UTILIZATION OF EFFLUENT FISH FARMS IN CULTIVATION USING AQUAPONICS

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PROJECT REPORT

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DECLARATION

We hereby declare that this project report entitled "**Utilization of Effluent Fish Farms in Cultivation Using Aquaponic System**" is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us of any degree, diploma, associate ship, fellowship or other similar title of any other university or society.

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CERTIFICATE

Certified that this project report entitled **"Utilization of Effluent Fish Farms in Cultivation Using Aquaponic System"** is a record of project work done jointly by **Ms. Akhila G.L.** and **Mr. Jasbeer K.T.** under my guidance and supervision and that it has notpreviously formed the basis for the award of any degree, diploma, fellowship or associate ship to them.

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Akhila G.L.

Jasbeer K.T.

Dedicated to

The Farming Society

Of India

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SYMBOLS AND ABBREVIATIONS

%	Percentage
/	Per
TAN	Total ammonia nitrogen
cm	Centimetre `
CO1	Coimbatore 1
$CuSO_4$	Copper sulphate
CWRDM	Centre for Water Resources Development & Management
DO	Dissolved Oxygen
dS/m	Deci Siemens per metre
EC	Electrical conductivity
Eng.	Engineering
FR	Floating raft
g	gram
HCl	Hydrochloric acid
HR	High Loading Rate
HRT	High retention Time
J.	Journal
KCAET	Kelappaji College of Agricultural Engineering and Technology
K_2SO_4	Potassium sulphate
kg	kilogram
$l\ min^{-1}$	litre per minute
m	metre
mg	milli gram
min	Minute
$ml\ s^{-1}$	milli litre per second
mm	millimetre
N	Normality

NaOH	Sodium hydroxide
NFT	Nutrient Film Technology
NH_3	Ammonia
NO_2^-	Nitrite
NO_3^-	Nitrate
º	Degree
PFDC	Precision farming development centre
PIC	Peripheral Interface controller
PVC	Poly vinyl chloride
RAS	Recirculating aquaculture system
sec	second
TNAU	Tamil Nadu Agricultural University
V	Voltage

CHAPTER I

INTRODUCTION

The most prevailing issues of the modern world are food and water crisis. Moreover, there is global concern about how future generations will produce more food sustainably. To meet future demands, aquaculture has emerged as a major food producing sector, and it is now a major global industry with total annual production exceeding 63.6 million tons. Nowadays, scarcity of water has become a major problem in many of the countries because of the increased human population as well as detrimental human activities.

Water is a prerequisite for successful aquaculture operations. Aquaculture practices also generate lot of wastewater, which may cause environmental pollution. Aquaponics is one of the solutions to these problems. Wastewater from the aquaculture system, which is nutrient-rich water, can be used for growing of plants without addition of any additional chemical nutrients.

Aquaponics is a technique within the wider context of sustainable intensive agriculture, especially in homestead applications. In this technique the use of nutrients is very less and hence more acceptable. Aquaponics is the integration of aquaculture and hydroponics, where aquaculture is the cultivation of aquatic animals or plants for food and hydroponics is the process of growing plants without soil. In aquaponics system, the fish consume food and excrete waste primarily in the form of ammonia. Bacteria convert the ammonia to nitrite and then to nitrate. The tank aquaculture also operates relatively independently of local environment conditions. The integration of hydroponic and tank aquaculture in aquaponic production addresses many of negative environmental impacts typically associated with intensive fish and crop production by recycling fish waste for use of crop fertilizer. Aquaponic system is one of the economical solutions for getting benefits from the waste-water from the fish farms as it save nutrients and produce fresh vegetables. With using this system successively its cost will be decreased and became more economic. The produced plants via this system considered as an organic product which is safe for human consumption.

Small proportion of ammonia is toxic to fish, where as nitrate is not toxic to fish. If nitrate increased over a specific limit it will be toxic to fish eaters (human being) and cause nitrate pollution and the eaters will suffer from methemoglobinemia disease. The blood of the affected people become brown and will not be able to carry oxygen to the rest of human organs. To avoid this problem in aquaculture, part of water should be discharged daily and add fresh water instead. Another solution to this problem is establishing hydroponic systems attached to the aquaculture and cultivate plants in the hydroponics in order to save discharged-water and get use of existing nitrate. Benefits of aquaponics are conservation of water resources and plant nutrients, intensive production of fish protein and reduced operating costs relative to either system in isolation and have wide scope in homestead cultivation.

Aquaponics is the cultivation of fish and plants together in a constructed, recirculating ecosystem utilizing natural bacterial cycles to convert fish waste to plant nutrients. Recirculating systems are designed in such a way to raise large quantities of fish in relatively small volume of water and then reusing wastewater after treating the water for the removal of toxic waste products. In aquaponic system the fish consume food and excrete waste primarily in the form of ammonia. Bacteria convert the ammonia to nitrite and then to nitrate.

In aquaponic system, effluent containing nutrients generated through fish rearing is passed through the rooting zone of the plants where it provides a nutrient source. The plant uses the nutrients for its growth. Nutrient uptake and sequestration in plant biomass removes nutrient from the effluent thereby improving water quality. To be most effective, the aquaponic system must be sized correctly with the optimum balance between nutrient production from fish culture and nutrient uptake by the plant component. Insufficient plant growing area will result in an accumulation of nutrients in recirculating system or the excessive release of nutrients in flow through systems. Too large plant growing area improve water quality but will also lead to slower plant growth rates and reduced production of plant crops. Waste generation by fish is directly related to the quantity and quality of feed applied.

Modern aquaponic systems can be highly successful, but they require intensive management and they have special considerations. Aquaculture water under various flow rates is such a factor which determines the growth parameters of the plant. Hydroponic troughs planted with crops, were integrated with an indoor recirculating aquaculture tank with a limited water exchange to regulate the water quality for intensive culture of fish. An increasing water flow rate supported the development of aerobic conditions in the hydroponic trough and hindered denitrification processes. Nevertheless, a low flow rate with lower out flowing oxygen contents promoted denitrification and highest $NO_{3-}N$ elimination was observed in lower flow rates.

Advantages of an aquaponic system

- Sustainable and intensive food production system.
- Aquaponics enables the production of fresh vegetables and fish protein in arid regions and on water limited farms, since it is water re-use system.
- Aquaponics is a working model of sustainable food production wherein plant and animal agriculture are integrated and recycling of nutrients and water filtration are linked.
- In addition to commercial application, aquaponics has become a popular training aid on integrated bio-system
- Greenhouse growers view aquaponics as a way to introduce organic hydroponic produce into the market, since the only fertility input is fish feed and all of the nutrients pass through a biological process.

- Higher yields and qualitative production.
- Construction materials and information base are widely available.

Disadvantages of an aquaponic system

- High initial cost
    - To fill up water tanks
    - To build the system
- Requires skill
- Constant monitoring of water parameters
- Pests and diseases can be devastating
- Fish and plants requirements do not match always perfectly.
- Not recommended in places where cultured fish and plants cannot meet their optimal temperature ranges.
- Energy demanding.
- Alone, aquaponics will not provide a complete diet.

Process

The nutrient rich wastewater from aquaculture is directed into the hydroponic system. Plants will absorb nutrients from the wastewater and improve water quality for the aquaculture system. The closed loop system mimics a natural system; the fish consume food and their waste is naturally converted to nitrate and other nutrients, the nutrients in the water are then taken up by the plants. The fish supply necessary plant supplements and the plant act as a natural water filter. The hydroponic bed functions as a biofilter so the water can then recirculate back to fish tanks.

There are three primary forms for aquaponics

- Nutrient Film Technique: A thin layer of nutrient rich water flows along a tube or closed gutter into which holes are cut and plants are placed, usually in small media filled plastic mesh pots. The upper part of the roots remains in the air while lower part grows vigorously in the well aerated water.

- Deep water or Floating raft method: In which nutrient rich water is introduced to grow tanks of 20-30 cm depth, on the surface of which plants are grown through holes in polystyrene rafts. The water is vigorously aerated to maximize nutrient uptake.
- Media based systems: Where the plants grow in medium such as gravel, clay balls etc. These beds may be “trickle fed” nutrient solution, or subject to periodic flooding and draining to maximize exposure to both air and nutrients. The media beds also function as biofilters.

Objectives of the study

- To study the effect of flow rate for the aquaponic system
- To find out the percentage of nutrients available in the aquaponic solution

CHAPTER II
REVIEW OF LITERATURE

A critical review of the previous research done in aquaponic systems, soilless culture and its applications are dealt with in this chapter. Major studies conducted in India and abroad are discussed below.

2.1 Aquaponic systems

Sneed *et al.*(1975) published the first description of an aquaponic system, which diverted aquaculture effluent through plant growing troughs. The concept was that the nutrients in aquaculture effluent could be put to good use to nourish and grow plants; meanwhile, potentially polluted fish water would be cleaned up before being released into the environment. Plants showed signs of nutrient deficiencies within a month, likely due to a couple of factors. In hindsight, fertilizer nitrate nitrogen was 150 times lower than it is today. Furthermore, the culture water was exposed to sunlight, which allowed microalgae to grow and further reduced the available nutrients. At around the same time, Dr. John Todd and Nancy Jack Todd led similar work at the New Alchemy Institute, which resulted in a natural wastewater treatment system marketed as a ‘living machine’.

Lewis *et al.* (1976) sought to address the dilute nutrient issue. They worked with the first recirculating aquaponic system, which was developed to operate with a high fish stocking density. While the idea was good, nitrate concentrations were too low at 6–10 mg/L, and producers were required to add a complete nutrient solution to support tomato growth. As a general rule of thumb, nitrate levels should be around 46 mg/L. The low nitrate levels coupled with high amounts of fish feed suggested that massive denitrification, or conversion of fertilizer nitrate to nitrogen gas, was occurring and the nitrogen was being released into the atmosphere.

Nair *et al.*(1985) developed a recirculating aquaponics system at the University of the Virgin Islands (UVI). Similar to the system of Lewis *et al.* (1978), it used complex components and engineering that kept operating costs high at $3.18/kg of tilapia produced (1985 prices). Tomato plants grew poorly despite an estimate that nitrogen production by fish should have exceeded plant requirements by ten fold. Unfortunately, the understanding and prevention of denitrification was not well understood at the time. Salts that inhibit the growth of some plant species (Jones 2005) accumulated in the system. Iron averaged 0.1 mg/L, which is less than the minimum of 1–2 mg/L suggested for hydroponic plant culture (Jones 2005). Researchers Mark McMurtry, Douglas Nelson, and Paul Nelson of North Carolina State University also developed a recirculating aquaponics system. They placed their plants in a gravel bed creating an in situ biofilter.

Zweig *et al.* (1986) developed a simple and productive aquaponic system by matching the feeding rate and biomass of the fish to the estimated nitrogen needs of the plants. Iron deficiency was addressed by replacing 20% of the fish feed with rabbit feed. While this work was an important step in the development of the technology, it went largely unnoticed.

David *et al.* (1993) studied energy and water use of a small scale raft aquaponic system. The objective of the study was to describe the operating conditions, input (energy water and fish feed)and outputs(edible crops and fish) and their relationship over two years for a small scale raft aquaponics operation. Comparing inputs to outputs, 104 l of water, 0.5 kg feed, and 56 Kwh energy were needed to produce a 1kg increase in tilapia. Raising tilapia was a net loss, while raising crops was a net gain when comparing market prices to energy costs.

Rakocy and Hargreaves (1993) reviewed aquaponics research and concluded that estimates of nutrient uptake and a deeper understanding of culture water nutrient dynamics are a necessity in the development of criteria for designing aquaponics systems.

Rakocy *et al*. (1993) attempted to track plant nutrient uptake in the UVI aquaponic systems operated with and without plants. Unfortunately, nutrients accumulated at equal rates in all systems and uptake by plants was not demonstrated. A follow up experiment was conducted to determine the optimal fish number-to-plant-growing-area ratio. In hindsight, we now believe that the nutrients produced by fish should have exceeded plant needs in all treatments. Lettuce head weights were about the same in all treatments irrespective of the range of fish stocking densities tested. The plants grown in the aquaponics system were smaller than those produced hydroponically (172–248 g; Kratky 2005), suggesting malnutrition. After refinement, the system produced lettuce heads of a comparable size (181–344 g; Rakocy *et al*.. 1997). A number of years later, it was demonstrated that the UVI system could be operated productively and continuously (Rakocy *et al.*2004). The final system consisted of four fish tanks, six plant troughs, a clarifier tank, screen filter tanks, degassing tanks, a sump tank, a base addition tank, a water pump, two air blowers, and over 200 air stones. A technically trained staff was used to operate it. Rakocy was effectively the first person to develop a fully-functional aquaponics system and thus, is often referred to as the 'grandfather of aquaponics.'

Rakocy *et al.* (1997) developed an aquaponic system for the intensive production of tilapia and hydroponic vegetables. They concluded that the hydroponic component has maintained good water quality through direct ammonia uptake and nitrification on the tank surface.

Richard *et al.* (2004) performed an experiment to find out the water quality parameters impacting nitrification in aquaponics. The objectives of the project were to determine nitrification activity response to pH between 5.5 and 8.5 in recirculating trickling biofilterscontaining perlite biofilters. Results indicate the optimum p^H for nitrification in this system is 8.5.

Tatsuaki *et al*. (2004) studied nitrosomonas communis strain of bacteria in an aquaponics plant. An ammonia-oxidizing bacterium (strain YNSRA) was isolated from the rhizoplane of the reed (Phragmites communis) used in an aquaponics plant which is a wastewater treatment plant. The hydroxylamine–cytochrome c reductase (HCR) of strain YNSRA was found to have a higher activity (25.60 u/mg) than that of Nitrosomonas europaea.

Azizah *et al.* (2010) conducted study on optimal hydraulic loading rate and plant ratios in recirculation aquaponic system. Fish production performance, plant growth and nutrient removal were measured and their dependenceon hydraulic loading rate(HLR) was assessed. The result indicated that waste discharge depended on hydraulic loading rate.

Lorena *et al.* (2011) studied waste production and valorisation in an integrated aquaponic system with bester and lettuce. The purpose of this study was to characterize the wastewater effluent emerging from sturgeon aquaculture and to evaluate its potential for hydroponic lettuce production. Higher ammonia excretion for sturgeons held in higher hydraulic retention time (HRT) was found. Similarly, lettuce registered greater amount of both biomass and yield in lower flow treatment. In terms of wastewater treatment efficiency, lower nitrate removal rate and higher total ammonia nitrogen (TAN) removal rate occurred in high flow rate treatments.

Mohamad *et al.*(2011) developed an aquaponic system with solar powered control pump. This paper describes the development of an aquaponic system using solar panel to control the water pump and air pump based on Peripheral Interface Controller (PIC) technology. Based on observation, the output power from inverter has produced 65.55% efficiency and the average output voltage of the solar panel is 16.16 V.

Flavius *et al.* (2011) reviewed the possibility of increasing the economical efficiency and sustainability of indoor fish farming by means of aquaponics. Aspects like sustainability and economical efficiency were reviewed. In order to improve human health, we must reconsider the agricultural sciences, for which new environmentfriendly technologies need to be developed. Sustainable indoor fish farming is the farming of the new millennium. Combining aquaculture with hydroponics they obtained a new innovation named aquaponics which respects principles of sustainable agriculture (wastewater bio-filtration by plants) and gives us the possibility to increase economical efficiency with an additional production.

Bradley *et al.* (2012) conducted a preliminary study of microbial water quality related to food safety in recirculating aquaponic fish and vegetable production systems. with respect to aquaponic GAP certification by third-party auditors, in aquaponics the simple and unavoidable fact is that raw animal (fish) manure is purposefully and persistently present on-farm and in intimate contact with the non-edible portion of a crop. Indeed, it is hard to imagine that fish and a variety of other aquatic and terrestrial animals are absent from the numerous irrigation systems around the United States that rely on surface water. Some California and Arizona leafy green growers are using water directly, unfiltered or treated, from the Colorado River for overhead irrigation, i.e., direct application of potentially hazardous water to the edible portion of the leafy greens. They recognized aquaponics as a viable, sustainable, and safe method of vegetable production.

Kevin *et al.* (2013) conducted a study onvegetable production in a recirculating aquaponic system using Nile tilapia (*Oreochromis niloticus*) with and without freshwater prawn (*Macrobrachium rosenbergii*). Two recirculating aquaponics systems were installed in a controlled environment greenhouse to study the growth and yield of lettuce (*Lactuca sativa*), Chinese cabbage (*Brassica rapa pekinensis*) and pac choi (*Brassica rapa*) using Nile tilapia (*Oreochromis niloticus*) culture with and without freshwater prawn (*Macrobrachium rosenbergii*). Two sets of data for the three vegetables and one for tilapia and prawn were gathered after the two 35 day growing seasons of vegetables. Results showed that average dissolved oxygen of 5.6 ppm at 98% saturation and 21°C temperature, and a pH of 7.1–7.7 were established by the systems that provided a favorable environment for tilapia, prawn and nitrifying bacteria. However, the pH was disadvantageous to vegetables. With a low concentration of total dissolved solids of less than 330 ppm which was far below the requirement, the high pH retarded the normal growth of the vegetables resulting in chlorotic and necrotic leaves. Results also revealed that the vegetables demonstrated significantly better growth in the system with prawns. Among the three vegetables, pac choi had the highest growth, yield, and productivity followed by Chinese cabbage and lettuce. It was determined that integrating prawn culture helped stabilize and diversify the system which aided in improving the harvest. It also confirmed that stocking density and component ratio were critical in designing an aquaponic system.

Rashmi *et al.* (2013) studied about small scale aquaponic system. The most prevailing issues of the modern world are food and water crises. It is neither possible to consume the pesticide affected food nor grow once own plants, due to scarcity of water and land. Under such conditions, there arises a need for portable agricultural system which uses less water, space and is purely organic. One such solution is asmall scale aquaponic system. This system is made by introducing an automation and data acquisition system; thereby there is no need for setting aside extra time for system care. This paper has used the data acquired from an existing aquaponic system to design and implement an effective small scale sustainable aquaponic system. This can lead to cost effective, sustainable ways of organic farming independent of the need for comparable land space requirement.

2.2 Effect of cultivation media

Roosta *et al.*(2012) studied the effects of different cultivation media on vegetative growth, ecophysiological traits and nutrients concentration in strawberry under hydroponic and aquaponic cultivation systems. A greenhouse experiment was conducted to study the effects of different substrate(various ratios of perlite and coco peat) on growth and development of strawberry in hydroponic and in aquaponic cultivation systems . The study was carried out in hydroponic greenhouse of Agriculture Department, Valiasr University of Rafsanjan, Iran in autumn of 2009. The disinfected platform pots were filled with differentratios of perlite: coco peat (sole perlite, 75% perlite + 25% coco peat) 50% perlite + 50% coco peat, 25% perlite + 75% coco peat, and sole coco peat). Three transplants were planted in each pot and three pots of each substrate were irrigated with hydroponic solution (1/2 concentration of Hoagland solution) and three others were irrigated with aquaponic solution (obtained from raft tanks). The pots were manually irrigated with the amount of 300mL solution three times a day.The results showed that in aquaponic treatment, higher coco peat application resulted in lower yield and the highest yield was produced on the substrate of sole perlite . The highest number of fruits was obtained on the substrate of sole perlite in both treatments.

Jessica (2012) studied the plant growth in aquaponic system through comparison of different plant media. Aquaponics is a form of sustainable agriculture that combines crop and fish cultivation into a water re-circulation system. Water containing fish waste is pumped to the plants, where nutrient water is absorbed and utilized for plant growth. Alternatively, plants provide filtering of the water of excess nutrients that can be toxic to the fish. This experiment tested two food crops (lettuce and radish) grown in three different medias (soil, coconut fiber, gravel) in two separate aquaponics systems (Nutrient Film Technique (NFT) and Floating Raft (FR)) to determine which media maximized plant growth in both systems. Each plant was planted and replicated in each pot (3X) and differing media (3X) as seed and grown for 8 weeks (NFT) and 5 weeks (FR). Growth rates were measured by recording heights weekly and biomass (mg) at the end of the experiment. Both lettuce and radishes had the greatest growth in soil in both systems. I believe soil is the most effective because it supplies the plants with maximum water soil without becoming overly saturated.

Karen *et al.* (2014) conducted study using two crops lettuce, and nasturtium. Nasturtium had higher removal rates and removed both total ammonia nitrogen (TAN) and nitrate resulting in 80% DIN removal while lettuce removed only 48%. Lettuce wasnot effective in the removal of nitrates.The result demonstrated both the crop and the cropping method have considerable effect on nutrient removal.

Zhen *et al.* (2015) reported the effect of plant species on nitrogen recovery in aquaponics. Nitrogen transformations in aquaponics with different edible plant species ie tomato and pak choi were systematically compared. The results showed that nitrogen utilization efficiencies of tomato and pak choi based aquaponic systems were 41.3% and 34.4% respectively.

David *et al.* (2015) studied commercial aquaponics production and profitability. The purpose of this research was to document the production methods, crop and fish yield, and profitability of commercial aquaponics in the United States and internationally. They found that more research and development are needed to determine if aquaponics will evolve into a profitable food production method.

Zhen *et al* (2016) studied the effects of pH on nitrogen transformations in media-based aquaponics. To investigate the effects of pH on performance and nitrogen transformations in aquaponics, mediabased aquaponics operated at pH 6.0, 7.5 and 9.0 were systematically examined and compared in this study. Results showed that nitrogen utilization efficiency (NUE) reached its maximum of 50.9% at pH6.0, followed by 47.3% at pH 7.5 and 44.7% at pH 9.0. Concentrations of nitrogen compounds (i.e., TAN,NO_2^-- N and NO_3^-- N) in three pH systems were all under tolerable levels. pH had significant effect onN_2O emission and N_2O conversion ratio decreased from 2.0% to 0.6% when pH increased from 6.0 to 9.0, mainly because acid environment would inhibit denitrifiers and lead to higher N_2O emission. 75.2–78.5% of N_2O emission from aquaponics was attributed to denitrification. In general, aquaponics was suggested to maintain pH at 6.0 for high NUE, and further investigations on N_2O mitigation strategy are needed.

2.3 Soilless Culture

Agung *et al.* (2015) studied soilless culture. The aim of study was to describe the specific purpose of soilless culture specifically in close-loop system and how substrate nutrition produces the better quality of the yields. Initially soilless production system was carried out by mimicking traditional methods based on production in soil or soil-based systems. 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. By implementing the soilless cultivation system, some researchers yielded a better quality of agricultural products, which is expected to meet the consumer preferences. One of our 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

Taweesak *et al.* (2015) studied the development of cut chrysanthemum production in two soilless systems. Chrysanthemum is an important cut flower grown widely in Cameron Highland, Malaysia. The chrysanthemum growers encountered soil-born diseases, nematodes and accumulation of salinity when production in the same area was practiced continuously. Soilless culture was a cultivation technique independent from soil condition. Chrysanthemum cuttings were grown in trough containing of coconut peat thickness 10 cm height and plantswere fertigated with nutrient solution by drip tape once a day for three weeks, after that the plants were fertigated three times a week. The growth and flowering of chrysanthemum in the two systems were observed. The growth and quality of flowers produced in the tray and the trough system were similar. No significant differences in flower characteristics were observed between the two systems except for flower color. Chrysanthemum produced in both soilless systems received the same price for grade A as soil grown chrysanthemum. This indicated that chrysanthemum production in soilless system can be adopted to eliminate soil related diseases in the highlands.

Subhrajit *et al* (2016) studied about the growth, yield, plant quality and nutrition of basil (Ocimum basilicum L.) under soilless agricultural systems. Traditional agricultural systems are challenged by globally declining resources resulting from climatechange and growing population. Alternative agricultural practices such as aquaponics (includes cropplant and aquatic species) and hydroponics (includes crop plant only) have the potential to generate highyield per unit area using limited land, water, and no soil. A soilless agricultural study was conducted atthe Georgia Southern University, Statesboro, GA, USA from August to November, 2015. The growth, yield,quality, and nutrition of basil (Ocimum basilicum L.) cultivar Aroma 2, were compared between aquaponicand hydroponic systems using crayfish (Procambarus spp.) as the aquatic species. Non-circulating floatingraft systems were designed using 95 L polyethylene tanks. Equal amounts of start-upfertilizer dose wereapplied to both systems. The objective was to understand how the additional nutritional dynamics associatedwith crayfish influence the basil crop. Both fresh and dry basil plant weights were collected afterharvest, followed by leaf nutrient analysis. Leaf chlorophyll content, water pH, nitrogen and temperaturewere measured periodically. Aquaponic basil (AqB) showed 14%, 56%, and 65% more height, fresh weight,and dry weight, respectively, compared to hydroponic basil (HyB). It is logical to assume that crayfishwaste (excreta and unconsumed feed) has supplied the additional nutrients to AqB, resulting in greatergrowth and yield. The chlorophyll content (plant quality) or leaf nutrients, however, did not differbetween AqB and HyB. Further research is needed to investigate aquaponic crayfish yield, overall nutritionaldynamics, cost-benefit ratio, and other plant characteristics under soilless systems.

2.4 Flow rate

Wilson *et al.* (2004) compared the reciprocating flow versus constant flow in an integrated, gravel bed, aquaponic test system. Murray cod, Maccullochella peelii peelii, and Green oak lettuce, Lactuca sativa, were used to test for differences between two aquaponic flood regimes; reciprocal flow (hydroponic bed was periodically flooded) and constant flow (hydroponic bed was constantly flooded), in a freshwater aquaponic test system, where plant nutrients were supplied from fish wastes, while plants stripped nutrients from the wastewater before it was returned to the fish. The Murray cod had FCRs and biomass gains that were statistically identical in both systems. Lettuce yields were good and a significantly greater amount of both biomass and yield occurred in the constant flow treatment. Constant flow treatments exhibited greater pH buffering capacity, required fewer bicarbonate (buffer) additions to control pH and maintained lower conductivity levels than reciprocal flow controls. Water consumption in the two systems was statistically identical. Overall, results suggest that a constant flow flooding regime is as good as, or better than, a reciprocating flooding regime in the aquaponic test system used.

Nicole *et al* (2016) evaluated aquaponic crops in a freshwater flow-through fishculture system. This study examined the establishment and growth performance of 34 food crops grown in a cool, low nutrient aquaponic system. Processwater from a spring-fed flow-through trout raceway, with an average fish biomass of 3630 kg, was used as the water and nutrient source for the plant growing operation. Process water temperature entering the plant growing channels was 13 °C with average concentrations of 0.35, 0.34 and 0.19 $mg{\cdot}L^{-1}$ for ammonium, nitrate, and phosphate, respectively. Crop types included lettuce, Asian greens, mustards, other greens, vegetables and herbs. Stand establishment (percent filled cells) and harvest and individual biomass were evaluated under three treatments; low flow (18.9 L/min), high flow (75.7 L/min), and an amended high flow treatment. The amended high flow treatment consisted of vermiculite planting media amended with composted fish waste and was placed in a channel receiving high flow. These treatments represented a gradient of nutrient availability with low flow receiving the fewest and the amended high flow treatment receiving the most nutrients. Due to space constraints cultivars were sown in two sets. Cultivars in set two were sown as space was made available when cultivars from set one were harvested. Stand establishment was greater than80% for most cultivars under all treatments. However, the herbs sage, garlic chives, and lovage had poor stand establishment as did the vegetables Swiss chard and beets, which were sown late in the study. For most cultivars, stand establishmentwas not significantly different among treatments. The majority of cultivars attained the lowestbiomass on the low flow treatment. Notable exceptions were cilantro, parsley, and minutina. Eight cultivars, including kohlrabi and the bibb lettuce ‘Rex’, grew best on the high flow treatment. The remaining 21 cultivars realized the greatest biomass on the amended treatment although in many cases the increase in biomass was minor. Additionally, for some cultivars, significant increases in stand establishment offset decreases in growth. Minimal improvements inwater quality was observed, probably as a result of nutrient mobilization from accumulated solids within the aquaponic channels.

2.5 Effect of flow rate on nutrient removal and plant growth

Endut *et al.*(2010) studied the effect of flow rate on water quality parameters and plant growth of water spinach (Ipomoea aquatica) in an aquaponic recirculating system. In this experiment, recirculating aquaculture-hydroponic system were designed to provide an artificial, controlled environment to optimize the growth of fish (or other aquatic species) and soil-less plants, complete control of water quality, the production schedule and fish product, while conserving water resources. Nutrient removal such as inorganic nitrogen and phosphate is essential for aquaculture wastewater treatment to protect receiving waters from eutrophication as well as for potential reuse of treated water. In this study, a prototype of an aquaponic system was built at the Freshwater Hatchery Unit on the University Malaysia Terengganu campus. The system consists of a fish culture tank, hydroponic trough, sump, sand filter and water holding tank. Hydroponic troughs were planted with water spinach (Ipomoea aquatica) that has been used to treat wastewater from an aquaculture system stocked with African catfish. The unplanted hydroponic trough was concurrently run as a control unit. The effect of five different water flow rates was tested inorder to relate nutrient removal, water quality with plant growth. The results showed that the aquaponic recirculating system removed 5-day biochemical oxygen demand (47-65%), total suspended solids (67-83%), total ammonia nitrogen (64-78%), and nitrite-nitrogen(68-89%), and demonstrated positive correlated with flow rates. Total phosphorus and nitrate-nitrogen removal rates varied from 43%-53% and 42%-65%, respectively, and were negatively correlated with flow rates. It was found that all flow rates were efficient in nutrient removal and in maintaining the water quality parameters within the acceptable and safe limits for growth and survival of fish.

Hussain *et al.*(2014) studied the effect of water flow rates on growth of Cyprinus carpio var.koi and spinach plant in aquaponic system. This experiment was aimed at standardization of water flow rates in aquaponic system inorder to correlate nutrient removal and water quality with growth of Cyprinus carpio var.koi Beta vulgaris var.bengalensis. Different flow rates ie., 3.2, 1.5 and 1.0 litre per min were assigned as treatments T1,T2and T3 respectively, with spinach plants, whereas S1,S2 were the treatments having flow rates of 1.5,1.0 litre per min, respectively, without plants. Control was set at flow rates of 3.2 litre per min without plants. Treatment T2 showed highest weight gain of koi carp fingerlings and also height gain of spinach plant as compared to other treatments. There was no significant difference in length gain, percentage weight gain, specific growth rate, feed conversion ratio, feed efficiency ratio, and protein efficiency ratio as compared to other treatments and control. The treatments T1,T2 and T3 efficiently remove nitrate (77-78%), phosphate (47.06-55.06%), and potassium (22.85-29.16%) from fish effluent tanks. These results suggest that flow rates 3.2,1.5,1.0 litre per minute were effective under aquaponic system. Of which, 1.5 litre per min can be suggested as optimum water flow rate for the growth of spinach and koi carp in aquaponic system as percentage weight gain in fish, percentage height gain, and yield of plants were higher compared to flow rates 3.2 and 1.0 litre per min.

Hassan *et al.* (2015) studied the utilization of effluent fish farms in tomato cultivation. The main objective was to study the extentto which the content of nutrients in water farming is sufficient for growing tomato plants. The result obtained indicated that the nutrient consumption increased with the flow rate.

Cerozi and Fitzsimmons(2016) studied about phosphorus dynamics modeling and mass balance in an aquaponics system. Aquacultural effluents are rich in P, a growing concern worldwide for potential environmental pollution. Thus integratingaquaculture with agriculture, e.g. aquaponics, shows promise to enhance nutrient and water use efficiency and overall environmental sustainability. The present study was carried out to quantify a P flow, P mass balance, and evaluate P removal efficiency by hydroponic lettuce integrated with tilapia aquaculture. Also, a phosphorus dynamics simulation modelwas developed to be a decision support systemfor phosphorus management. 15 tilapia juveniles (20g) and four 15-day-old lettuce seedlings comprised each aquaponics experimental unit (n=3). At days 0, 7, 14, 21 and 28 after transplanting, water samples were taken from each aquaponics biofilter to determine the reactive and total concentration of phosphorus. The P dynamics model was validated by comparing predicted to observed values of dissolved P over time. The linear regression equations between predicted and measured values were compared with the 1:1 line for statistically significant differences (p b 0.05) in slope and intercept values. The adequacy of the model was determined by testing if intercept equals zero and slope equals one separately using the one sample Student t-test. Comparison of simulated and measured values of dissolved P dynamics showed a good fit around the 1:1 line with the slope (b= 1.005) and intercept values (a = 0.0189) being not statistically different (p N 0.05) from 1.0 and 0, respectively. The assimilation of P in the fish and plant components comprised 71.7% of the total P input, indicating high P utilization by the system. The overall high P utilization by fish and plants identified in this study showed that aquaponics is an excellent tool for recycling phosphorus while yielding a high-quality crop.

CHAPTER III

MATERIALS AND METHODS

This chapter include the materials used and methods employed for this project, conducted in the courtyard of PFDC building in Kelappaji College of Agricultural Engineering and Technology, Tavanur, Malappuram, Kerala. In the first trial, the aquaponics setup of this project was installed in one of the veranda of PFDC facing north. In the second trial of the project, the aquaponics setup was placed in the courtyard of PFDC.

3.1 Location of Study

The experiment was conducted at KCAET, Tavanur, in Malappuram district, Kerala. The place is situated at $10^{o}52' 30''$ North latitude and 76^{o} East longitude**.** Agro climatically, the area falls within the border line of Northern zone and Central Zone of Kerala. Major part of the rainfall in the region is received from the South West monsoon.

3.2 Details of the structure

Angle bars and iron rods were used for making the frame of the structure. The structure has a length of 1.75 m and has a width of 0.75 m. The height of the structure was 1.15 m. Three PVC pipes were supported on the structure along the length. The diameter of PVC pipes used was 4 inch. End cap of 110 mm were provided at the end of all PVC pipes. Three pipes of 15 mm diameter were used to collect water coming out of the PVC pipes. The three pipes were connected to another pipe of 35 mm diameter, which conveyed the water to the sedimentation cup. The sedimentation cup has a diameter of 220 mm. An aquarium pump of 18 watt was used to pump water to the PVC pipes. Three pipes of 15 mm diameter were connected to aquarium pump to pump water to the PVC pipes. Three valves each of 15 mm diameter were connected to above mentioned pipes to adjust the flow rate. Holes of 75 mm were drilled at a spacing of 270 mm centre to centre distance. Six holes were made on a PVC pipe. A cup with upper diameter 85 mm and bottom diameter 65 mm and of height 70 mm were inserted into the holes.

The materials used for the fabrication of the aquaponic structure is shown in the Table 3.1

Table 3.1 Materials used for construction of aquaponic structure

MATERIALS	QUANTITY
Angle bar(2.5 inch)	15m
M S rod(1.5 cm dia)	1.5 m
PVC pipe(3 inch dia)	3 m
Tank(500L)	1
Pump(18 watt)	1
Aerator(30 l/s)	1
End cap(110mm)	6
Plastic pipes(15mm)	2 m
Plastic cups (top diameter 85mm and bottom	18
Sedimentation tank(22mm dia)	1
Coarse aggregate(0.5 inch)	1.5 kg
Control valve	3

Plate 3.1 Aquaponic Structure

Plate 3.2 Setup of the Aquaponic System

3.3 Aquaponic System

The aquaponic system consists of a fish tank with 500 l capacity containing fifty number of tilapia (Tilapia nilotica) fish. These fishes were selected because they produced more ammonia as compared to other varieties and they multiply on their own and these fishes are resilient against fluctuations in dissolved oxygen level, pH and temperature. Initially the tank was filled three-fourth with water. When the fish is fed with its food, the water gets contaminated with fish waste. The major component present in the fish waste is ammonia. Ammonia is very much toxic for the fish even at low concentrations. One of the major advantages of the aquaponic system is that the ammonia excreted by the fish is being continuously removed by the bacteria present in the water. Nitrosomonas bacteria present in water oxidize ammonia to nitrite and nitrobacter converts the nitrite to nitrate. Nitrate is the form in which nitrogen is absorbed by the plants. This nitrogen rich water is used to grow plants. The water is pumped from the tank to the different pipes, plants absorb the nitrate and water is returned back to the tank.

3.4 Experimental design

The experiment was designed to study the effect of different flow rates on plant growth to compare the growth parameters of plants (plant height, node to node distance, root length, number of leaves). The percentage of nutrients present in the aquaponic solution was also found out. Two trials were done. The system was run for a period of 56 days which includes the time for setting up of biofilter, time from planting to harvesting, and gap of 7 days between the two trials. For the development of the biofilter, the system was run idly for a period of two weeks for the development of bacteria.

3.5 System cycling and starting biofilter colony

System cycling means the initial process of building a bacterial colony when first starting the aquaponic system and it takes about two to three weeks. Cycling involves introducing ammonia source to the unit, feeding the bacterial colony and creating a biofilter. Biofiltration is essential in aquaponics because small ammonia and nitrite are toxic even at low concentration, while plants need nitrate to grow. Plants should be added only after the cycle is complete.

3.6 Planting Medium

There are many different medias in which plants can be grown. The medium used in this experiment was gravel. Gravel medium have adequate surface area for bacterial growth. Due to large surface area, there is sufficient space for air and water to flow within the medium. They have neutral pH and are inert (meaning the medium will not leach out any potentially toxic substances) and they are easily available and it is almost chemically inert. Gravel is abundant in many locations around the world. Once washed of dust and dirt, gravel is almost completely chemically inert, except for small releases of microelements such as iron and magnesium and the absorption of phosphate and potassium ions within the first few months of starting a unit. The recommended size of gravel is 8-20 mm in diameter. Smaller gravel is likely to clog with solid waste and larger gravel does not offer the surface area or plant support as required.

3.7 Water flow rate

Optimization of flow rate was studied by conducting experiments with different flow rates in an aquaponic system for the period of 56 days. Before starting of the experiment, tank was properly cleaned. The experimental design consisted of 2 trials, each having 3 replicates. Different flow rates, i.e., 7.5, 3, and 2 l min^{-1}, were assigned for T1, T2, and T3 treatments, respectively. S1, S2 and S3 were the treatments with same water flow rates in order to relate to nutrients removal, water quality and growth of the plant. The rate of water turnover should be designed to ensure good water quality. Water should be passed through the hydroponic grow media enough times per day to be adequately filtered and therefore to ensure appropriate removal of waste compounds that are toxic to fish. Excessively high flow rates, however will reduce to too great of an extent the amount of time toxic wastes in fish tank effluent spend in contact with microbes in the biofilter. This will cause some of these compounds to be flushed back into the fish tank before they are converted to safer forms or assimilated by the hydroponic plants. Increasing water flow rates tends to increase the removal of BOD_5, TSS, NH_3-N and NO_2^- - N, while decreasing flow rate increases the removal of PTOT, NO_3^- - N. Water flow rates may need to be adjusted if water quality tests show that greater removal of any nutrients is required to meet water quality requirements for the tilapia.

3.8Selection of plants

The CO 1 variety of amaranthus was used for the experiment. It is a high yielding variety released from TNAU. Leaves are green in colour and are tolerant to leaf spot disease. It belongs to the family of *Amarantaceae*. It is a herbaceous crop with upright growth habit, cultivated for both, its seeds and its leaves which are used as a vegetable or green. Both leaves and seeds contain protein of an unusually high quality. Amaranthus is a valuable nutritious feedstuff with high production ability.

3.9 Planting methods

The plants are planted in the medias having different flow rates. The first pipe is set for a flow rate of 2 l $min^{-1}$and the second pipe is set for a flow rate of 3 l min^{-1}. The third pipe is set for a flow rate of 7.5 l min^{-1}. The cups were filled with the gravel and the seedlings were planted into it. Fourteen days old amaranthus seedlings were transplanted into the medias of the aquaponic structure and six seedlings were planted in each row.

3.10 Parameters which affect the bacterial growth

Electrical conductivity (EC) and pH are the important parameters which should be monitored on a weekly basis. The EC value should be in the range of 0.1 to 0.4 dS m^{-1}. The pH range varies from 5 to 8. When pH value goes below 5, required quantity of lime is added and when the water becomes highly alkaline, cow dung is added. Addition of lime or cow dung is done till the pH level reaches the optimum. When pH becomes alkaline we can even go for adding HCl, but production of salt is a major issue.

3.11 Data Recorded

3.11.1 Weekly

Measurement of pH and electrical conductivity

EC and pH was measured in weekly basis using a pH meter and EC meter respectively.

A pH Meter was used for measuring the pH(concentration or the activity of hydrogen ions) of the aquaponic solution. It comprises of a simple electronic meter and a pair of probes, or a combination probe, and some form of display calibrated in pH. The probe is the key part, it is a rod-like structure made of glass, with a bulb containing the sensor at the bottom. pH of the solution was measured by dipping the probe into it. Before and after use the probe was cleaned using distilled water.

Electrical conductivity was measured using a meter and probe. The probe consists of two metal electrodes spaced 1 cm apart. Unit of measurement is deci Seimens per meter. The probe was cleaned with distilled water before and after use. Observations are made by dipping the probe into a sample of the solution taken in a beaker.

Plate 3.3 EC meter and pH meter

Biometric observations

For analyzing the growth pattern of the crops, six plants were selected from each rooting media. Biometric observations such as plant height, inter nodal distance and number of leaves were taken once in a week. The root length was taken before planting and after the harvest. The data collected from the plants were tabulated.

Height of the plant

The heights of the plants were measured from the surface of the rooting media to the tip of the shoot.

Node to node distance

The distance from one node to another node was measured in cm.

Number of leaves per plant

Numbers of leaves of plants of each rooting media were counted once in a week.

3.11.2 At harvest

Root length

The total length of roots was measured.

Yield (g/plant)

Matured crops were harvested and the yield was recorded

Plate 3.4 Matured Plants

3.12 Water Quality Parameters

The water quality parameters such as Nitrate (NO_{2}), Nitrite(NO_{3}), Potassium, Phosphate are tested in CWRDM , Kozhikode. The other water quality parameters such as EC and pH were measured by using EC meter and pH meter respectively.

CHAPTER IV

RESULTS AND DISCUSSION

The study was undertaken with the objectives of utilization of fish effluent in cultivation using aquaponics, and to evaluate the performance of crops cultivated in different flow rate. Two trials were done for the study. CO1 variety of amaranthus was used for the study. Electrical conductivity and pH of the aquaponic solution was measured on a weekly basis. Biometric observations were also noted.

4.1 pH Measurement

Measurement of pH was done on a weekly basis. The variation in pH could lead to the failure of the project and hence pH was strictly monitored and was maintained within the range 5 to 8. If the pH value is more than 8, then the ammonia excreted by the fishes will get evaporated, and if pH drops below 5, the acidity is increased to such an extent that the fishes cannot survive. The measured pH has always been acidic, the maximum value being 7 and the least value being 5.3.

Table 4.1 Variation of pH (first trial)

SL NO	DURATION	pH MEASUREMENT IN FIRST TRIAL
1	First week	7
2	Second week	6
3	Third week	6
4	Fourth week	6.5
5	Fifth week	6.5
6	Sixth week	5.5
7	Seventh week	5.3

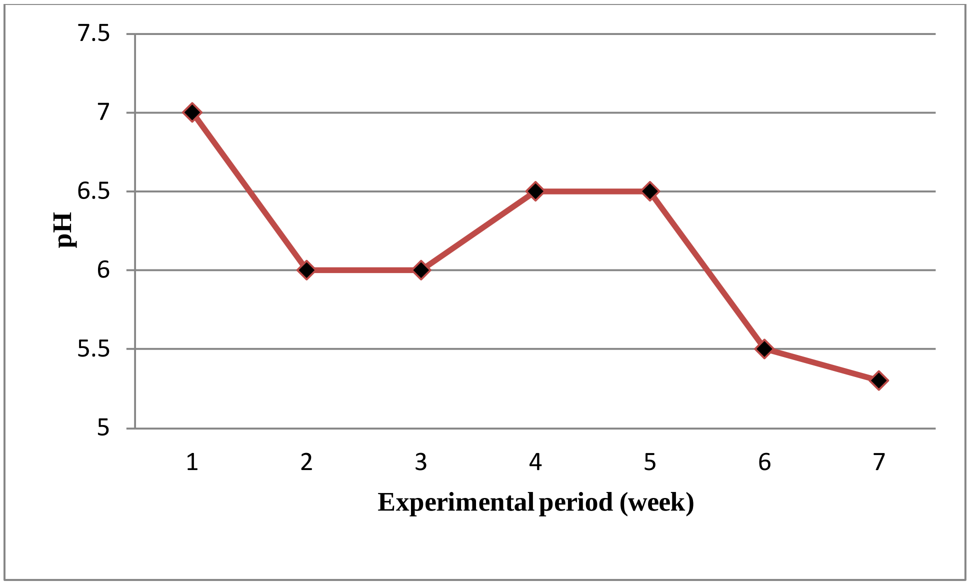

Fig. 4.1 Variation of pH during the experimental days (first trial).

4.2 Electrical conductivity measurement

EC was measured on a weekly basis and was maintained in the range 1.2 to 1.9 dS/m.

Table 4.2 Variation of EC of aquaponic solution(first trial).

SL NO	DURATION	EC VALUE IN FIRST TRIAL (dS/m)
1	First week	1.2
2	Second week	1.5
3	Third week	1.7
4	Fourth week	1.7
5	Fifth week	1.8
6	Sixth week	1.9

7	Seventh week	1.9

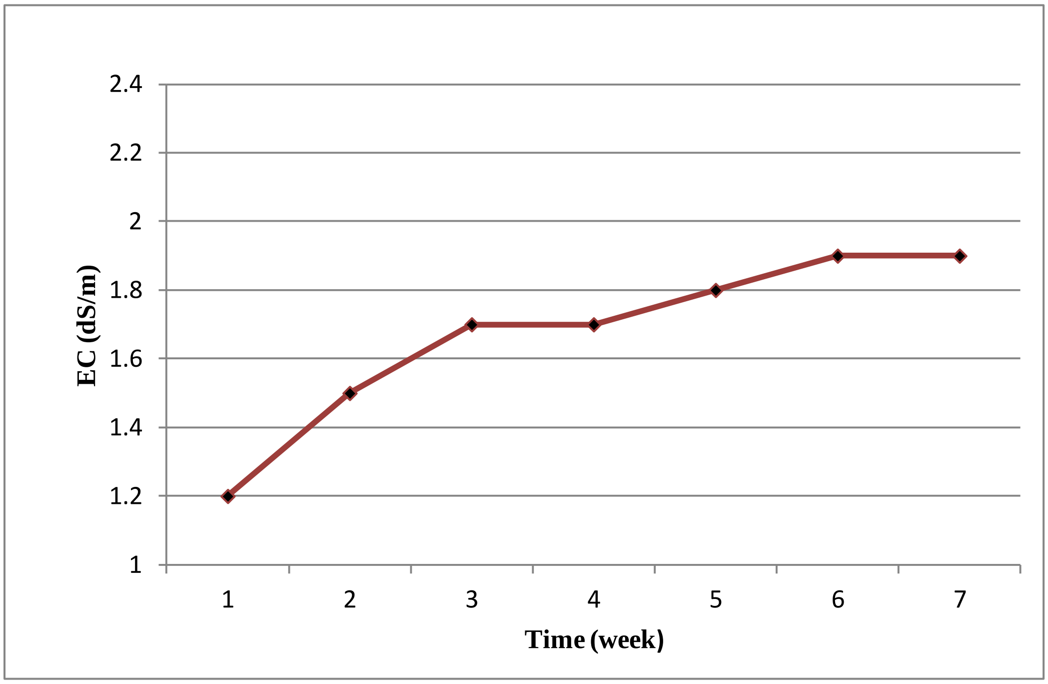

Fig. 4.2 Variation of EC during the seven week (first trial).

4.3 Biometric observations for first trial

This section includes plant height, number of leaves, intermodal distance, root length and the yield. The plant height, intermodal distance, number of leaves, and yield are found to vary for plants in different flow rate.

4.3.1 Plant height

Plant height is the distance measured from the tip of the plant to the top of the rooting media. These measurements were taken on weekly basis. The observation on plant height was first taken one week after planting. The best performance was shown by plants planted in the flow rate of 7.5 l min^{-1}. The least height recorded was for plants in the flow rate of 2 l min^{-1}.

Table 4.3 Variation of plant height in different flow rates (first trial)

SL.NO	FLOW RATE ($l\ min^{-1}$)	DURATION	PLANT HEIGHT(cm)
1	2	FIRST WEEK	5.8
2		SECOND WEEK	8.4
3		THIRD WEEK	18.67
4		FOURTH WEEK	24.36
5		FIFTH WEEK	31.97
6		SIXTH WEEK	40.41
7		SEVENTH WEEK	48.46
8	3	FIRST WEEK	6.1
9		SECOND WEEK	9.82
10		THIRD WEEK	25.43
11		FOURTH WEEK	33.67
12		FIFTH WEEK	40.93
13		SIXTH WEEK	52.43
14		SEVENTH WEEK	60.12
15	7.5	FIRST WEEK	6.1
16		SECOND WEEK	10.82
17		THIRD WEEK	30.6
18		FOURTH WEEK	42.47
19		FIFTH WEEK	55.36
20		SIXTH WEEK	60.89
21		SEVENTH WEEK	69.18

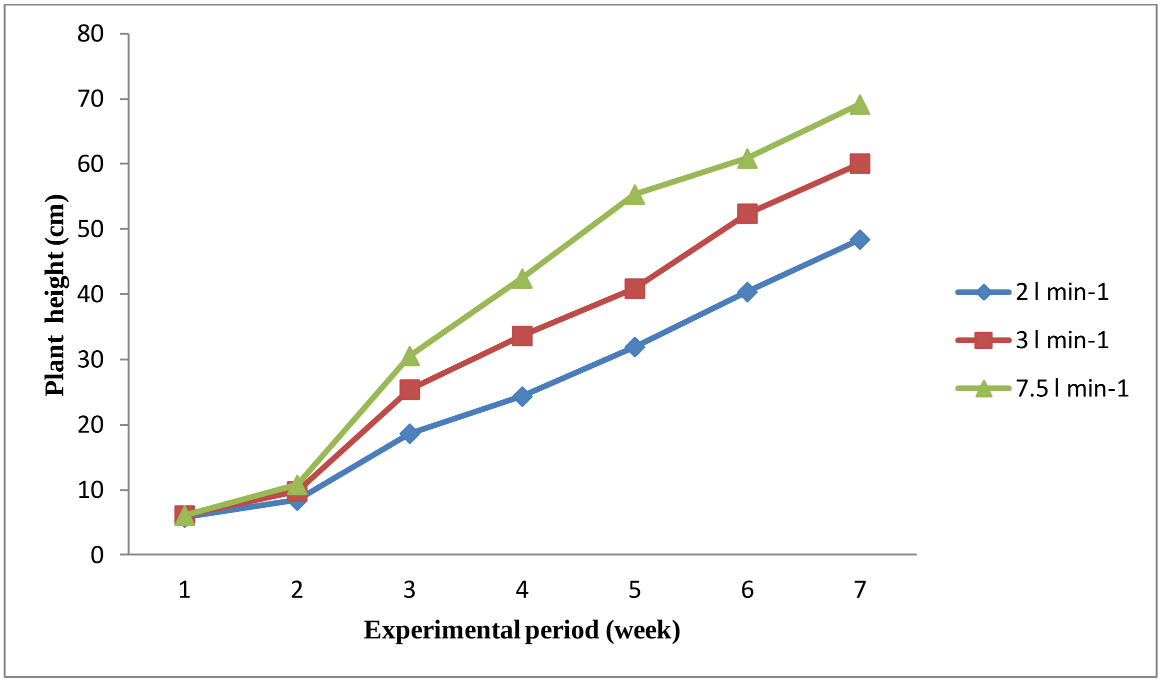

Fig. 4.3 Variation of plant height in different flow rates during seven week (first trial).

4.3.2 Node to node distance

The distance between consecutive nodes, these measurements were first taken after one week of planting. After that, the observations were taken in a weekly interval. Maximum internodal distance observed in the flow rate of 7.5 l min^{-1}. The least intermodal distance is observed in the flow rate of 2 l min^{-1}.

Table 4.4 Variation of node to node distance in different flow rates (first trial).

SL.NO	FLOW RATE ($l\ min^{-1}$)	DURATION	NODE TO NODE DISTANCE (cm)
1	2	FIRST WEEK	0.73
2		SECOND WEEK	1.25
3		THIRD WEEK	1.88
4		FOURTH WEEK	2.4
5		FIFTH WEEK	3
6		SIXTH WEEK	3.2
7		SEVENTH	3.4
8	3	FIRST WEEK	0.78
9		SECOND WEEK	1.55
10		THIRD WEEK	2.2
11		FOURTH WEEK	2.75
12		FIFTH WEEK	3.05
13		SIXTH WEEK	3.56
14		SEVENTH	4.43
15	7.5	FIRST WEEK	0.8
16		SECOND WEEK	1.73
17		THIRD WEEK	2.41
18		FOURTH WEEK	2.83
19		FIFTH WEEK	3.11
20		SIXTH WEEK	3.80
21		SEVENTH	4.73

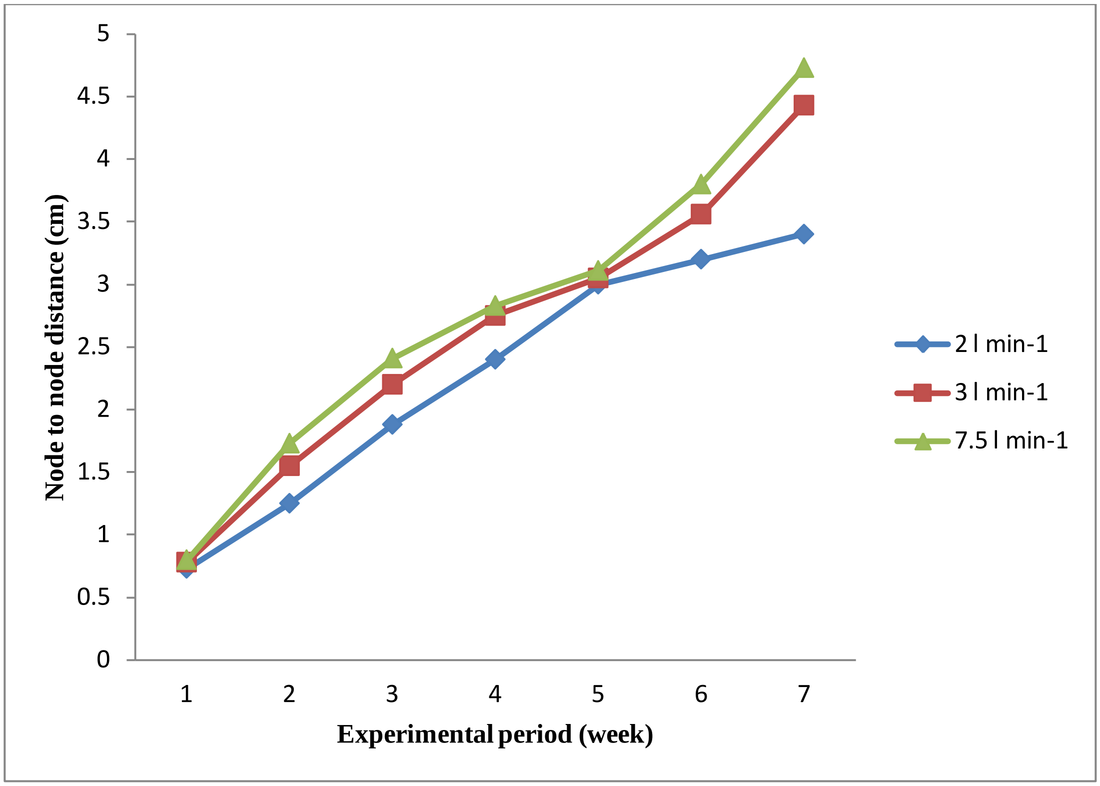

Fig. 4.4 Variation of node to node distance in different flow rates during seven week (first trial).

4.3.3 Number of leaves

The total number of matured leaves was counted. The observation on number of leaves was first taken one week after planting. After that, the observations were taken in a weekly interval. Plants in the flow rate of 7.5 l min^{-1}exhibited better performance. The least number of leaves were observed in the flow rate of 2 l min^{-1}.

Table 4.5Variation of number of leaves in different flow rates (first trial).

SL.NO	FLOW RATE ($l\ min^{-1}$)	DURATION	NUMBER OF LEAVES
1	2	FIRST WEEK	5
2		SECOND WEEK	7
3		THIRD WEEK	9
4		FOURTH WEEK	15
5		FIFTH WEEK	18
6		SIXTH WEEK	23
7		SEVENTH WEEK	28
8	3	FIRST WEEK	5
9		SECOND WEEK	7
10		THIRD WEEK	10
11		FOURTH WEEK	18
12		FIFTH WEEK	25
13		SIXTH WEEK	36
14		SEVENTH WEEK	45
15	7.5	FIRST WEEK	5
16		SECOND WEEK	7
17		THIRD WEEK	16
18		FOURTH WEEK	27
19		FIFTH WEEK	38
20		SIXTH WEEK	45
21		SEVENTH WEEK	59

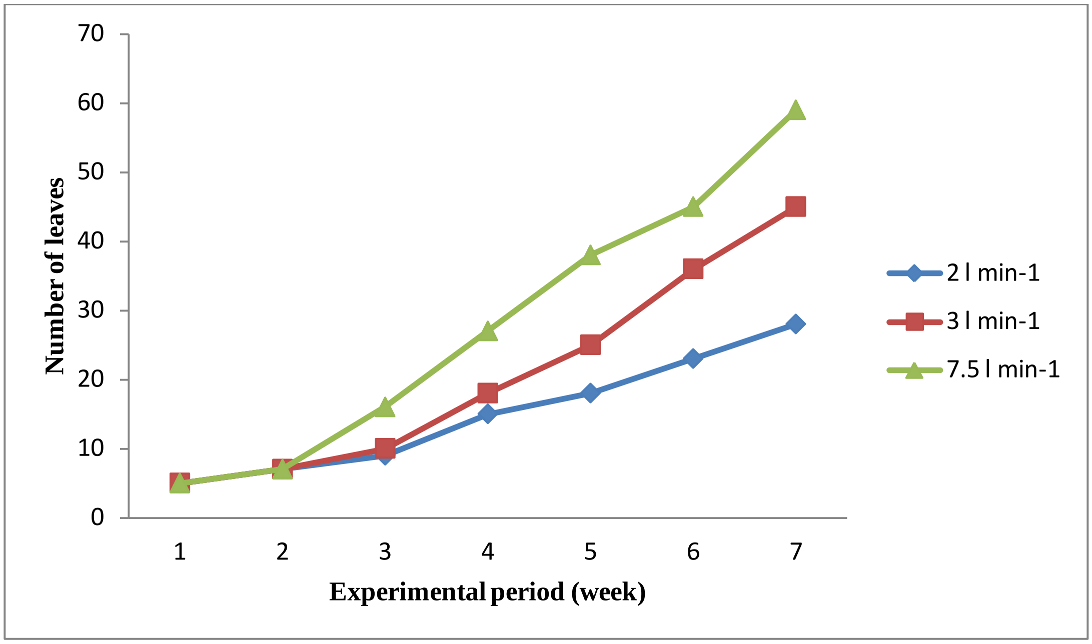

Fig. 4.5 Variation of number of leaves in different flow rates during seven week (first trial).

4.3.4 Root length

Measurements of root length were done before planting and after harvesting. Root length of all plants in different flow rates was measured and the longest root growth was seen in the flow rate of 7.5 l min^{-1}.

Table 4.6 Variation of root length in different flow rates during seven week (first trial).

SL.NO	FLOW RATE(l min^{-1})	BEFORE PLANTING(cm)	AFTER HARVEST(cm)
1	2	3.1	39
2	3	3.15	46
3	7.5	3.15	67

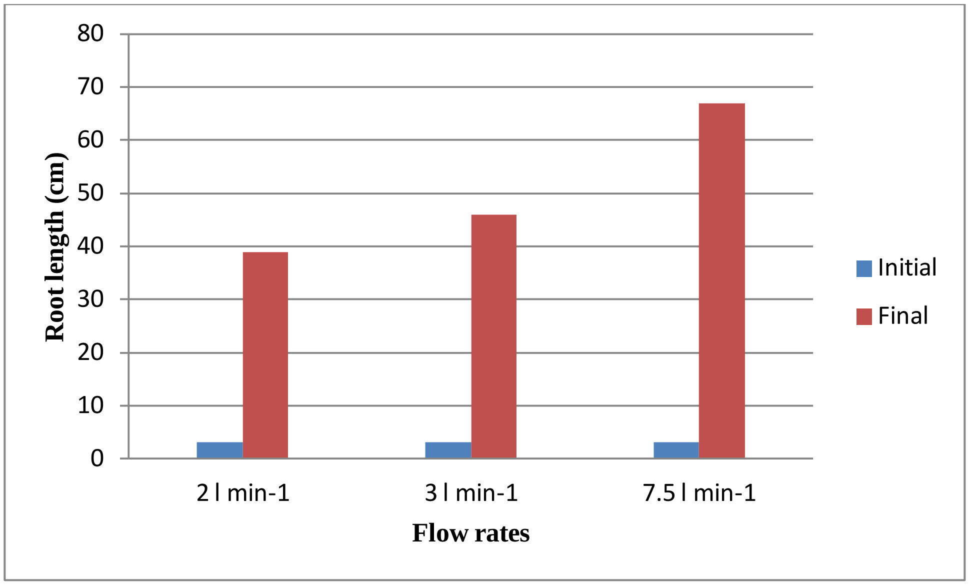

Fig. 4.6 Variation of root length in different flow rates during seven week (first trial).

4.3.5 Yield

The observation on yield for amaranthus was taken one month after planting. A comparison of yield between different rooting media was done. The highest yield was obtained from the flow rate of 7.5 l min^{-1}. The least yield was obtained from the flow rate of 2 l min^{-1}.

Table 4.7 Variation of yield from different flow rates during seven week (first trial).

SL NO.	FLOW RATE (l min^{-1})	YIELD (g plant^{-1})
1	2	36.03
2	3	40.56
3	7.5	53.2

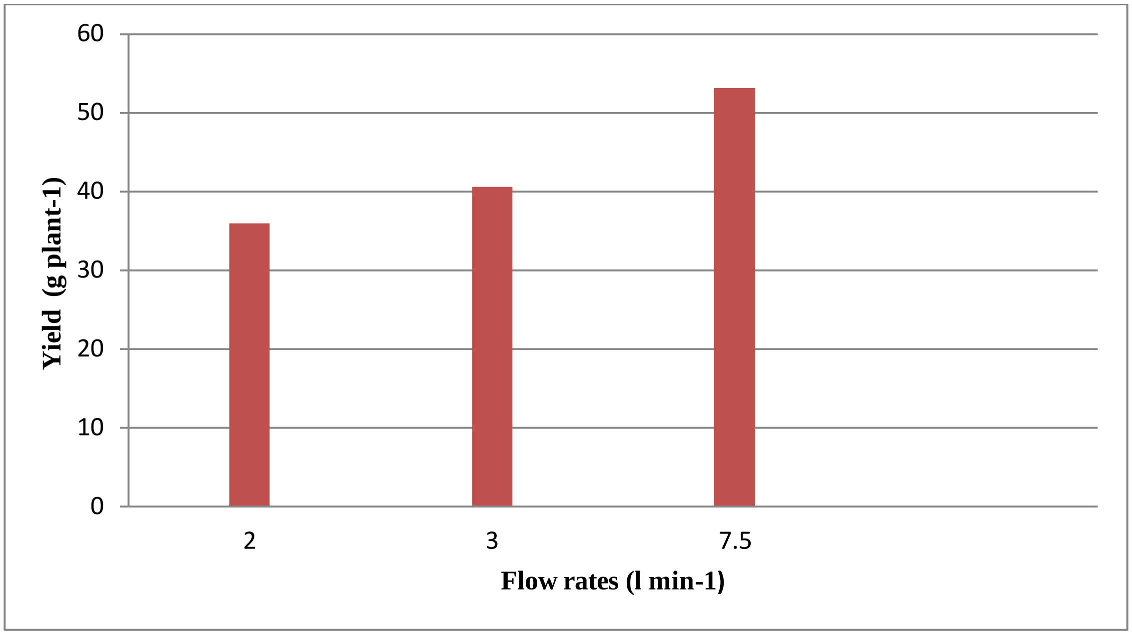

Fig. 4.7 Variation of yield from different flow rates during seven week (first trial).

4.3.6 Effect of flow rate on general crop parameters

Trying different flow rates of 2 l min^{-1}, 3 l min^{-1}, 7.5 l min^{-1}, the maximum yield, biometric parameters such as root length, number of leaves, inter nodal distance, plant height are higher in the flow rate of 7.5 l min^{-1}.

Hassan (2015), by conducting a study to which extent the content of nutrients in water farming is sufficient for growing tomato plants. The obtained results indicated that the nutrients consumption increased with increasing the flow rate. The root and shoot length increased with increasing effluent flow rate, when the effluent flow rate increased from 4.0 to 6.0 L h^{-1}, the length of root and shoot significantly increased from 50.33 to 55.33 and 149.33 to 191.33 cm, respectively, at the end of growing period. The fresh and dry mass of shoot significantly increased from 998.01 to 1372.10 and 83.71 to 275.09 g plant^{-1}, respectively, with increasing flow rate from 4.0 to 6.0 L h^{-1}.The fruit yield significantly increased from 1.06 to 1.37 kg plant^{-1} with increasing flow rate from 4.0 to 6.0 L h^{-1}

4.3.7 Water quality parameters

Water quality parameters such as Nitrate, Nitrite, Potassium, Phosphate are tested in CWRDM, Kozhikode.

Table 4.8 Variation of different water quality parameters (first trial).

SL NO	Parameters	Tap water	Sample 1	Sample 2
1	Nitrate-NO_3, mg l^{-1}	0.50	7.70	3.39
2	Nitrite-NO_2, mg l^{-1}	BDL	0.07	0.28
3	Potassium, mg l^{-1}	5.70	21.51	3.9
4	Phosphate-P, mg l^{-1}	0.07	0.16	0.15

Sample 1: Water at transplanting time

Sample 2: Water at harvesting time

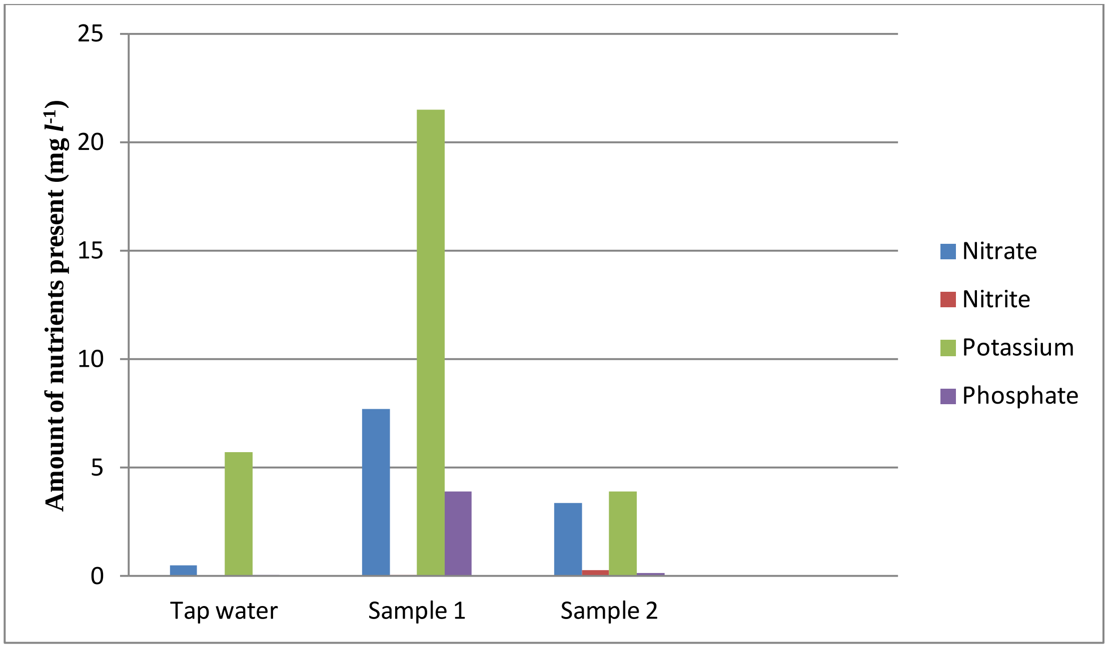

Fig. 4.8 Variation of different water quality parameters (first trial).

4.4 Variation of pH in second trial

Table 4.9 Variation of pH in second trial

SL.NO	DURATION	AQUAPONIC SOLUTION
1	First week	6.5
2	Second week	6.2
3	Third week	6
4	Fourth week	6
5	Fifth week	5.5
6	Sixth week	5.3
7	Seventh week	5.3

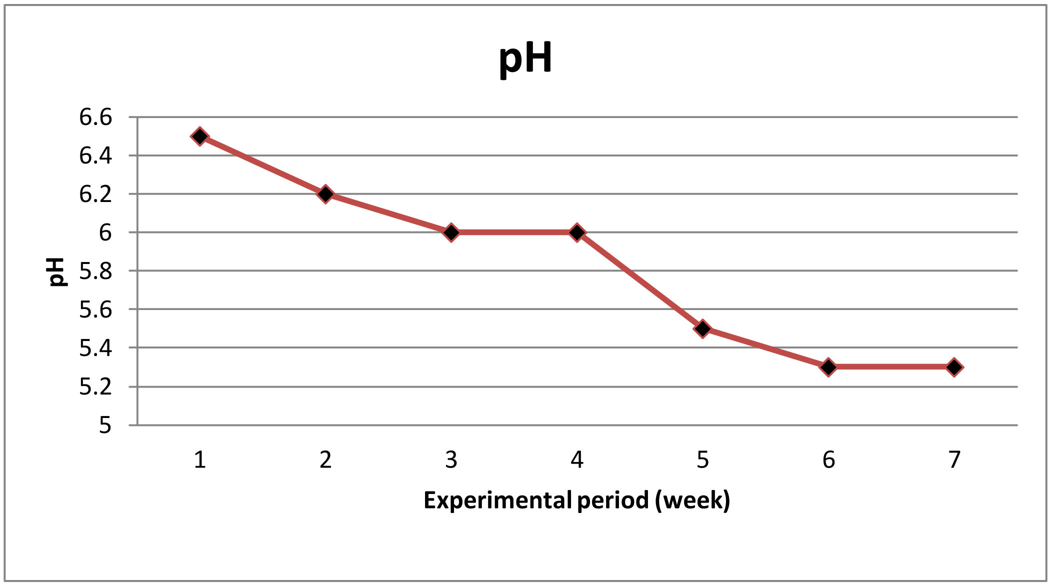

Fig. 4.9 Variation of pH in the aquaponic system during seventh week (second trial).

4.5 Variation of EC in second trial

Table 4.10 Variation of EC of aquaponic solution (second trial)

SL.NO	DURATION	EC VALUE(dS/m)
1	First week	1.3
2	Second week	1.5
3	Third week	1.8
4	Fourth week	1.8
5	Fifth week	1.7
6	Sixth week	1.9
7	Seventh week	1.9

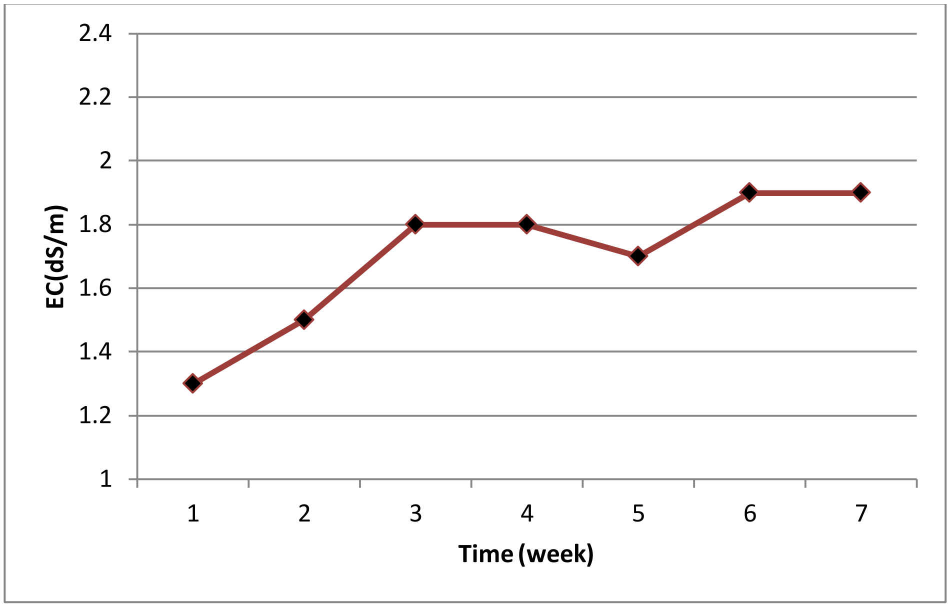

Fig 4.10 Variation of EC of aquaponic solution (second trial)

4.6 Biometric observations for second trial

CO1 variety of amaranthus was used for the second round of trial. Plant height, number of leaves, root length, intermodal distance was recorded at the same flow rate.

4.6.1 Plant height

Plant height is the distance measured from the tip of the plant to the top of the rooting media. These measurements were taken on weekly basis. The observation on plant height was first taken one week after planting. The best performance was shown by plants planted in the flow rate of 7.5 l min^{-1}. The least height recorded was for plants in the flow rate of 2 l min^{-1}.

Table 4.11 Variation of plant height in different flow rates during seventh week (second trial).

SL.NO	FLOW RATE ($l\ min^{-1}$)	DURATION	PLANT HEIGHT(cm)
1	2	FIRST WEEK	5.33
2		SECOND WEEK	12.67
3		THIRD WEEK	23.45
4		FOURTH WEEK	29.61
5		FIFTH WEEK	38.27
6		SIXTH WEEK	46.38
7		SEVENTH WEEK	55.84
8	3	FIRST WEEK	5.5
9		SECOND WEEK	12.85
10		THIRD WEEK	28.91
11		FOURTH WEEK	40.09
12		FIFTH WEEK	51.37
13		SIXTH WEEK	57.98
14		SEVENTH WEEK	69.33
15	7.5	FIRST WEEK	5.61
16		SECOND WEEK	13.23
17		THIRD WEEK	37.86
18		FOURTH WEEK	46.56
19		FIFTH WEEK	59.16
20		SIXTH WEEK	68.91
21		SEVENTH WEEK	78.83

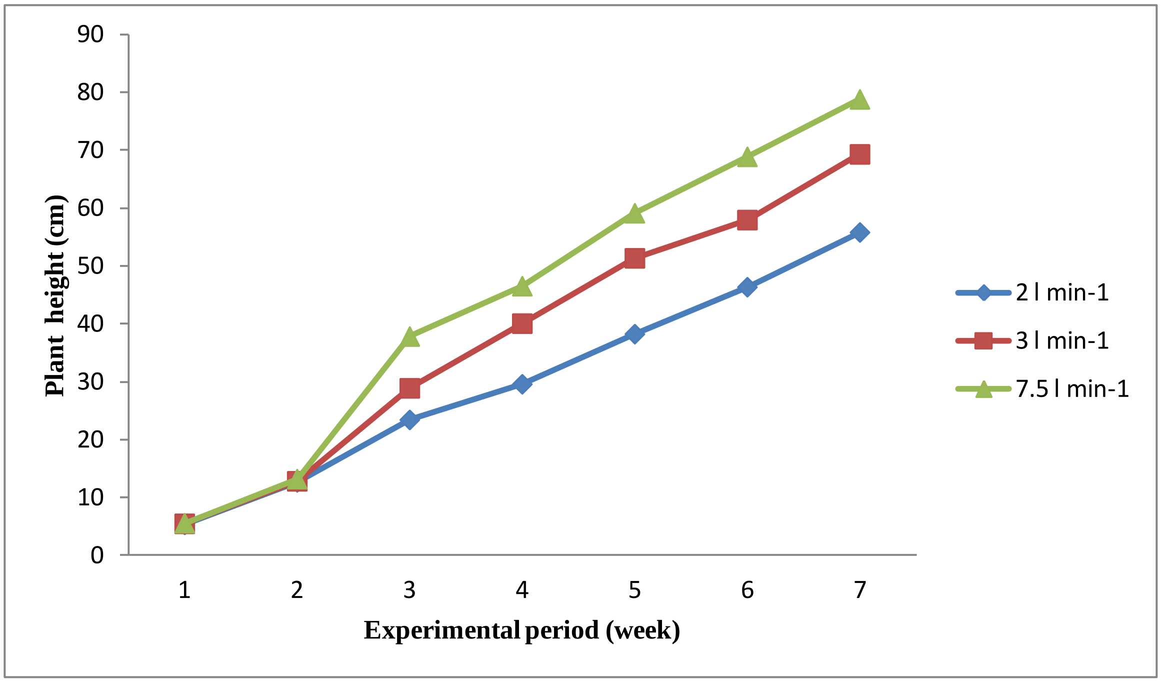

Fig. 4.11 Variation of plant height in different flow rates during seventh week (second trial).

4.6.2 Node to node distance

The distance between consecutive nodes was measured one week after planting. After that, the observations were taken in a weekly interval. Maximum internodal distance was observed with the flow rate of 7.5 l min^{-1}. The least intermodal distance is observed in the flow rate of 2 l min^{-1}.

Table 4.12 Variation of node to node distance in different flow rates (second trial).

SL.NO	FLOW RATE ($l\ min^{-1}$)	DURATION	NODE TO NODE DISTANCE (cm)
1	2	FIRST WEEK	0.43
2		SECOND WEEK	0.83
3		THIRD WEEK	1.3
4		FOURTH WEEK	1.56
5		FIFTH WEEK	1.61
6		SIXTH WEEK	1.9
7		SEVENTH WEEK	2.21
8	3	FIRST WEEK	0.58
9		SECOND WEEK	1.02
10		THIRD WEEK	1.41
11		FOURTH WEEK	1.67
12		FIFTH WEEK	1.98
13		SIXTH WEEK	2.29
14		SEVENTH WEEK	2.58
15	7.5	FIRST WEEK	0.64
16		SECOND WEEK	1.16
17		THIRD WEEK	1.68
18		FOURTH WEEK	1.9
19		FIFTH WEEK	2.1
20		SIXTH WEEK	2.48
21		SEVENTH WEEK	2.83

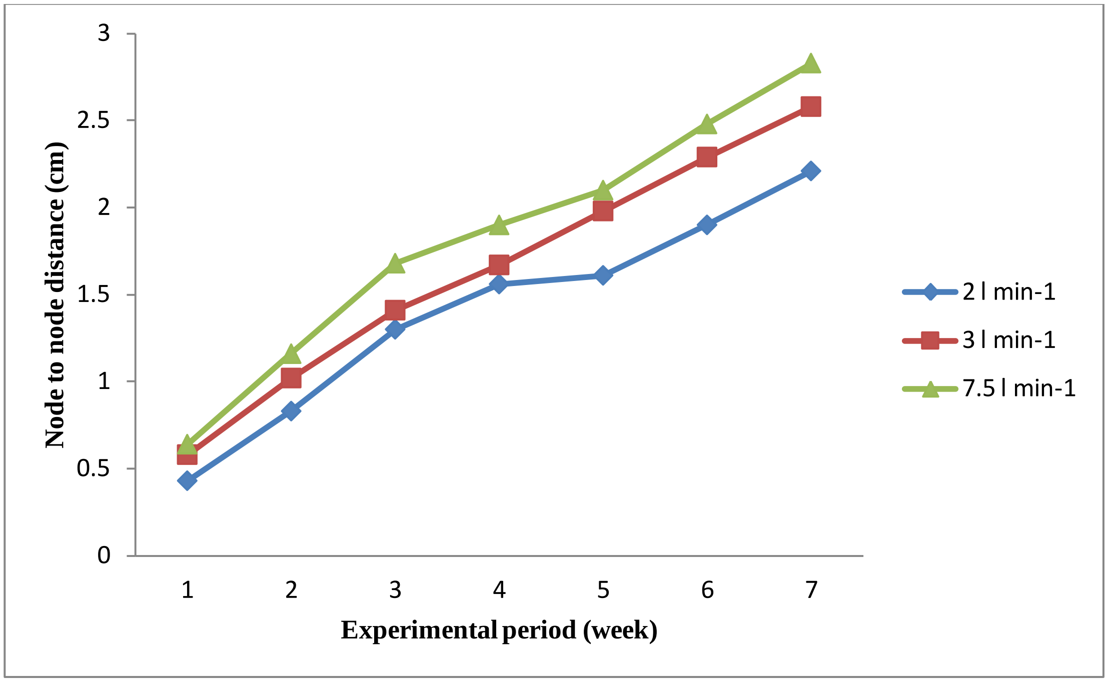

Fig. 4.12 Variation of node to node distance in different flow rates during seventh week (second trial).

4.6.3 Number of leaves

The total number of matured leaves was counted. The observation on number of leaves was first taken one week after planting. After that, the observations were taken in a weekly interval. Plants in the flow rate of 7.5 l min^{-1} exhibited better performance. The least number of leaves were observed in the flow rate of 2 l min^{-1}.

Table 4.13 Variation of number of leaves in different flow rates (second trial).

SL.NO	FLOW RATE ($l\ min^{-1}$)	DURATION	NUMBER OF LEAVES
1	2	FIRST WEEK	4
2		SECOND WEEK	6
3		THIRD WEEK	10
4		FOURTH WEEK	15
5		FIFTH WEEK	23
6		SIXTH WEEK	27
7		SEVENTH WEEK	30
8	3	FIRST WEEK	6
9		SECOND WEEK	7
10		THIRD WEEK	12
11		FOURTH WEEK	19
12		FIFTH WEEK	30
13		SIXTH WEEK	38
14		SEVENTH WEEK	49
15	7.5	FIRST WEEK	5
16		SECOND WEEK	7
17		THIRD WEEK	20
18		FOURTH WEEK	24
19		FIFTH WEEK	39
20		SIXTH WEEK	57
21		SEVENTH WEEK	68

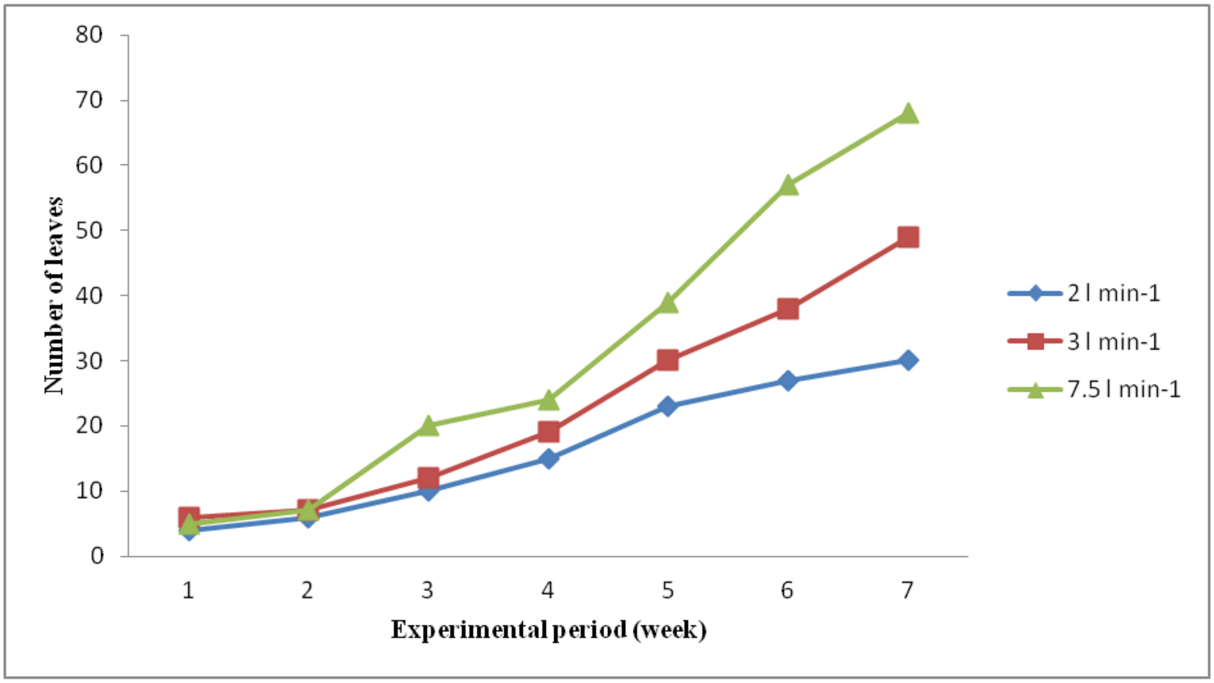

Fig. 4.13 Variation of number of leaves in different flow rates (second trial).

4.6.4 Root length

Measurements of root length were done before planting and after harvesting. Root length of all plants in different flow rates was measured and the longest root growth was seen in the flow rate of 7.5 l min^{-1}.

Table 4.14 Variation of root length in different flow rates during seventh week (second trial).

SL.NO	FLOW RATE ($l\ min^{-1}$)	BEFORE PLANTING(cm)	AFTER HARVEST(cm)
1	2	2.6	14
2	3	2.9	17.8
3	7.5	3.03	22

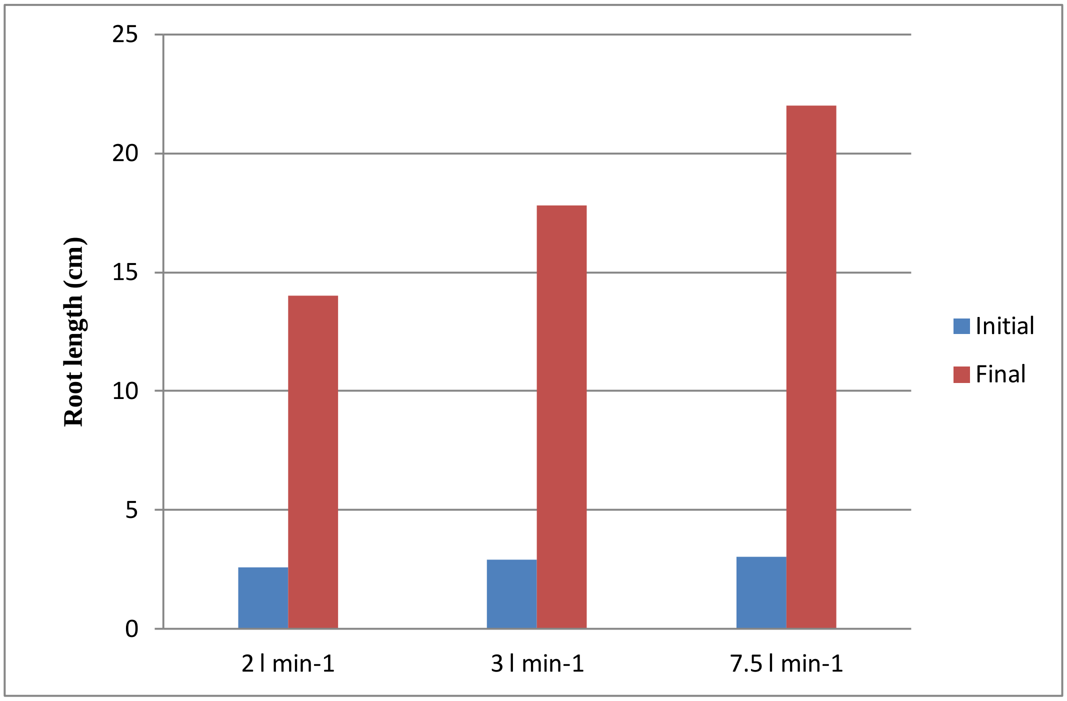

Fig 4.14 Variation of root length in different flow rates during seventh week (second trial).

4.6.5 Yield

The observation on yield for amaranthus was taken one month after planting. A comparison of yield between different rooting media was done. The highest yield was obtained from the flow rate of 7.5 l min^{-1}. The least yield was obtained from the flow rate of 2 l min^{-1}.

Table 4.15 Variation of yield from different flow rates during seven week (second trial).

SL NO.	FLOW RATE(l min^{-1})	YIELD (g plant^{-1})
1	2	30.03
2	3	36.2
3	7.5	43.34

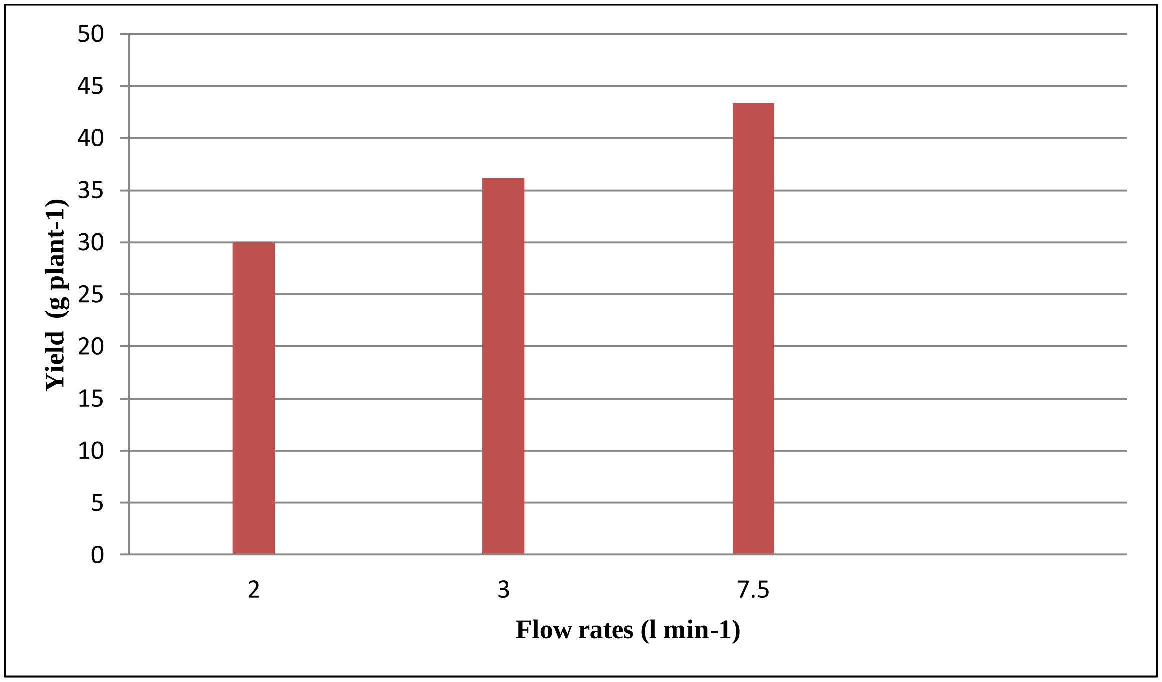

Fig 4.15 Variation of yield from different flow rates during seventh week in second trial.

4.6.6 Water quality parameters

Water quality parameters such as Nitrate, Nitrite, Potassium, Phosphate are tested in CWRDM, Kozhikode.

Table 4.16 Variation of different water quality parameters in second trial.

SL NO	Parameters	Tap water	Sample 1	Sample 2
1	Nitrate-NO_3, mg l^{-1}	0.50	9.04	4.36
2	Nitrite-NO_2, mg l^{-1}	BDL	0.07	0.44
3	Potassium, mg l^{-1}	5.70	32.82	5.15
4	Phosphate-P, mg l^{-1}	0.07	0.23	0.18

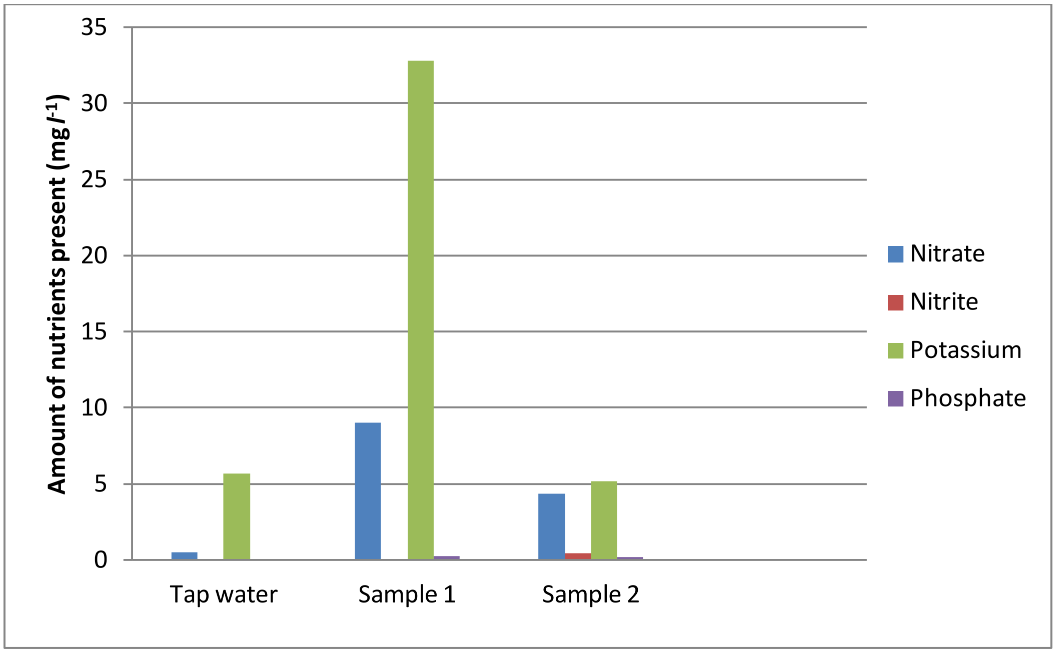

Fig 4.16 Variation of different water quality parameters in second trial.

CHAPTER V

SUMMARY AND CONCLUSION

The present experiment was conducted to study the utilization of fish effluent in cultivation using aquaponics and to compare the performance evaluation of crops grown in different flow rates.

The first trial of experiment was conducted at one of the veranda of PFDC facing north and the second trial of the experiment was conducted at the courtyard of the PFDC.

A structure was fabricated with dimension 1.75×0.75×1.15 m. The PVC pipes with plants were supported on the structure. Water from tank circulated through pipes. Fishes (tilapia) were grown in the tank.

Amaranthus (CO1) was used for both trials. Plants were planted in gravel medium. The flow rate of the system was maintained at 2 l min^{-1}, 3 l min^{-1} and 7.5 l min^{-1}. The pH of the system was always maintained between 5 and 8. The EC was maintained in the range 0.5 to 2 dS/m. The pH and EC was measured on weekly basis. Biometric observations like plant height, number of leaves, internodal distance was measured on a weekly basis. Other biometric parameters including root length was measured at the starting and ending of the experiment. The yield of the experiment was taken at the end of each experiment. All observations were recorded and analyzed. pH and EC was monitored regularly and was maintained in the optimum range.

The results analyzed from both the trials revealed that the flow rate of 7.5 l min^{-1} was best suited for the plants grown in the aquaponic system. The lowest yield obtained was for the flow rate of 2 l min^{-1}.

The maximum height, number of leaves, root length and the internodal distance and yield was measured. The maximum height, number of leaves, root length, yield and the internodal distance was obtained for plants with a flow rate of 7.5 l min^{-1}. The least values were obtained for the flow rate of 2 l min^{-1}.

The project demonstrated the ability of aquaponic system to produce amaranthus using Tilapia as the nutrient source. Aquaponic system produces two saleable products. Even though large scale commercial production in India is less at present, it is possible that this technique can be widely used due to its energy efficiency and high water use efficiency.

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UTILIZATION OF EFFLUENT FISH FARMS IN CULTIVATION USING AQUAPONICS

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ABSTRACT

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Bachelor of Technology
In
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ABSTRACT

The most prevailing issues of the modern world are food and water crises. Due to scarcity of water and land, it is not possible to consume the pesticide affected food nor grow plants individually. Under such conditions, there arises a need for portable agricultural system which uses less water, space and is purely organic. One such solution is a small scale aquaponic system. Aquaponics is the integration of aquaculture and hydroponics. Aquaculture is the cultivation of aquatic animals or plants for food and hydroponics is the process of growing plants without soil. In this system,the fish consume food and excrete waste primarily in the form of ammonia. Bacteria convert ammonia to nitrite and then to nitrate. The aquaponic system produces two food sources for consumption, the crops grown in the bed and fish reared in the tank. This system has the potential to increase the stability of families by helping them become financially secure. It provides a simple and practical solution to the food security issues. It uses resources efficiently and creates little waste.

A structure of dimension 1.75×0.75×1.15 m was fabricated. The PVC pipes with plants are supported on the structure. Aquaponic system consists of a fish tank with a volume of 500 l in which the fish is reared. The fish used in this experiment was Tilapia. The sewage of the tank consists of fish waste. The ammonia excreted by the fish is being continuously removed by the bacteria present in water. Nitromonas bacteria present in water oxidize ammonia to nitrite and nitrobacter converts the nitrite to nitrate.Nitrate is the form in which nitrogen is absorbed by the plants.The water is pumped from the tank to the different pipes, plants absorb the nutrients and then water is returned back to the tank.Different flow rates of 2 l min^{-1},3 l $\text{min}^{-1}$and 7.5 l min^{-1} were set by adjusting the control valves.The medium used was gravel. The plants were planted in gravel media and different flow rates were maintained. The seedlings of amaranthus, CO1 variety were used for planting.

The parameters which affect the bacterial growth are pH and EC. The EC value should range from 0.1 and 0.4 dS/m. The pH varies from 5 to 8. EC and pH were measured in weekly basis using pH meter and EC meter. The biometric parameters like plant height, node to node distance, root length, number of leaves, yield are measured. The water quality parameters like nitrate, nitrite, phosphate, potassium are measured in CWRDM, Kozhikode.

The result obtained from the experiment was that the biometric parameters such as plant height, node to node distance, root length, number of leaves and yield are higher in the plants grown under a flow rate of 7.5 l min^{-1}. The least performance was observed in the plants under a flow rate of 2 l min^{-1}. The water sample from aquaponic system was also tested.