SMART FERTIGATION FOR GREENHOUSE CULTIVATION

BY

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY, TAVANUR- 679 573

KERALA, INDIA

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PROJECT RREPORT

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY TAVANUR- 679 573

KERALA, INDIA

2024

DECLARATION

We hereby declare that this project entitled **" SMART FERTIGATION FOR GREENHOUSE CULTIVATION "** 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:31/05/2024

ANJANA P S (2020-02-036)

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CERTIFICATE

Certified that the project entitled **"SMART FERTIGATION FOR GREENHOUSE CULTIVATION"** is a record of project work done jointly by **Ms. ANJANA P S (2020-02-036**), Mr. HISHAM C (2020-02-016) and Mr. MOHAMMED MUZAMMIL K (2020-02-015) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associate ship to them.

Place: Tavanur

Date:31/05/2024

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DEDICATED TO OUR AGRICULTURAL ENGINEERING PROFESSION

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SYMBOLS AND ABBREVIATIONS

symbols	Abbreviation
-	Minus
%	Percentage
$(NH_4)_2HPO_4$	Di ammonium phosphate
$(NH_4)_2SO_4$	Ammonium sulfate
+	Plus
°C	Degree Celcious
AC	Alternating Current
AI	Artificial Intelligence
ANN	Artificial Neural Network
AWG	American Wire Gauge
AWG	American Wire Gauge
C	Compatible
$Ca(NO_3)_2$	Calcium Nitrate
$Ca(NO_3)_2 \cdot 4H_2O$	Calcium Nitrate Tetrahydrate
cm	Centimetre
$CO(NH_2)_2$	Urea
Cv	Coefficient Of Variation
DC	Direct Current
EC	Electrical Conductivity
et al.,	And Co Workers
ETo	Evapotranspiration
FAO	Food And Agriculture Organization
Fig	Figure
FIP	Fertilizer Injector Pump
GND	Ground
GSM	Global System For Mobile Communication
H	Hours
H_3PO_4	Phosphoric Acid

ha	Hectare
HP	Horse Power
i.e.	That Is
IDE	Integrated Development Environment
IDE	Integrated Development Environment
IN	Input
IoT	Internet Of Things
K	Potassium
K_2SO_4	Potassium Sulfate
KAU	Kerala Agricultural University
KCAET	Kelappaji College Of Agricultural Engineering And Technology
KCl	Muriate Of Potash
kg	Kilogram Per Hectare
kg/cm^2	Kilogram Per Centimeter Square
KNO_3	Potassium Nitrate
KPCH 1	KAU Parthenocorpic Hybrid Variety 1
l	Litre
Lab	Laboratory
LAI	Leaf Area Index
LC	Limited Compatible
LCD	Liquid Crystal Display
lph	Litre Per Hour
m	Meter
MAP	Mono Ammonium Phosphate:
mg/kg	Milligram Per Kilogram
$MgSO_4$	Magnesium Sulfate
MHz	Megahertz
ml	Milliliter
mm	Millimetre

Mn	Manganese
N	Nitrogen
NC	Not Compatible
NH_4	Ammonium
$NH_4H_2PO_4$	Mono Ammonium Phosphate
NH_4NO_3	Ammonium Nitrate
NO_3	Nitrate
NTC	Non-Treated Vines
P	Phosphorus
PCB	Printed Circuit Board
pH	Negative Logarithm Of Hydrogen Ion
PLC	Programmable Logic Controller
PVC	Poly Vinyl Chloride
RFID	Radio Frequency Identification
SDF	Subsurface Drip Fertigation
SF	Single-Fertilization
SMS	Short Message Service
SpF	Split Fertigation
t/ha	Tonnes Per Hectare
UV	Ultra Violet
V	Volt
VCC	Voltage Common Collector
Wi-Fi	Wireless Fidelity
WSNs	Wireless Sensor Networks
Zn	Zinc

INTRODUCTION

CHAPTER I

INTRODUCTION

The global food system faces significant challenges due to the projected population increase to 9.7 billion by 2050. This necessitates a transformation in agriculture to meet the rising food demands while minimizing environmental impacts. Agriculture must become more sustainable and resilient, addressing its dual role in climate change. It is both affected by and contributes to climate change, creating a complex challenge. Implementing sustainable agricultural practices is essential to feed the growing population and mitigate the negative effects on the environment, ensuring long-term food security and ecological health (Erekalo *et al*., 2024).

Climatic risks from extreme weather variability are significantly impacting agricultural production in India. With over 60% of crops being rainfed, Indian agriculture is highly vulnerable to changes in precipitation patterns induced by climate change. Recent trends indicate an increase in weather-related risks such as heat waves, cold snaps, droughts, and floods, with a notable rise in extreme temperature and rainfall events. This growing variability in weather patterns underscores the urgent need for adaptive strategies to mitigate the impacts on agricultural productivity. Additionally, India faces the challenge of meeting rising food and fiber demands driven by its growing population. To address this, the country must expand agricultural production while conserving water and other vital natural resources. Farmers are under immense pressure to produce high-quality, safe food in an economically viable and environmentally sustainable manner. Balancing these demands is crucial to ensure long-term agricultural productivity and environmental health (Agarwal *et al*., 2022).

Water, nutrients, energy, and labor are essential components that determine farm efficiency and profitability. Efficient water management practices, such as drip irrigation and rainwater harvesting, can help conserve this precious resource.

Similarly, the use of balanced and judicious fertilizer application is necessary to maintain soil health and optimize crop yields without causing environmental harm. Energy efficiency is another critical factor, as the use of renewable energy sources and modern farming equipment can reduce costs and environmental impact. Labor efficiency, through the adoption of mechanization and advanced farming techniques, can enhance productivity while reducing the physical burden on farmers.

The critical issues of excess, shortage and quality deterioration of water as a resource demands special attention. The current situation of water resources in India, concerning both quality and quantity of water underscores the urgent need for careful and efficient usage of it in the coming years. Traditional methods of water management in India are now insufficient, as the gap between water demand and the renewability of resources continues to narrow.

While irrigation projects have improved water resources, traditional water transport and irrigation methods remain highly inefficient. This inefficiency has led to significant water wastage and environmental problems like waterlogging, salinization, and soil degradation, reducing the productivity of fertile land. Advanced irrigation techniques, such as drip and sprinkler systems, are recognized as the most effective solutions for optimizing the use of surface and groundwater resources, addressing these issues, and ensuring sustainable agriculture.

The purpose of irrigation scheduling is to determine the precise amount and timing of water application to crops, based on at least one variable of the soil-plant-atmosphere system. Adopting an appropriate irrigation scheduling method is crucial for maintaining the physiological processes of crops and ensuring optimal yield. Additionally, efficient irrigation scheduling reduces water use and energy consumption. Conversely, inadequate or poorly designed irrigation scheduling can lead to over- or under-irrigation, resulting in low grain yield and irrigation water productivity, waterlogging, soil salinization, and rising water table levels Liu and Yang, (2021).

Drip irrigation is acknowledged as an advanced and efficient irrigation technique, particularly suited for arid and windy climates, in comparison to sprinkler irrigation. It offers numerous advantages over surface irrigation, such as potential water savings, higher fertilizer efficiency, improved crop yield quality and uniformity, adaptability to various field shapes, sizes, and slopes, and reduced labor costs. However, its adoption can be hindered by the need for higher initial investment, increased energy costs, maintenance work, and the requirement for modernized management skills (Qi *et al*., 2024).

Nutrient concentrations in reclaimed water vary depending on the type of treatment and can fluctuate throughout the irrigation season. To maintain a balanced macronutrient supply, it is crucial to monitor nutrient content in real time. Inconsistent macronutrient levels or supplying nutrients when they are not needed can cause excessive vegetative growth, uneven fruit maturity, and diminished yield quality and quantity. Conversely, when nutrient levels are too low, additional fertilizers are necessary to meet crop requirements. To overcome these threats smart fertigation systems are introduced to the agricultural field (Ahmad *et al*., 2022).

Plants require a range of essential nutrients for optimal growth, broadly categorized into macronutrients and micronutrients. Among these, nitrogen (N), phosphorus (P) and potassium (K) collectively known as NPK are the primary macronutrients vital for plant development.

Nitrogen is particularly critical as it is the first limiting macronutrient, necessary for the synthesis of proteins and chlorophyll, and it supports the growth of leaves, stems, and other vegetative structures. Additionally, nitrogen enhances root growth, improves fruit quality, and increases the protein content of fodder crops. Phosphorus, the second limiting macronutrient, is crucial for the formation of nucleic acids and membrane phospholipids, and it is involved in signal transduction pathways, enzyme activation, and energy transport processes. Potassium, known for its high mobility, is efficiently absorbed by plants and plays a significant role in various physiological functions. Together, nitrogen, phosphorus, and potassium have the most substantial impact on the formation of biological macromolecules in plants, underscoring their importance in agricultural practices Patra and Mandal, (2023).

The Internet of Things (IoT) has become a vital tool in various fields. In agriculture, IoT is used to create interconnected systems that optimize yields while minimizing resource usage. This is achieved through IoT sensors, which are intelligent devices capable of detecting anomalies and transmitting data over a network. IoT agriculture sensors can monitor crop growth, build models to predict crop behaviour under various conditions, reduce water consumption, and automate irrigation systems. Additionally, these sensors can monitor and control greenhouse climates. Implementing IoT in greenhouse farming minimizes the need for human intervention and manual monitoring (Lynda *et al*., 2023).

In a greenhouse environment, where conditions such as temperature, humidity, and light can be closely controlled, smart fertigation systems enhance these controls by providing a tailored nutrient and water regimen. These systems typically include components like soil moisture sensors, nutrient delivery systems, automated irrigation controllers, and software platforms for data analysis and remote management. Smart fertigation systems are an integral part of modern greenhouse management, driving sustainable agricultural practices and enhancing productivity to meet the growing demand for fresh produce.

The present research aimed at testing a novel system for smart fertigation for greenhouse cultivation and field evaluation. The main objectives are

- Development of a smart fertigation system.
- Field evaluation of the developed system.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

2.1 FERTIGATION

Fertigation is one of the recent techniques of applying nutrients to the soil through micro irrigation system. The system permits application of various fertilizer formulations directly at the active root zone.Fertigation is a powerful method for precisely controlling fertilizer placement, timing, and type based on soil fertility and crop growth stage. When integrated with efficient irrigation systems, it maximizes yield while minimizing inputs. Continuous, small applications of soluble nutrients enhance nutrient uptake, leading to improved fertilizer efficiency, increased crop yields, and labour savings. Optimal timing and placement of fertilizers improve fertilizer use efficiency and crop yield quality (Kumar, 1992).

The intensification of agriculture through irrigation and increased fertilizer use can lead to pollution due to higher nutrient levels in both underground and surface waters. Traditional open irrigation systems are less efficient in water application, while pressurized systems like drip irrigation can improve efficiency. Drip irrigation can create a limited root system that requires frequent nutrient supply, often met through fertigation, where fertilizers are applied with irrigation water. Managing fertilizer concentrations based on crop needs in measured irrigation water quantities can maximize crop yield and quality while minimizing leaching beyond the root zone (Hangi and AnatLowenngart, 1995).

Fertigation system is becoming more popular because of its advantages like, higher fertilizer use efficiency, increased availability of nutrient content to the plant, saving of fertilizer to the range of 20-40 per cent, regular supply of crop nutrients at right proportions and right time, saves labour and energy and facilitates the application of chemicals other than fertilizers for specific purposes (Khan *et al*., 1999).

It has also been reported that drip fertigation increased the availability of soil micronutrients Glonek and Komosa, (2013). The addition of nutritive salts in fertigation was found to increase soil aggregate stability (Moreira *et al*., 2015).

The advantage of fertigation is precise nutrient supply in time and space. Economical and sustainable crop production can be achieved with optimal fertigation. In fertigation, precise timing and precise rate of fertilizer can be applied to crops as per requirement and at different growth stages, which is not possible in the conventional method of fertilization. Research findings indicate that fertigation increases crop production and biomass carbon in soil (Lal, 2020).

In 2022 Saji *et al* conducted a study aimed to standardizing the irrigation and fertigation requirements for snake gourd (*Trichosanthes cucumerina*) of the Manusree variety under a rain shelter. Conducted at the PFDC instructional farm in Kerala from October 2020 to January 2021. The study concluded that precision farming practices, with 100% ETc irrigation and 150% fertigation, make snake gourd cultivation feasible and profitable, as indicated by a benefit-cost ratio greater than one. These findings can help farmers optimize their irrigation and fertigation practices and inform future crop water demand analyses.

This study analysed maize cultivation with an emerging organic fertilization management technique, i.e., pre-seeding injection, followed by side-dressing fertigation, through a life cycle assessment approach at the farm gate with the aim of evaluating its influence on crop production as a whole, with a focus on nitrogen emissions during field application. This was done on two sample farms, one of which was fertigated using drip irrigation and the other by pivot irrigation. The results, expressed per tonne of dry matter produced, clearly indicate that alternative fertilization management leads to important benefits on acidification, particulate formation and eutrophication, reduced by up to about 80% compared to the reference fertilization scenario, which is an excellent result, especially if production is contextualised in an area under strong environmental pressure (Bacenetti *et al*., 2023).

In 2023 Delbaz *et al*., conducted a study to examine the effects of surface and drip fertigation methods and different fertilizer application levels on crop yield. The main objective of this study was to investigate the effectiveness of different fertigation methods (surface and drip) on crop yield, nutrient use efficiency, and water productivity compared to traditional fertilization methods. They identified the elements include the study population, the independent variable or intervention, the control or comparison group, and the dependent variable or outcome. A search strategy was designed. The meta-analysis of this study showed that the fertigation practice increased crop yield, respectively. The reason for this is that in fertigation methods, fertilizer distribution is more uniform, and fertilizer is applied at the right time to plants.

Hamani *et al*., (2023) conducted a study about grain yield and water-nitrogen dynamic of drip-irrigated winter wheat. Two years of field experiments were carried out to assess the influences of different N fertigation and water regimes on winter wheat grain yield, evapotranspiration, water-N productivity, and optimization procedure. Results demonstrated that optimizing irrigation and N application regimes positively influenced wheat grain yield, evapotranspiration, and water-N productivity also resulted in the highest water use efficiency .This treatments are considered as the optimal coupling of irrigation and N application regime for the winter wheat production.

Callau-Beyer *et al*., (2024) conducted an experiment on Effect of high frequency subsurface drip fertigation on plant growth and agronomic nitrogen use efficiency of red cabbage. The study was established to analyse possible benefits of Subsurface drip fertigation (SDF), i.e. nitrate losses reduction without decrease in yield, as alternative to the conventional application of nitrogen fertilizer. Yield, root distribution and nitrogen uptake of plants were evaluated. In conclusion SDF has the potential of effectively controlling nitrogen supply to plants, thereby increasing yield and agronomic efficiency. This holds even for conditions of high rainfall. On the other hand, excess of water dosage may lead to leaching in a wet year. Therefore, proper control of water supply is crucial for utilizing the benefits of the SDF system.

Mian *et al*., (2024) compared two different methods of plant nutrition: one-single application (single-fertilization-SF) and two applications with the same amount adopting the fertigation (split fertigation-SpF), including a control not-treated, in a specific Italian region where grapevine Schiopettino cv. is being cultivated and this practice was not investigated yet. SpF promoted the photosynthesis parameters compared to a SF and to the non-treated vines (NTC). Different systems of soil fertilization have been developed over the years, including organic and inorganic fertilization. Organic fertilization involves the use of natural sources of nutrients such as animal manure, compost, and green manure, whilst inorganic fertilization involves the use of synthetic fertilizers such as urea, ammonium nitrate, and potassium chloride. In conclusion fertigation (SpF) promoted the photosynthesis parameters compared to a single fertilization (SF) and to the non-treated vines (NTC). On these basis, the biological and physiological activity of the whole plant was enhanced.

A study was conducted by Irrigation and fertilization factors that affecting grape yield. The aim of this study was to address the problems of water scarcity and low water and fertilizer use efficiency in vineyards in the Guanzhong Plain of Shaanxi, China. In the experiment, drip fertigation technology was used, including three irrigation levels and four fertilization levels. Traditional fertilization and a rainfed treatments were used as control treatments. Field experiments were conducted to determine irrigation and fertilization intervals corresponding to higher crop yields and water and fertilizer utilization efficiency in different precipitation patterns. The results showed that, compared with the rainfed and traditional fertilization treatments, the drip fertigation treatments significantly increased grape yields and improved water and fertilizer use efficiency (Peng *et al*., 2024).

2.2 SELECTION OF FERTILIZERS

Most of the water-soluble and liquid fertilizers are suitable for fertigation. When choosing a fertilizer, three main considerations have to be taken into account:

(1) plant type and stage of growth; (2) type of soil and irrigation system; and (3) quality of available water.

2.2.1 Solubility of fertilizers

Solid fertilizers vary in their dissolution rate and in the amount that can be dissolved in a given volume of water. Solubility of fertilizers is generally reduced when two or more fertilizers are mixed together. This characteristic is crucial for the suitability of a fertilizer to be used in fertigation.

Table 2.1Solubility, nutrient content, and soil reaction of some common fertilizers used in fertigation

Fertilizer	*Chemical formulae*	*Grade* [a]*N–P–K*	*Other nutrients*	*Soil reaction*	*0°C*	*10° C*	*20° C*	*30° C*
Urea	$CO(NH_2)_2$	45-0-0	–	Acidic	–	78	–	–
Ammonium nitrate	NH_4NO_3	34-0-0	–	Acidic	118	152	192	242
Ammonium sulfate	$(NH_4)_2SO_4$	20-0-0	24%S	Acidic	71	73	75	78
Calcium nitrate	$Ca(NO_3)_2\cdot 4H_2O$	15-0-0	17% Ca	Basic	102	112	121	150
Mono ammonium phosphate	$NH_4H_2PO_4$	11-48-0	1.4%Ca 2.6%S	Acidic	23	29	37	46
Di-ammonium phosphate	$(NH_4)_2HPO_4$	21-53-0	–	Acidic	43	–	–	–
Phosphoric acid	H_3PO_4	0-52-0	–	Very acidic	548	–	–	–
Muriate of potash	KCl	0-0-62	–	Neutral	28	31	34	37
Potassium nitrate	KNO_3	13-0-44	–	Basic	13	21	31	45
Potassium sulfate	K_2SO_4	0-0-53	8%S	Neutral	7	9	11	13

[a]ConcentrationsofN,P_2O_5,andK_2O,expressedasapercentageofweightofthefertilizer [a]

Anjaly and Abdul Hakkim (2016)

2.2.2 Compatibility of fertilizers

Some fertilizers should not be mixed together in one stock tank because of very quick formation of an insoluble salt. Examples for such incompatibility are:

- Calcium nitrate with any sulphate or phosphates results in formation of precipitates of calcium sulphate and calcium phosphate respectively.
- Ammonium sulphate with potassium chloride or potassium nitrate results in formation of potassium sulphate precipitate.

In order to control precipitates, jar test may be done in which the fertilizers are mixed in exactly in same concentration as intended to be used in the stock tanks in a jar containing the same water used for irrigation. If a precipitate forms or if the solution has a cloudy appearance, the test should be repeated with lower concentrations of the fertilizers Anjaly and Abdul Hakkim (2016).

Table 2.2 Fertilizer compatibility chart

Fertilizer	**Urea**	**NH_4NO_3**	**$(NH_4)_2SO_4$**	**$Ca(NO_3)_2$**	**KCl**	**K_2SO_4**	**MAP**	**$MgSO_4$**	**H_3PO_4**
Urea	C	C	C	C	C	C	C	C	C
NH_4NO_3	C	C	C	C	C	C	C	C	C
$(NH_4)_2SO_4$	C	C	C	NC	C	LC	C	C	C
$Ca(NO_3)_2$	C	C	NC	C	C	NC	NC	NC	NC
KCl	C	C	C	C	C	LC	C	C	C
K_2SO_4	C	C	LC	NC	LC	C	C	LC	C
MAP	C	C	C	NC	C	C	C	NC	C
$MgSO_4$	C	C	C	NC	C	LC	NC	C	C
H_3PO_4	C	C	C	NC	C	C	C	C	C

C–Compatible, LC–Limited compatible, NC–Not compatible

Source:(Chandran*etal.*,2011)

2.2.3 Soil pH

The ideal pH range for optimal nutrient availability is 6-6.5 Anjaly and Abdul Hakkim (2016).The primary factor influencing root zone pH is the ratio of NH4 to NO3 in irrigation water, particularly in sandy soils and inert substrates with low buffering capacity. Rhizospheric pH is crucial for phosphorus availability as it affects solubilization, precipitation, and desorption or adsorption of phosphates. Additionally, pH impacts the availability of micronutrients (Fe, Zn, Mn) and their toxicity. The form of nitrogen absorbed affects the plant's cation-anion balance and carboxylate production. Predominant NH4 absorption leads to increased cation uptake, root excretion of H+, and decreased rhizospheric pH. NH4 is detrimental to crops like tomatoes and strawberries in root zones above 30°C as it inhibits the uptake of essential cations (Ca2+, Mg2+, K+). When NO3- anions are absorbed, the plant takes up more anions than cations. Excess anions stimulate carboxylate synthesis and release OH- and dicarboxylic acid into the soil, raising root zone pH. This increases phosphorus availability as carboxylates adsorb to iron oxides and clays, releasing adsorbed phosphorus into the soil solution (Imas, 1999).

2.3 FERTILIZER INJECTION METHODS

It's crucial to select appropriate fertigation equipment that allows for regulation of fertilizer quantity, proportions, application duration, and timing. This ensures optimal nutrient delivery tailored to the crop and irrigation system. Choosing the wrong equipment can damage irrigation systems, reduce operational efficiency, and decrease nutrient effectiveness. Each fertilizer injector is designed for specific flow rates and pressures. Many modern injectors feature automatic operation using pulse transmitters to convert injector pulses into electric signals. These signals then control the injection of preset quantities or proportions based on the irrigation system's flow rate. Injection rates can also be regulated using flow regulators, chemical-resistant ball valves, or electronic/hydraulic control units integrated with computers. To prevent backflow or siphoning of water and fertilizer solution into tanks and household supplies, installing suitable non-return valves or anti-siphoning valves is essential. These valves help maintain the integrity of the irrigation system and prevent contamination of water sources with fertilizers. The three methods of injection are:

1. Fertilizer tank
2. Ventury Injector
3. Fertilizer pump

2.3.1 Fertilizer tank

In this setup (Fig.2.1), a tank housing the fertilizer solution is linked to the irrigation pipe at the supply point. A portion of the irrigation water is then redirected from the main line to pass through the fertilizer tank, where the fertilizer is present in either fluid or granular form (Anjaly and Abdul Hakkim 2016). A pressure-reducing valve is employed to induce a slight decrease in pressure between the off-take and return pipes of the tank. This pressure differential prompts water from the main line to traverse through the tank, leading to the dilution of the fertilizer and the subsequent flow of the diluted fertilizer into the irrigation water.

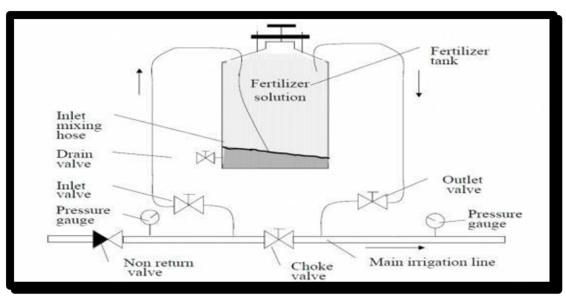

Fig. 2.1 Fertilizer tank Source:(Imas,1999)

Li *et al*., (2007) found that a significantly higher coefficient of variation (Cv) resulted from the use of a differential pressure tank for water and fertilizer application compared to a proportional pump or a venturi injector, particularly for a given emitter type. This discrepancy was attributed to the differential pressure tank's characteristic of releasing fertilizer at a decreasing rate.

2.3.2 Ventury Injector

The device shown in the Figure 2.2 is a simple and cost-effective solution for fertigation. It operates on the principle of venturi action, where a partial vacuum is generated within the system, allowing for the suction of fertilizers into the irrigation system Anjaly and Abdul Hakkim (2016). This vacuum is produced by diverting a portion of water flow from the main line and channeling it through a narrow constriction. As the water flows through this constriction, its velocity increases, resulting in a drop in pressure. This pressure drop causes the fertilizer solution to be drawn from the tank into the venturi through a suction pipe, where it mixes with the irrigation water.

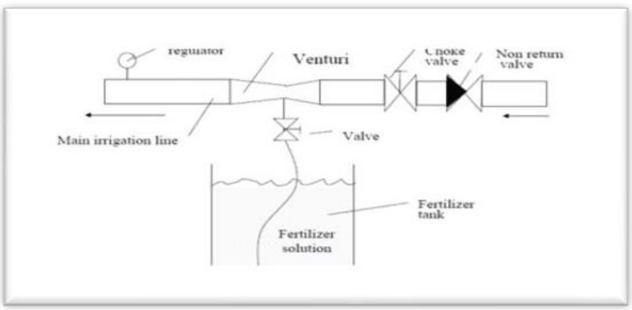

Fig.2.2 Ventury injector Source:(Imas,1999)

Jain Irrigation Systems Limited conducted experiments to assess the performance of a venturi injector. The findings indicated that for a venturi injector with a diameter of 20 mm, operating at an inlet pressure of 1 kg/cm2 and an outlet pressure of 0.2 kg/cm2, the motive flow rate was measured at 8.4 liters per minute. Simultaneously, the suction rate of the venturi injector was determined to be 70.8 liters per hour Anjaly and Abdul Hakkim (2016).

2.3.3 Fertilizer pump

The fertilizer pump is a key element of the control head system, a standard component designed for injecting fertilizer into irrigation water at specific ratios Anjaly and Abdul Hakkim (2016). This setup typically involves a non-pressurized tank to hold the fertilizer solution, allowing for precise regulation of fertilizer availability to each plant. Common types of pumps used in this system include piston or diaphragm pumps, which are powered by the water pressure within the irrigation system. This setup ensures that the injection rate and water flow remain proportional throughout the system (Shirgure, 2013). Figure 2.3 illustrates the operational principle of a fertilizer pump.

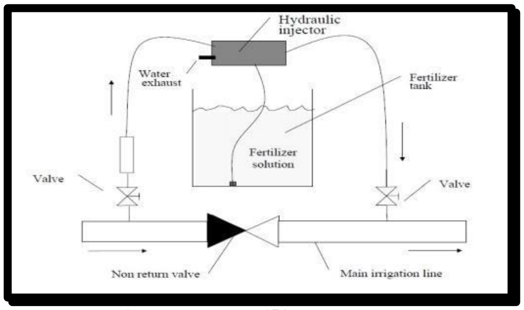

Fig.2.3 Fertilizer pump

Source:(Imas,1999)

2.3.4 Comparison of fertigation equipment

Table 2. 3 Comparison of fertigation equipment

Characteristics	Ventury Injector	Fertilizer tank	Fertilizer pump
Use of granular/solid fertilizer	To be dissolved Before application	Possible	To be dissolved before application
Use of liquid fertilizer	Possible	Possible	Possible
Discharge rate	Low	High	High
Concentration control	Medium	None	Good
Head loss	Very high	Low	Low
Ease of operation	Medium	High	Low
Price	Low(Rs.1500)	Medium(Rs. 4000)	High(Rs.12000)

Source:(Chandran*etal.*,2011)

2.4 IMPACT OF FERTIGATION ON GROWTH AND YIELD OF CROP

Haynes, (1985) explored the application of fertigation in drip irrigation systems, noting several advantages such as reduced labor, enhanced flexibility in fertilizer application, and increased fertilizer efficiency. Fertigation allows nutrients to be directly delivered to the plant root zone according to its demand during critical growth stages (Mikkelsen, 1989).

Bachav, (1995) conducted a field experiment comparing fertigation with conventional fertilizer application methods regarding yield, quality, and economic returns. Fertigation at weekly intervals proved to be more convenient and economically profitable for farmers.

Hagin and Lowengart, (1996) emphasized that drip irrigation, by generating a restricted root system, necessitates frequent nutrient supply. Applying fertilizers through irrigation water allows for the maximization of crop yield and quality while minimizing leaching losses below the rooting volume.

Prabhakar and Hebber, (1996) observed the highest tomato fruit yield of 45.7 t/ha when recommended doses of fertilizers were applied via fertigation, resulting in yields 22-27% higher compared to conventional soil application methods.

Srinivas, (1999) highlighted the benefits of applying soluble fertilizers like urea and muriate of potash through drip irrigation, including a reduction in fertilizer use by 20-25% and decreased nitrate-nitrogen leaching into groundwater.

Singh *et al*., (2001) investigated water and nutrient use efficiency in sprouting broccoli grown in sandy loam soil using fertigation, achieving significant fertilizer savings of 20-40%.

Kumari and Anitha, (2006) conducted experiments on nutrient management in chili-based cropping systems in Kerala, observing improved growth and yield performance with higher nutrient doses.

Kumar *et al*., (2007) aimed to increase water and fertilizer use efficiency in drip-irrigated brinjal crops. Their findings suggested that optimal yields were achieved with 75% of pan evaporation and 75% of recommended nitrogen and potassium fertigation.

Yasser *et al*., (2009) investigated the impact of fertigation scheduling on tomato yields under arid conditions, finding significant enhancements in tomato yields, water use efficiency, and fertilizer use efficiency compared to traditional fertilization methods. Fertigation also proved to be cost-effective compared to solid set sprinkler irrigation systems.

2.5 FERTIGATION AUTOMATION

Umair and Usman, (2010) have demonstrated the effectiveness of ANN-based controllers in improving water use efficiency and crop yield, particularly in environments like greenhouses. Simulations consistently show better water management, reduced wastage, and improved crop health with these systems. Future advancements include integrating IoT devices for real-time data accuracy and exploring machine learning techniques like deep learning to enhance prediction accuracy and robustness. Overall, ANN-based irrigation controllers offer precise and efficient water management, promising significant advancements in water conservation and agricultural productivity.

Giri and Wavhal, (2013) introduced a method to improve accuracy in agricultural practices using a Wireless Sensor Network (WSN) combined with linear programming. Their system, which is both cost-effective and wireless, enables efficient monitoring of irrigation. By integrating WSN and linear programming, the method optimizes water use and enhances the precision of irrigation schedules. This innovative approach not only reduces costs but also promotes better resource management in agriculture. Their work highlights the potential of combining modern technologies to create more efficient and sustainable agricultural practices, ultimately contributing to improved productivity and water conservation.

Khamkar's, (2014) study, "Design and Implementation of Expert System in

Irrigation of Sugarcane: Conceptual Study," presents a theoretical framework for developing an expert system aimed at optimizing irrigation practices for sugarcane cultivation. This rule-based system integrates agronomic knowledge with real-time environmental data to provide precise irrigation recommendations, aiming to enhance crop yield while minimizing water use. Key components of the system include soil moisture sensors, weather forecasting, and growth stage monitoring. The study also addresses potential implementation challenges such as data accuracy, system integration, and user accessibility, highlighting the need for field trials to validate the system's practical effectiveness. Although primarily conceptual, Khamkar's work lays a foundational approach for leveraging technology in sustainable agricultural practices.

Various researchers have explored IoT-based developments for irrigation. Kansara *et al*. (2015) introduced an automated irrigation system using sensors, which automates the watering process. This system offers farmers significant savings in money, time, and effort compared to traditional manual methods. By leveraging real-time data from sensors, the system ensures precise and efficient water delivery, reducing waste and optimizing crop health. This innovative approach demonstrates the potential of IoT technology to revolutionize agricultural practices, enhancing sustainability and productivity while alleviating the burdens associated with manual irrigation methods.

Anjaly and Hakkim, (2016) conducted a study to develop and evaluate the performance of an automated fertigation system. Field evaluation of the developed automate fertigation system was conducted with salad cucumber crop inside a poly house. A comparative analysis was conducted between biometric observations and yield parameters of the three groups of crop, one planted inside the polyhouse and fertigated automatically with the developed system (T1) and other two groups, one inside the polyhouse with manual fertilizer application (T2) and the other in the open field with manual fertilizer application (T3). Biometric observation of four plants selected from each plot was subjected to Student-t test and the yield parameters of seven plants selected from each plot was subjected to ANOVA. From the present study it can be inferred that the automated fertigation system installed inside the polyhouse (T1) can be considered as the best treatment as it gave the maximum value of yield parameters and biometric observations.

Geng and Dong, (2017) developed a classification model employing a deep learning algorithm to evaluate soil condition and relative humidity in agricultural land. This model accurately assesses soil status, aiding in optimal crop development. By leveraging advanced computational techniques, the system provides real-time insights into soil health, enabling timely adjustments in irrigation and fertilizer application. This approach enhances agricultural productivity by ensuring crops receive the appropriate moisture levels and nutrients. The innovative use of deep learning highlights its potential in precision agriculture, offering farmers a reliable tool to monitor and manage soil conditions effectively for sustainable crop growth and yield optimization.

Sarojini *et al*. (2017) engineered an automated drip irrigation system utilizing a programmable logic controller (PLC) and biosensors for efficient irrigation management. This system integrates PLC technology with biosensors to monitor and regulate the irrigation process meticulously. By continuously analyzing soil moisture and other relevant parameters, the system optimizes water usage, ensuring crops receive adequate hydration while minimizing wastage. It underscores the importance of advanced automation in agriculture, enhancing water efficiency and crop yield. Their approach represents a significant stride towards sustainable farming practices, demonstrating how technological integration can streamline irrigation processes for improved agricultural productivity and environmental conservation.

Vanitha and Deepak, (2017) focused on assessing soil moisture conditions using the Raspberry Pi microcontroller. Their system integrates a webcam for visualizing crop field conditions, with data accessible on a remote server. This setup enables real-time monitoring and analysis of soil moisture levels, crucial for effective irrigation management. Additionally, the system utilizes GSM technology to send SMS notifications, alerting farmers to critical changes in soil conditions. Their innovative approach demonstrates the practical application of low-cost, accessible technology in precision agriculture, enhancing decision-making capabilities and promoting efficient water use for sustainable crop production.

Jinu and Hakkim (2018) present a comprehensive analysis of an affordable automation solution designed to naturally ventilated greenhouses. The primary objective of this research was to develop and evaluate a low-cost automation system capable of maintaining optimal microclimatic conditions within the greenhouse and automated irrigation and fertigation within a greenhouse. The research findings support the feasibility and benefits of implementing such automated solutions, paving the way for broader adoption and further advancements in greenhouse climate control technologies and automated fertigation.

Prasanna and Rani, (2019) conducted research focusing on remote monitoring of soil properties through IoT and machine learning technologies. Their study emphasizes predicting soil properties to optimize agricultural productivity and achieve higher yields. By leveraging IoT devices for continuous data collection and machine learning algorithms for analysis, their approach enables precise monitoring and management of soil conditions. This proactive strategy supports farmers in making informed decisions regarding irrigation, fertilization, and crop management practices. The research highlights the transformative potential of integrating advanced technologies into agriculture, offering practical solutions to enhance crop yield sustainability and efficiency.

Togneri *et al*. (2019) investigated advancements in IoT-based smart irrigation systems. Their architecture supports diverse analytical approaches for precision irrigation, enhancing machine learning methodologies. The study anticipates various stakeholder benefits: IoT professionals benefit from simplified system deployment, while farmers gain from reduced costs and safer crop yields. By integrating advanced analytics and customizable features, they emphasize the potential for optimizing water use efficiency and improving agricultural outcomes through technological innovation in smart irrigation systems. This research underscores the transformative impact of IoT in modernizing agriculture towards sustainability and productivity.

Dasgupta *et al*. (2020) conducted research integrating IoT devices, Wireless Sensor Networks (WSN), and AI techniques for detecting unwanted plants in crop fields. Their study employed drones for data capture, leveraging deep learning methods to identify and manage these plants efficiently. By utilizing WSN and IoT for real-time data collection and AI algorithms for automated analysis, their approach enhances precision agriculture practices. This innovative method not only improves weed management strategies but also promotes sustainable farming by minimizing herbicide use and optimizing crop health. The research highlights the potential of integrating advanced technologies to address agricultural challenges effectively and sustainably.

Recent advancements like communication, embedded system, and sensor technology help in modernizing the agriculture, a smart one. The general architecture of ESDCS protocol in automated system, the Internet of Things (IoT) plays a vital role in collecting the field data from the deployed sensor nodes and sends it to the data center for effective decision making. The IoT integrates the Wireless Sensor Networks (WSNs), cloud computing, RFID, communication devices, and end user application, etc., that improves the computational and operational efficiency of the agricultural activity. IoT provided tools, knowledge, and services to perform the automation in smart agriculture and achieve high yield (Karunanithy *et al*., 2020).

The Internet of Things (IoT), in basic terms, can be defined as the interconnection of devices (physical and virtual) that have sensors, processing capability, and software within a network (such as the internet) to enable intelligent decision making. Within the context of agriculture, smart farming is becoming the norm and there has been wide adoption of agricultural drones and sensors. These can create maps of the farmland, indicating the level of variables such as temperature, pH, nutrient concentration, and water concentration. The maps can be used to schedule and control irrigation, fertilizer, and pesticide applications, among other farm processes, to a high degree of accuracy. Self-driving tractors are being manufactured that can automate these processes. Business Insider predicts that there will be around 12 million agricultural sensors in use across the world by 2023 (Meola, 2021).

Sharma and Kumar, (2021) developed an IoT-based irrigation system designed specifically for monitoring paddy fields. This system utilizes a variety of sensors to create an intelligent irrigation setup that adjusts watering based on the precise needs of the crops. By continuously monitoring soil moisture, temperature, and other relevant parameters, the system optimizes water usage to enhance crop health and productivity. Their research highlights the application of IoT technology in precision agriculture, aiming to improve yield outcomes and promote sustainable water management practices tailored to the unique requirements of paddy cultivation.

Bhavsar *et al*. 2023 analysed smart drip and sprinkler irrigation systems integrated with IoT technology, aiming to address challenges and enhance efficiency in agricultural practices. It reviews various irrigation technologies, emphasizing smart drip and sprinkler systems, and conducts comparisons to identify the most efficient methods. A summary table highlights similarities among different approaches. The goal is to optimize water usage and streamline farmers' operations, thereby promoting sustainable agriculture. By leveraging IoT for real-time data monitoring and control, these systems enable precise irrigation management tailored to crop needs, contributing to water conservation and enhancing agricultural productivity.

Nandhini *et al*. (2023) conducted a study on an automated nutrient monitoring and control system for vertical hydroponics. The system, which leverages Internet of Things (IoT) technology, monitors and maintains optimal pH and Electrical Conductivity (EC) levels in the nutrient solution, providing real-time data accessible via an Android application. In a 42-day trial, mint was grown using this system, demonstrating significant improvements in plant growth metrics such as leaf number, size, and plant height compared to traditional soil cultivation. The water use efficiency (43.46 kg/m^3) and nutrient use efficiency (2.83 kg/kg) were notably higher than conventional methods. The study suggests that while the trial used a low-value crop, the system has the potential for cultivating high-value crops for greater profitability, offering a promising solution for efficient, space-saving urban agriculture.

Nichols *et al*. (2024) discuss irrigation automation, which involves retrofitting or integrating hardware for remote monitoring, control, scheduling, notifications, and reporting in agriculture. Remote monitoring provides growers with real-time updates on field conditions, tree health, and irrigation system performance. This data equips growers with insights into optimal water application for upcoming cycles and irrigation frequency. The control and scheduling features enable remote execution of crop water plans, reducing labor requirements. Notifications alert irrigation teams to any anomalies during irrigation operations, ensuring timely responses to maintain system efficiency and crop health. This review underscores the transformative impact of automation in enhancing agricultural productivity and water management practices.

The present research aimed at testing a novel system for the processing tomato smart fertigation. The study was mainly focused to verify the attainment of the nutrient requirements of the different treatments, to evaluate the possible savings of fertilizer inputs and to assess the physiological state of the plants, their fruit quality and productivity. With this aim, an algorithm was developed and implemented to supply macronutrients (e.g. N, P, K) in addition to those already found in reclaimed water, in order to meet plant nutrient needs according to their phenological stage. This paper demonstrates the novel implementation of the smart fertigation system, which can be exploited to save nutrients and to cope with the natural fluctuations in the concentration of nutrients in the treated wastewater (Odone *et al*., 2024).

2.5.1 COMPONENTS OF SMART FERTIGATION SYSTEM

Fertigation is the insertion of fertilizers, soil alteration, and other water soluble products into an irrigation method. Fertigation also is the combination of two different things, which are fertilizer and irrigation. Fertigation allows the water and fertilizers distribute to each plant, thus avoiding losses of significant quantities of water due to evaporation (Hassan *et al*., 2022).

2.5.1.1 Sensors

These are the backbone of the smart fertigation system, providing real-time data on soil moisture, temperature, humidity, nutrient levels, and other relevant parameters. Common sensors used include soil moisture sensors, weather sensors, pH sensors, EC (Electrical Conductivity) sensors, and nutrient sensors.

2.5.1.2 Controller

The controller processes data from the sensors and makes decisions regarding the timing and amount of water and nutrients to be delivered to the crops. It can be a microcontroller or a more sophisticated computer-based system capable of running algorithms for precise control.

2.5.1.3 Actuators

Actuators are responsible for delivering water and nutrients to the crops based on the instructions from the controller. They may include pumps, valves, injectors, and drip irrigation systems.

2.5.1.4 Fertilizer and Nutrient Delivery System

This system stores and delivers fertilizers and nutrients to the irrigation water in the desired concentration. It typically includes tanks for holding liquid fertilizers, injectors for mixing them with water, and a delivery mechanism to distribute the fertigated water to the crops.

2.5.1.5 Communication System

A smart fertigation system often includes a communication module to enable remote monitoring and control. This could be through Wi-Fi, cellular networks, or other wireless communication protocols, allowing farmers to access real-time data and adjust settings from anywhere.

2.5.1.6 User Interface

A user interface is essential for farmers to interact with the system. This could be a smartphone app, a web-based dashboard, or a dedicated control panel, providing farmers with insights into crop conditions, system status, and the ability to make adjustments as needed.

2.5.1.7 Data Analytics and Decision Support

Advanced smart fertigation systems may incorporate data analytics and decision support tools to analyse historical data, predict future crop needs, and optimize irrigation and fertilization strategies for improved crop yield and resource efficiency.

2.5.1.8 Automation and Integration

Automation features enable the system to operate autonomously based on predefined parameters and algorithms. Integration with other farm management systems, such as crop monitoring and management platforms, can provide a holistic view of farm operations and facilitate data-driven decision-making.

Ahmed *et al*. (2018) described a solution involving multiple sensor nodes on farmland, with each node covering a certain area. Each sensor node sends data to the main node through the XBee protocol. The main node is connected to the internet and allows real time monitoring of the farmland state. The system was seen to work well over a coverage area of 1.5 square kilometers.

Raut *et al*. (2018) implemented a system that detected soil moisture levels using a moisture sensor and nutrient deficiency using a colour sensor. The required amounts of nitrogen, potassium, and phosphorus were added to a water tank. The solution was supplied to the soil if the soil moisture sensor reading was below a certain value and the whole operation was reported via email. The system, however, could not have given accurate soil measurements because the colour of the soil is not an accurate indication of the level of particular nutrients within the soil.

2.6 ADVANTAGES OF SMART FERTIGATION

Automating crop irrigation supports the optimum amount of water without the availability of labor to control valves and analyze the plant growth status. The developmental phases in IoT and WSN technologies and the recent advances in sensors for the implementation of irrigation systems for agriculture, have sped up the evolution of smart irrigation systems García *et al*. (2020) .

Hassan *et al*. (2022) successfully developed an Arduino-based fertigation system, revolutionizing smart agriculture. The Arduino functions as a controller, enhancing efficiency and reliability by precisely managing water flow rate and fertilizer distribution based on preset schedules. Through accurate calculations, the system ensures optimal nutrient supply to all plants across rows, minimizing wastage of water and fertilizer. This compact solution signifies a significant advancement in agricultural technology, offering promise for sustainable and resource-efficient farming practices.

2.7 FEATURES OF SMART FERTIGATION

Soil moisture monitoring includes measuring the soil water availability which has been used widely for irrigation scheduling. The disadvantage of soil moisture-based irrigation scheduling is that plant water uptake and stress do not only respond to the soil water content but also to atmospheric parameters, nutrient content, root zone salinity, and pest and disease infestation (Delgoda *et al*., 2016).

Weather-based monitoring includes the real-time estimation of reference evapotranspiration (ETo) using the collected weather parameters and, thus, the water lost by plants and soil (Abioye *et al*., 2023).

Monitoring the smart irrigation process is based on three types, such as soil-based, weather-based, and plant-based monitoring (Bwambale *et al*., 2022).

Monitoring plant–water indices, such as the correlation between crop water stress and soil water deficit provides an optimum estimation of irrigation scheduling. The sensitivity of the measurement for determining plant–water deficit conditions at a particular crop stage highly influences the efficacy of plant-based irrigation scheduling (Gu *et al.*, 2020).

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

3.1 LOCATION OF THE STUDY

The experiment was carried out in the instructional farm of KCAET, Tavanur, Kerala. The site is situated on the cross point of 10^o 51‟18” N Latitude and 75^o 59‟11” E Longitude at an altitude of 8.54 m above mean sea level.

3.2 WEATHER AND CLIMATE

The area has humid sub-tropical climate with major rainfall contributed by south west monsoon followed by the north east monsoon. The experimental site lies in humid area. The summers are dry and hot, whereas winter is cool. The experimental site consists of laterite soil with undulating topography. The meteorological parameters like temperature, humidity and intensity of sunlight were measured inside and outside the polyhouse.

3.3 PERIOD OF STUDY

The study was conducted during the month of March 2024 to May 2024. The system was developed and installed in the polyhouse during the month 15 of March 2024 to 31 of May and the field evaluation of the system was under taken during the rest of the study period using salad cucumber crop.

3.4 AUTOMATED FERTIGATION SYSTEM

Manual fertilizer application is a tedious and labor consuming process. Fertilizer application through drip saves labor. Automatic fertigation allows farmers to deliver adequate nutrient quantity and concentration along with irrigation to plant active root area throughout the growing season automatically thereby saving labour, money and time. An automated system was developed by setting logical circuits between various electrical components during the study. The developed automated fertigation reduces the chance of over or under fertigation and also saves more labor and it will be accurate in terms of dosage and time.

3.4.1 Fertilizer tank

A fertilizer tank which is shown in the Plate 3.1 with an agitator was used for fertigation. Fertilizer tank had100 l capacity and fertilizers were filled manually to the tank. Water was filled for making solution through solenoid valves by a push button switch which was in turn controlled by level sensors. Solenoid valves of a particular tank will activate only when the tank is empty and it will deactivate if the tank is full and it will allow filling again only after the tank is empty.

Plate 3.1 Fertilizer tank

3.4.2 Fertilizer injection pump

Fertilizer injection pump (FIP) was shown in the Plate 3.2 is used to inject fertilizer into the drip line. FIP with an injection rate of 10 l/h was used in this design. It works with 230V. Table 3.1 shows the specifications of the FIP used in the design.

Table 3.1 Specifications of FIP

Particulars	Specifications
Voltage	12V
Maximum discharge flow	10 l/h
Material	Plastic

Plate 3.2 Fertilizer injection pump

3.4.3 Components needed to automate fertigation.

Automating fertigation involves integrating several components to manage the precise application of water and fertilizers to plants. Here are the primary components needed:

3.4.3.1 Arduino microcontroller (esp8266)

Arduino microcontroller esp8266 is an open-source platform used for building electronics projects. Arduino is a programmable circuit's board which we can write a program based on your projects. Arduino program uploaded with IDE (Integrated Development Environment) software that runs on the computer was used to write and upload computer code to the Arduino physical board. There is only 1 way to power the Arduino Nano, the board can be powered through a type-B miniUSB cable or from a 9V battery. The barrel jack is usually connected to a type-B miniUSB cable. The board can be powered by 5-20 volts but the manufacturer recommends to keep it between 7-12 volts.

We used the ESP8266 Arduino microcontroller (Fig: 3.1) is a highly integrated Wi-Fi microchip designed by Espress if Systems, renowned for its affordability and versatility in Internet of Things (IoT) applications. Featuring a 32-bit Tensilica Xtensa LX106 microcontroller, the ESP8266 operates at clock speeds up to 160 MHz and includes a full TCP/IP stack for seamless internet connectivity. Its built-in Wi-Fi capability supports IEEE 802.11 b/g/n standards, making it ideal for wireless communication projects. With multiple GPIO pins, the chip can interface with a variety of sensors and actuators.

It is programmable via several environments, including the Arduino IDE, NodeMCU for Lua scripting, and Micro Python, offering flexibility for developers. The ESP8266 also boasts energy- efficient operation with various power-saving modes. Popular among both hobbyists and professionals, also supported by a robust community and extensive resources, facilitating the development of a wide range of connected devices and smart applications.

Specifications

- Model: ESP8266-12E
- Wireless Standard: 802.11 b/g/n
- Frequency range: 2.4 GHz - 2.5 GHz (2400M-2483.5M)
- Wi-Fi mode: Station / SoftAP / SoftAP+station
- Stack: Integrated TCP/IP
- Output power: 19.5dBm in 802.11b mode
- Data interface: UART / HSPI / I2C / I2S / Ir
- Remote Control GPIO / PWM
- Supports protection mode: WPA / WPA2
- Encryption: WEP / TKIP / AES
- Power supply: from 4.5 VDC to 9 VDC (VIN) or via micro USB connector
- Consumption: with continuous Wi-Fi transmission about 70 mA (200 mA MAX) in standby < 200µA
- Operating temperature: from -40°C to +125°C
- Dimensions (mm): 58×31.20×13
- Weight: 10 grams

Fig. 3.1 ESP8266

3.4.3.2 Soil NPK sensor

The soil NPK sensor we used is shown in the Figure 3.2 is suitable for detecting the nitrogen, phosphorus, and potassium content in the soil. It helps in determining the fertility of the soil thereby facilitating the systematic asses in the soil condition. The sensor can be buried in the soil for a long time. It has a High-quality probe, rust resistance, electrolytic resistance, salt& alkali corrosion resistance, to ensure the long-term operation of the probe part. Therefore, it is suitable for all kinds of soil. It is suitable for the detection of alkaline soil, acid soil, substrate soil, seedling bed soil & coconut bran soil.

The sensor doesn't require any chemical reagent. Since it has High measurement accuracy, fast response speed, and good interchangeability, it can be used with any microcontroller. The sensor cannot use directly with the microcontroller as it has a Modbus Communication port. Hence it needs any Modbus Module like RS485/MAX485 and connect the sensor to the microcontroller.

The sensor operates on 9-24V & power consumption is very low. While talking about the accuracy of the sensor, it is up to within 2%. The nitrogen, phosphorous & potassium measuring resolution is up to 1mg/kg (mg/l).

Using this Soil NPK Sensor, you can make your own Arduino Soil NPK Meter or any Cloud IoT Based Soil Nutrient Content Monitoring System.

Specifications

- Power: 9V-24V
- Measuring Range: 0-1999 mg/kg (mg/l)
- Operating Temperature: 5-45 °C

- Resolution: 1mg/kg
- Precision: ±2% F.S.
- Output Signal: RS485
- Baud Rate: 2400/4800/9600
- Protection Class: IP68

Fig. 3.2 Soil NPK sensor

3.4.3.3 MAX485 TTL to RS-485 Interface Module

We used the MAX485 TTL to RS 485 Interface Module shown in the Fig. 3.3 allows us to use the RS 485 differential signaling for robust long-distance serial communications up to 1200 meters or in electrically noisy environments and is commonly used in industrial environments. It supports up to 2.5MBit/Sec data rates, but as distance goes up, the maximum data rate that can be supported comes down.

The data starts out as a typical TTL level serial as far as the microcontroller is concerned while the RS-485 module takes care of converting the electrical signals between TTL and the differential signaling used by RS-485. A significant benefit of RS-485 is that it supports multiple devices (up to 32) on the same cable, commonly referred to as ‘multi-drop’.

Specifications of MAX485 TTL to RS 485 Interface Module

- Uses MAX485 Interface chip
- Uses differential signaling for noise immunity
- Distances up to 1200 meters
- Speeds up to 2.5Mbit/Sec
- Multi-drop supports up to 32 devices on same bus
- Red power LED
- 5V operation

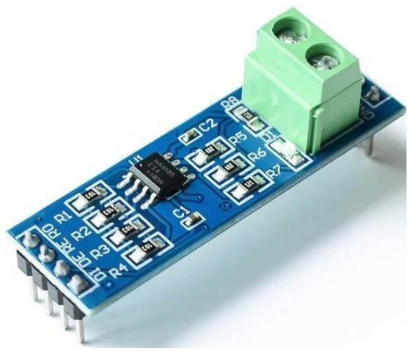

Fig. 3.3 RS 485 module

3.4.3.4 IoT platform

An IoT platform is an application or service that provides built-in tools and capabilities to connect everything in an IoT ecosystem. By providing functions including device lifecycle management, device communication, data analytics, integration, and application enablement.

An IoT platform serves as the cornerstone for developing IoT solutions that bring value to businesses, customers, end users, and partners. By providing visibility, security, and control over connected assets, an IoT platform facilitates the efficient initiation and scaling of IoT projects. This enables the launch of customer-centric services and helps businesses stay competitive in a dynamic market environment.

3.4.3.5 Power supply

A 9-12V DC power supply is an essential device that converts alternating current (AC) from a standard electrical outlet into a stable direct current (DC) voltage within the range of 9 to 12 volts. This type of power supply is widely used to power various electronic devices and components that require a specific DC voltage to operate efficiently and safely. Common applications include powering routers, modems, LED lighting systems, Arduino and other microcontroller projects, and various consumer electronics. These power supplies typically come with standard barrel connectors or other types of plugs to ensure compatibility with a wide range of devices. The stability and reliability of the output voltage are crucial to prevent damage to sensitive electronic components and to ensure consistent performance.

Additionally, many 9-12V DC power supplies include features like overvoltage protection, short circuit protection, and thermal shutdown to enhance safety and durability.

3.4.3.6 Connecting Wires

Connecting wires that used was shown in the Fig: 3.4 are essential components in electrical and electronic systems, serving as the conductive pathways that link various components within a circuit. Typically made from highly conductive materials such as copper or aluminum, these wires are insulated with materials like plastic or rubber to ensure safety and prevent short circuits. Available in various types and sizes, determined by factors like the American Wire Gauge (AWG) system, connecting wires are tailored to meet specific current-carrying requirements. Their applications range from simple household wiring to complex industrial machinery and electronic devices. With color-coded insulation for easy identification, these wires ensure organized and efficient electrical connections, playing a crucial role in the functionality and reliability of electrical circuits. Here jumper wire and USB type B were used.

Fig. 3.4 Connecting wires

3.4.3.7 Single sided PCB prototype board

We used the single sided PCB shown in the Fig. 3.5 are circuit boards with one layer of conducting material on one side of the board, while the other side is used for incorporating different electronic components.

Single sided circuit boards are relatively simple when it comes to their design meaning they require fewer resources and subsequently have a low density. This combination allows high cost-effective and affordable manufacturing, as due to their simplicity they can be produced at higher speeds in larger quantities with less potential problems to encounter and without losing the high-quality performance ABL strive to produce. Additionally, this means a shorter lead time for clients as these boards can be produced at speed and in bulk with ease.

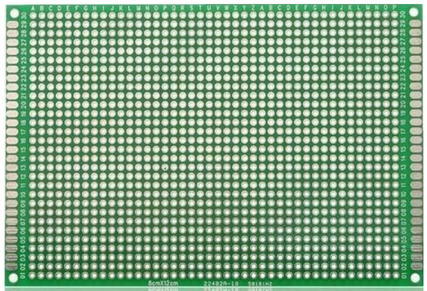

Fig. 3.5 Single sided PCB prototype board

3.4.3.8 Extension Board

Extension boards shown in the Plate 3.3 are devices that allow multiple electrical devices (ESP8266, NPK sensor, Fertilizer injection pump) to be connected to a single power outlet. A view of the extension board used is shown below.

Plate 3.3 Extension board

3.4.3.9 Wi-Fi Modem

In the study, the ESP 8266 IoT was connected to the internet using a Jio Wi-Fi modem which is shown in the plate 3.4 was used. Jio, a well-known telecom provider in India, offers its users a Jio Wi-Fi modem as a means of high- speed internet access. JioFi, also referred to as the Jio Wi-Fi modem, is a portable hotspot that enables users to wirelessly connect numerous devices to the internet. In addition to offering high-speed internet access via the 4G network, it also has the ability to make voice and video calls. To use the JioFi device, users need to insert the Jio sim card into the device and turn it on. They can then connect their devices to the Wi-Fi network created by the JioFi device using the Wi-Fi password provided with the device. The specification are given in table 3.2

Table 3.2 Specifications of Jio Wi-Fi modem.

Model	Router M2S black
Device throughput	Up to 150 Mbps
Voice support	No call support
Expandable memory capacity	32 GB
Cost	Rs.4000

Plate 3.4 Jio Wi-Fi modem

3.4.3.10 Relay module

A relay module is an electronic component used to control high-power devices with a low-power signal, such as from a microcontroller or an Arduino. It acts as an electrically operated switch that can turn on or off a circuit by isolating the control signal from the high- power load.

When a low-power control signal is applied to the input pin (IN), it activates the transistor. The transistor allows current to flow through the relay coil, energizing the electromagnet. The electromagnet pulls the switch contacts, changing their state. For example, a normally open (NO) contact closes, completing the circuit and allowing current to flow to the high-power device. When the control signal is removed, the coil is de-energized, the electromagnet releases, and the contacts return to their default state. The relay module shown in Fig. 3.6 was used in the system.

Fig. 3.6 Relay module

3.4.3.11 Agitator

Agitator shown in the plate 3.5 were used for mixing the fertilizer inside each tank with water to make thorough fertilizer solution before every pumping into the drip irrigation system. It was working with 230 V AC.

Plate 3.5 Agitator

3.5 DETAILS OF SOFTWARES USED IN AUTOMATION

3.5.1 Arduino Integrated Development Environment (IDE) Software

Code was written and uploaded to the Arduino board using the Arduino IDE shown in the Fig. 3.7. C and C++ are supported languages by Arduino were used. The prepared code can be saved as a file with the .ino extension. The program written in this software can be upload to an Arduino board using a USB cable.

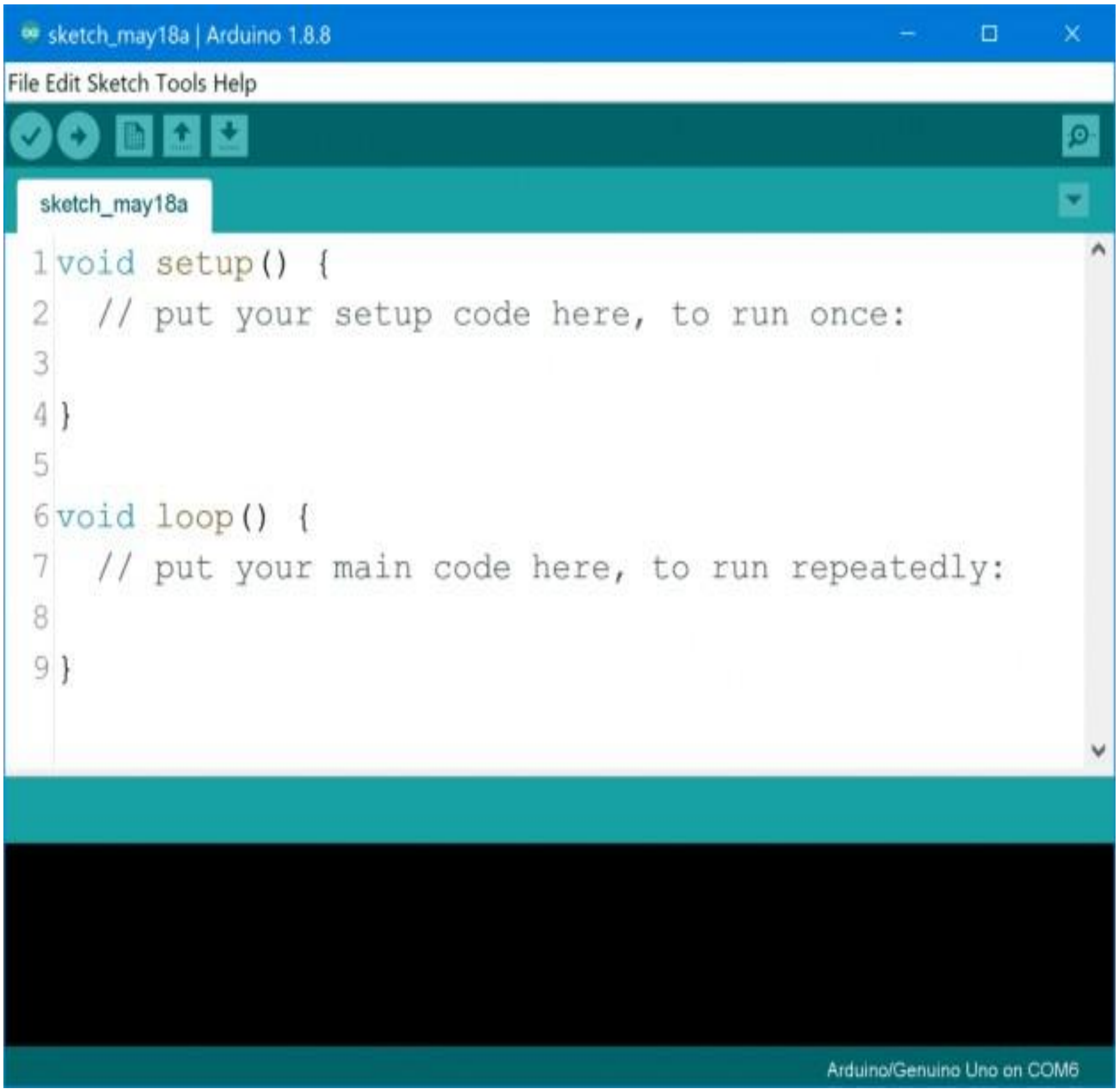

Fig. 3.7 Arduino IDE

3.5.2 ThingSpeak IoT

For this setup we used ThingSpeak IoT platform ThingSpeak is a cloud-based IoT analytics platform service that let users to collect, view, and examine real-time data streams. User can send alerts, instantly visualize live data, and send data to ThingSpeak from devices.

3.5.2.1 Features of ThingSpeak IoT

i. Data collection: ThingSpeak allows users to send data from various sensors and devices to the cloud. This can be done through HTTP, MQTT, or MQTT over WebSockets.

ii. Data storage: Collected data is stored in channels, which can hold multiple fields of data, metadata, and location information.

iii. Data Analysis: Users can perform data analysis and processing using MATLAB code directly within the ThingSpeak platform. This includes real-time analysis and visualization of data.

iv. Visualization: ThingSpeak provides tools to create real-time graphs and visualizations, which can be embedded in web pages or shared publicly.

v. Triggers and Alerts: Users can set triggers to perform actions when data meets certain conditions. This could include sending notifications, activating devices, or executing MATLAB code.

vi. API Integration: ThingSpeak offers RESTful and MQTT APIs for easy integration with other IoT platforms and service

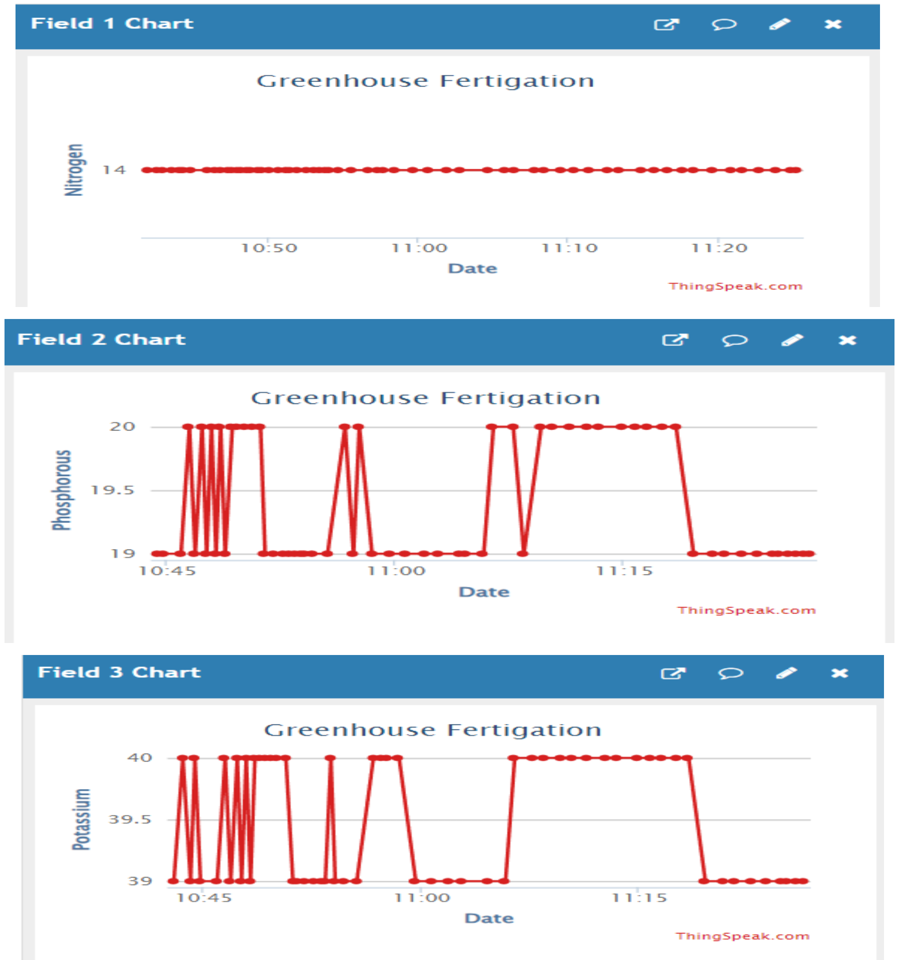

Fig. 3.8 ThingSpeak interface of soil neutrient concentration

3.6 CALIBRATION OF NPK SENSOR

The NPK sensor used in the system was already pre calibrated. In order to avoid any error in the experiment again calibration was done. Three different soil samples were taken from KCAET Tavanur. The collected samples were tested from the District Soil Testing Lab of Malappuram. Upon receiving results from the lab the soil samples were tested using the NPK sensor, and compared the both values. A view of connection NPK sensor with ESP8266 shown and the corresponding sensor reading is shown in Plate 3.6

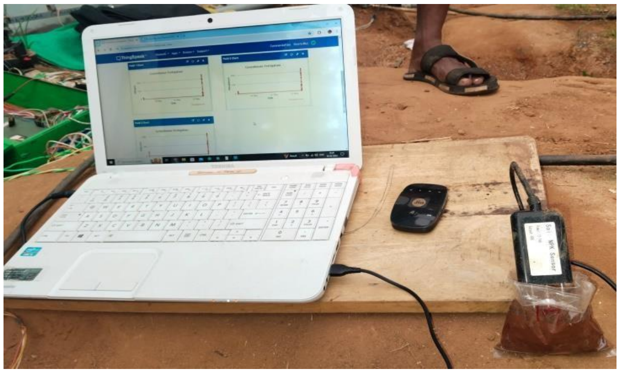

Plate 3.6 Calibration of soil NPK sensor

3.7 INTERFACING VARIOUS COMPONENTS WITH ESP8266

ESP8266 was the microcontroller used and it was the main processing unit. Sensors, RS 485 module, Relay module display were interfaced with this microcontroller. The process of interfacing various components with ESP8266 microcontroller and the source code developed is explained in the following subheads.

3.7.1 Interfacing RS 485 with soil NPK sensor

Table 3.3 displays the different pins of the NPK sensor and RS 485 module. The NPK sensor consists of four pins: data pins (485A and 485B) and power pins (VCC and GND). Pin 485A is connected to pin A of the RS 485 module for the study, and pin 485B is connected to pin B of the RS 485 module. A wire is used to link the VCC to the 12V power source. The microcontroller's GND pin is connected to the GND pin shown in the Fig.3.9.

Table 3.3 RX 485 module pins and its connection with NPK sensor

NPK sensor	RS 485 module
485A	A
485B	B
GND	GND

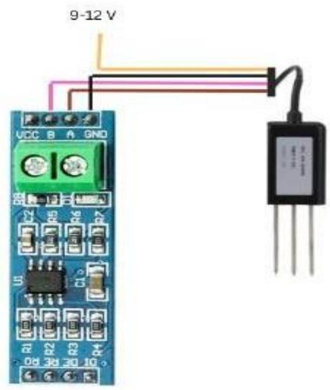

Fig.3.9 Various pins of RS 485, NPK sensor and their interfacing

3.7.2 Interfacing RS 485 with ESP8266

Various pins of RS 485 module and ESP8266 are shown in Fig.3.10. Interfacing an ESP8266 with an RS 485 module involves several steps to ensure proper communication between the devices. As shown in Table 3.4 for the study D2 pin of RS 485 module is connected to pin RO on the ESP8266. While pin D3 of RS 485 to pin D1 of ESP8266, pin D0 to pin RE, pin D1 to DE, Vin of RS 485 to VCC of ESP8266. The GND pins are connected together.

Table 3.4: Connection of RS 485 module pins with ESP8266 pins

RS 485 Module	ESP8266
D2	RO
D3	D1
D0	RE
D1	DE
Vin	Vcc
GND	GND

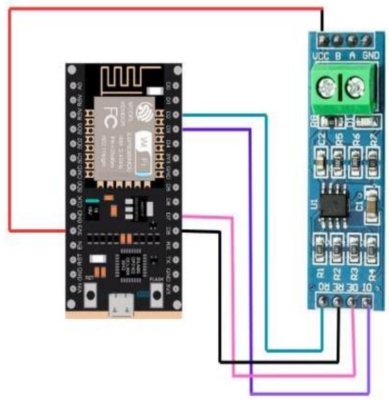

Fig. 3.10 Various pins of ESP8266, RS 485 and their interfacing

3.7.3 Interfacing ESP8266 with relay module

Various pins of relay module and ESp8266 are shown in Fig 3 . 1 1 interfacing an ESP8266 with relay module involves several steps to ensure proper communication between the devices. For the study In 1 pin of Relay module is connected to pin D6 on the ESP8266. While pin Vcc of Relay module to pin Vin of ESP8266. The GND pins are connected together.

Table 3.5: Relay module pins and connection with ESP8266 pins

Relay module	ESP8266
In1	D6
Vcc	Vin
GND	GND

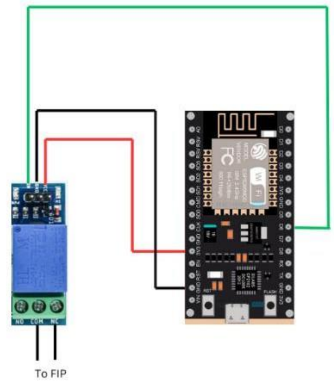

Fig: 3.11 Various pins of ESP8266, Relay module and their interfacing

3.7.4 Interfacing relay module with FIP

The relay module is connected to FIP through wires to provide power for the proper working of FIP.

3.7.5 Source code/ Code for connecting NPK sensor with microcontroller.

The code is developed and uploaded into the microcontroller. All the pins are connected together and the developed code is given below:

```
#include
<ESP8266WiFi.h>
#include
<SoftwareSerial.h>
#include <LiquidCrystal.h> // Include the LCD library


const char* ssid = "JioFi_2149165";           // replace with
your WiFi SSID const char* pass = "cq7yi4qeqq";   //
replace with your WiFi password
String apiKey = "VXWC8RZ8PCVPWG82"; // Enter your ThingSpeak
API Key const char* server = "api.thingspeak.com";
const uint32_t
TIMEOUT = 500UL;
```

```
#define RE 16        //
D0
#define DE 5      // D1
#define RELAY_PIN D6 // Define relay pin as D6

WiFiClient client;
SoftwareSerial swSerial(4, 0); // RX, TX
(D2,D3) LiquidCrystal lcd(12, 14, 13, 15,
16, 17); // LCD pins

// Modbus packets
uint8_t  nitro[]  =  {0x01,  0x03,  0x00,  0x1e,  0x00,
0x01,  0xe4,  0x0c};  uint8_t  phos[]  =  {0x01,  0x03,
0x00, 0x1f, 0x00, 0x01, 0xb5, 0xcc}; uint8_t pota[] =
{0x01, 0x03, 0x00, 0x20, 0x00, 0x01, 0x85, 0xc0};
uint8_t rxByte; int x = 0;

  void setup() {
   Serial.begin(96
   00);
   swSerial.begin(
   9600);
   pinMode(RE,
   OUTPUT);
   pinMode(DE,
```

```
  OUTPUT);
  pinMode(RELAY_PIN, OUTPUT);
  digitalWrite(DE,
  LOW);
  digitalWrite(RE,
  LOW);
  digitalWrite(RELAY_PIN, LOW); // Ensure motor is
  initially off delay(1000);
  lcd.begin(16, 2); // Initialize the LCD
  lcd.print("Connecting...");

  WiFi.begin(ssid, pass);

  while (WiFi.status() !=
    WL_CONNECTED) { delay(500);
    lcd.print(".");
  }
  lcd.clear();
  lcd.print("WiFi connected");
}

void loop() {
  // Read Modbus values
  int nitroValue =
  readModbusValue(nitro, sizeof(nitro));
  int phosValue =
```

```
readModbusValue(phos, sizeof(phos));
int potaValue =
readModbusValue(pota, sizeof(pota));

lcd.setCursor(
0, 0);
lcd.print("Nitr
ogen: ");
lcd.print(nitro
Value);
lcd.print("
mg/kg");

lcd.setCursor(
0, 1);
lcd.print("Phos
phorous: ");
lcd.print(phosV
alue);
lcd.print("
mg/kg");
// Control motor based on nitrogen, phosphorus, and
potassium values if (nitroValue < 100 || phosValue <
100 || potaValue < 100) { digitalWrite(RELAY_PIN,
HIGH); // Turn motor on
  lcd.set
```

```
  Cursor
  (0, 2);
  lcd.pri
  nt("Mo
  tor
  ON");
} else {
  digitalWrite(RELAY_PIN, LOW); //
  Turn motor off lcd.setCursor(0, 2);
  lcd.print("Motor OFF");
}

if
  (client.conne
  ct(server,
  80)) {  String
  postStr       =
  apiKey;
  postStr   +=   "&field1="   +
  String(nitroValue);    postStr
  +=          "&field2="         +
  String(phosValue);    postStr
  +=          "&field3="         +
  String(potaValue);    postStr
  += "\r\n\r\n\r\n";
```

```
    client.print("POST /update
    HTTP/1.1\n");
    client.print("Host:
    api.thingspeak.com\n");
    client.print("Connection:
    close\n");
    client.print("X-THINGSPEAKAPIKEY: " + apiKey
    + "\n"); client.print("Content-Type: application/x-
    www-form-urlencoded\n"); client.print("Content-
    Length: ");
    client.print(postSt
    r.length());
    client.print("\n\n"
    );
    client.print(postSt
    r);
    lcd.setCursor(0,
    3);
    lcd.print("Data
    sent to TS");
  }
  client.stop();

  delay (2000);
}
```

```
int readModbusValue(uint8_t msg[],
 size_t msgSize) { uint32_t startTime =
 0;
 int value = 0;

 digitalWrite(
 DE, HIGH);
 digitalWrite(
 RE, HIGH);
 delay(10);
 swSerial.writ
 e(msg,
 msgSize);
 swSerial.flush
 ();
 digitalWrite(
 DE, LOW);
 digitalWrite(
 RE, LOW);

 // read any data received
 and print it out startTime =
 millis();
 x = 0;
```

```
while (millis() - startTime
 <= TIMEOUT) { if
 (swSerial.available()) {
  byte rxByte =
  swSerial.read()
  x++;
  if (x == 5) {
   value = rxByte; // Convert the fifth
   byte to decimal break;
  }
 }
}delay(100); return value;
}
```

3.8 SETTING UP ThingSpeak IoT

ThingSpeak is an IoT (Internet of Things) platform that allows users to collect, store, analyze, visualize, and act on data from sensors and devices. Developed by MathWorks, ThingSpeak enables the integration of sensor data with MATLAB, facilitating advanced data analysis and visualization.

3.8.1Create a ThingSpeak Account

Go to the ThingSpeak sign-up page. Follow the instructions to create an account and log in.

3.8.2 Create a Channel

Once logged in, navigate to the "Channels" tab and click "New Channel". Fill in the channel details, such as name, description, and fields. Save the channel by clicking "Save Channel".

After creating the channel, you will see the channel view. Note down the Write API Key and Read API Key, which will use in the Arduino sketch.

3.8.3 Configure Your Arduino Device

Open the Arduino IDE. Go to Sketch > Include Library > Manage Libraries. Search for "ThingSpeak" and install it. Open an example sketch by navigating to File > Examples > ThingSpeak > Examples from Custom Libraries > WriteSingleField. Modify the sketch to include your Wi-Fi credentials and ThingSpeak API key.

3.8.4 Upload the Sketch

Connect the Arduino board to the computer. Select the correct board and port from the Tools menu. Click the upload button to upload the modified sketch to the Arduino.

3.8.5 Visualize Data on ThingSpeak

Go to your channel view on ThingSpeak. The data being updated in real-time in the field plots. Use the visualization tools provided by ThingSpeak to create charts, gauges, and other visual representations of the data as shown in the Fig.3.12.

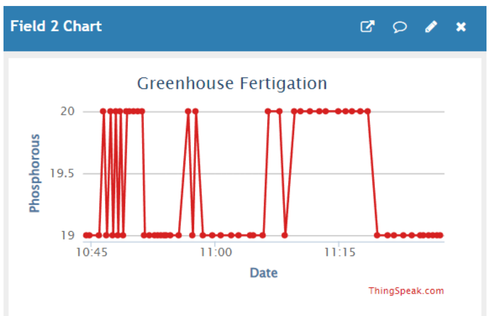

Fig. 3.12 ThingSpeak platform

3.9 OVERALL CIRCUIT DIAGRAM

All the components NPK sensor, RS 485 module, Relay module and FIP were interfaced to the ESP8266 microcontroller. An overall circuit diagram showing the connections is shown in the Fig.3.13.

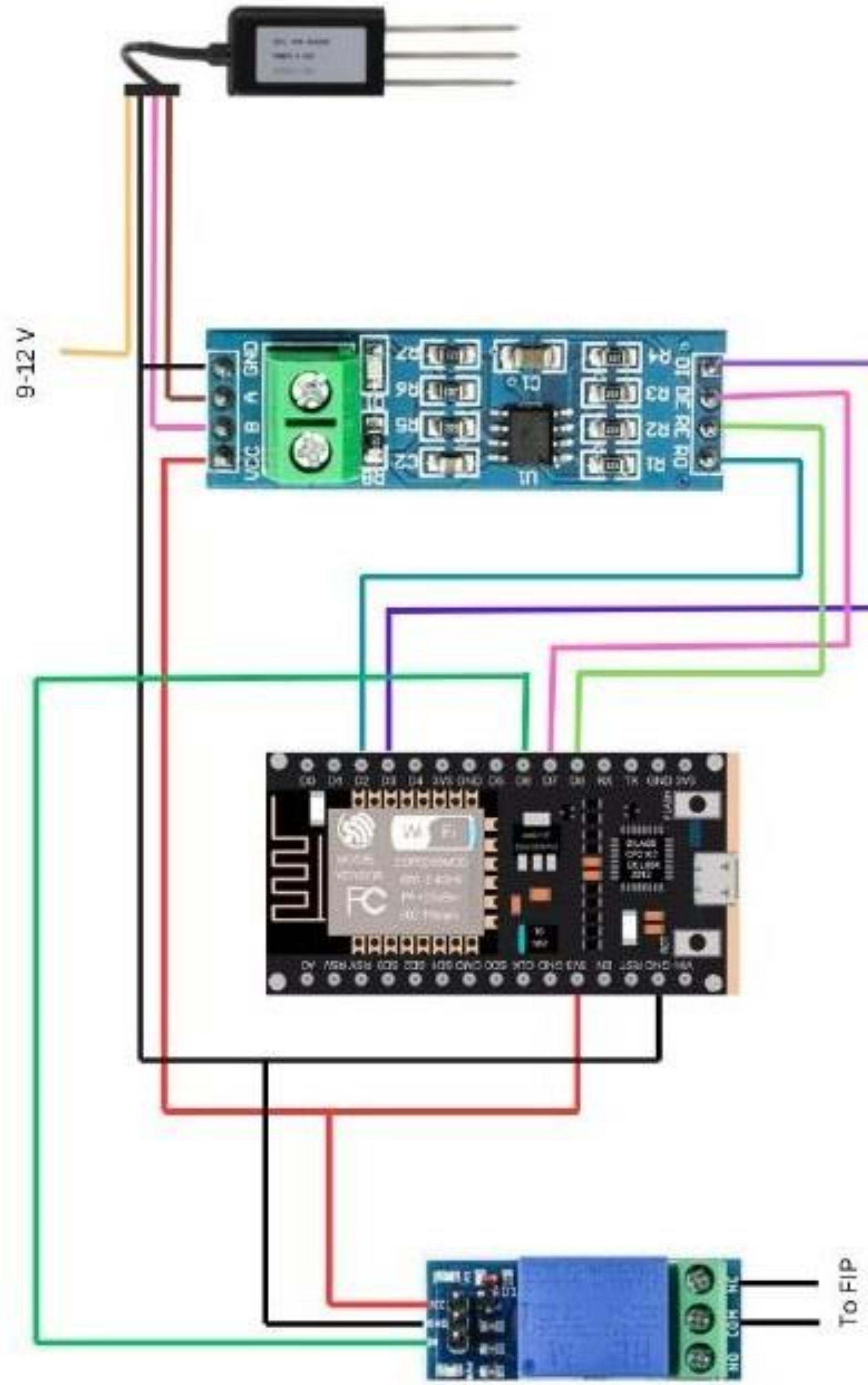

Fig. 3.13 Overall circuit diagram

3.10 DRIP IRRIGATION UNIT

At the center of the bed, online drip laterals were laid for providing water and fertilizer effectively to the root zone depth. Online drippers were spaced at 45 cm apart with a discharge rate of 2 lit/hr. The plants were irrigated daily through drip irrigation system. Irrigation water was pumped using 5 hp mono block pump set and conveyed through the main line of 63 mm diameter PVC pipes after filtering through the disc filter. From the main pipe, sub main of PVC pipes (50 mm) were installed. From the sub mains water was conveyed to laterals of diameter 16 mm.

3.11 FLOWCHART OF IoT BASED AUTOMATION SYSTEM

The NPK sensor was buried in the soil. Then it starts to give the readings of N P K through the ThingSpeak platform. In the coding the low threshold and high threshold value of the nutrients was already given. When the sensor senses the low threshold vale it will give to ESP8622 microcontroller and it starts the fertilizer injection pump and drip irrigation pump both simultaneously. Then fertigation starts. When the sensor senses the value of nutrients in soil at high threshold it will give signal to microcontroller and it causes the fertilizer injection pump to turn off and stops the application of fertilizer while the irrigation pump runs for extra 10 minutes. Flowchart is shown in the Fig.3.14.

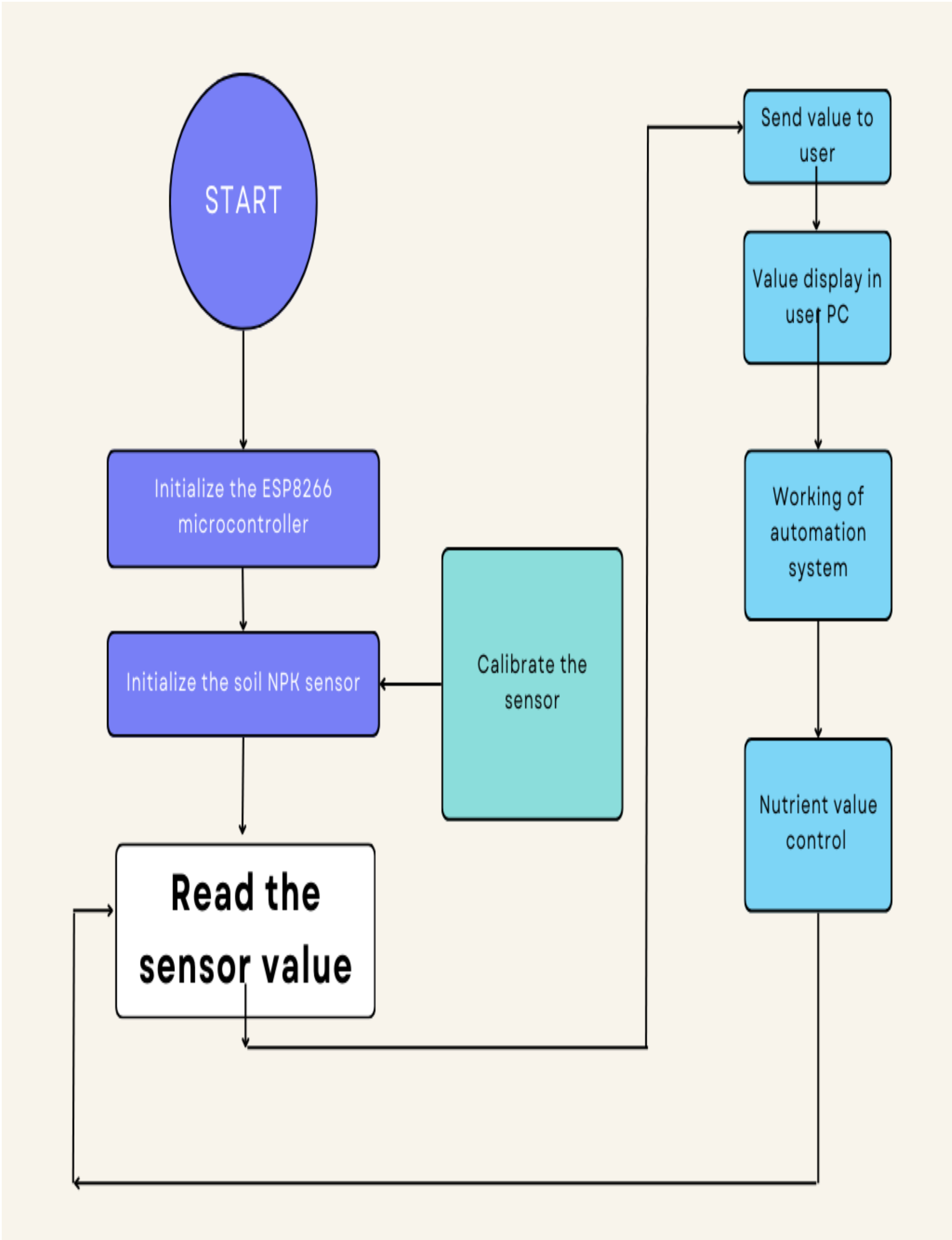

Fig. 3.14 Microcontroller program workflow

3.12 EXPERIMENTAL SETUP

3.12.1 Polyhouse

Polyhouses are essentially naturally ventilated climate-controlled structures primarily utilized for applications such as growing vegetables, floriculture, and planting material acclimatization. The experiment was carried out in the naturally ventilated polyhouse as shown in the Plate 3.7 of area 292 m^2 (36 m length and 8 m width) is oriented in East-West direction situated in the instructional farm of KCAET, Tavanur. Frame of the structure was made up of galvanized steel pipe and covered with 200 micron UV stabilized polyethylene film. The sides of the polyhouse were covered by insect proof net of 40 mesh for natural ventilation and protection against entry of insect and pests. The polyhouse was divided into two parts one is 20 m long where automation system is installed and the other part which is 6 m long where manual fertilization is used.

Plate 3.7 Polyhouse

3.12.2 Crop and variety

Salad Cucumber (Cucumis sativus) variety KPCH 1 (KAU Parthenocorpic hybrid variety 1) was used for the experiment. It is a high yielding variety which grows vigorously and mostly bears female flowers. The fruit skin is glossy green with few spines and it tastes crispy and sweet, making it suitable for salad or frying and the crop is most suited for polyhouse cultivation. Seeds were sown in a pro tray containing mixture of vermicompost and coir pith in 1:1 ratio to a depth of 0.5 cm on

1/3/2024 under the supervision instructional farm KCAET. Due to adverse climatic condition seedlings got damaged with intensified heat and pest infestation. After repeated sowing of seeds in pro tray we got seedlings on 12/3/2024 seedlings were transplanted into the polyhouse on 13/4/24. (Plate 3.9 shows the seedlings in the pro tray before transplanting in the plot).

3.12.3 Experimental procedure

Evaluation of the automated fertigation system was carried out by installing the system in a polyhouse of 292 m^2. Total 152 plants were planted in the polyhouse and were automatically fertigated, another 120 plants were planted in the same poly house which was fertilized manually and the biometric and plant growth parameters of randomly selected plants from each plot were noted and was compared with each other to evaluate the efficiency of the system using statistical analysis.

3.12.4 Layout of the experiment

First set of plants as shown in the Plate 3.8 with automated fertigation system were grown inside the polyhouse in four beds at a length of 18 m and width of 1.2 m with plant to plant spacing of 45 cm, each row containing 38 plants. The next set of plants as shown in the Plate 3.9 in which fertilizer was applied manually was grown in the polyhouse in four beds at a length of 14 m and width of 1.2m with plant to plant spacing of 45 cm, each row containing 30 plants. Drip irrigation system with an emitter spacing of 45cm was installed in all the plots with drips of 2 lph capacity.

Plate 3.8 Automated fertigation plot

Plate 3.9 Non automated fertigation plot

Plate: 3.10 Seedlings in protrays

3.13 FERTIGATION

The fertigation system was installed inside the polyhouse. The required amount of different fertilizers (NPK) for the plant was filled in fertilizer tank and the tank was filled with desired quantity of water with the help of push button switch. Fertilizers used were Mono- Ammonium Phosphate and Potassium Nitrate. For the thorough mixing of the fertilizer solution agitator was provided. After mixing, the solutions were pumped to the drip system through FIP. Other nutrient fertilizers such as calcium nitrate which were essential for plant growth were directly fed into the mixing tank in the form of solutions whenever it was necessary.

3.14 PEST AND DISEASE CONTROL

Crops that are productive and well-grown tend to be less prone to illness. On the other hand, there are situations in which particular circumstances are necessary to prevent disease and pests. Crops that receive regular irrigation and fertilization often grow quickly, but they can also become more vulnerable to pests like leaf miners, aphids, and whiteflies. During the growing times, daily inspection and control are essential to reduce economic loss.

Weeding was done manually after every 20 days. To protect the plants from attacking of red mites oberon was sprayed twice a week.

3.15 FIELD DATA COLLECTION

3.15.1Biometric observations

Biometric analysis on growth of the plant was done. The main crop growth parameters like height of the plant, days to initial budding, days to first flowering, days to 50 percentage flowering, days to first harvest, Leaf Area Index (LAI) were observed. The crop was transplanted on 12/04/2024. Biometric observations of 4 randomly selected plants were taken from each plant.

3.15.2 Height of plant

Height of the plant was measured from ground level to tip of top most leaf. Readings were recorded for each selected plants from different treatment plots from the transplanted date at an interval of 7 days.

3.15.3 Inter nodal length

The inter nodal length of the selected plants was measured from the transplanted date at an interval of 7 days.

3.15.4 Number of leaves per plant

The number of leaves in selected plants from each plot was counted from transplanted date at an interval of 7 days.

3.15.5 Leaf area index

The average length and width of leaves of the selected plants were taken from the date of transplanting at an interval of 7 days and leaf area index was calculated using the equation Anjaly and Abdul Hakkim (2016).

3.15.6 Number of days taken for flower initiation

The time taken by the crop to start initial budding stage from date of transplanting was observed. The number of days for each plot was recorded.

3.15.7 Number of flowers per plant

The number of leaves in selected plants from each plot was counted from the day flower initiation at an interval of 7 days.

RESULTS AND DISCUSSIONS

CHAPTER IV
RESULTS AND DISCUSSIONS

The study was conducted during the period from March 2024 to May 2024 at Instructional farm KCAET, Tavanur. The system was developed and evaluated during the months of April to May 2024. Field evaluation of the developed automated fertigation system was carried out with salad cucumber crop inside a poly house during the months of April to May 2024 and a comparative analysis was done between the biometric observations of the two groups of crop planted inside the polyhouse viz. fertigated automatically with the developed system and with manual fertilizer application. The results of the study are presented in this chapter.

4.1 CALIBRATION OF NPK SENSOR

The calibration of the NPK sensor was done before the installation of system. The sensors were calibrated using the data acquired from the sensor and the data obtained through the testing of soil. There were no significant difference between the sensor readings and values obtained from the soil testing lab. Hence no change was required in the calibration of sensor. The values recorded are shown in Table 4.1

Table 4.1: Calibration chart

Sample 1	N	P	K
Tested value	45	63	127
Sensor value	47	61	124
Sample 2	N	P	K
Tested value	55	58	120
Sensor value	53	59	124
Sample 3	N	P	K
Tested value	142	111	195
Sensor value	137	115	198

4.2 PERFOMANCE OF FERTIGATION SYSTEM

The developed system was installed in the polyhouse and observed the working of system. The system works under the influence of threshold value of Nitrogen, the system start fertigation when the N value go below low threshold and ends the fertigation when N value go above high threshold value. The graph representing the variation in soil nutrients is shown in Fig. 4.1.

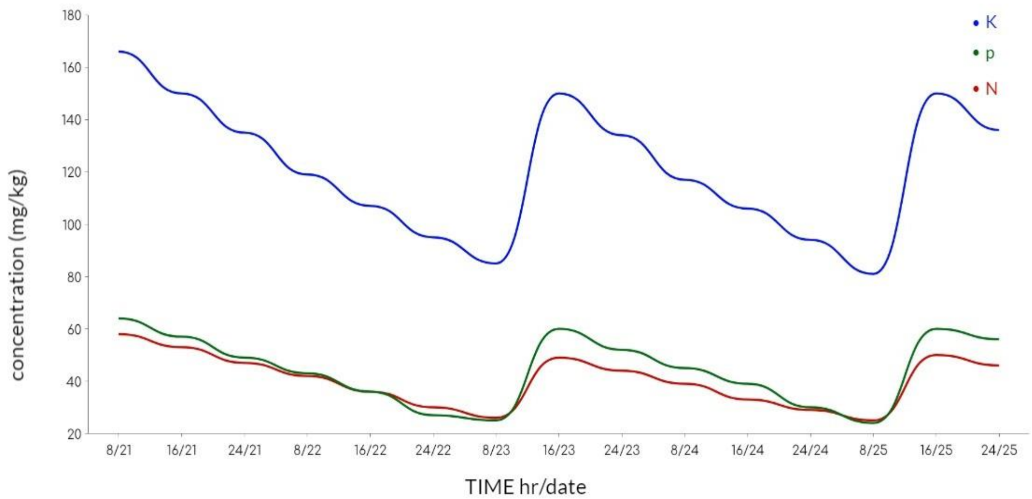

Fig. 4.1 Fertigation graph

4.3 BIOMETRIC OBSERVATIONS

4.3.1 Height of the plants

The growth of the plants was recorded at definite intervals of 7 days on the plant height was subjected to t- test and the results are shown in the tables. The results represent the mean data of five plants grown in automated fertigated field and five plants grown in manually fertigated field. In t-test, the treatments were compared.

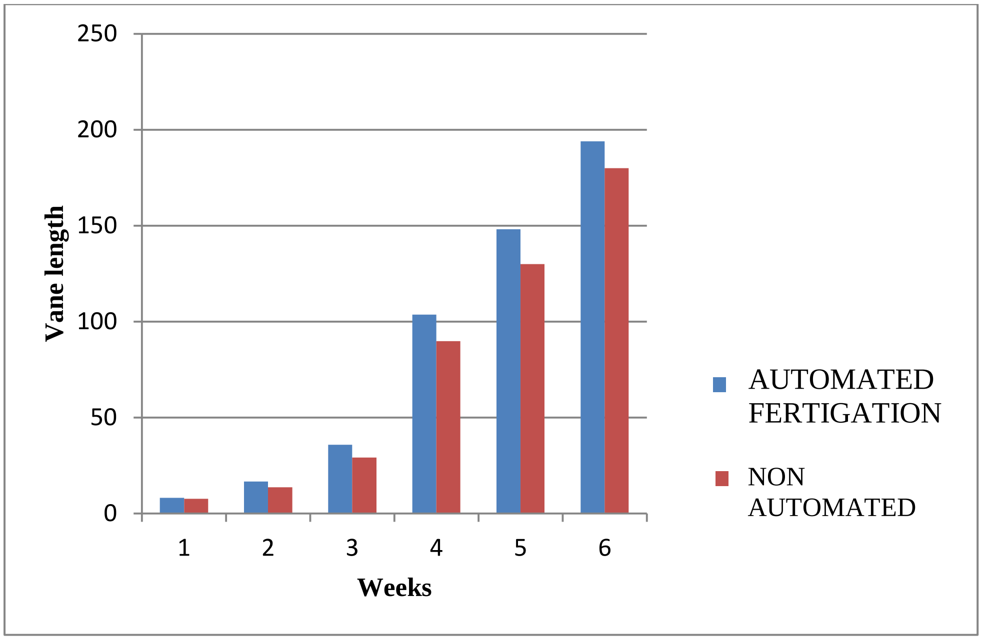

Fig. 4.2 Effect of different treatments on plant height of cucumber

The results showed that the automated plot has more superiority in plant height shown in the Fig. 4.3 than the non-automated plot. The concentration and availability of various nutrients in the soil for plant uptake depends on the soil solution phase which is mainly determined by soil moisture availability. The higher available soil moisture provided due to continuous water and nutrient supply under drip fertigation had led to higher availability of nutrients in the soil and thereby increased the nutrient uptake by the crop, and hence promoting the growth of cucumber.

4.3.2 Inter nodal length

The inter nodal length of the plants were recorded at 7 days interval. The measured data was recorded and subjected to t-test. The data were taken from five plants from each plot and the compared result is shown Fig. 4.3.

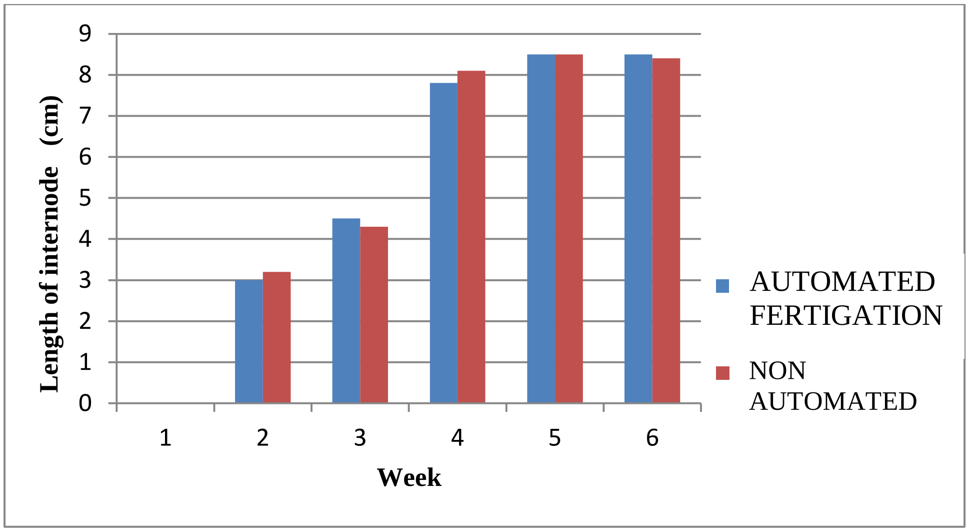

Fig. 4.3 Effect of inter nodal length on different treatments

From the graph it is shown that the inter nodal length is almost equal in both plots. Hence the inter nodal length does not have significant effect due to mode of fertilizer application.

4.3.3 Number of leaves

The numbers of leaves were counted at definite intervals of 7 days from five different plants from the automated field and manual field. The measured data was subjected to t-test. The compared result is shown in Fig.4.4.

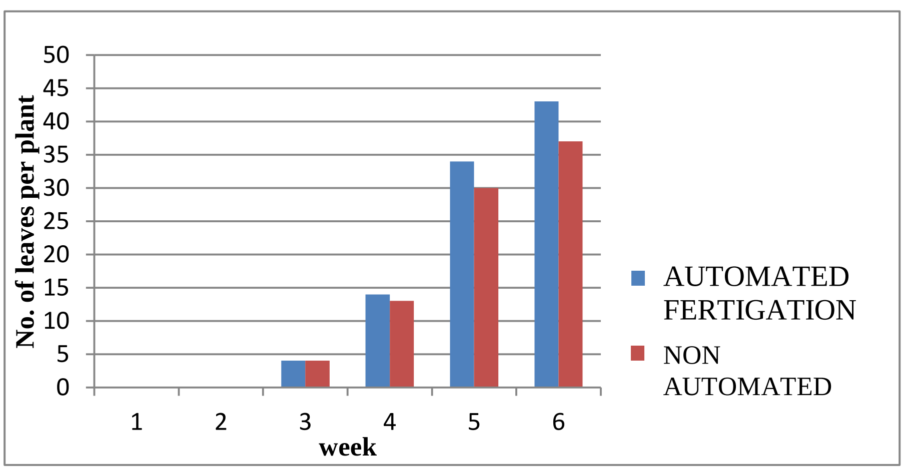

Fig.4.4 Effect of different treatments on number of leaves per plant of cucumber

In the first two stages, the number of leaves are very less so it is taken as insignificant. As the time increases we can see the variation in the number of leaves in both plots. The automated plot has more number of leaves compared to the manual field. This indicates that proper application of fertilizer increases the number of leaves per plant.

4.3.4 Leaf area index (LAI)

Mean value of length and width of leaves of five randomly selected plants were taken at weekly intervals from each plot and the leaf area index was computed and t - test was performed and the treatments were compared individually with each other. The computed result is shown in Fig.4.5.

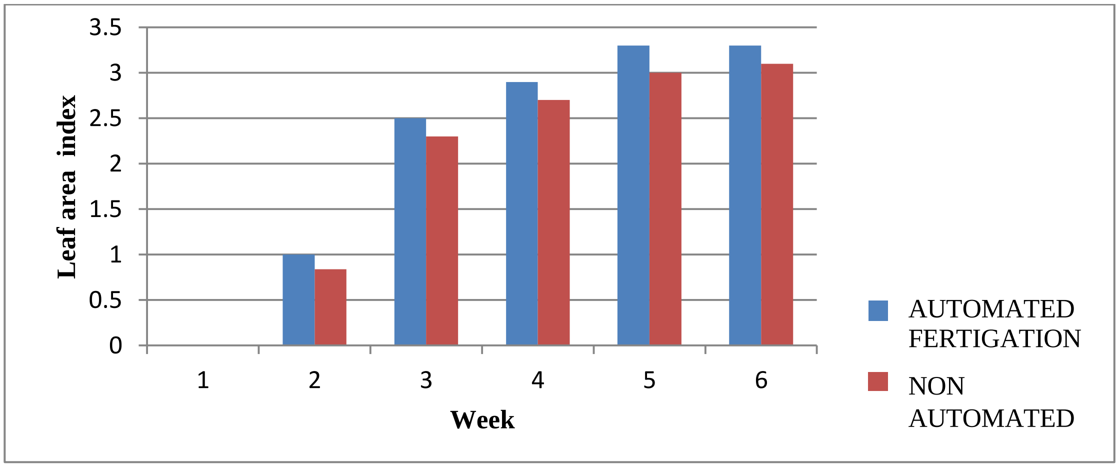

Fig.4.5 Effect of different treatments on Leaf Area Index of cucumber

In the first stages the LAI values are non-significant. After the first stages there is a difference in LAI. The LAI is numerically higher in automated plot than manual plot. This indicates that uniform application of fertilizer through drip fertigation give maximum growth for cucumber.

4.3.5 Number of flowers

The Number of flowers of the plants were recorded at 7 days interval. The flower initiation started between fourth and fifth week of planting as shown in Fig.4.6.

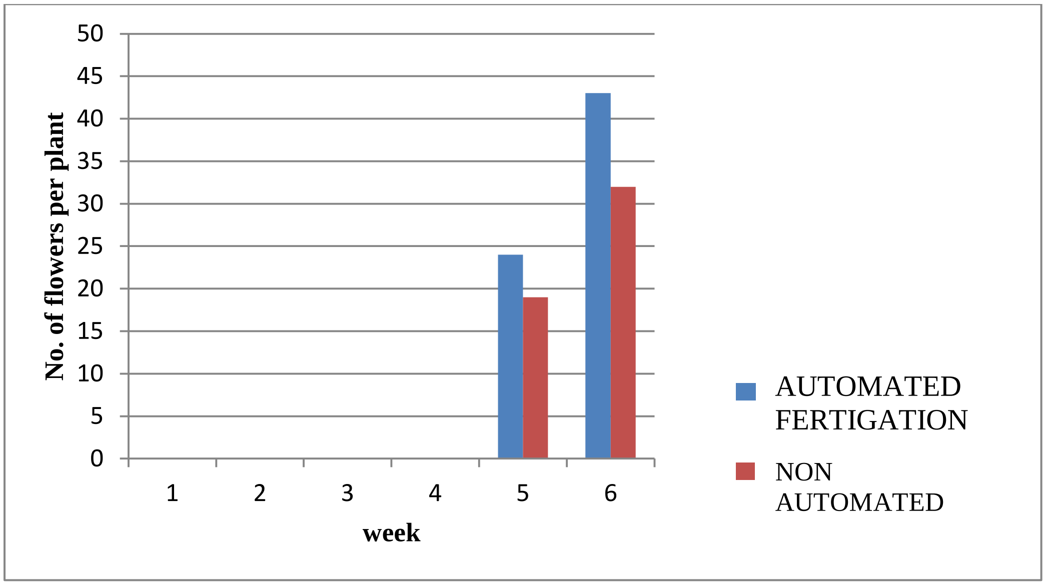

Fig.4.6 Effect of different treatments on number of flowers per plant of cucumber

From the graph it is shown that the number of flowers is more in automated field.

4.3.6 Number of fruit buds per plant

The Number of fruit buds per plant were recorded at 7 days interval. Fruits initiated by fifth week of planting shown in Fig.4.7.

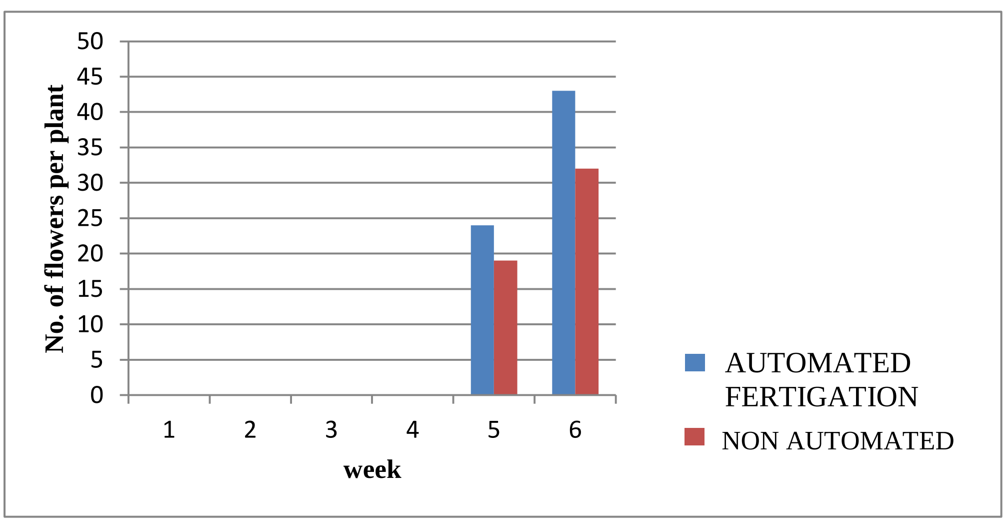

Fig.4.7 Effect of different treatments on number of fruit buds per plant of cucumber

The automated fertigation system demonstrated significant advantages over manual fertilizer application in terms of plant height, leaf number, leaf area index, and the number of flowers and fruit buds. These findings suggest that automated fertigation can enhance the growth and productivity of salad cucumber crops by ensuring a consistent and optimal supply of nutrients and moisture. Implementing such a system can lead to better crop management, higher yields, and increased efficiency in agricultural practices.

SUMMARY AND CONCLUSION

CHAPTER V
SUMMARY AND CONCLUSION

Incorporating irrigation at appropriate intervals and in the right amounts can boost crop productivity. Scheduled fertilizer application is almost a must for any crop to deliver its greatest potential. In order to apply fertilizer evenly throughout a field, a technique known as fertilization involves combining fertilizer with irrigation water and applying it via micro irrigation systems. Farmers can save effort, money, and time by using automatic fertigation to ensure that active plant roots receive the right amount and concentration of nutrients along with irrigation water throughout the growth season.

The present study "Smart fertigation for green house automation" was aimed analyze the performance evaluation of automated fertigation system working with the help of soil NPK sensor. The evaluation of working of NPK sensor, the statistical analysis of biometric observation of the system were evaluated.

The field experiment was conducted in the polyhouse situated at the instructional farm inside KCAET Tavanur. The polyhouse is divided into two parts, while each part containing four plots. The total area chosen for the experiment was 219 sqm. A comparative analysis was conducted between biometric observations of the both group of crop, one is fertigated automatically and the other is manually fertigated.

Crop growth parameters like height of plants, inter nodal lengths, number of leaves per plant, leaf area index and number of flowers per plant were observed for both treatments. The height of the plants was measured at an interval of 7 days and it can be observed that the rate of growth was more in the automated field compared to the manual field. The inter nodal length variation in both plots were almost equal in every measured week. The number of leaves per plant measured at an interval of 7 days it also show that the number of leaves were more in the automated plot. The leaf area index was calculated for both plots and it also shows an increase in automated plot.

From the present study it can be inferred that the automated fertigation system installed inside the polyhouse can be considered as the best treatment as it gave the maximum value of biometric observations. Thus it can be concluded that the developed system for automatic fertigation ensured better yield for cucumber variety 'KPCH 1 (KAU Parthenocarpy hybrid variety 1)' grown inside the polyhouse. Moreover, the system was fully operated automatically therefore no need to go into the field for fertigating the crops. The fertigation was done instantaneously according to the availability of nutrients in the soil, hence the rate of loss of fertilizer was minimized and the efficiency of fertigation can be increased. The developed automated fertigation system reduces the chances for over or under fertigation, saves labor and maintains accurate dosage whenever the nutrient availability in the soil reduces below the required threshold value.

In conclusion integration of a soil NPK sensor with Arduino technology presents a significant advancement in soil nutrient monitoring for agricultural purposes. The continuous monitoring capability offers farmers valuable insights into soil health, enabling precise and timely fertilization practices, optimizing crop yield and minimizing environmental impact through nutrient management. However, further research is warranted to address calibration requirements for diverse soil types and to explore additional parameters that enhance the sensor's capability. Future research may be carried out to compare the system efficiency inside the polyhouse and open field, it can be a better scope for future.

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CHAPTER VI
REFERENCES

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ABSTRACT

SMART FERTIGATION FOR GREENHOUSE CULTIVATION

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ABSTRACT

Smart fertigation is an innovative approach integrating irrigation and fertilization management, tailored for greenhouse environments to optimize crop production and resource utilization. By leveraging advanced technologies such as Internet of Things (IoT) sensors, automation systems, and data analytics, smart fertigation systems can precisely monitor and control the delivery of water and nutrients to plants.

This study investigates the implementation and performance of a smart fertigation system designed for greenhouse cultivation, utilizing soil NPK sensors integrated with Arduino technology. The system automates the application of fertilizers through a micro-irrigation network, ensuring precise nutrient delivery based on real-time soil nutrient levels. The experiment was conducted in a polyhouse and compared the growth metrics of cucumber plants subjected to automated fertigation versus manual fertigation. Results indicate superior plant growth in the automated system, with noticeable difference in plant height, leaf count, and leaf area index. The smart fertigation system not only optimizes nutrient use efficiency but also minimizes labor and fertilizer wastage, representing a substantial advancement in sustainable agriculture practices. Future research can be done to explore the system's calibration for diverse soil types and its comparative efficiency in open-field conditions.