
Length of crop is moderate	Crop length is maximum
Pest attack was maximum	Less problem of disease and pests
Inadequate usage of water	Precise usage of water
Weed growth maximum	Weed growth minimum
More Labour Requirement	Labour Saving
Deep root depth	Shallow root depth

4.6. ADVANTAGES OF IOT BASED DRIP IRRIGATION

Several advantages are held in IoT based drip irrigation, which felt during our experiment. Following are some of the advantages:

- Timely irrigation — plants being watered when needed.
- Management of higher flow rates.
- Accurate cut-off of water compared to manual checking.
- Reduced runoff of water and nutrients.
- Reduced labour requirement
- Less weed growth.

4.7. CONSTRAINTS OF IOT BASED DRIP IRRIGATION

Even though there are several merits, some demerits were also found in IoT based drip irrigation. The disadvantages are listed below:

- Daily monitoring is required.
- Needs constant electric supply.
- Costly compared to conventional method.
- Skill is required to install and operate the system.
- Possibility of clogging of drippers due to continuous application.

4.8. COST ANALYSIS

Table 4.6 Cost Analysis

Sl. No.	**Components**	**Qty**	**Rate (Rupees/unit)**	**Cost**
	Drip Irrigation Components			
1.	PVC Pipe (1.5 inch)	8m	30	240
2.	12mm Lateral Pipe	8m	10	80

3.	Micro-tube	15m	3	45
4.	4lph dripper	25	3	75
			Total	440
	Circuit Components			
5.	Node MCU 12E	1	400	400
6.	LCD Display	1	220	220
7.	I2C Module	1	240	240
8.	Relay Module	1	210	210
9.	Mercury Wi-fi	1	2300	2300
10.	Capacitive Moisture sensor	1	135	135
11.	12V DC Adapter	1	250	250
12.	Jumper wires	20	5	100
13.	12V Pump	1	950	950
14.	Bread board	2	100	200
			Total	5005
	Accessories			
15.	Grow bag	21	20	42
16.	Vermi compost	8Kg	70	560
17.	End caps	10	1	10
18.	Cable tie	1	150	150
19.	Extension wire	4m	21	84
20.	Jably clip ½ inch	4	5	20

21.	Wifi Adapter	1	250	250
22.	Others (M seal, PVC bond, tape, SIM etc.)			500
			Total	1994
	Total			**6939/-**

4.9. FUTURE SCOPE OF IOT BASED DRIP IRRIGATION

In the coming years, the demand for new, low-cost, low-power drip irrigation technology will continue to grow, particularly in developing countries.

- It can be more intelligent system which predicts user actions, nutrient level of plants, time to harvest etc.
- With machine learning algorithms, more advancements can be done in the future.
- Different types of climatic parameters including temperature, EC, RH etc can be incorporated.
- Number of sensors can be increased according to the area of cultivation.
- Providing water pump for controlling option to farmers.

CHAPTER 5

SUMMARY AND CONCLUSION

The study employed a comparative analysis to assess the performance of conventional irrigation and IoT based automated drip irrigation using soil moisture sensors. Amaranths Co-1 variety was selected as the crop of choice and cultivated under both conditions. The biometric observations of the crop were noted for evaluation. The crops were grown in a vertical farming structure installed in the rainshelter oriented in east-west direction which is located in the instructional farm of KCAET Tavanur.

Soil media was prepared by mixing soil, sand, dried and powdered cow dung & vermicompost in the ratio 1: ½:1: ½ on volume basis. Total 21 grow bags were filled with 2 seedlings each on the vertical farming structure where one row consists of 3 growbags. This mixture was provided with fertilizers as per the package of practices recommendation of Kerala Agricultural University.

During the initial phase of study, Amarathus crop was grown with manual irrigation. In the second phase of study, Amaranthus crop with IoT based automated drip irrigation was provided. For this, Node MCU ESP 12-E microcontroller was coded using Arduino IDE and Blynk application was also used for the purpose. Various components like capacitive moisture sensor, I2C module, LCD display, relay, pump etc., were connected to Node MCU based on the pin configurations, and AC current was provided to this circuit. When the sensor detects low moisture in the soil, pump will be automatically turned ON and provide water to the drip irrigation system and automatically turn off when soil attain required moisture. Live moisture content of soil and pump status were obtained in mobile phone through Blynk application.

The soil moisture sensor was analyzed from May 7 to May 18 through Blynk application. On May 7, the initial moisture already present was 30 per cent and it has been reduced to 24 within few hours. The automated system analyzed the moisture content present in the soil through sensor and the pump starts operating, thus providing water through emitters. This increased moisture content to around 28% and the system continued. Upon observing the 12 hours analysis on May 7, it was determined that the moisture content remained consistently within the range of 24%-31%. Moisture analysis for weekly basis from May 7 to May 13 was also recorded. After selecting and examining the moisture chart, it was found that the moisture level could be maintained between 28%-31%. The various fluctuations depending on its growth phase until maturity were analyzed from the moisture chart.

The performance of both irrigation systems was compared by analyzing biometric observations of the crops. The length of crop, width of leaf and weight of crop grown under conventional irrigation method were 50-60 cm, 8-12 cm, 2.90kg those for automated drip irrigation were 80-120 cm, 14-28 cm, 4 kg respectively. From the observations, it can be inferred that high yield and more resistance to pest and diseases were found for automated drip irrigation system.

The overall results of the study revealed that automated drip irrigation system have better performance than conventional irrigation method. The crop grown under automated drip irrigation systems shows more yield, maximum crop length, high pest and disease resistance, high water use efficiency, low weed growth and shallow root depth. But the system has certain constrains like high cost, need of constant supply of electricity, requirement of skilled persons for installation and maintenance and the possibilities of clogging of drippers due to continuous operation.

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AUTOMATION OF DRIP IRRIGATION IN VERTICAL FARMING

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PROJECT REPORT

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In

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Faculty of Agricultural Engineering and Technology

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF IRRIGATION AND DRAINAGE ENGINEERING

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

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KERALA, INDIA

2023

ABSTRACT

Watering the plant is the most important cultural practice and one of the labour-intensive tasks in daily greenhouse operation. Watering systems ease the burden of getting water to plants when they need it. Knowing when and how much to water is two important aspects of irrigation process. The introduction of "Automation in drip irrigation" can bring a green revolution in greenhouse. With advancing technology growth in the agriculture sector, the internet-of-things (IOT) technology provides a solution much simpler and faster for drip irrigation. The use of wireless sensor networks, IoTs, and communication technology for the automation of irrigation is an entirely new and futuristic field of research for development. It eliminates the manual opening and closing of valves. It starts and stops pump exactly as and when required thus optimizing the energy requirement. Irrigation system can be started at any desired time. Automating the data acquisition process of the soil conditions and various climatic parameters that govern plant growth allows information to be collected with less labour requirements.

The study entitled "An IoT based Drip Irrigation system for Vertical farming structure in Rain shelter" was taken up to develop an automated system for naturally ventilated Rain shelter situated in PFDC, located in the instructional farm of KCAET. The study was carried out using Amaranthus during the month of February to May, 2023 in two phases, one with conventional type of irrigation and other with automation in drip irrigation. It was found that the automation system installed was successful in minimal use of water to effective root zone which increases plant quality as well as productivity.