VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM

A

PROJECT REPORT ON

"HYDROPONIC IRRIGATION SYSTEM FOR CONSERVATION OF WATER AND REUSE"

(KSCST Sponsored)

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CERTIFICATE

Certified that the project work entitled **"HYDROPONIC IRRIGATION SYSTEM FOR CONSERVATION OF WATER AND REUSE"** is carried out by **AKSHAY KUMAR M. P., KARTHIK S., RASHMI S. P.** and **SANTHOSH K. V.,** bonafide students of Vidyavardhaka College of Engineering in partial fulfillment for the award of Degree of Bachelor of Engineering in Civil Engineering from Visvesvaraya Technological University, Belgaum during the year 2017-18. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the completion of Bachelor of Civil Degree.

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Abstract

The population growth, urbanization, indiscrimination due to use of the freshwater, climatic change and demand for nutritional food has led to the era of water scarcity problems worldwide. In agricultural activities, water plays a major role for plant growth. Due to shortage of water, the reuse of wastewater in irrigation is highly recommended as an alternative solution. The hydroponic technique is a soilless farming in which NFT is one of the method where the nutrient solution is circulated in the system continuously which is absorbed by plants roots directly. The kitchen wastewater have high rich nutrients like Nitrogen, Phosphorous, Potassium, Calcium, Magnesium, Sulphur, Iron and Chorine which are responsible for plant growth and photosynthesis process. Hence, in this research work the performance of Nutrient Film Technique (NFT) was studied by replacing nutrient solution with kitchen wastewater (organic nutrient solution) to grow plants in most economical manner. The wastewater after circulation in NFT gets purified which is reused by maintaining water level in supply tank and circulating in NFT achieving conservation of water. The amount of nutrient uptake from kitchen wastewater as a solvent by cherry tomato plant was checked by laboratory analysis for every 7 days. Research revealed that 98% germination was achieved in 22 days. The average stem height and thickness were 22.5cm and 0.5cm, respectively for crop duration of 56 days. The maximum percentage increase in pH and EC values are 13.79% and 19.23% respectively during growth period. The maximum percentage decrease of N, P and K values in wastewater was 87.46%, 91.63%, 34.76% respectively. The N: P: K values observed in plants were 2: 1: 0.02 respectively. From the above observation, it can be concluded that the performance of NFT was good and economical achieving 77% harvest with high percentage of nutrient absorption from kitchen wastewater. 23% plants got aborted due to injury in plant root and breakage of pump. The DO values were increasing after irrigation representing purification of water and good rate of photosynthesis.

Keywords: Hydroponic System, Nutrient Film Technique (NFT), Cherry tomato, Kitchen wastewater, Irrigation.

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LIST OF SYMBOLS

Symbols	Abbreviation
°	Degree
%	Percentage
ɣ	Specific Gravity
Φ	Diameter

LIST OF ACRONYMS

NFT	Nutrient Film Technique
N	Nitrogen
P	Phosphorous
K	Potassium
HWS	Hydroponic Waste Solution
HWMS	Hydroponic Wastewater Management System
WUE	Water-Use Efficiency
pH	Potential of Hydrogen
EC	Electrical Conductivity
DO	Dissolved Oxygen
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
HP	Horse Power
kW	KiloWatt
L/min	Liter/minute
kN/m^3	kiloNewton/ cubic meter
m^3/sec	cubic meter/second
mg/L	Milligram/Litre
d S/m	Deci Simens/meter
cm	Centimeter
Mm	Millimeter
C	Celsius
mL	Milliliter

Chapter 1

INTRODUCTION

1.1 General

Conventional agricultural practices can cause a wide range of negative impacts on the environment. "Conventional agriculture" has been historically defined as the practice of growing crops in soil with proper irrigation technique is used. Some of the negative impacts of conventional agriculture include the high and inefficient use of water, large land requirements, high concentrations of nutrients and pesticides in runoff and soil degradation accompanied by erosion. However, approximately 38.6% of the ice-free land and 70% of withdrawn freshwater is already devoted to agriculture. Conventional agricultural systems use large quantity of irrigation fresh water and fertilizers with relatively marginal returns.

Soil-based agriculture is facing some major challenges with the advent of civilization all over the world such as decrease per capita land availability due to rapid urbanization and industrialization. The uncertainties in rainfall pattern have lead to challenges in the conventional irrigation techniques. In order to meet food demand and cater the needs of sufficient water for irrigation, new technologies are to be adopted. Many alternative methods are available nowadays which would make it easier for society to grow crops either for personal needs or for economic purposes.

Hydroponics, aeroponics and aquaponics are modern agriculture systems that utilize nutrient-rich water rather than soil for plant nourishment. Because it does not require fertile land in order to be effective, those new modern agriculture systems require less water and space compared with the conventional agricultural systems, one more advantage of those technologies is the ability to practice the vertical farming production which increase the yield of the area unit. The benefits of the new modern agriculture systems are numerous. In addition to higher yields and water efficiency, when practiced in a controlled environment, those new modern systems can be designed to support continuous production throughout the year.

1.2 Objective

The main objective of this research work is to assess the performance of hydroponic irrigation system using wastewater.

1.3 Specific objective

- Physico-chemical parameters of wastewater
- Selection of plant and study of yield
- Study of Hydroponic system using kitchen wastewater

Chapter 2

LITERATURE REVIEW

Preamble

Various researchers have conducted research on this topic and authored journals, those research reviews are considered in this study.

2.1 Type of Hydroponics

Mamta D Sardare et al., (2013), has conducted a research on **“A Review on Plant without Soil – Hydroponics”**. In 1960 with 3 billion population over the World, per capita land was 0.5 ha but presently, with 6 billion people it is only 0.25 ha and by 2050, it will reach at 0.16 ha. Due to rapid urbanization and industrialization as well as melting of icebergs (as an obvious impact of global warming), arable land under cultivation is further going to decrease. Again, soil fertility status has attained a saturation level and productivity is not increasing further with increased level of fertilizer application. Besides, poor soil fertility in some of the cultivable areas, less chance of natural soil fertility build-up by microbes due to continuous cultivation, frequent drought conditions and unpredictability of climate and weather patterns, rise in temperature, river pollution, poor water management and wastage of huge amount of water, decline in ground water level, etc. are threatening food production under conventional soil-based agriculture. Under such circumstances, in near future it will become impossible to feed the entire population using open field system of agricultural production only. Naturally, soil-less culture is becoming more relevant in the present scenario, to cope-up with these challenges. The author concluded that country like India, where urban concrete conglomerate is growing each day; there is no option but adopting soil-less culture to help improve the yield and quality of the produce so that we can ensure food security of our country. However, Government intervention and Research Institute interest can propel the use of the present technology.

Hydroponics is a technology for growing plants in nutrient solutions with or without the use of artificial medium to provide mechanical support. Major problems for hydroponic cultivation are higher operational cost and the causing of pollution due to discharge of waste nutrient solution. The nutrient effluent released into the environment can have negative impacts on the surrounding ecosystems as well as the potential to contaminate the groundwater utilized by humans for drinking purposes. The reuse of non-recycled, nutrient-rich hydroponic waste solution (HWS) for growing plants in greenhouses is the possible way to control environmental pollution. Many researchers have successfully grown several plant species in hydroponic waste solution with high yield. Hence in the present paper **"Reuse of hydroponic waste solution"** by **Ramasamy Rajesh Kumar et al., (2014)**, review addresses the problems associated with the release of hydroponic waste solution into the environment and possible reuse of hydroponic waste solution as an alternative. Recharge and reuse of HWS may be valuable as economic, control environmental pollution and could contribute to reduce the consumption of irrigation water.

The driving force of future agricultural industry is to provide sufficient yield that satisfy the needs of consumers and meet their interests in terms of quality. Soilless cultivation is intensively used in protected agriculture to improve control over the growing environment and to avoid uncertainties in the water and nutrient status of the soil. Recently the type of soilless culture transformed from open to close-loop system is known for better result in water use efficiency, while maintaining the quality of the yield. In the present study **"Soilless Culture System to Support Water Use Efficiency and Product Quality: a Review"** by **Agung Putra P et al., (2015)**, concluded that Soilless culture can be the effective tool to increase the crop yield and, if closed irrigation systems are adopted could increase the water-use efficiency, also reduce the environmental impact of greenhouses and nurseries. Author concerns in determining the soilless cultivation system is an understanding of its benefits, which is a flexible growing method that lets the grower have full control over the growing environment, including the active root zone. These systems, which can increase the efficiency of water-usage while maintaining its quality, should be more intensively implemented in any scale to support eco-agriculture.

Guilherme Lages Barbosa et al., (2015), has conducted a research on **"Comparison of Land, Water and Energy Requirements of Lettuce Grown Using Hydroponic vs. Conventional Agricultural Methods"**. The land, water and energy requirements for hydroponics were compared with the conventional agriculture and crop production considered was lettuce in Yuma, Arizona and USA. In this research the data considered were crop budgets, agricultural statistics given by government and compared with theoretical data obtained by experimental hydroponic system by generating engineering equations populated with literature values. Yields of lettuce per greenhouse unit (815 m^2) of 41 ± 6.1 $kg/m^2/y$, water and energy demands of 20 ± 3.8 L/kg/y and 90,000 ± 11,000 kJ/kg/y (±standard deviation) respectively. In comparison, conventional production yielded 3.9 ± 0.21 $kg/m^2/y$ of produce, with water and energy demands of 250 ± 25 L/kg/y and 1100 ± 75 kJ/kg/y, respectively. Hydroponics offered 11 ± 1.7 times higher yields but required 82 ± 11 times more energy compared to conventionally produced lettuce. In the present paper author concluded that hydroponic gardening of lettuce uses land and water more efficiently than conventional farming and could become a strategy for sustainably feeding the world's growing population, if the high energy consumption can be overcome through improved efficiency and/or cost-effective renewable.

The study was carried out by installing the Flood and Drain Vertical Hydroponic System for cultivating Chinese leafy vegetable Pak-choi of family *Brassicaceae*. The sowing of 112 seeds of Pak-choi was done in perforated net pots containing media of coco-pit (8% N: P: K treated) and vermiculite in 1:1 proportion. Irrigation technique used for the crop was deep flow technique through beds. The average pH readings before and after each irrigation was 6.40 and 6.76 and the average values of electrical conductivity (EC) before and after each irrigation was 0.79 mmhos/cm and 0.97 mmhos/cm, respectively and also the average moisture content of media before and after each irrigation was 18% and 71% respectively, available moisture content for complete growth of crop ranged from 46.73% to 57.05%. The water requirement of Pak-choi crop was 2.63 cm and the fertilizer applied was 1.9 gm N: P: K for overall growth of crop. The harvesting of crop was done after 70 days from sowing and the yield of crop was 7 kg from 1.8 m^2 area. The total cost of system was estimated to be Rs. 3400/-. **"Design of Flood and Drain Vertical Hydroponic System"** by **Ashwini Patwardhan**

(2016), concluded that highest germination of 96% was achieved with hydroponic system, which was 26% more than germination percentage quoted by the manufacturing company of seeds. Yield of Pak-choi crop in hydroponic system was twice than the yield obtained from field conditions. Therefore, the Flood and Drain Vertical Hydroponic System designed gave 66% more cropping area than the open field.

Philomena George et al., (2016), has conducted a research on **"Hydroponics-(Soilless Cultivation of Plants) for Biodiversity Conservation"**. Hydroponics is a system of agriculture that utilizes nutrient-laden water than soil for plant growth. The fertile land in order to be effective does not required natural precipitation, this shows people living in rural and urban regions can grow food by this technique and gain profit. Aeroponic and hydroponic systems do not require pesticides, they require less water and space compared to traditional agricultural systems and it can also be stacked (Vertical Farming) in order to limit space use. It makes them optimal for use in cities, where space is particularly limited and populations are high-self-sustaining city-based food systems. It results in reduced strain on distant agriculture farms, transportation costs and fewer carbon emissions. Optimization of land area and the preservation of biodiversity has become the need of the hour in both developing as well as developed countries. Hydroponics helps to limit terrestrial biodiversity loss through the reversion of large tracts of current farmland into sustainable and fundamentally natural environments. In short hydroponic gardens produce the healthiest organic, pesticide free crops with high yields and are consistently reliable. Hydroponic growing is the best way to overcome global food and water shortages and produce the highest quality, nutritious produce in any type of climate. It is a precise scientific growing method developed from experiment, experience and observation. The hydroponic growing method provides for reliable and repeatable and safe food production.

Ali AlShrouf (2017), has conducted a research on **"Hydroponics, Aeroponic and Aquaponic as Compared with Conventional Farming"**. Hydroponic growing systems use mineral nutrient solutions to feed the plants in water of using soilless media while Aquaponics is the integration of aquaculture and hydroponics. Many studies of commercial-scale hydroponic, aeroponics and aquaponics production showed the potential positives role in the present new technologies in the sustainable food security. In the present, agricultural farming systems could be one sustainable alternative to provide different type of produces that it requires less water, less fertilizer and less space which will increase the yield per unit area. In this paper, author concluded that modern cultivation systems are the conservation of water and increase productivity per unit area. While all three can be implemented in a raised garden, all three are very similar in every way except hydroponics and aeroponics requires the addition of fertilizer and there's no fish in the nutrient solution. In aquaponics, plants and fish live a symbiotic life with the fish feeding the plants, and the plants cleaning and filtering the fish's environment. Hydroponics is the base for all these methods and would be the easiest to set up. It could be later adpted to create an aquaponics setup. However, the aeroponics requires more maintenance and care in creating a semi-enclosed to fully-enclosed environment. Aeroponics, hydroponic and aquaponics systems reduce water loss and increase water use efficiency compared to the conventional agriculture.

2.2 Wastewater as Nutrient Solution

The purpose of the present article is to investigate the applications of hydroponic wastewater management systems (HWMS) as wastewater treatment facilities for the Dead Sea vicinity. In addition, it aims at managing the wastewater through generating commercially valuable plants using a proposed HWMS. A commercial hydroponic system was adapted for studying the potential heavy metals removal from primary treated municipal sewage effluent. The system consisted of five plastic gullies, 3 meters long by 100 mm wide. Primary treated effluent was used to irrigate lettuce in one series and a commercial nutrient solution was used to irrigate the same type of lettuce in another series as a control, both by Nutrient Film Technique (NFT). Lettuces accumulated heavy metals in leaf tissues at concentrations higher than the maximum recommended levels (As=6.5, Cd=3.8, Pb=20 mg kg^{-1}). The results showed that lettuce plants grew well in a modified hydroponic system (best in the glasshouse) and would be further improved by suitable distribution of plants of different ages along the NFT channels in the proposed full-scale NFT treatment plant. **"Hydroponics Removal of Wastewater's Contaminants for the Generation of Commercially Valuable**

Plants and Environmentally Sound Effluent for The Dead Sea Communities" by **Abdellah Rababah (2007)**, concluded that heavy metals (As, Cd, Cu, Pb) in NFT plants may cause health problems if consumed by humans or animals. Alternative plants (i.e. flowers) of minimum health risk are therefore recommended for an NFT system utilizing a mixed industrial or domestic effluent. Edible plants, however, may be recommended if As, Cd, Cu and Pb is reduced and the effluent is disinfected.

Hydroponics has the advantages of requiring small space, could operate with any size of flow, greatly reduces or eliminates soil borne weeds, diseases and parasites, doesn't require special drainage system, and grows almost any plant and in various spaces as available around the house (various containers, channels, pipes, etc.). The growth rate on a hydroponic plant is 30-50 percent faster than a soil plant, grown under the same conditions. In the present paper **"Performance of Hydroponic System as Decentralized Wastewater Treatment and Reuse for Rural Communities"** by **Marwan Haddad et al., (2009)**, used two irrigation system Flood and drain for the hydroponic channels, continuous dripping for the hydroponic barrels and also discussed the performance and feasibility of using hydroponics as decentralized wastewater treatment plants in the rural areas of the West Bank. From result obtained, it was concluded that the hydroponic systems in both barrel and channel forms were proved to be successful.

In the present paper **"The Effects of Secondary Treated Wastewater on *Brassica Campestris Sp. Parachinensis* Growth Using Soil and Hydroponic Cultivation"** by **Shakrani S A et al., (2012)**, discusses the effects of secondary treated wastewater irrigation on mustard greens vegetable (*Brassica Campestris Sp. Parachinensis*) growth with soil and hydroponics cultivation. The study involves the assessment of nutrients such (NO_3^-, NO_2^-, PO_4^{3-} and K) and heavy metals such (Cr, Co, Cu, Fe, Mn, Ni, and Zn) in wastewater. The results revealed that the concentrations of nutrients and heavy metals were relatively significant in both biological and final secondary treated wastewater. Besides, higher plant growth was found on soil cultivation as a comparison to hydroponic cultivation. The results reflected the availability of soil to act as a filter to metals thus reduced the unfavorable effects of heavy metals to the plant growth.

However, if an adequate amounts of macronutrients concentrations such as nitrogen, phosphorus and potassium availability in wastewater, successful growing plants will be achieved either in soil or soilless cultivation.

Salinity causes great growth and yield reduction on crop in many parts of the world. The aim of the present paper is to investigate how the root features of tomato plant cultivated in hydroponics are modified under salt stress conditions. Tomato plants underwent three salinity levels; 2.2, 1.0, 1.5 dSm^{-1}, through NaCl addition, corresponding to 0, 100 and 150 mM NaCl. Each experimental treatment was replicated twice arranging the pots according to block scheme. In each pot, there were 6 plants giving a total of 12 plants per experimental treatment. Salt addition to the nutrient solution occurred 7 days after transplant to avoid osmotic shock to plant. Nutrient solution pH was daily adjusted to 6.0 for all the treatment. **"Specific Root Length and Diameter of Hydroponically – Grow Tomato Plants under Salinity"** by **S Lovelli et al., (2012)**, concluded that in hydroponically grown tomato plants were measured a reduction in total weight and length of the root system as salinity increased and a shallower root system in the more sever treatment. An increase of specific root length was found in the middle section of the root system under high salinity and it corresponded to a significant increase of roots belonging to the lowest diametric class in the more severe salt treatment. It can be considered as an important evidence of an adaptation to salinity in conditions where soil modifications due to salinity do not interfere with direct plant responses. Salt stimulates a morphogenic response giving greater root surface area to uptake nutrients and water.

G Pilatakis et al., (2013), has conducted a research on **"The use of primary and secondary treated municipal wastewater for cucumber irrigation in hydroponic system"**. Municipal wastewater may be used in agriculture but requires a careful monitoring of several hygiene parameters. The impact of direct application of treated wastewater in plant growth and development in hydroponically grown cucumber was studied. Cucumber seedlings used under 5 treatments of nutrient solution, which were basic nutrient solution (control), primary (PA) and secondary (SA) wastewater with or without nutrient solution enrichment (NS). The author concluded that use of PA+NS reduced plant height, leaf number and flowers produced as well as leaf size in cucumber plants but increased stem diameter. When SA+NS used, no similar changes observed. The increased fruit number and fresh weight, when PA and SA used, resulted in increased yields as marked at the first week. The NS enrichment in PA reduced (up to 25%) plant yield while no differences observed in total fruit number among the treatments. No differences observed in plant biomass, root length and leaf chlorophyll levels among the treatments. The leaf photosynthetic rate and stomata conductance increased in plant grown in PA+NS and SA, but they did not differ in SA+NS. The use of wastewater resulted in disease spread in roots and fruits (by cross-contamination). Further exploitation is necessary for microbial load reduction with wastewater application.

The present study **"Efficiency of Wastewater Treatment with Hydroponics"** by **Prayong Keeratiurai (2013)**, used the wastewater from the fish pond for hydroponics. It was combined the benefits in terms of crop production and wastewater treatment. The assumption of the present research expected that plants could use the nutrients that contained in the wastewater. The wastewater was treated using the aerobic technology with hydroponic reactor on hydraulic retention times (HRTs) 1, 3, 5, and 7 days. The collected wastewater samples at inlet and outlet of hydroponic reactor. The parameters analyzed were temperature, pH, dissolved oxygen (DO), total kjeldahl nitrogen (TKN), total phosphorous (TP), total potassium (TK), total sulphur (TS), suspended solids (SS), volatile suspended solids (VSS), total dissolved solids (TDS) and chemical oxygen demand (COD) with the standard methods. They were used to evaluate the performance of the wastewater treatment with a hydroponic. The results of parameter analysis showed that the pH values of effluent were in the ranges of 7.33-8.0 with the temperature of 27ºC-29ºC. These ranges of pH and temperature value have litter effects or did not effect in significant to the performance of hydroponic. The total reductions on 1, 3, 5, and 7 days of hydraulics retention times of TDS, COD, TKN, TP and TK ranged from 20.4% to 70.0%, 52.0% to 79.0%, 12.23% to 50.56%, 8.33% to 33.33%, and 0% to 44.44%, respectively. The result showed that hydroponic could treat wastewater from fish pond and it also showed the increasing of dissolved oxygen in wastewater of 1, 3, 5, and 7 days of hydraulics retention times in DO ranged from 33.33% to 66.67%. The results obtained in these investigations show that it was possible to recover nutritious substances from fish processing wastewater by hydroponics. Hydroponic production systems have potential for the treatment and reuse of wastewater in intensive aquaculture systems.

Arjina Shrestha et al., (2015), has conducted a research on **“Hydroponics”** that “HYDROPONICS” is the growing of plants in a liquid nutrient solution with or without the use of artificial media. Commonly used mediums include expanded clay, coir, perlite, vermiculite, brick shards, polystyrene packing peanuts and wood fiber. It has been recognized as a viable method of producing vegetables (tomatoes, lettuce, cucumbers and peppers) as well as ornamental crops such as herbs, roses, freesia and foliage plants. Due to the ban on methyl bromide in soil culture, the demand for hydroponically grown produce has rapidly increased in the last few years. In the present paper author explained about that commercial hydroponic growers need a more accurate control of the components in a nutrient solution to achieve commercial success. The macro-elements like Nitrogen, Phosphorus, Potassium, Calcium, Magnesium and Sulphur having concentration range about 100-200, 30-15, 100-200, 200-300, 30-80 and 70-150 respectively and micro-elements like Boron, Copper, Iron, Manganese, Zinc and chlorine having a concentration range about 0.03, 0.01-0.10, 2-12, 0.5-2, 0.05 and 0.05-0.5, respectively should be found in the nutrient solution. Author suggested that it can be used in underdeveloped countries for food production in limited space and it is even feasible to grow hydroponically in areas of poor soil conditions such as deserts. The desert sand serves as a good growing medium and seawater can be used to mix nutrient solution once the salts have been removed. The popularity of hydroponics has increased dramatically in a short period of time leading to an increase in experimentation and research in the area of indoor and outdoor hydroponic gardening.

In hydroponics, plants are grown with the use of water and nutritional solution only. The nutritional solution contains the essential nutrients like N, P and K which are required for growth of the crops. The water which was treated in sewage treatment plants is discharged into the municipal drainages as it contains human excreta; it is rich in the N (Nitrogen), P (Phosphorous) and K (Potassium). So, such water can be used by hydroponics system to grow the plants in the most economical manner. In the present paper **“Use of Treated Waste Water as Nutrient Solution in Hydroponics Technique”** by **Aamod S Joshi et al.,**

(2016), tries to compare conventional as well as various hydroponics techniques to grow the crops and plants which one uses in day to day life. The author concluded that the crops can be grown successfully using hydroponics technique and treated waste water can help to satisfy the need of the plants, but not a sufficient source of nutrition. An additional organic fertilizer like Compost will be needed to satisfy the nutritional requirement of the plants.

The scarcity and pollution of freshwater are extremely crucial issues today and the expansion of water reuse has been considered as an option to reduce its impact. In the present study **"Treated Greywater Reuse for Hydroponic Lettuce Production in a Green Wall System: Quantitative Health Risk Assessment"** by **Fasil Ejigu Eregno et al., (2017)**, aims to assess the efficiency of an integrated greywater treatment system and hydroponic lettuce production as a part of a green wall structure to evaluate the health risk associated with the production and consumption of lettuce through a quantitative microbial risk assessment (QMRA) and a chemical health risk assessment. The study was conducted based on the unique configuration of a source separation system; an on-site greywater treatment system; a green wall structure as a polishing step; and hydroponic lettuce production in the green wall structure. The final effluent from the system was used to grow three lettuce varieties by adding urine as a nutrient solution. Both water samples and plant biomass were collected and tested for *Escherichia coli* (*E. coli*) and heavy metals contamination. The author concluded that system has gained a cumulative 5.1 $\log_{10}$ reduction of *E. coli* in the final effluent and no E. coli found in the plant biomass. The estimated annual infection risk for *Cryptosporidium, Campylobacter*, and *Norovirus* was 10^{-6}–10^{-8}, 10^{-8}–10^{-10}, and 10^{-10}–10^{-11} respectively. These results indicate that the system attained the health-based targets, 10^{-6} disability adjusted life years (DALYs) per person per year. Similarly, the health risk index (HRI) and targeted hazard quotient (THQ) results did not exceed the permissible level, thus the chemical health risk concern was insignificant.

In the southern regions of China, it is very hot and relative humidity is high during summer. Similar conditions also prevail inside the greenhouse. In the present paper author observed that when roof ventilations were closed at noon, the greenhouse temperature could rise as high as 50°C. This resulted in serious plant injury and in certain cases, death of plants. The investigation is a comparative study of heat stress on cherry tomato (*Lycopersicon esculentum* Mill. var.*cerasiforme*) cultivated in different substrate systems during summer time. The study was undertaken in a glasshouse from June to September 2007 in Hangzhou (Zhejiang Province). Their main objective was to assess the critical temperature at a precise growth stage and thereafter propose an appropriate cultivation system which can mitigate the thermal stress during summer. **"The Effects of High Temperature Regime on Cherry Tomato Plant Growth and Development When Cultivated in Different Growing Substrates Systems"** by **Andre Nduwimana et al., (2017)** concluded there was a negative linear relationship between temperature and relative humidity, also between temperature and CO_2 in all the rooms. It is therefore very difficult to assess the effects of high temperatures on plants if it is considered independently. Growth, expressed in terms of stem elongation and internode's length was markedly related to the growing medium; the effect of temperature was less noticeable at seedling stage. Stem elongation and internode's length decreased progressively from NFT, soil, perlite, and peat / perlite to peat respectively. Highly significant differences in the leaf expansion with temperature were noticed, stressed tomato plants showed a significant decrease in leaf area. However, leaf expansion was independently affected by growing medium and temperature regime applied. High temperatures critically affected the plant development especially during flowering stage. The fruit set was seriously compromised and high numbers of aborted flowers were observed at temperatures higher than 35/25°C (day/night temperatures). However, flower initiation and multiplication were less affected. Growers should be cautious to ensure that the flowering periods do not coincide with the hottest months of the year.

2.3 Design of NFT System

Roberto Lopez - Pozos et al., (2011), has conducted a research on **"The Effects of Slope and Channel Nutrient Solution Gap Number on the Yield of Tomato Crops by a Nutrient Film Technique System under a Warm Climate"**. Inadequate oxygenation of the nutrient solution (NS) in recirculation hydroponic systems leads to root hypoxia in several plants as a result of low oxygen solubility and it is most notable in warm climates. Hypoxia affects crop nutrient and water absorption which results in reduced crop yield. However, increased air supply to the NS serves as a source of oxygen for the roots. To evaluate the incorporation of oxygen into the system, author varied the slope of 14-m long containers from 2% to 4% and applied zero, one, two or three gaps of NS. The channel width measured 10 cm and was equidistant from the end points. The effect of the dissolved oxygen in the NS was measured by the production of a tomato cultivar. The oxygen dissolved in the NS was 5% greater in the channels with a 4% slope compared with those with a 2% slope. The channels that included the gaps incorporated a higher quantity of dissolved oxygen during cultivation. The author concluded that the slope of the container influenced the oxygenation of the NS with 4% slopes resulting in higher dissolved oxygen compared with the 2% slope. These results suggest that in warmer climates, the use of a steeper slope and the incorporation of gaps in the NFT channel can significantly improve crop productivity.

Dian Siswanto et al., (2017), has conducted a research on **"Design and Construction of a Vertical Hydroponic System with Semi-Continuous and Continuous Nutrient Cycling"**. The hydroponic system was used adapts the ebb and flow system and the nutrient film technique (NFT). It was constructed from four polyvinyl chloride (PVC) pipes with a length of 197 cm, a diameter of 16 cm and a slope of 4°. The author concluded that in semi-continuous irrigation treatment, nutrients flow, four to six times for each of ten minutes depending on plant development and the estimated evapo-transpiration occurring, while in a continuous nutrient system the nutrients are streamed for twenty-four hours without stopping at a maximum flow rate of 13.7 L per second.

2.4 Selection of Tomato Plant

Kunio Okano et al., (2001), has conducted a research on **"Single-Truss Tomato System - A Labor-Saving Management System for Tomato Production"**. In the single-truss system of tomato growing, the main shoot in pinched, leaving a few leaves above the first truss and only the first truss is harvested. The objective of single-truss system is to reduce labor requirement for training, pruning and harvesting. A "wet-sheet culture" system has been developed, in which a water-retaining sheet made of non-woven fabric is used as a growing medium. Fruit quality can be easily improved by the application of salinity stress. A large number of nursery plants are required in the single-truss system because of the dense planting and frequent replanting. Mass production of nursery plants in plug trays is recommended. In the single-truss system, no serious problems occurred even when very young plug seedlings were transplanted. An alternative way might be the use of cuttings. The roots of tomato plant cuttings emerge easily if the cutting is placed in a medium such as rockwool. The single-truss system may be suitable for large-scale production of tomato. Continuous predictable production may be possible if the environment in the greenhouse could be adequately controlled.

Valenzano V et al., (2008), has conducted a research on **"Effect of Growing System and Cultivar on Yield and Water-Use Efficiency of Greenhouse-Grown Tomato"**. The aim of the present research was to compare the cultivation of tomato (*Solanum lycopersicum L.)* plants in soil with two hydroponic systems: the Nutrient Film Technique (NFT; closed cycle) and rock wool (open cycle), in terms of yield and water-use efficiency (WUE). Two trials were carried out, one in Winter-Spring (WS) and the other in Autumn-Winter (AW). In both trials, four tomato cultivars were used: two of the beefsteak fruit- type (Diana F_1 and Jama F_1) and two of the cherry fruit-type (Naomi F_1 and Conchita F_1). The author concluded that the two hydroponic systems showed greater earliness; on average, 10 day and 8 day earlier than in soil, in the WS and AW trails, respectively. In the hydroponic systems, total yields were 11% and 7% higher in the WS and AW trials, respectively, than in the soil system. Cultivation in soil gave good results in term of WUE in both trials, due to the use of tensiometers, suitable watering volumes and mulching. Between the two hydroponic systems, NFT gave a higher yield, with lower water and fertilizer use and a greatly reduced environmental impact.

The nutrient uptake ability of tomato plant in Nutrient Film Technique (NFT) culture was investigated by using NFT method. All the treatments started with rainwater and then six different concentrations of nutrient solution were added to each system according to solution consumption. The concentration of each mineral element in the nutrient solution increased with the addition of the supplement solution until the 3rd day and thereafter leveled off until the 7th day, indicates that when absorption concentration became in stable state, except for the ion in the highest strength solution for potassium and magnesium elements, and that most of the newly added ions were absorbed stably by plants from low to high concentration of nutrient solution. At that point when each ion concentration in the nutrient solution reached a critical level, the tomato plants were no longer able to uptake ions from the solution and the minimum uptake concentration was evaluated. The critical concentration for tomato obtained in the present experiment was 0.01-0.02 me/L for NO_3-N, 0.20 me/L for PO_4-P, 0.05- 0.10 me/L for K, 0.40-0.50 me/L for Ca and 0.10 me/L for Mg. In the present paper **"Uptake Ability of Tomato Plants** (***Solanum Lycopersicum*** **L.) Grown Using Nutrient Film Technique (NFT) by Ascending Nutrient Concentration Method"** by **Jocelyn Amihan Gonzales et al., (2010)**, concluded that tomato plants can uptake nutrients even from extremely low nutrient concentrations. These results suggest that cultivation with low nutrient concentration could be applicable if each nutrient element was stably supplied and balanced with the absorption. In the further studies should be conducted on the uptake ability from low nutrient solution concentration and evaluate at different growth stages of the plant of a specific variety at a given season.

The effect of the concentration of nutrient solution, irrigation frequency and the volume of substratum on growth, dry matter and fruit production was evaluated, and the economical impact was compared according to costs and yield. During 2007 and 2008, in the Experimental Field of the Universidad Autonoma Chapingo, Chapingo Mexico, Concentrations of nutrient solution (100, 75 and 50%), irrigation frequency per day (1, 4, 7 and 10), and volumes of substratum per plant (5, 10 and 15 L) were assessed in a completely randomized block design in a factorial treatment arrangement replicated three times. The results showed significant differences ($P<0.05$) between years, concentrations of nutrient solution, irrigation frequency and volumes of substratum in growth and yield of dry matter and fruit. In 2008, there was major growth and yield of dry matter and fruit, compared to 2007. Fruit and dry matter yields were higher with the nutrient solution at 100%, but there was a decrease by 4.7 and 5.1% with the concentration at 75% and with nutrient solution at 50% the yield dropped by 24.4 and 105%. With seven irrigations, stem thickness and leaf area index diminished by 2.1 and 1.8%, respectively, compared to ten irrigations per day. With a substrate volume of 5L, stem thickness diminished by 4.8% and plant height by 1.4%, compared to 15L; in fruit yield there was no significant decrease with 10L, for which it may be possible and economically convenient to use a container of 10L capacity. **"Growth and Yield of Tomato (*Solanum lycopersicum L.*) as Affected by Hydroponics, Greenhouse and Irrigation Regimes"** by **Francisco Suazo-Lopez et al., (2014)**, concluded that it is convenient to utilize the nutrient solution at 75% in seven irrigations per day and substratum volume of 10 L for tomato production in hydroponics and greenhouse in order to obtain the highest profit (73.9%). As a result of increase in the cost of agricultural inputs (chemical fertilizers, containers, and pesticides) and to water shortage, the results of the present study contribute to increasing efficiency in tomato production and producer competitiveness.

The tomato variety Anagha was raised in Ebb and flow hydroponic system (flood and drain system) to evaluate the ideality of growing media (coco peat, expanded clay pellets and pebbles). **"Standardization of Growing Media for the Hydroponic Cultivation of Tomato"** by **T Reshma et al., (2017)**, revealed that the plants grown in coco peat medium performed the best in terms of yield per plant (1.67 kg), average fruit weight (45.86g), plant height (69.36 cm), crop duration (85.73 days) etc. followed by pebbles. The coco peat medium contained comparatively high amount of potassium (0.36 %) and also possessed high water holding capacity. Performance of plants grown in expanded clay pellets was very poor. Fruit quality in terms of total soluble solid content and titrable acidity was not significantly affected by the treatments.

From the above literature review the tomato plant **(Jocely Amihan Gonzales, 2010)** uptakes the nutrient even from low concentration and has fiborous root system. Coco coir and expanded clay pellets were suitable growing media **(T Reshma). (Arjina Shrestha, 2015)** Wastewater as nutrient solution parameters analysed were N, P, K, C, Mg, S, Fe, B, Cu, Mn, Zn and Cl. Closed type Nutrient Film Technique was considered **(Valenzano V, 2008)** for higher yield with lower water and without fertilizer which reduces environmental impact. NFT design considerations were **(Dian Siswanto, 2017)** pipe length, diameter, slope, number of holes and spacing in pipe, size of netpot, discharge of nutrient solution and water-use efficiency. Climatic parameters considered were temperature, relative humidity, carbon dioxide and light intensity **(Andre Ndumimana, 2017)**. Physical parameters considered were stem elongation, internodes length, plant height, leaf area, number of aborted flowers, fruit yield and dry weight **(Andre Ndumimana, 2017).**

From the literature it can be concluded that cherry tomato has fast growth rate, good yield and fibrous root system, the clay pebbles has the property of maintaining pH and also have water holding capacity hence considered in this research work. The parameters like Nitrate, Phosphorus, Potassium, Calcium, Magnesium, Sulphur, Iron and Chloride are most important for plant growth and photosynthesis process. Physico-chemical parameters such as BOD, COD, DO, pH, electrical conductivity and climatic conditions such as temperature, light intensity and relative humidity are considered in this research work. From the literature, the NFT design considerations were pipe length, diameter, slope, number of holes and spacing in pipe, size of netpot, discharge of nutrient solution and water-use efficiency.

Chapter 3

MATERIALS AND METHODOLOGY

3.1 Introduction on Hydroponic System

Soil-less culture mainly refers to the techniques of Hydroponics. The term Hydroponics was derived from the Greek words *hydro'* means water and *ponos'* means labour. It is a method of growing plants using mineral nutrient solutions, without soil. Terrestrial plants may be grown with their roots in the mineral nutrient solution only or in an inert medium such as perlite, expanded clay pellets, coco coir, gravel and mineral wool. Hydroponics is the technique of growing plants in soil-less condition with their roots immersed in nutrient solution. This system helps to face the challenges of climate change and also helps in production system management for efficient utilization of natural resources and mitigating malnutrition. In India, Hydroponics was introduced in year 1946 by an English scientist, W. J. Shalto Duglas and established a laboratory in Kalimpong area, West Bengal. Mr. Shalto Duglas has also written a book on Hydroponics, named as "Hydroponics the Bengal System". Later on during 1960s and 70s, commercial hydroponic farms were developed in Abu Dhabi, Arizona, Belgium, California, Denmark, German, Holland, Iran, Italy, Japan, Russian Federation and other countries. During 1980s, many automated and computerized hydroponics farms were established around the world. Home hydroponics kits became popular during 1990s. There are different types of hydroponic system as shown in Figure 3.1

3.2 Type of Hydroponic System

3.2.1 Passive systems

In a passive system, the plants roots are in touch with the nutrient solution and the plants are supported using a suspension method. The main disadvantage of this system is that it is difficult to support plants as they grow and get heavier. However, a passive system is a very basic system and is therefore easy for a beginner to set up. A passive system tends to be very portable and quite inexpensive. One example of a passive system is the Wick System.

3.2.1. a Wick System

A wick system uses a lamp wick or wick made of nylon, polyester or rayon to supply nutrient solution to the roots. Some of the more commonly used growth material is Vermiculite, Perlite, Pro-Mix and Coconut Fiber. A pot is supported above the nutrient tray solution and a wick soaked in this solution is passed through the drainage hole into the nutrient tray. Leave 10cm of the wick inside the pot and ruffle the ends for better circulation of nutrient solution. The main drawback of this system is that plants that are large or use large amounts of water may use up the nutrient solution faster than the wick can supply it.

3.2.2 ACTIVE SYSTEM

Active systems are more efficient and productive because they use pumps to supply nutrient solutions to the plants and a gravity system to drain off any excess solution which is then recycled and reused. Various types of materials used to quick drain system are perlite, rockwool, expanded clay pebbles or Coconut Coir. The main difference between an active and passive system is that an active system uses pumps to supply nutrient solution whereas a passive system uses a wick to draw in the nutrient solution.

3.2.2. a Water Culture

In this method, styrofoam sheets are used to float plants (which are fixed in baskets) on top of the nutrient solution. An air pump supplies air to the air stone that bubbles the nutrient solution and supplies oxygen to the roots of the plants. Usually, short term crops are cultivated using this system and any problems in relation to stagnation of the solution is solved by circulating air from the bottom. This system is used for lettuce production and to cultivate other greens. The main drawback of this system is that it doesn’t work well with large plants or with long term plants.

3.2.2. b Ebb and Flow System

An Ebb and Flow System is also called a flood and drain system. Using this system provides uniform distribution of nutrient solution to all the plants. Here, the nutrient solution can flood the material for 15 minutes every hour or two hour. The Ebb and Flow system has the additional benefit in that it can be automated using a computer. The main drawback of this system is that the roots can dry out quickly when the watering cycles are interrupted.

3.2.2. c Nutrient Film Technique (NFT)

The Nutrient Film technique uses an automated pump and reservoir system to supply and recycle nutrients. NFT system has constant flow of nutrient solution so no timer required for the submersible pump. The nutrient solution is pumped into the growing tray and flows over the roots of the plants and then drain back into the reservoir. The main drawback of this system is that the plants can suffocate and die because of a lack of oxygen using this system.

3.2.2. d Drip (or Top Feed) System

One of the advantages of the Drip system is that it is able to withstand short-term power / equipment failure. Nutrient solution is dripped onto the plants with the remaining solution being drained back to the reservoir. The supply of the solution is timed and as a result, this system can be very expensive and difficult to set up.

3.2.2. e Aeroponics

A recent development in which plants are suspended in midair and then supplied with nutrients has resulted in a system known as Aeroponics. Nutrients are sprayed to the roots and their exposure to air provides them with maximum oxygen. In this system, the supply of nutrients and oxygen is maximized. However, care needs to be taken in order to maintain 100% relative humidity. The main drawback of this system is the functioning of the pump and reservoir in the event of power failure. As it is a reasonably new system, it is currently quite expensive to set up and is more often used in laboratory studies.

From the above Review, we considered that in a closed type hydroponic method, the amount of nutrient solution per plant largely affects the changes in concentration and composition during the cultivation period. In general, smaller the quantity of the nutrient solution more variable in the quality of the nutrient solution. Thus, the management system for nutrient solution is very important. It is therefore necessary to measure the nutrient and water uptake rate of the plant for better management of nutrient solution. In most of the studies they used pots or containers, showed that there is a change in the concentration and the amount of water uptake for a certain period. However, under low mineral concentration in hydroponic solution it is difficult to get exact values because solution concentration changes within a short period of time. In the NFT system, the root system of the plant can contact nutrient solution frequently and this method was thought to be better to measure the minimum absorption concentration compared with other growing systems. Hence, NFT was adopted in this study.

3.3 Selection of Nutrient Film Technique

3.3.1 Nutrient Film Technique (NFT)

The system of Nutrient Film Technique (NFT) was originally designed and developed by Allen Cooper. The concept is described by Cooper as follows: "A very shallow stream of water containing all the dissolved nutrients required for growth is recirculated past the bare roots of crop plants in a water tight gully. Ideally, the depth of the recirculating stream should be very shallow, little more than a film of water-hence the name nutrient film. This ensures that the thick root mat which develops in the bottom of the gully has an upper surface which although moist is in the air. Consequently, there is an abundant supply of oxygen to the roots of the plants".

The nutrient film technique (NFT) is similar to the ebb and flow system in that it utilizes a pump to move nutrients in a continuous constant flow. The difference with NFT is that the solution flows directly over the roots. The nutrient film technique use shallow tubes that are slightly angled so that the pump moves the nutrient solution to the higher portion of the system. The nutrient solution gradually moves by gravity to the lower portion. A tube system with holes bored for the plants is used instead of trays, mainly because this system is easier to angle for proper flow over the roots. Most horticulturalists plant directly through the holes, but it is okay to use net pots and many horticulturalists use no planting medium (e.g., potting soil) with the nutrient film system. The roots fall through the net directly into the nutrient solution. The nutrient solution does not completely soak the roots. The film ensures that the entire root is not submerged so the upper part of the roots remains dry. Because it contains moving parts, NFT is considered an active system as shown in Figure 3.2

When using the nutrient film technique it is important not to grow heavy plants that require a lot of support because the roots are not in a medium that can sustain the weight of a heavy plant. It is necessary to use a self-standing trellis to support plants with heavy fruits such as tomatoes.

The Crops grown in NFT system are tomatoes, lettuce, endive, Chinese cabbage and similar leafy crops, cucumbers, zucchini and courgettes, beans, sweet peppers, egg plants, chillies, parsley and other herbs, silver beet, strawberries and many types of ornamentals. The system is not, in its normal form adapted for the production of root and tuber crops.

In the NFT system, the root system of the plant are in direct contact with organic nutrient solution frequently and this method was thought to be better to measure the minimum absorption concentration compared with other growing systems. Hence, NFT was adopted in this study. Also in NFT system the water consumed by plants is less compared to conservation method.

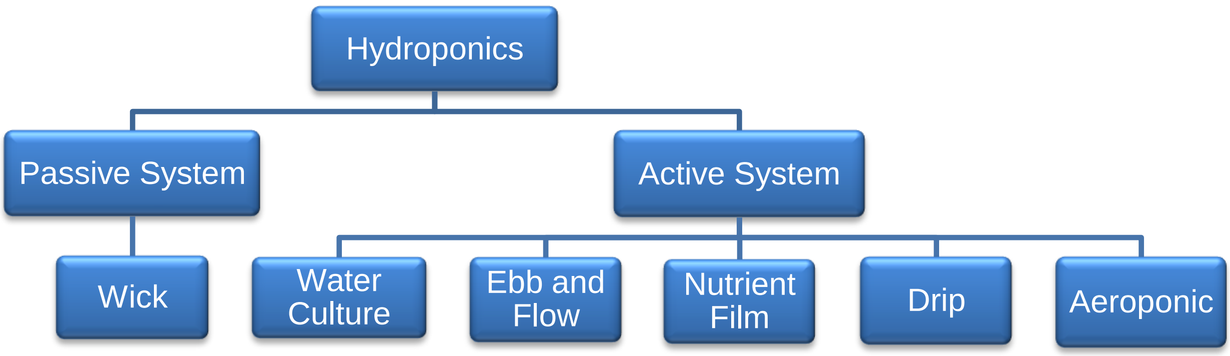

Figure 3.1: Classification of Hydroponic System

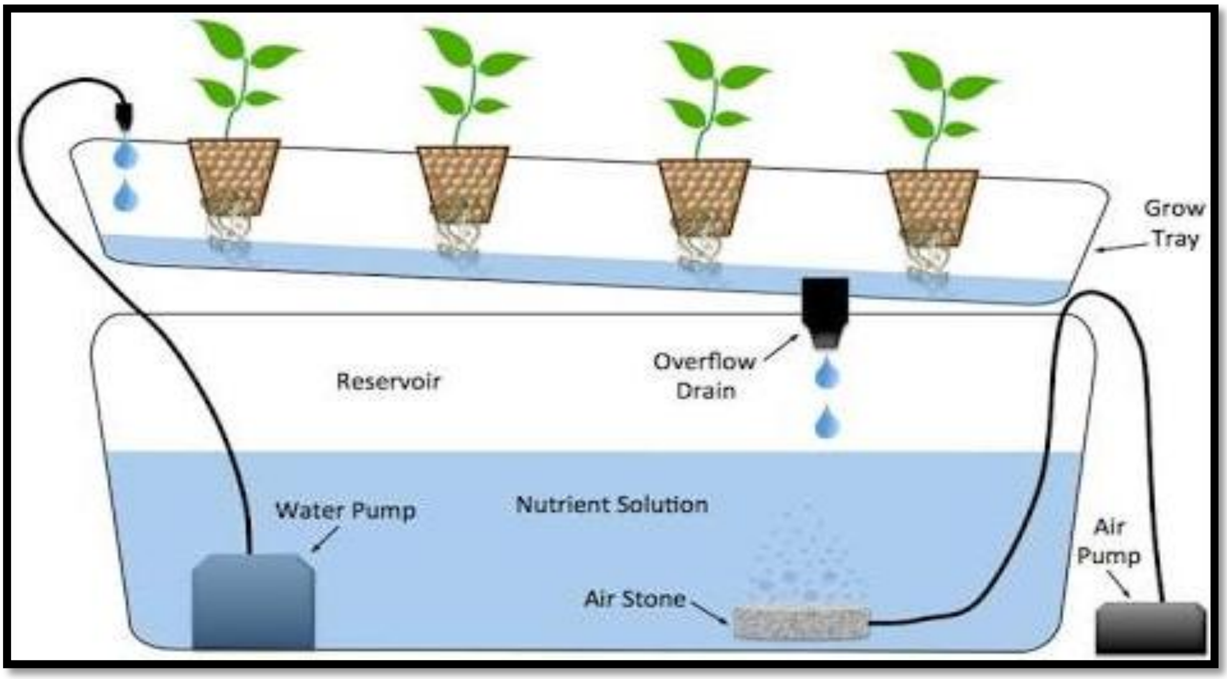

Figure 3.2: Nutrient Film Technique Setup

3.4 Sampling Area

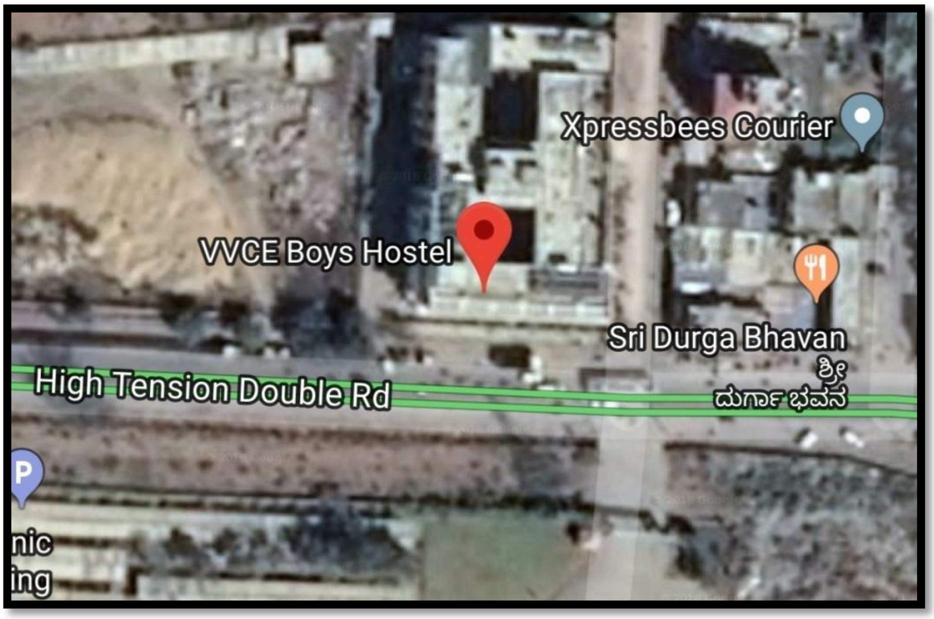

Plate 3.1 Satellite view of VVCE Boys Hostel

Table 3.1 Study area details

Sampling Area Details	
Sampling area location	VVCE Boys Hostel
Latitude and longitude	12°20'6.60" N and 76°37'3.11" E
Number of septic tank	1
Sampling point	1
Dimension of tank	
Sampling technique	Grab sampling technique
Experimental Setup Area Details	
Experimental Setup Area location	VVCE B-Block
Latitude and longitude	12°20'16.75" N and 76°37'12.73" E
Area Dimension	1.5 X 1.3 m

Table 3.2: Experiment setup specification

Specification	Quantities	Dimensions
A- shaped wooden frame	2	1.5*1.2*1.6
Angle between A-frame and floor	-	69.44°
PVC pipes	8	1m long & Φ 3"
The submersible pump	2	(capacity of 0.028HP)
Nutrient storage tank	2	20 L
No of plastic cups	5 (in each pipe)	
No of holes in each cup	Around 20	Φ 0.25-0.30 cm
No of plants	5 (in each pipe)	Total 40 plants
Total Length of circulation Pipe	5 L	5 m

3.4.1 Sampling point

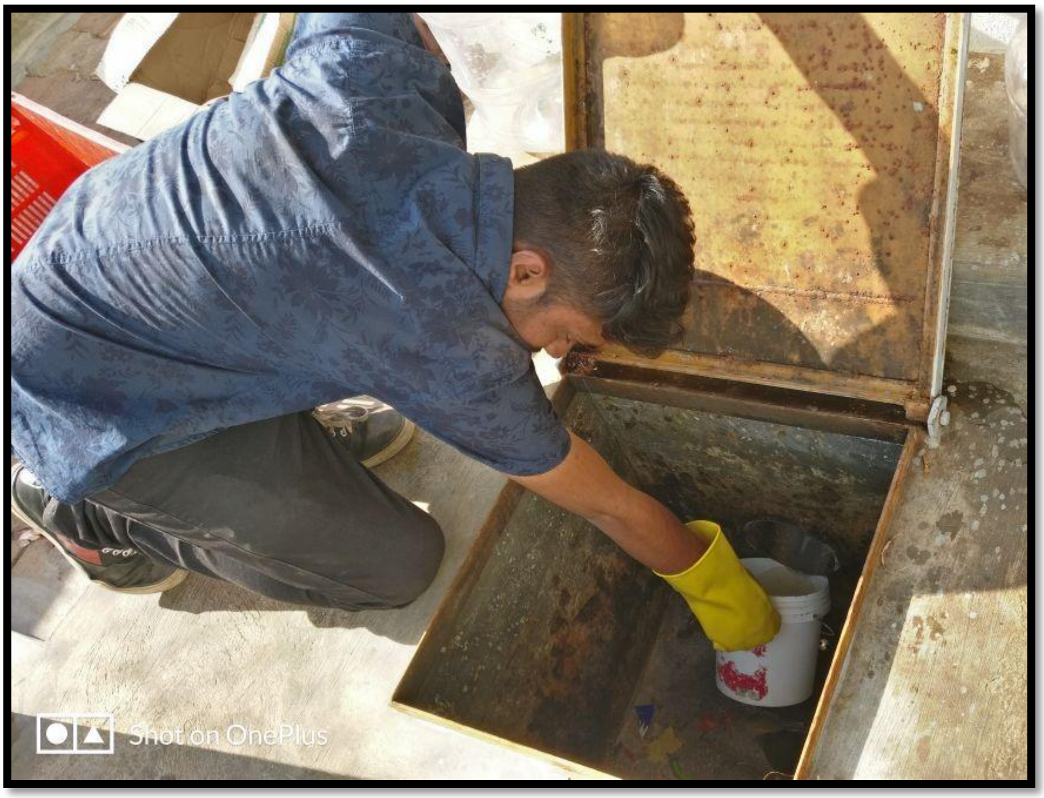

Plate 3.2: Collection of Kitchen Wastewater from VVCE Boys Hostel

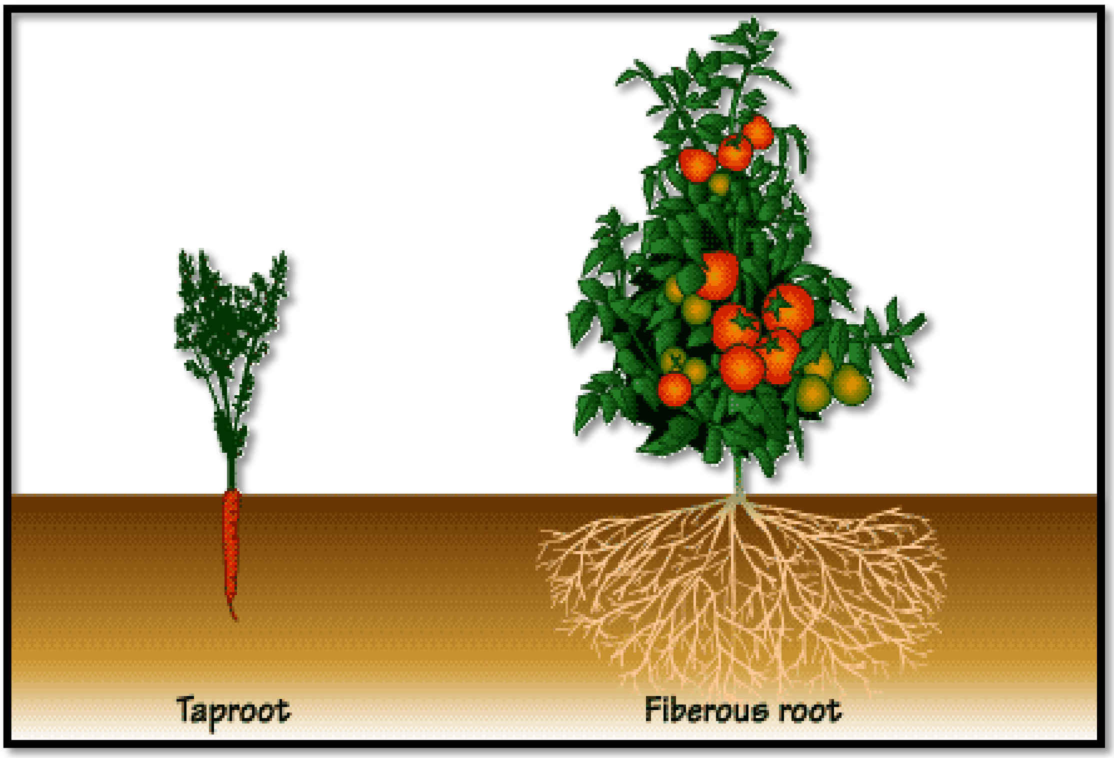

Figure 3.3: Root System

3.4.2 Sampling Technique

In this research work, Grab sampling technique is used to collect the sample so that all minerals can be collected during sampling time.

A grab refers to performance only at the time that the sample was collected at one single point and then made sampling at same point ‘n’ number of times without changing the sampling point.

3.5 Laboratory Analysis

As per appendix A, the main parameters on which plant nutrition depends are macro and micro nutrient. nitrate, phosphorus, potassium, calcium, magnesium, sulphate and boron, zinc, copper, manganese, molybdenum, iron, chloride as macro nutrients and micro nutrients respectively.

Kitchen wastewater are free from solid waste which will be used in irrigation are analyzed for the macro and micro nutrient. The parameters considered for analysis are Nitrate, Phosphorus, Potassium, Calcium, Magnesium, Sulphur, Iron and Chloride which are most important for plant growth and photosynthesis process. Physico-chemical parameters to be analyzed are BOD, COD, DO, pH, Electrical Conductivity and Climatic conditions to be recorded are Temperature, Light Intensity and Relative Humidity.

3.6 Advantages and Disadvantages of NFT

3.6.1 Advantages of NFT

- Produces healthy, plants in a few weeks
- Lower water and nutrient consumption
- Avoids the supply, disposal and cost problems associated with media based systems
- Relatively easy to disinfect roots and hardware compared to other types of system
- The absence of medium makes it easy to inspect roots for signs of disease, feed, adequacy, etc.
- Regular feeding prevents localized salt build-up in the root zone and maintains uniform root zone pH and conductivity

- Environmentally friendly - minimal potential for localized groundwater contamination

3.6.2 Disadvantages of NFT

- NFT system are dependent upon electricity, which means additional costs and the threat of loss of power
- Pump failure can result in plant death within a few hours, especially in hot weather
- Not suitable for plants with large tap-root systems (e.g. carrots)
- Compared to run-to-waste systems, it is less suitable for saline (salty) waters because the salinity of the recirculating water gradually increases

3.7 Application of the project

- The setup is portable with less space occupant and provides high yield in less duration hence, can be used in hotels, canteens and hostel mess to grow vegetables and green leaves
- This technique can also be used in apartment and houses to grow green leaves and vegetable in small quantity using kitchen wastewater
- Reuse and purification of wastewater which provides end product as purified water used for gardening

The vertical farming technique can also be used in reducing air pollution using pollutant absorbing plants obtained from Mexico

3.8 Selection of Crop

3.8.1 Types of Root System

The root system is the **descending** (growing downwards) portion of the plant axis. When a seed germinates, **radicle** is the first organ to come out. It elongates to form **primary** or the **tap root**. It gives off lateral branches (**secondary** and **tertiary** roots) and thus forms the root system. It branches through large and deep areas in the soil and anchors the plant very firmly. It also plays another vital role of absorbing water and mineral salts from the soil and transporting them upwards. Root systems are mainly of two types: Tap root and Fibrous root as shown in Figure 3.3

3.8.1. a Tap root system: It is the root system that develops from the radicle and continues as the primary root (tap root) which gives off lateral roots. They provide very strong anchorage as they are able to reach very deep into the soil. It is the main root system of dicots e.g. gram, china rose and neem.

3.8.1. b Fibrous root system: In this root system, the primary root is short lived. A cluster of slender, fiber-like roots arises from the base of the radicle and plumule which constitute the fibrous root system. They do not branch profusely, are shallow and spread horizontally, hence cannot provide strong anchorage. Fibrous root system is the main root system of monocots, e.g. maize, grasses and wheat.

In this research work, Cherry Tomato was selected as it has fast growth rate, good yield and due to its Fibrous root system. According to section 2.4 the Tomato plant can up take nutrients even from extremely low nutrients concentration, Also it requires less Water requirement.

3.9 Selection of Growing media

3.9.1 Growing Media / Substrate

One of the most important decisions a hydroponic farmer has to make is the type of medium to be used. Different media are appropriate for different growing techniques.

- **Diahydro:** Diahydro is a natural sedimentary rock medium that consists of the fossilized remains of diatoms. Diahydro is extremely high in Silica (87-94%), an essential component for the growth of plants and strengthening of cell walls
- **Expanded clay:** It is made by baking the clay pellets and known under the trade name of 'Hydroton' or LECA (light expanded clay aggregate). Hydroton or expanded clay pellets are suitable for hydroponic systems in which all nutrients are carefully controlled in water solution. The clay pellets are inert, pH neutral and do not contain any nutrient value. The clay is formed into round pellets and fired at high temperature (1200°C) in rotary klins. This makes the clay to pop-up and become porous. The main advantage of hydroton is it is light in weight and does not compact over time. This is an ecologically sustainable and reusable growing medium because of its ability to be cleaned

and sterilized by washing in solutions of white vinegar, chlorine bleach or hydrogen peroxide and rinsing completely. But there is an opinion that clay pebbles are best not re-used even when they are cleaned due to root growth which may enter the medium. Breaking open a clay pebble after a crop has been grown will reveal this growth

- **Rock wool:** Rock wool, also called mineral wool is the most widely used media in hydroponics. It is an inert substrate for both free drainage and re-circulating systems. It is produced by aerosolization of molten mineral compounds which results in a fibrous medium accessible to capillary action that is not degraded by microbiological activity
- **Coir:** Coco peat, also known as coir or coco, is the leftover material after the fibres have been removed from the outermost shell of the coconut. Coir is a 100% natural growing medium
- **Perlite:** Perlite is made from volcanic rock after being superheated into very lightweight expanded glass pebbles. It is used either loose or in plastic sleeves immersed in water. It is also used in potting soil mixes to decrease soil density and facilitates drainage. Perlite generally holds more air and less water. If not contained, it can float if flood and drain feeding is used. It is a fusion of granite, obsidian, pumice and basalt. This volcanic rock is naturally fused at high temperatures undergoing what is called "Fusionic Metamorphosis"
- **Vermiculite:** Like perlite, vermiculite is another mineral that has been superheated until it has expanded into light pebbles. Vermiculite holds more water than perlite and has a natural "wicking" property that can draw water and nutrients in a passive hydroponic system. If too much water and not enough air surround the plant roots, it is possible to gradually lower the medium's water retention capability by mixing in increasing quantities of perlite
- **Sand:** Sand is the cheapest and easily available medium. However, the main disadvantages of using sand are that it is heavy, it does not always drain well and it must be sterilized between use
- **Gravel/Quartz:** Quartz or gravel of size <2mm can be used as a medium after washing it with dilute acid and properly rinsing with water. Indeed, plants growing in a typical traditional gravel filter bed, with water circulated using electric power head pumps, are in effect being grown using gravel

hydroponics. Although it is heavy but it has advantages such as it is inexpensive, easy to keep clean, drains well and won't become waterlogged

- **Brick shards:** Brick shards have similar properties as that of gravel. But they have the added disadvantages of possibly altering the pH and require extra cleaning before re-use

The clay pebbles has the property of maintaining pH and also have water holding capacity hence, in this research clay pebbles are used in NTF system as growing media. The algae growth was observed on 33 days hence, baby jelly was used to cutoff the sunlight contact with root system of plant. But this affected the NFT performance which resulted in abortion of 3 plants.

3.10 Design of NFT

Based on water requirements per each plant the whole setup is designed as shown in Plate 3.3 and design specification are maintained in Table 3.2,

3.10.1 Design of pump

- Number of plants = 40
- Discharge per plant required = 2 L/min
- Total discharge, Q = Number*Discharge per plant

$$Q = 40*2$$

$$Q = 80 \text{ L/min} = \frac{80}{(1000*60)}$$

$$Q = 1.33*10^{-3} \text{ m}^3/\text{sec}$$

- Discharge height, H = 1.6m
- Specific Gravity, γ = 9.81 kN/m^3
- Power required, P = γ*Q*H

$$P = 9.81*1.33*10^{-3}*1.6$$

$$P = 0.0208 \text{ kW} = 20.87 \text{ Watt}$$

- Horse Power $= \frac{\text{Power required}}{0.735} = \frac{0.0208}{0.735}$

  Horse Power = 0.028 HP

A NFT system consists of 1m long PVC pipes (Φ 3”) with a slope of 2% and the pipes are provided with end caps. ‘A’ shaped wooden frame structure which is fitted with hinges and hook for the placement of pipes. The submersible pump (2 No. of 0.028HP) used to pump the nutrient solution from tank of capacity 40L to

NFT head continuously by recalculating it with a flow rate of 2LPM per plant. The total eight beds with each bed 5 plant for a total of 40 plants. Growing pots of white coloured plastic reusable cups are used with perforations at base with ensures capillary action to draw water in and a way out for the growing roots.

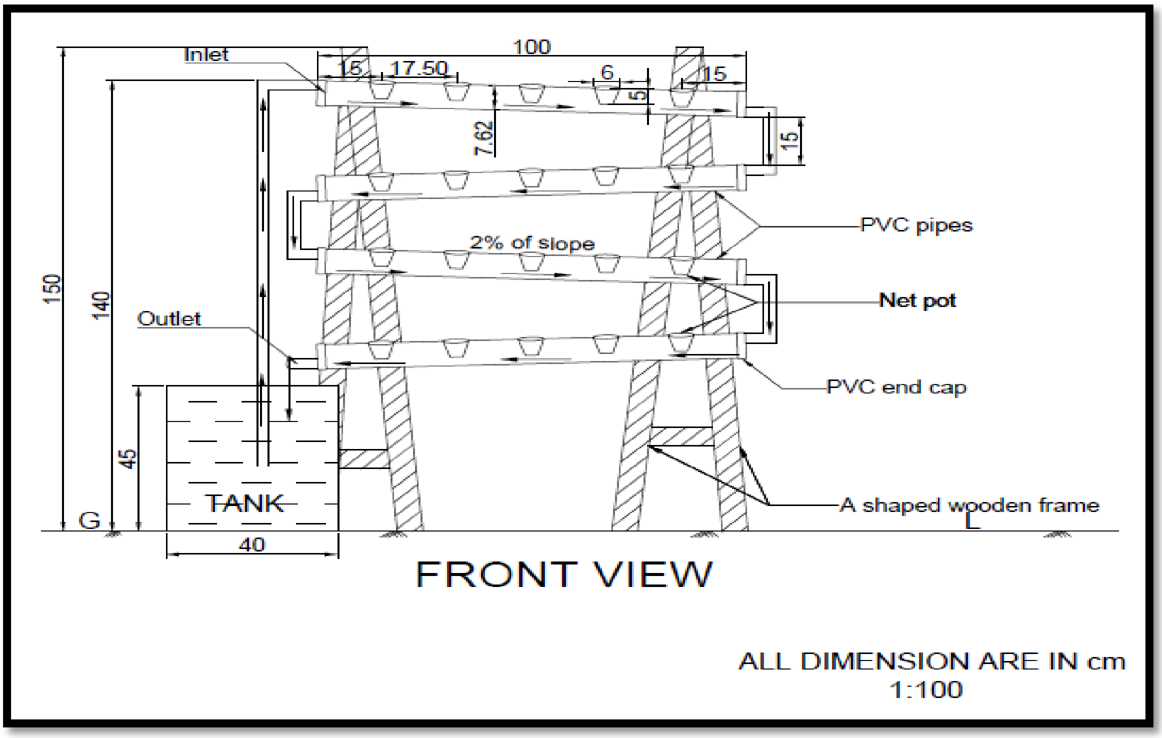

Figure 3.5.a Sketch of front view as per design specification

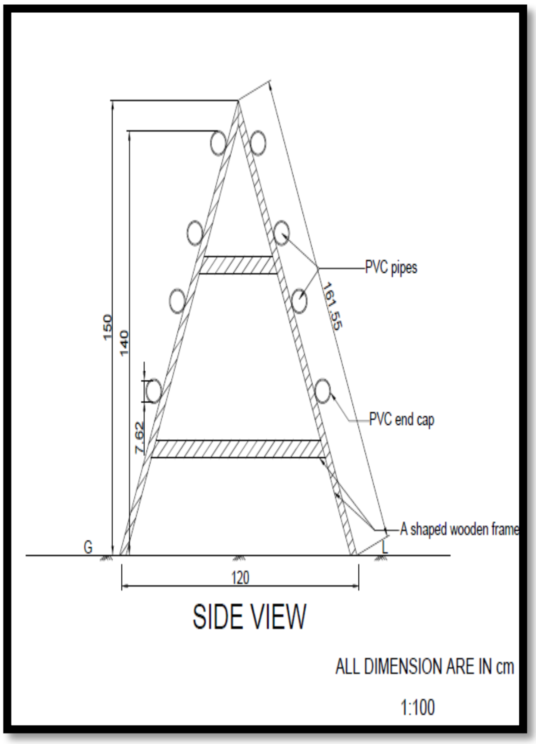

Figure 3.5.b Sketch of side view

Plate 3.3: NFT setup of as per design specification

3.11 Germination of Seeds

- Dry weight of 700gms coco coir was taken and mixed thoroughly by adding 1L of water
- Germination tray was filled with mixed coco coir and small holes were made in each pot for placing of seeds
- Seeds were placed in each pot and completely filled with mixed coco coir then seeds were irrigated twice a day up to 25 days
- After the process of germination, the appearance of seedlings with four leaves was been transferred from tray to growing net pots filled with clay pebbles were placed in NFT setup

3.12 Performance test of NFT

- In this research work, kitchen wastewater was used as nutrient solution which was circulated in NFT system
- The wastewater after circulation in NFT gets purified
- Performance of NFT technique was checked by quantity of water consumed by the plants for every 7 days also by laboratory analysis made for each sample collected before and after irrigation
- The purified water was not discarded instead circulated in NFT system and water level was maintained by adding wastewater to the sump tank and used over again to conserve water
- Physical parameter of plants were also analyzed for every 7 days by recording the parameters such as height, number of leaves, steam thickness, number of fruits after transferring the plants into NFT system
- The above process was repeated for every 7days to check the nutrient absorption by plants and water conservation until the yield was obtained (Fruit)
- The algae growth was observed on 33 days hence, baby jelly was used to cutoff the sunlight contact with root system of plant. But this affected the NFT performance which resulted in abortion of 3 plants.

Chapter 4

RESULT AND DISCUSSIONS

4.1 Kitchen Wastewater Analysis

The Figure 4.1 indicates that the pH value of Kitchen wastewater before irrigation is lower due to decrease in decomposition of organic matter and increases after irrigation due to decrement in decomposition activities.

Table 4.1 depicts the percentage increment of pH value before and after irrigation. The maximum percentage increment of 14.6% is achieved on 35 days whereas, minimum value of 5.84% on 7 days. The pH value is increasing with respect to days indicating high nutrient absorption.

The Figure 4.2 illustrates the EC values of kitchen wastewater before irrigation is less due to dilute solution whereas; the solution becomes concentrated after irrigation. The water acts as solvent for salts present in wastewater, due to absorption of dissolved nutrient along with water by the plants thereby EC value increases after irrigation.

Table 4.2 depicts the percentage increment of EC value before and after irrigation. The maximum percentage increment of 19.23% is achieved on 35 days whereas, minimum value of 13.04% on 7 days. The EC value is increases with respect to days indicating high nutrient absorption.

The Figure 4.3 indicates that the Nitrate value of Kitchen wastewater before irrigation is high and decreases after irrigation indicating uptake of nitrate by plants.

Table 4.3 depicts the percentage decrement of Nitrate value before and after irrigation with the maximum percentage decrement of 87.46% is achieved on 14 days whereas, initial minimum value of nitrate was 48.53% on 7 days. The Nitrate concentration value is varying with respect to days indicating high nutrient absorption which is responsible for the plant's overall growth.

The Figure 4.4 indicates that the Phosphorous value of Kitchen wastewater before irrigation is high and decreases after irrigation indicating uptake of phosphorous by plants.

Table 4.4 depicts the percentage decrement of Nitrate value before and after irrigation with the maximum percentage decrement of 91.63% is achieved on 42 days whereas, initial minimum value of phosphorous was 49.54% on 7 days. The Phosphorous concentration value is varying with respect to days indicating high nutrient absorption which is responsible for photosynthesis and also helps in root growth.

The Figure 4.5 indicates that the potassium value of Kitchen wastewater before irrigation is high and decreases after irrigation indicating uptake of potassium by plants.

Table 4.5 depicts the percentage decrement of Nitrate value before and after irrigation with the maximum percentage decrement of 87.46% is achieved on 14 days whereas, initial minimum value of potassium was 48.53% on 7 days. The Nitrate concentration value is varying with respect to days indicating high nutrient absorption which is responsible for all stages of plant development.

The Figure 4.6 indicates that the Calcium value of Kitchen wastewater before irrigation is high matter and decreases after irrigation due to absorption of nutrients by plant.

Table 4.6 depicts the percentage decrement of Calcium value before and after irrigation. The maximum percentage decrement of 20.20% is achieved on 35 days whereas, minimum value of 5.23% on 21 days. The Calcium concentration value is varying with respect to days indicating high nutrient absorption which is responsible for the growth of plant cells.

The Figure 4.8 indicates that the Sulphate value of Kitchen wastewater before irrigation is high and decreases after irrigation due to absorption of nutrient by plant.

Table 4.8 depicts the percentage decrement of Sulphate value before and after irrigation. The maximum percentage decrement of 60.52% is achieved on 35 days whereas, minimum value of 8.83% on 14 days. The Sulphate value is varying with respect to days indicating high nutrient absorption which is responsible for protein production in plant.

The Figure 4.9 indicates that the Iron value of Kitchen wastewater before irrigation is high and decreases after irrigation due to absorption of nutrient by plant.

Table 4.9 depicts the percentage decrement of Iron value before and after irrigation. The maximum percentage decrement of 89.13% is achieved on 14 days whereas, minimum value of 49.40% on 35 days. The Iron value is varying with respect to days indicating high nutrient absorption which is responsible for photosynthesis and respiration.

The Figure 4.7 and Table 4.7 depicts that the magnesium concentration has increased after irrigation by 30.16% with respect to days. Whereas, the Figure 4.10 and Table 4.10 depict that the chlorine concentration has increased after irrigation by 10.24% with respect to days this may be due to clogging of pores in the roots resulted in concentrated solution after irrigation.

The Figure 4.11 indicates that the DO value of Kitchen wastewater before irrigation is lower and increases after irrigation due to absorption of nutrient by plant.

Table 4.11 depicts the percentage increment of DO value before and after irrigation. The maximum percentage increment of 100% is achieved on 7, 21 and 35 days is due to purification of wastewater whereas, minimum value of 31.37% on 28 days. The DO value is varying with respect to days indicating high nutrient absorption. High DO levels can drastically increases a plant's ability to utilize nutrients and helps to grow healthy plants.

The Figure 4.12 indicates that the BOD value of Kitchen wastewater before irrigation is high and decreases after irrigation due to absorption of nutrient by plant.

Table 4.12 depicts the percentage decrement of BOD value before and after irrigation. The maximum percentage decrement of 17.19% is achieved on 14 days whereas, minimum value of 12.50% on 21 days which is due to reduction of decomposed matter. The BOD value is varying with respect to days indicating high nutrient absorption. As BOD levels are high, DO level decrease because the oxygen that is available in the water is being consumed by the bacteria.

The Figure 4.13 indicates that the COD value of Kitchen wastewater before irrigation is high and decreases after irrigation due to absorption of nutrient by plant.

Table 4.13 depicts the percentage decrement of COD value before and after irrigation. The maximum percentage decrement of 43.42% is achieved on 35 days is due to whereas, minimum value of 12.14% on 7 days. The COD value is decreasing with respect to days indicating low biomass concentration and higher efficiency of the NFT.

4.2 Plant Details during Germination

Figure 4.14 and Figure 4.15 shows that, the number of plants, number of leaves and plant height approximately vary linearly. From day 14 to 17 it can be observed there is no increase in number of plants germinated due to decrease in light intensity. From the table 4.14 depicts that the light intensity on 7th day as high as 514 Lux which has resulted in increase in plant height and number of leaves.

4.3 Plants details in NFT

Table 4.15, 4.16, 4.17 and 4.18 represents the number of plants, leaves, stem height and stem thick respectively which is increasing with respect to days except number of plants which is decreasing after 21 days this may be due to injury in plant roots and breakage of pump. Table 4.19 represents range of climatic parameters in study area depicting high temperature and low relative humidity during summer season critically affecting the plant growth and photosynthesis.

Table 4.1: Percentage increment of pH before and after irrigation

Date	Days	pH Before Irrigation	pH After Irrigation	Percentage Increment (%)
23-03-18	0 - 7	7.25	7.7	5.84
29-03-18	7 - 14	7.7	8.3	7.23
05-04-18	14 - 21	6.8	7.5	9.33
12-04-18	21 - 28	7.5	8.5	11.76
19-04-18	28 - 35	7.6	8.9	14.61
26-04-18	35 – 42	7.7	8.9	13.48
03-04-18	42 - 49	7.5	8.7	13.79
10-04-18	49 - 56	7.3	8.5	14.11

Table 4.2: Percentage increment of EC before and after irrigation

Date	Days	EC Before Irrigation (d S/m)	EC After Irrigation (d S/m)	Percentage Increment (%)
23-03-18	0 - 7	2	2.3	13.04
29-03-18	7 - 14	2.3	2.7	14.81
05-04-18	14 - 21	2.2	2.6	15.38
12-04-18	21 - 28	2.6	3	13.33
19-04-18	28 - 35	2.1	2.6	19.23
26-04-18	35 – 42	2.3	2.6	11.54
03-04-18	42 - 49	1.8	2.2	18.18
10-04-18	49 - 56	2.3	2.7	14.81

Table 4.3: Percentage decrement of Nitrate before and after irrigation

Date	Days	Nitrate Before Irrigation (mg/L)	Nitrate After Irrigation (mg/L)	Percentage Decrement (%)
23-03-18	0 - 7	17.35	8.93	48.53
29-03-18	7 - 14	8.93	1.12	87.46
05-04-18	14 - 21	22.64	11.1	50.97
12-04-18	21 - 28	11.1	1.7	84.68
19-04-18	28 - 35	8.3	1.3	84.34
26-04-18	35 – 42	7.8	0.98	87.44
03-04-18	42 - 49	10.8	1.58	85.37
10-04-18	49 - 56	15.3	2.5	83.66

Table 4.4: Percentage decrement of Phosphorous before and after irrigation

Date	Days	Phosphorous Before Irrigation	Phosphorous After Irrigation	Percentage Decrement (%)
23-03-18	0 - 7	36.13	18.23	49.54
29-03-18	7 - 14	18.23	4.32	76.30
05-04-18	14 - 21	220.10	38.98	65.46
12-04-18	21 - 28	22.54	9.99	55.68
19-04-18	28 - 35	16.19	5.26	67.51
26-04-18	35 – 42	17.36	2.32	86.67
03-04-18	42 - 49	18.88	1.58	91.63
10-04-018	49 - 56	36.13	14.23	60.63

Table 4.4: Percentage decrement of Potassium before and after irrigation

Date	Days	Potassium Before Irrigation	Potassium After Irrigation	Percentage Decrement (%)
23-03-18	0 - 7	37.8	21.5	5.70
29-03-18	7 - 14	21.5	18.5	16.21
05-04-18	14 - 21	95.56	91.5	4.25
12-04-18	21 - 28	97.5	88.57	9.16
19-04-18	28 - 35	26.20	16.83	34.76
26-04-18	35 – 42	53.06	47.46	10.55
03-04-18	42 - 49	52.89	48.23	8.81
10-04-18	49 - 56	59.42	54.36	8.51

Table 4.6: Percentage decrement of Calcium before and after irrigation

Date	Days	Calcium Before Irrigation (mg/L)	Calcium After Irrigation (mg/L)	Percentage Decrement (%)
23-03-18	0 - 7	198.5	172.3	13.20
29-03-18	7 - 14	172.3	155	10.04
05-04-18	14 - 21	143.5	136	5.23
12-04-18	21 - 28	136	110	19.12
19-04-18	28 - 35	198	158	20.20
26-04-18	35 – 42	245	173	29.39
03-04-18	42 - 49	168.2	143.20	14.86
10-04-18	49 - 56	178.1	135.23	24.07

Table 4.8: Percentage decrement of Sulphate before and after irrigation

Date	Days	Sulphate Before Irrigation (mg/L)	Sulphate After Irrigation (mg/L)	Percentage Decrement (%)
23-03-18	0 – 7	8.96	8.15	9.04
29-03-18	7 – 14	8.15	7.43	8.83
05-04-18	14 – 21	12.13	9.97	17.81
12-04-18	21 – 28	9.97	5.7	42.83
19-04-18	28 – 35	9.27	3.66	60.52
26-04-18	35 – 42	11.2	9.23	17.59
03-04-18	42 – 49	10.32	8.73	15.41
10-04-18	49 – 56	9.35	5.32	43.10

Table 4.7: Percentage increment of Magnesium before and after irrigation

Date	Days	Magnesium Before Irrigation (mg/L)	Magnesium After Irrigation (mg/L)	Percentage Increment (%)
23-03-18	0 - 7	64	73.3	12.69
29-03-18	7 - 14	73.3	85	13.76
05-04-18	14 - 21	106.5	139.6	23.71
12-04-18	21 - 28	115.3	152.6	24.44
19-04-18	28 - 35	62.3	89.2	30.16
26-04-18	35 – 42	104.2	128.35	18.82
03-04-18	42 - 49	112	149.2	24.40
10-04-18	49 - 56	135.8	151.3	10.24

Table 4.9: Percentage decrement of Iron before and after irrigation

Date	Days	Iron Before Irrigation (mg/L)	Iron After Irrigation (mg/L)	Percentage Decrement (%)
23-03-18	0 - 7	1.85	0.92	50.27
29-03-18	7 - 14	0.92	0.1	89.13
05-04-18	14 - 21	0.52	0.12	76.92
12-04-18	21 - 28	0.32	0.06	81.25
19-04-18	28 - 35	0.83	0.42	49.40
26-04-18	35 – 42	0.91	0.49	46.15
03-04-18	42 - 49	0.63	0.28	55.56
10-04-18	49 - 56	0.78	0.22	71.79

Table 4.10: Percentage increment of Chloride before and after irrigation

Date	Days	Chloride Before Irrigation (mg/L)	Chloride After Irrigation (mg/L)	Percentage Increment (%)
23-03-18	0 - 7	167.5	183.56	8.75
29-03-18	7 - 14	183.56	204.49	10.24
05-04-18	14 - 21	186.23	198.2	6.04
12-04-18	21 - 28	198.2	215.36	7.97
19-04-18	28 - 35	256.49	261.49	1.91
26-04-18	35 – 42	156.49	173.5	9.80
03-04-18	42 - 49	179.5	197.5	9.11
10-04-18	49 - 56	163.8	182.3	10.15

Table 4.11: Percentage increment of DO before and after irrigation

Date	Days	DO Before Irrigation (mg/L)	DO After Irrigation (mg/L)	Percentage Increment (%)
23-03-18	0 - 7	0	3.1	100.00
29-03-18	7 - 14	3.1	5	38.00
05-04-18	14 - 21	0	3.5	100.00
12-04-18	21 - 28	3.5	5.1	31.37
19-04-18	28 - 35	0	3.2	100.00
26-04-18	35 – 42	0	3.3	100.00
03-04-18	42 - 49	0	2.8	100.00
10-04-18	49 - 56	0	3.6	100.00

Table 4.12: Percentage decrement of BOD before and after irrigation

Date	Days	BOD Before Irrigation (mg/L)	BOD After Irrigation (mg/L)	Percentage Decrement (%)
23-03-18	0 - 7	3700	3200	13.51
29-03-18	7 - 14	3200	2650	17.19
05-04-18	14 - 21	4000	3500	12.50
12-04-18	21 - 28	3500	3000	14.29
19-04-18	28 - 35	3450	2900	15.94
26-04-18	35 – 42	3250	2370	27.08
03-04-18	42 - 49	3570	2168	39.27
10-04-18	49 - 56	3780	2456	35.03

Table 4.13: Percentage decrement of COD before and after irrigation

Date	Days	COD Before Irrigation (mg/L)	COD After Irrigation (mg/L)	Percentage Decrement (%)
23-03-18	0 - 7	140	123	12.14
29-03-18	7 - 14	123	82	33.33
05-04-18	14 - 21	220	193	12.27
12-04-18	21 - 28	193	136	29.53
19-04-18	28 - 35	152	86	43.42
26-04-18	35 – 42	232	153	34.05
03-04-18	42 - 49	186	97	47.85
10-04-18	49 - 56	175	95	45.71

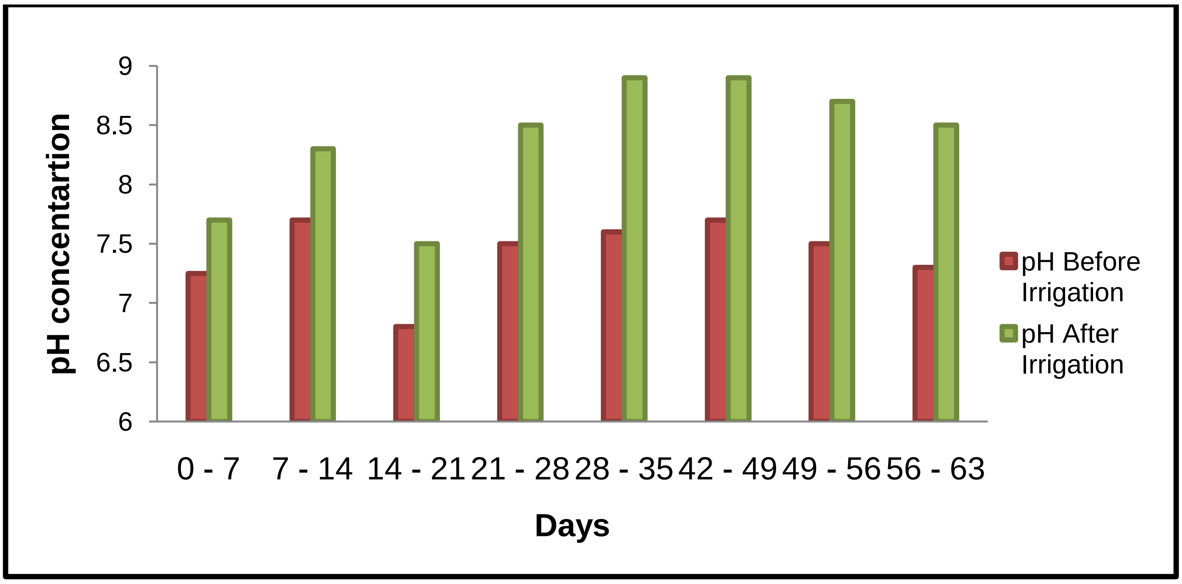

Figure 4.1: pH value of kitchen wastewater before and after irrigation

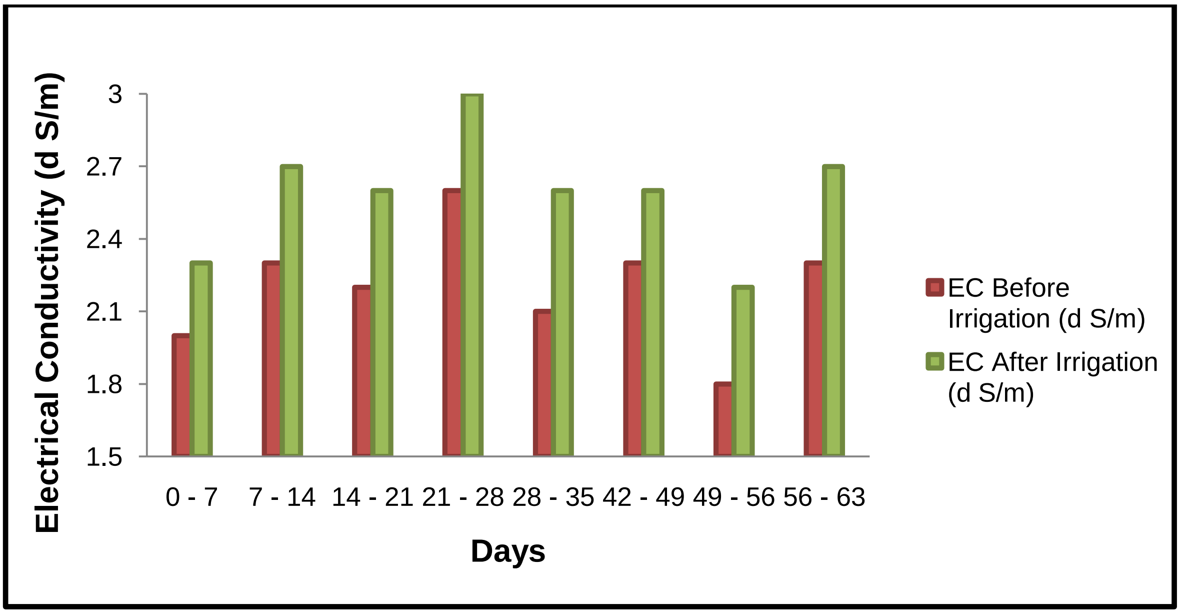

Figure 4.2: EC value of kitchen wastewater before and after irrigation

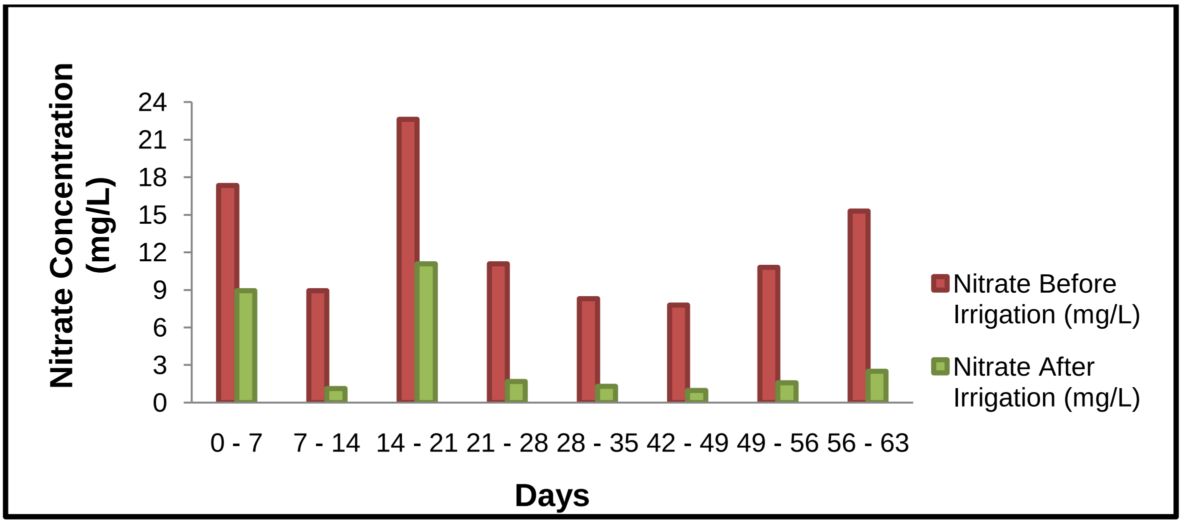

Figure 4.3: Nitrate value of kitchen wastewater before and after irrigation

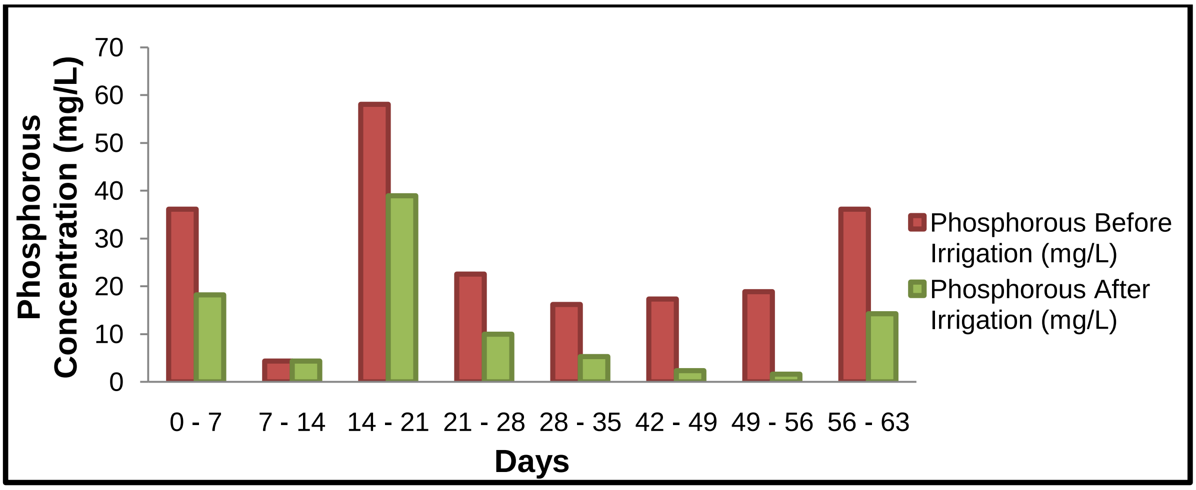

Figure 4.4: Phosphorous value of kitchen wastewater before and after irrigation

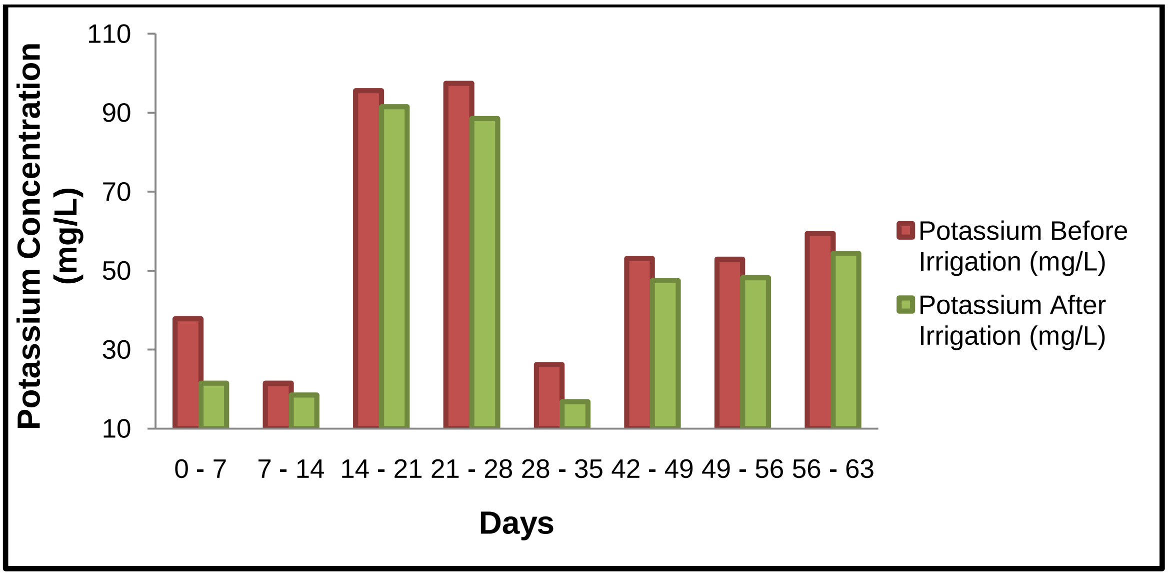

Figure 4.5: Potassium value of kitchen wastewater before and after irrigation

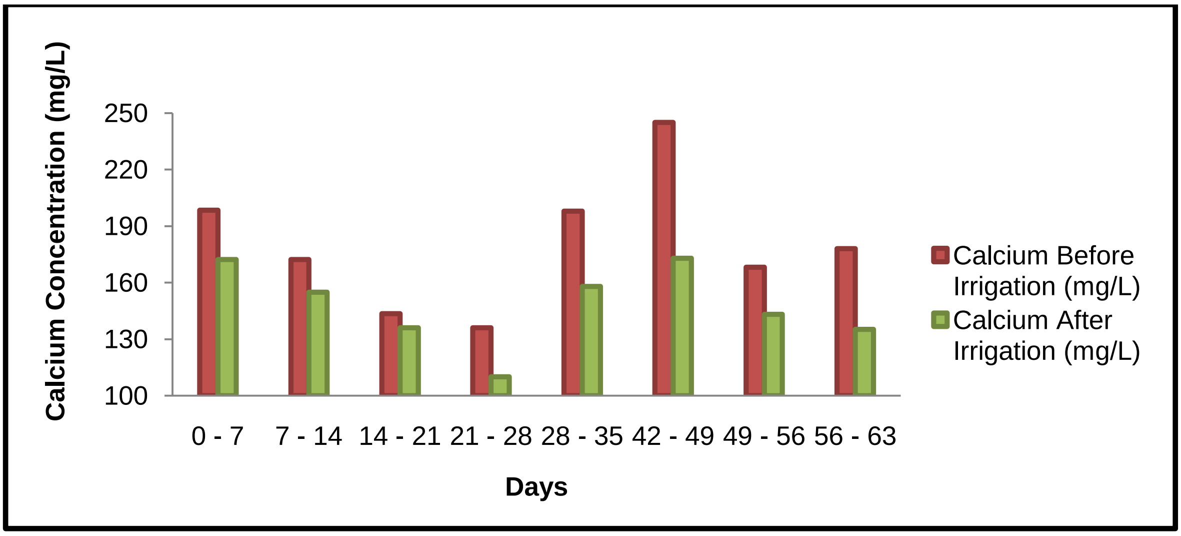

Figure 4.6: Calcium value of kitchen wastewater before and after irrigation

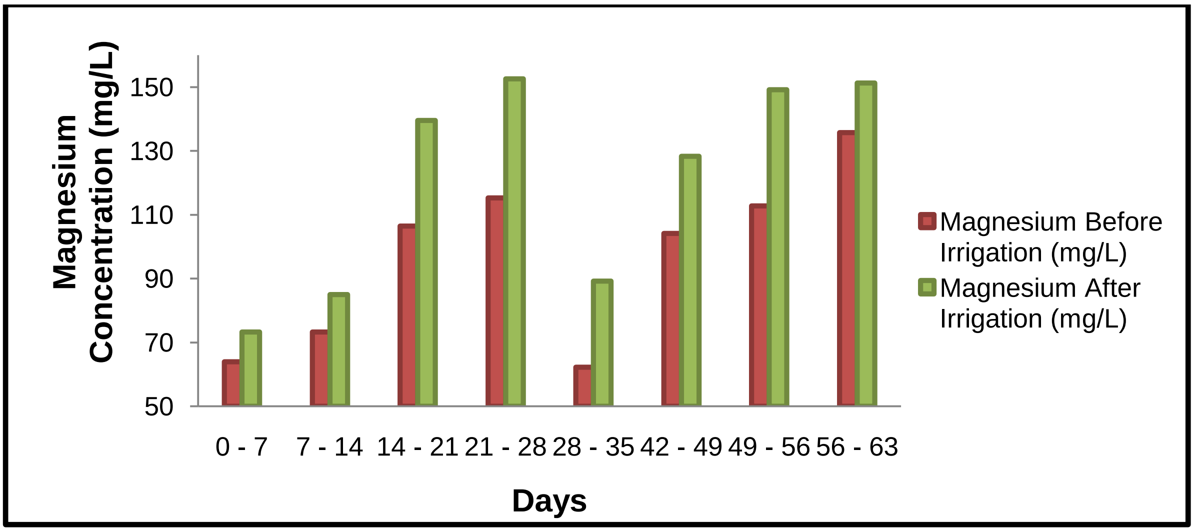

Figure 4.7: Magnesium value of kitchen wastewater before and after irrigation

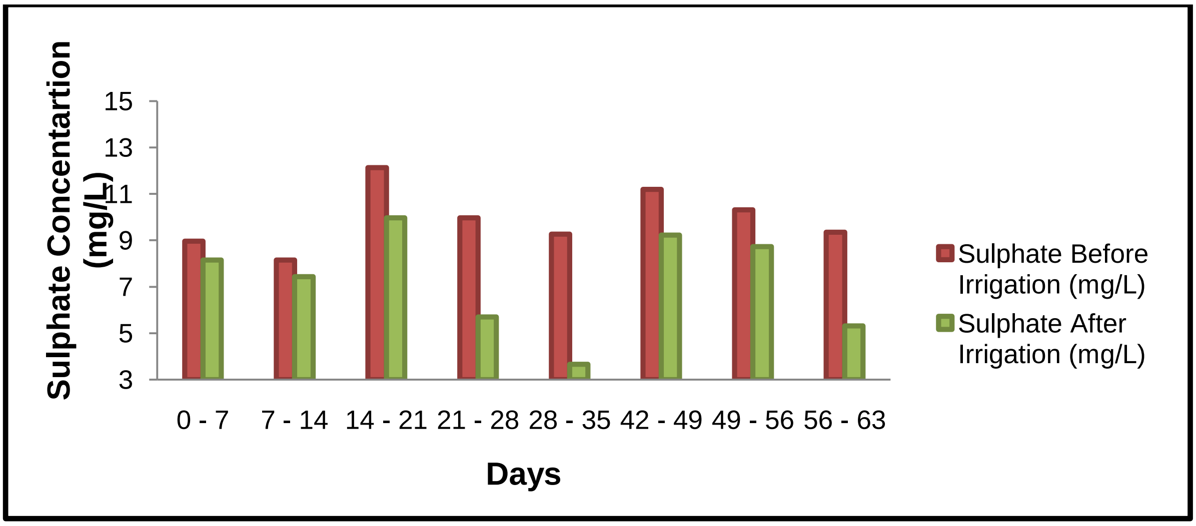

Figure 4.8: Sulphate value of kitchen wastewater before and after irrigation

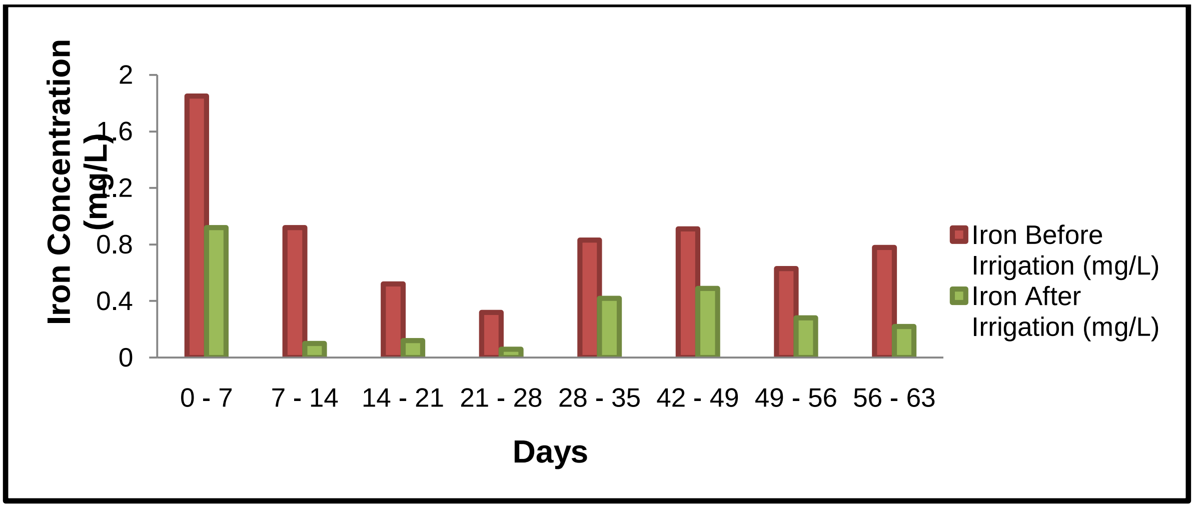

Figure 4.9: Iron value of kitchen wastewater before and after irrigation

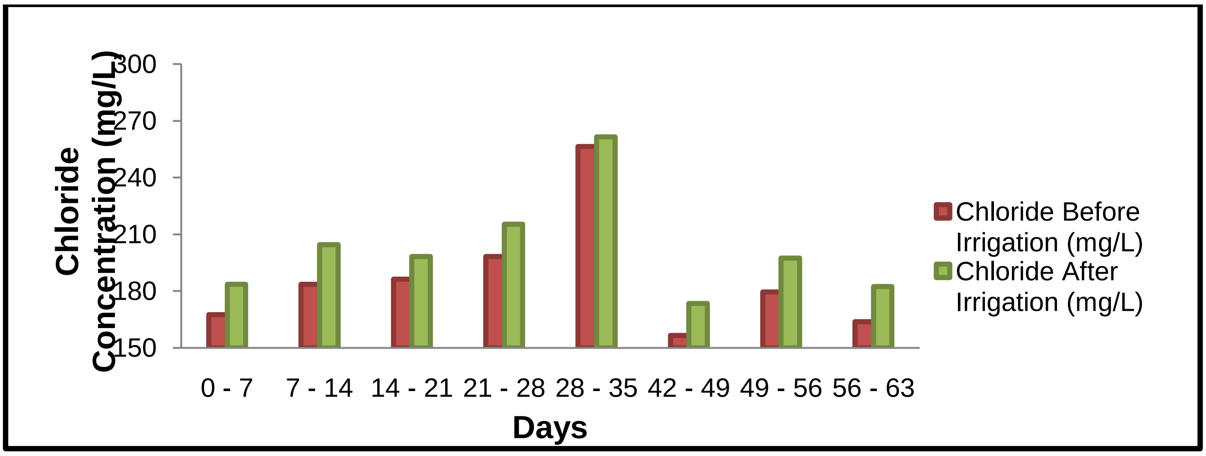

Figure 4.10: Chloride value of kitchen wastewater before and after irrigation

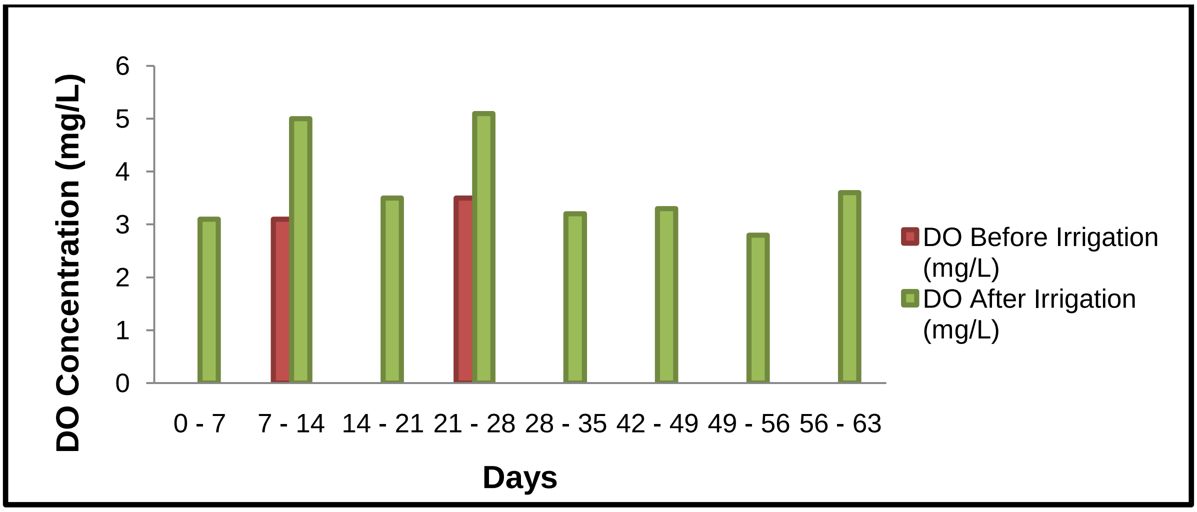

Figure 4.11: DO value of kitchen wastewater before and after irrigation

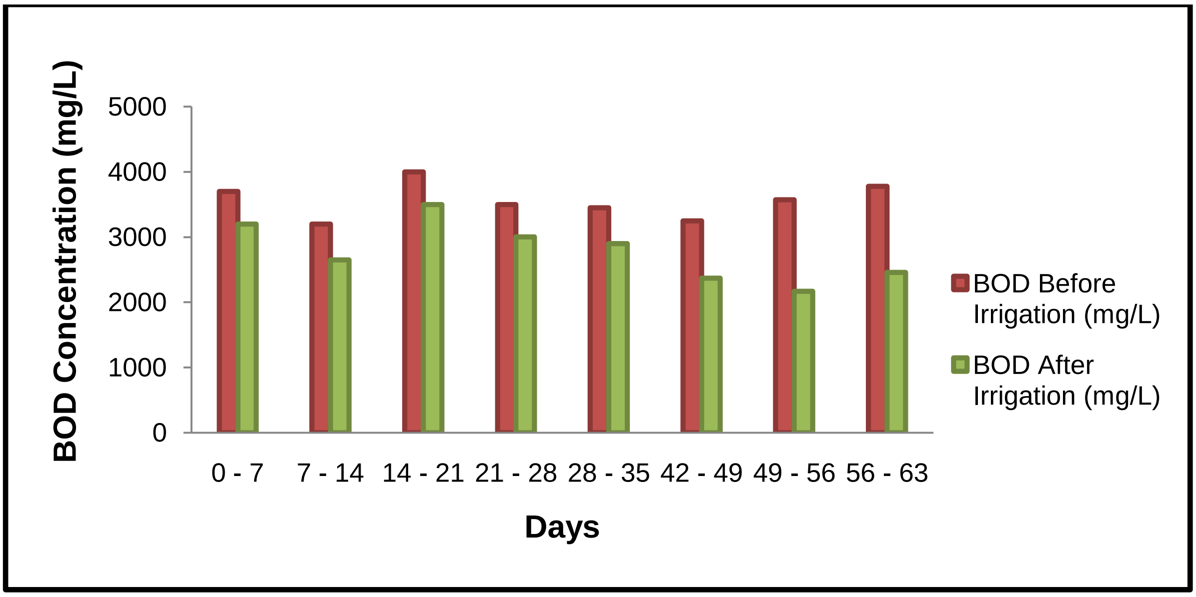

Figure 4.12: BOD value of kitchen wastewater before and after irrigation

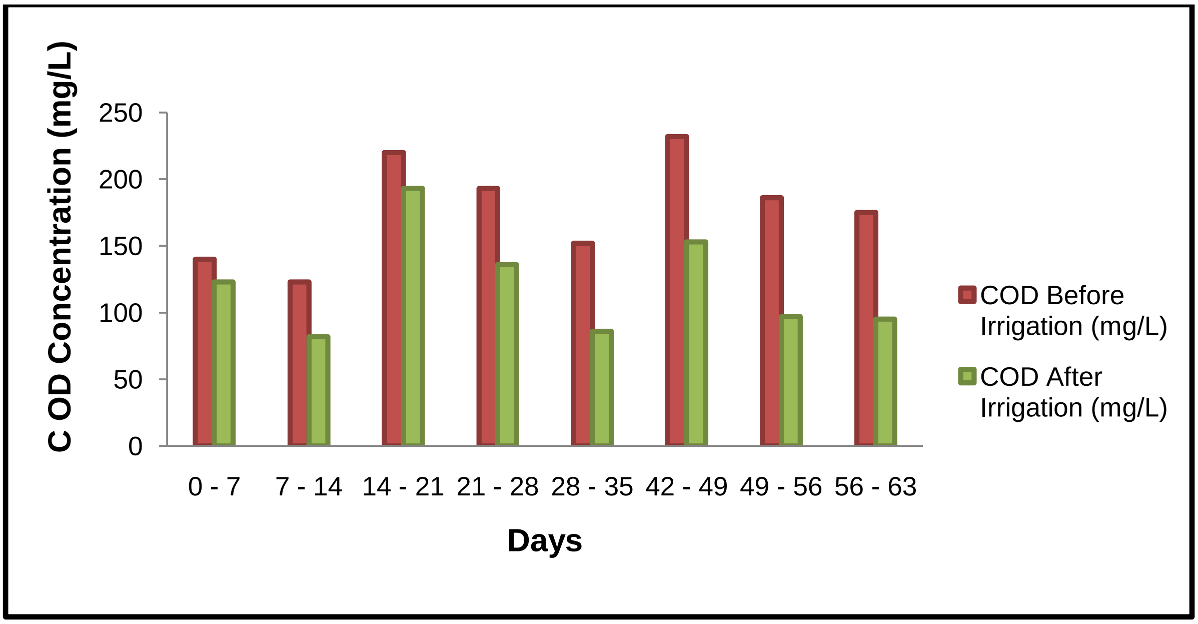

Figure 4.13: COD value of kitchen wastewater before and after irrigation

Table 4.14: Plant growth Analysis during Germination

Date	Days	Temperature (°C)	Quantity of Water applied (mL)	Light Intensity (Lux)	Plant Details		
					No. of Plants	No. of Leaves	Avg. Stem Height (cm)
28-02-18	1	28	400	12	0	0	0
01-03-18	2	27	400	340	0	0	0
02-03-18	3	27	400	406	0	0	0
03-03-18	4	27	400	520	8	0	0.2
04-03-18	5	27	400	480	22	2	0.4
05-03-18	6	27	400	493	35	2	0.5
06-03-18	7	27	500	358	43	2	0.8
07-03-18	8	27	500	456	55	2	1
08-03-18	9	27	500	449	62	2	1.7
09-03-18	10	28	500	514	65	2	2.6
10-03-18	11	27	500	420	71	2	3.3
11-03-18	12	27	500	375	76	2	4.1
12-03-18	13	27	500	480	77	3	4.3
13-03-18	14	27	500	409	79	3	4.8
14-03-18	15	26	600	325	79	3	5.5
15-03-18	16	26	600	375	79	3	5.9
16-03-18	17	26	600	346	81	4	6.3
17-03-18	18	26	600	372	83	4	6.8
18-03-18	19	27	600	390	83	4	7.3
19-03-18	20	27	600	430	84	5	7.7
20-03-18	21	28	600	490	86	5	8.6
21-03-18	22	27	600	432	91	5	8.8
22-03-18	23	27	600	420	93	5	9.2

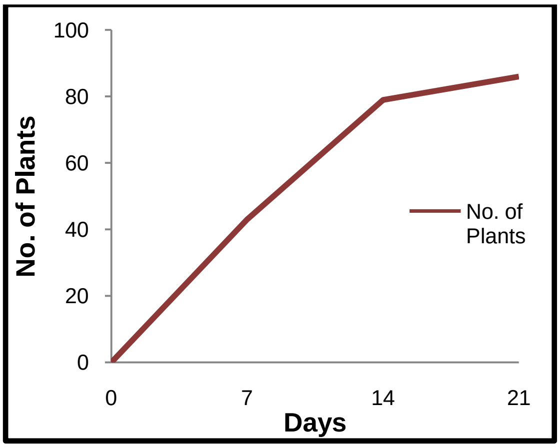

Figure 4.14: Number of plants

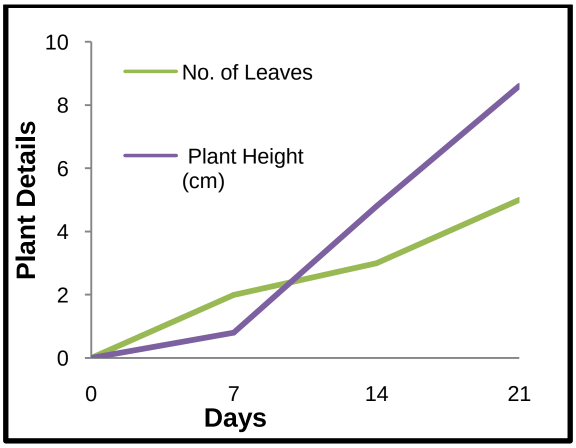

Figure 4.15: Number of leaves & stem height

Table 4.15: Number of Plants in NFT

Date	Days	Number of Plants							
		Left Barrels				Right Barrels			
		Barrel 1	Barrel 2	Barrel 3	Barrel 4	Barrel 5	Barrel 6	Barrel 7	Barrel 8
22-03-18	0	5	5	5	5	5	5	5	5
29-03-18	7	5	5	5	5	5	5	4	5
05-04-18	14	5	5	5	5	5	5	4	5
12-04-18	21	5	4	5	5	5	5	4	5
19-04-18	28	5	4	5	4	5	5	4	5
26-04-18	35	5	4	5	4	5	5	4	5
03-05-18	42	5	4	5	4	5	5	4	5
10-05-18	49	4	3	5	3	5	5	4	5
17-05-18	56	4	3	5	3	5	5	4	5

Table 4.16: Number of Leaves in NFT

Date	Days	Number of leaves							
		Left Barrels				Right Barrels			
		Barrel 1	Barrel 2	Barrel 3	Barrel 4	Barrel 5	Barrel 6	Barrel 7	Barrel 8
22-03-18	0	6	4	4	5	7	5	4	5
29-03-18	7	8	5	7	7	9	7	5	8
05-04-18	14	11	6	11	10	12	9	7	11
12-04-18	21	13	8	13	13	14	12	10	14
19-04-18	28	18	10	15	15	17	14	12	17
26-04-18	35	21	12	18	18	20	16	14	19
03-05-18	42	23	15	22	20	23	18	16	22
10-05-18	49	26	18	22	22	25	20	18	25
17-05-18	56	32	21	25	28	27	23	21	28

Table 4.17: Stem Height in NFT

Date	Days	Stem height (cm)							
		Left Barrels				Right Barrels			
		Barrel 1	Barrel 2	Barrel 3	Barrel 4	Barrel 5	Barrel 6	Barrel 7	Barrel 8
22-03-18	0	9.2	7.5	7.2	8	8.9	8.2	7	8
29-03-18	7	9.8	9	8.5	9.3	9.5	9.5	8.2	9.2
05-04-18	14	11.5	10.3	9.8	10.5	11.5	10.8	9.5	11.5
12-04-18	21	13.8	11.8	11.2	12.5	13.8	12	10.3	13
19-04-18	28	15.2	13.2	13.5	13.8	16.2	13.2	11.5	15.4
26-04-18	35	17.5	15	15.2	15.5	17.5	15.5	13.2	17.5
03-05-18	42	18.7	16.2	16.8	16.9	19.4	17.3	15.5	19.5
10-05-18	49	20.2	17.5	18.3	18.5	21.5	19.2	16.2	21.4
17-05-18	56	25.3	18.3	15.6	13.5	23.5	22.2	17.1	22.5

Table 4.18: Stem Thick in NFT

Date	Days	Stem Thick (cm)							
		Left Barrels				Right Barrels			
		Barrel 1	Barrel 2	Barrel 3	Barrel 4	Barrel 5	Barrel 6	Barrel 7	Barrel 8
22-03-18	0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
29-03-18	7	0.15	0.1	0.1	0.1	0.15	0.15	0.1	0.15
05-04-18	14	0.2	0.15	0.15	0.15	0.2	0.2	0.15	0.2
12-04-18	21	0.3	0.2	0.2	0.2	0.25	0.25	0.2	0.25
19-04-18	28	0.3	0.25	0.25	0.25	0.3	0.25	0.25	0.3
26-04-18	35	0.35	0.3	0.3	0.3	0.3	0.3	0.3	0.3
03-05-18	42	0.4	0.4	0.4	0.35	0.4	0.35	0.4	0.4
10-05-18	49	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
17-05-18	56	0.5	0.45	0.45	0.45	0.5	0.5	0.45	0.5

Table 4.19: Concentration in nutrient solution

Elements	Concentration range required	Concentration range observed	
		Before Irrigation	After Irrigation
Nitrate (mg/L)	100 to 200	7.8 – 22.64	0.98 – 8.93
Phosphorous (mg/L)	30 to 15	17.36 – 220.10	1.58 – 38.98
Potassium (mg/L)	100 to 200	21.52 – 95.56	16.83 – 91.7
Calcium (mg/L)	200 to 300	136 - 245	110 – 173
Magnesium (mg/L)	30 to 80	62.3 – 135.8	73.3 – 152.6
Sulphate (mg/L)	70 to 150	8.15 – 12.13	3.66 – 9.87
Iron (mg/L)	2 to 12	0.32 – 1.85	0.06 – 0.92
Chloride (mg/L)	-	163.8 – 256.49	173.5 – 261.49
pH	5.5 to 6.5	6.8 – 7.7	7.5 – 8.9
Electrical Conductivity (d S/m)	1.5 to 3.0	1.8 – 2.6	2.2 – 3.0
DO (mg/L)	4 - 14	0 – 3.5	2.8 – 5.1
BOD (mg/L)	-	3200 - 4000	2168 – 3500
COD (mg/L)	-	123 - 232	82 – 193

Table 4.20: Climatic condition of Study Area

Climatic Parameter	Standard	Observed
Temperature (°C)	15 – 28 °C	27 – 29 °C
Light Intensity (LUX)	400 - 500	375 – 452
Relative Humidity (%)	80 - 90	52 – 65
Quantity of water used in NFT (L)	-	21.5

Chapter 5

CONCLUSIONS

Based on literature review, experimental study on performance of NFT and results obtained, the following conclusions are draw

- The performance of NFT used in this research work was excellent and economical achieving 77% harvest with high percentage of nutrient absorption from kitchen wastewater
- 23% of plant got aborted due to injury in plant roots and breakage of pump
- The cherry Tomato was used in this research work as it has fast growth rate, good yield with less nutrient absorption and fibrous root system which is suitable for barrel system.
- The relative humidity, Light intensity and temperature observed was ranging 52-65%, 375-452 Lux and 27-28 °C, respectively which was well within the range required for hydroponic system
- The average stem height and thickness were 25cm and 0.5cm, respectively for crop duration of 56 days
- Retardation of plant growth was observed due to high temperature and low humidity during summer season. Hence, greenhouse can be used in future work
- The BOD and COD value is decreasing with respect to days indicating low biomass concentration and higher efficiency of the NFT
- The maximum percentage increase in pH and EC values are 13.79% and 19.23%, respectively during growth period
- The maximum percentage decrease in N, P and K values was 87.46%, 91.63% and 34.76%, respectively representing effective uptake of nutrients by plants
- The magnesium and chlorine concentration has increased after irrigation by 30.16% and 10.24%, respectively with respect to days this may be due to clogging of pores in the roots
- The N: P: K values observed in plants were 2: 1: 0.02, respectively
- The DO values were increasing after irrigation representing purification of water and good rate of photosynthesis

SCOPE OF FUTURE STUDY

- The change in slope of the barrel and angle of ‘A’ wooden frame which leads to increase in DO in nutrient solution and uniform distribution of light intensity over all plants
- The performance test of NFT can also be checked under green house controlled condition
- The perfomance of NFT will be varied with respect use of other growing media and varying discharge
- Different types of crops such as, Duck weed to check the efficiency of NFT

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Appendix A

A. Nutrients Required for Plants

Nutrients are divided into two groups: macronutrients and micronutrients nutrients.

A.1 Macronutrients

- **Nitrogen:** Nitrogen is central to plant growth. It is a major component of amino acids which are the building blocks of all proteins including enzymes, which control metabolic processes. Nitrogen is present in chlorophyll, the green pigment required for photosynthesis. It is also responsible for the plant's overall growth, increasing seed and fruit production and leaf quality. Calcium nitrate and potassium nitrate are major fertilizers used in most hydroponics mixes. Ammonium nitrate and Ammonium sulphate are also used in small amounts to supply the ammonium form of nitrogen
- **Phosphorus:** Phosphorus is used in photosynthesis and in the production of flowers and seeds. It also encourages root growth. Plants deficient in phosphorus can develop sparse dark green leaves with brown or purple discoloration of the lower leaf surface. The most common fertilizers used to supply phosphorus in hydroponics mixes are mono-ammonium phosphate and potassium dihydrogen phosphate
- **Potassium:** Potassium is necessary during all stages of plant development, particularly during fruit development. It is absorbed by plants in larger amounts than any other nutrient with the exception of nitrogen and in some cases calcium. It is involved in the production of chlorophyll, sugars and starches and regulates stomatal opening in the leaves. The main fertilizers used to supply potassium in hydroponics mixes are potassium nitrate and potassium dihydrogen phosphate. Potassium sulphate and potassium chloride can be used to supply small amounts
- **Calcium:** Calcium is used for the manufacture and growth of plant cells. It controls the transport and retention of other elements as well as overall plant strength. The main source of calcium in hydroponics mixes is calcium nitrate. Calcium chloride can be used in small amounts

- **Oxygen:** Oxygen is required for plant respiration and for water and nutrient uptake. Plant roots grown in water quickly exhaust dissolved oxygen and need additional air which can be supplied by aerating the nutrient solution
- **Magnesium:** Magnesium is essential for photosynthesis as it is central to the chlorophyll molecule structure. It also helps activate many enzymes required for plant growth. Magnesium is supplied in the hydroponics nutrient solution as magnesium sulphate or magnesium nitrate
- **Sulphur:** Sulphur is essential for protein production. It promotes enzyme activation and is a component of some vitamins, improving root growth and seed production. In hydroponics mixes sulphur is supplied as magnesium sulphate and is often also supplied as part of many micronutrients

A.2 Micronutrients

While micronutrients are only needed in very small amounts they are vital to healthy plant growth as they are either involved in photosynthesis or important components of many enzyme processes.

- **Iron:** Iron is important in both photosynthesis and respiration. It is needed for the plants to make sugars and starches. Iron also has an important role in the activity of many of the enzymes in a plant. Iron is supplied in the nutrient solution most commonly as iron chelate EDTA. There are other types of iron chelates, such as iron EDDHA and iron DTPA which can be used. Iron can also be supplied as iron sulphate
- **Chlorine:** Chlorine is essential for photosynthesis. It activates the enzymes which release oxygen from water. Chlorine is supplied in the nutrient solution, if necessary with calcium chloride, potassium chloride or manganese chloride
- **Manganese:** Manganese is used in chlorophyll and is needed to make enzymes work. It is also used by plants to take up nitrogen. Manganese is supplied in the nutrient solution as with manganese sulphate or manganese chelate. Manganese chloride can also be used
- **Boron:** Boron is important in flowers and pollen development. Boron is usually supplied in the nutrient solution as sodium borate (borax) or boric acid
- **Zinc:** Zinc is used by the plant to access stored energy. It is also part of enzymes and plant hormones. Zinc is supplied in the nutrient solution as zinc sulphate or zinc chelate

- **Copper:** Copper is used in a range of plant processes and is a component of enzymes. Copper is supplied in the nutrient solution as either copper sulphate or copper chelate

Molybdenum: Molybdenum is used by the plant to process nitrogen. Molybdenum is supplied in the nutrient solution as either sodium molybdate or ammonium molybdate

APPENDIX B

B.1 Tissues of Plants

The ground tissue of plants includes all tissues that are neither dermal nor vascular. It can be divided into three types based on the nature of the cell walls i.e., Parenchyma, Collenchyma and Sclerenchyma cells and plant have different type of transport tissue i.e., Xylem and Phloem cells as Shown in Figure B.1

B.1.1 Parenchyma cells: It has thin primary walls and usually remains alive after they become mature. Parenchyma forms the "filler" tissue in the soft parts of plants usually present in cortex and pith of stems, the cortex of roots, the mesophyll of leaves, the pulp of fruits and the endosperm of seeds. They have large central vacuoles, which allow the cells to store and regulate ions, waste products and water. The main function of this cell,

- In leaves, they form the mesophyll and are responsible for photosynthesis and the exchange of gases, parenchyma cells in the mesophyll of leaves are specialised parenchyma cells called chlorenchyma cells (parenchyma cells with chloroplasts)
- Storage of starch, protein, fats, oils and water in roots, tubers (e.g. potatoes), seed endosperm (e.g. cereals) and cotyledons (e.g. pulses and peanuts)
- Secretion (e.g. the parenchyma cells lining the inside of resin ducts)
- Wound repair and the potential for renewed meristematic activity
- Other specialised functions such as aeration (aerenchyma) provide buoyancy and helps aquatic plants in floating

B.1.2 Collenchyma cells: It has thin primary walls with some areas of secondary
thickening. Collenchyma cells are usually living and have only a thick primary cell wall made up of cellulose and pectin.
The main function of this cell,

- It provides extra mechanical and structural support, particularly in Epidermis regions of new growth mainly in growing shoots and leaves
- Chlorenchyma cells carry out photosynthesis and manufacture food

B.1.3 Sclerenchyma cells: It has thick lignified secondary walls and often dies when mature. Sclerenchyma provides the main structural support to a plant.

Sclerenchyma is the tissue which makes the plant hard and stiff. Unlike the collenchyma, mature sclerenchyma is composed of dead cells with extremely thick cell walls (secondary walls) that make up to 90% of the whole cell volume. The main function is strengthening and supporting elements in plant parts that have ceased elongation.

Two types of sclerenchyma cells exist: fibers and sclereids. Their cell walls consist of cellulose, hemicellulose and lignin.

- **Fibers:** Fibers or bast are generally long, slender, so called prosenchymatous cells, usually occurring in strands or bundles. Such bundles or the totality of a stem's bundles are colloquially called fibers. Their high load-bearing capacity and the ease with which they can be processed have since antiquity made them the source material for a number of things, like ropes, fabrics and mattresses. Sclerenchyma fibers are of great economic importance, since they constitute the source material for many fabrics (e.g. hemp, jute and ramie)
- **Sclereids:** Sclereids are a reduced form of sclerenchyma cells with highly thickened, lignified walls. These have a shape of a star. They are small bundles of sclerenchyma tissue in plants that form durable layers, such as the cores of apples and the gritty texture of pears. Compared with most fibres, sclereids are relatively short

B.1.4 Xylem: It transports water and solutes from the roots to the leaves.

B.1.5 Phloem: It transports food from the leaves to the rest of the plant.

Transpiration is the process by which water evaporates from the leaves, which results in more water being drawn up from the roots.

<u>Plant Respiration and Photosynthesis Formula</u>

- **Respiration:** Oxygen + Water -> Carbon dioxide + Water + Heat energy
- **Photosynthesis:** Carbon dioxide + Water + Light Energy -> Oxygen + Glucose

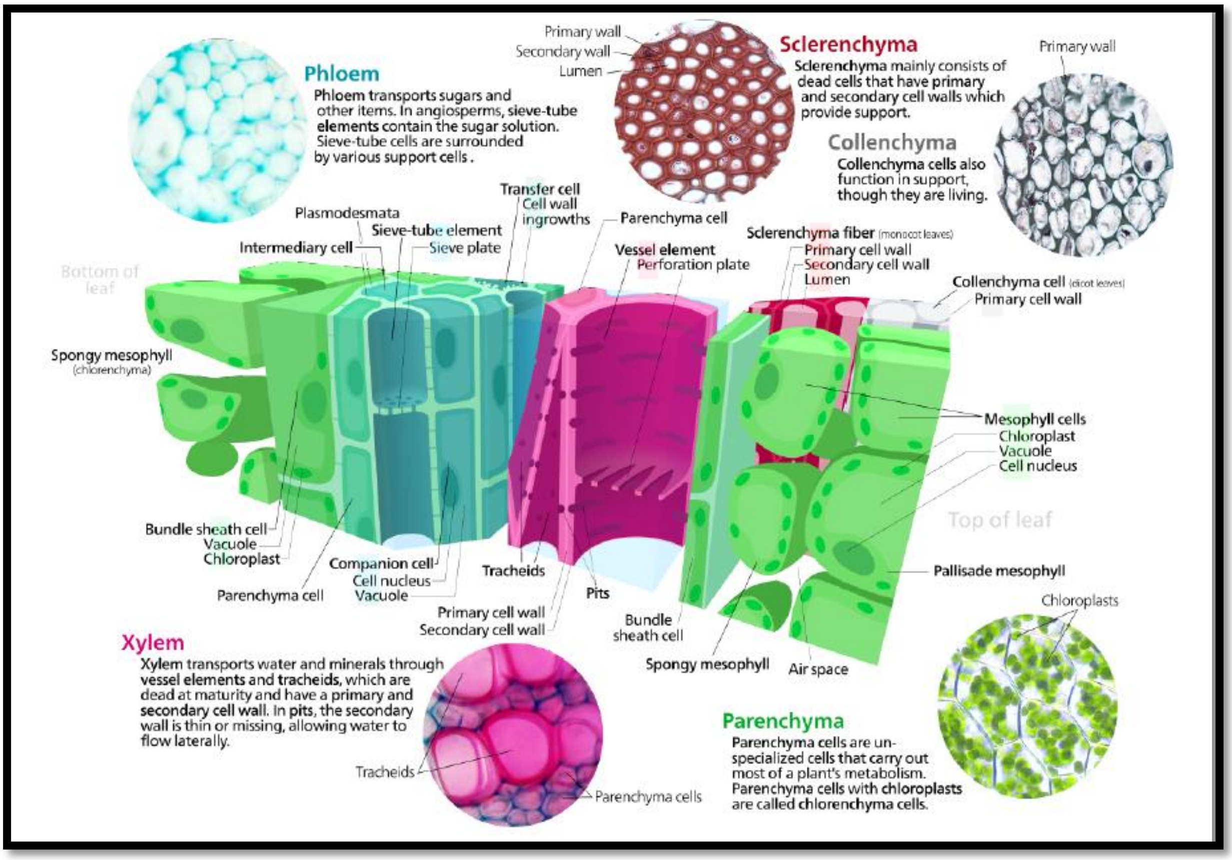

Figure B.1: Plant Tissues