COMPARATIVE EVALUTION OF SIMPLIFIED HYDROPONIC TECHNIQUES FOR VEGETABLE CULTIVATION

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PROJECT REPORT

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DEPARTMENT OF IRRIGATION AND DRAINAGE ENGINEERING
KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING & TECHNOLOGY

Tavanur, malappuram - 679573 ,
Kerala , India

2017

DECLARATION

We hereby declare that this project report entitled " Comparative Evalution of Simplified Hydroponic Techniques for Vegetable Cultivation" is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

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CERTIFICATE

Certified that this project work entitled " Comparative Evaluation of Simplified Hydroponics Techniques for Vegetable Cultivation" is a record of project work done jointly by Mr. Ajay jayakumar, Ms. Binsha K T, Ms. Jesna d silva under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

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DEDICATED TO BELOVED PARENTS AND TEACHERS

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SYMBOLS AND ABBREVIATIONS

SYMBOL	ABBREVATIONS
AC	Alternating current
B	Boron
Ca	Calcium
Cd	Cadmium
Cl	Chlorine
Cm	Centimeter
Cu	Copper
Dept.	Department
Dr.	Doctor
DS	Drip system
ds/m	Desi-siemen per meter
EC	Electrical conductivity
EFS	Ebb and flow system
e.g.	Example
et al.	And others
Exp	experiment
Fe	iron
Fig.	Figure
FS	Floating system
G	Gram
j	Journal
h	Hour
i.e.	that is
K	Pottasium
KAU	Kerala Agricultural University
KCAET	Kelappaji college of agricultural engineering and technology

Kg	kilogram
Kg/ha.mm	Kilogram per hectare millimeter
l	Litre
l/min	Litre per minute
m	Metre
meq/l	Milli equivalent per litre
Mg	Magnesium
Mg/l	Milligrams per litre
ml	Millilitre
mm	Millimetre
Mn	Manganeese
Mo	Molybdeum
N	Nitrogen
ND	Not determined
NFT	Nutrient film technique
P	Phosphorous
ppm	Parts per million
PVC	Poly venyl chloride
Rs	Rupees
S	Sulphur
Si	Silicon
V	Voltage
Viz	Namely
W	Watt
Zn	Zinc
%	Percentage
°	Degree
°C	Degree celcius
&	And
Ø	Diameter

CHAPTER 1

INTRODUCTION

In conventional agricultural practices, the commonly used propagation medium is soil. It is an important factor in the production of crops . But in recent years many soil problems have come into existence. Presence of disease causing organisms and nematodes, unsuitable soil compaction, poor drainage, degradation due to erosion etc.And some of Soil fertility decline and development of salinity have been a matter of concern. In addition, conventional crop growing in soil is somewhat difficult as it involves large space, lot of labour and large volumes of water. Moreover, in metropolitan areas, soil is not available for crop growing at all, or in some areas , it may be scarcity of fertile cultivable arable lands due to their unfavorable geographical or topographical conditions. Under such circumstances, soil-less culture like hydroponics and aeroponics techniques can be introduced successfully. Limited spaces, lack of cultivable land and apartment living have led the people to transform their balconies to home gardens. Hydroponics and Aeroponics gardening can improve air quality, improve water use efficiency by reuse and recycling of water and minimum energy consumption.

Historical records reveal that world had done experiment with plants cultivated in soil free mixtures of sand and gravel much earlier, The hanging gardens of Babylon and the floating gardens of the Mexican Aztecs are both early examples of early hydroponic gardening. It is also found that Egyptian hieroglyphics depicting the cultivation of plants in water can be dated as far back as several thousands years, BC!. This is a new forms of a gardening experience . This technique of gardening began to be noticed due to experimentation of Dr.W.E Gericke of University of California. He is the “father of Hydroponics” The term hydroponics was derived from the greek words ‘hydro’ meaning water and ‘ponos’ meaning labour. “working with water”- a method of cultivation, in which plants are provided with nutrients required for growth by a “nutrient solution”, which is simply water that’s has been enriched with dissolved essential elements, without soil. This system helps to face the challenges of climate change and also helps in production system management for efficient utilization of natural resources.

In a Hydroponics garden, this nutrient solution can be circulated around the roots by either the passive force of gravity, or by the active force of an electro-mechanical pump. Some systems bathe the roots in nutrient solution and use an air pump to oxygenate the solution from below,This helps to prevent stagnation and provides roots with much needed oxygen. It is basically growing plants & vegetables without using traditional soil. Hi-tech horticulture and protected cultivation with soil less media and simplified hydroponics are gaining momentum in present day horticultural scenario.

Plants grown Hydroponically are generally healthier than their soil-grown counter parts. They receive a near-perfectly balanced diet, and rarely come in contact with soil borne pests and diseases. Super-efficient hydroponic systems conserve water and nutrients by preventing evaporation and runoff. Arid regions where water is scarce can now grow crops using hydroponics. Since Hydroponics systems deliver water and nutrients directly to the plants, crops can be grown closer together without starving each other, and healthier plants also contribute to higher yields. By growing crops in a clean environment, under ideal conditions, hydroponics saves the cost of soil preparation, insecticides, fungicides and losses due to drought and ground flooding. When grown outdoors in soil, plants expend a tremendous amount of energy developing a large root system to search for moisture and nutrients. When grown Hydroponically, their roots are directly bathed or sprayed with nutrients dissolved in water. Since they no longer need to search for food, most of their energy can be redirected to the production of foliage, flowers, fruits and vegetables.

Hydroponics farms can be made on small land banks producing high yield. It is clear from the above facts that Hydroponics can bring a 2nd Green Revolution in india. Keeping pace with the scaling food demands, urban food supplies need to be tripled. Hydroponics can be one of the possible solutions to increase the agricultural production.

In Hydroponics, two aspects of nutrition needs to be considered: the supply of nutrients from the delivery system and the plant nutrient response. For most common plants, critical levels for most nutrients have been determined. The frequency and volume of the nutrient solution applied depends on the type of substrate used (volume and physio-chemical characteristics), the crop (species and stage of development), the size of the container, the crop and irrigation systems used and the prevailing climatic conditions. Plant should be fed daily. The correct time to administer the nutrient solution is betweeen 6.00 and 8.00 am, though water requirements will vary considerably throughout the day, and from one day to another.

The cool thing about hydroponics is that there are many different types available. Some of the best hydroponic systems on the market combine different types of hydroponics into one Hydroponics is unique in that there are multiple techniques you can use to get the nutrient solution to your plants.

AEROPONICS

Carter in 1942 first researched on air culture growing and described a method of growing plants in water vapor to facilitate examination of roots.It was Went in 1957 who first coined the air-growing process as “Aeroponics” growing coffee plants and tomatoes with air-suspended roots and applying a nutrient mist to the root selection. Aeroponic is a form of hydroponic technique. The word Aeroponic is derived from the Latin word “aero” (air) and “ponic” (work). Aeroponic growth refers to growth achieved in an air culture. Such conditions occur in nature.

While the concept of the aeroponic system is quite simple, it's actually the most technical of all 6 types of hydroponic systems. However it's still fairly easy to build your own basic aeroponic system, and a lot of home growers like growing in them as well, and even get really good results using this type of hydroponic system.

Aeroponics is an improvement in artificial life support for non-damaging plant support, seed germination, environmental control, and drip irrigation techniques that have been used for decades by traditional agriculturalists. Excellent aeration is the main advantage of Aeroponics. These techniques have been given special attention from NASA; since a mist is easier to handle than a liquid in a zero gravity environment.

Aeroponics is defined by NASA as a system where roots are continuously or discontinuously in an environment saturated with fine drops (a mist or aerosol) of nutrient solution. The method requires no substrate and entails growing plants with their roots periodically wetted with a fine mist of automatized nutrients. The first commercially available aeroponic apparatus was manufactured and marketed by GTi in 1983. It was known then as the "Genesis Machine". The Genesis machine was marketed as "Genesis rooting system". At the time, the achievement was revolutionary of terns of a developing (artificial air culture) technology. The Genesis simply connected to a water faucet and an electrical outlet.

Plant roots are suspended mid-air inside a chamber kept at a 100% humidity level and fed with a fine spray of nutrient solution. This mid-air feeding allows the roots to absorb much needed oxygen, thereby increasing metabolism and rate of growth reportedly up to 10 times of that in soil. And there is nearly no water loss due to evaporation. Laboratory research on air culture growing utilizing vapors began in the mid 1940s. Today aeroponics is used in agriculture around the globe. Aeroponic culture differs from both hydroponics and in vitro (plant tissue culture) growing. Unlike hydroponics, which uses water as a growing medium and essential mineral to sustain plant growth, aeroponics is conducted without growing medium.

Aeroponics is conducted in air combined with micro-drop of water, almost any plant can grow to maturity in air with a plentiful supply of oxygen, water and nutrients. Some growers favor aeroponic systems over other methods of hydroponics because the increased of nutrient solution delivers more oxygen to plant roots, stimulating growth and helping to prevent formation. Clean air supplies oxygen which is an excellent purifier for plants and the aeroponic environment. For natural growth to occur, the plant must have unrestricted access to air. Plants must be allowed to grow in a natural manner for successful physiological development. The more confining the plant support becomes, the greater incidence of increasing disease pressure of the plant and the aeroponic system.

Aeroponic equipment involves the use of sprayers, misters, foggers, or other devices to create a fine mist of solution to deliver nutrients to plant roots. Aeroponic systems are normally closed-looped systems providing macro and micro-environments suitable to sustain a reliable, constant air culture. Numerous inventions have been developed to facilitate aeroponic spraying and misting. The key to root development in an aeroponic environment is the size of the water droplet. In commercial applications, a hydro-atomizing spray at 360° is employed to cover large areas of roots utilizing air pressure misting.A variation of the mist technique employs the use Ultrasonic foggers of to mist nutrient solutions in low-pressure aeroponic devices. Water droplet size is crucial for sustaining aeroponic growth. Too large a water droplet means less oxygen is available to the root system. Too fine a water droplet, such as those generated by the ultrasonic mister, produce excessive root hair without developing a lateral root system for sustained growth in an aeroponic system. Mineralization of the ultrasonic requires maintenance and potential for component failure. This is also a shortcoming of metal spray jets and misters. Restricted access to the water causes the plant to lose turgidity and wilt.

There are sixteen elements needed for plant growth. Plants extract several of these elements, such as oxygen, carbon, and hydrogen, from water and air. The rest of the elements must be supplied through the nutrient solution. The primary macronutrients are nitrogen (N), phosphorus (P), and potassium (K). The secondary macronutrients are calcium (Ca), magnesium (Mg), and sulphur (S). These distinctions are made based on how much of each nutrient plants need. Micronutrients, or trace elements, such as iron (Fe), manganese (Mn), boron (B), molybdenum (Mo), zinc (Zn), copper (Cu), and chlorine (Cl) are used in very small amounts by plants, hence the name micronutrients. Micronutrients are sometimes present as impurities in the water and in the solid substrate.

Nitrogen is central to the development of new leaves and stems as well as to overall growth and performance. An overabundance of nitrogen causes soft, weak growth and possible delay of fruit and flower production. Symptoms of nitrogen deficiency are yellowing leaves and weak, spindly growth.

Phosphorus is used by the plant in photosynthesis and in the production of flowers and seeds. It also encourages strong root growth. When phosphorus levels are low, the older leaves begin to turn deep green and develop brown or purple discoloration. Other symptoms may be stunted growth and chlorosis, or yellowing, of the lower leaves.

Potassium is necessary during all stages of growth, particularly during fruit development. It is involved in the manufacture of sugars, starch and chlorophyll. Potassium helps the plant make good use of air and water by regulating stomata openings in the leaves and also helps build strong roots. Deficiency symptoms are mottling and yellowing of older leaves, generally along the margins, and flower and fruit drop.

Calcium is used by the plant in the manufacture and growth of cells. It also acts as a buffer for excess nutrients in soil. Calcium deficiency is recognizable by the curling and stunting of young leaves and dieback of the shoot tip. Too much calcium can stunt the growth of a young plant.

Magnesium is fundamental in the absorption of light energy and is central to the structure of the chlorophyll molecule. Symptoms of magnesium deficiency include curled leaf margins, yellowing of older leaves (veins remain green), and, eventually, bright green coloration of the growing tips.

Advantages are excellent aeration is the main advantage of Aeroponics. These techniques have been given special attention from NASA; since a mist is easier to handle than a liquid in a zero gravity environment.

Hydroponics was method of growing plants using mineral nutrients solutions instead of soil. Aeroponic was a form of hydroponics technique. Hydroponics and aeroponics plays very important role for the commercial food production. Hydroponics grown plants will get perfectly balanced diet.

OBJECTIVES

- Design and development of simple hydroponic systems for vegetable cultivation.
- Evaluation of systems for plant growth and yield parameters.
- Comparison of growth performance of plant in aeroponic systems with different operating conditions.
- Comparison of growth performance of plant in aeroponic and deep water culture systems.

CHAPTER 2

REVIEW OF LITERATURE

There are lots of experiments and studies still going on to develop sophisticated as well as simplified techniques for home made hydroponics and aeroponic systems. Some of the relevant studies are reviewed in this chapter under the following sub headings

2.1. NON CIRCULATING / FLOATING HYDROPONIC SYSTEMS

Weitang *et al.* (2004) carried out a study on tomato fusarium wilt and its chemical control strategies in a hydroponic system. Tomato (*Lycopersicon esculentum* Mill.) was cultivated in a hydroponic system with unlimited growth cultivation mode by using a deep flow technique. The identified wilt pathogen Fusarium oxysporum Klotz was used to infect the plants. Seven fungicides, prochloraz, carbendazim, thiram, toclofos-methyl, hymexazol, azoxystrobin and carboxin, were tested in vitro for their inhibitory activities against the pathogen by mycelial growth inhibition with median effective concentration (EC50) values of 0.019, 0.235, 26.292, 53.606, 69.961, 144.58 and 154.03 µg/ml separately. Prochloraz and carbendazim were the most effective fungicides in inhibiting mycelial growth. The preventive effect was 69.6% after 0.4 µg/ml prochloraz was added to the liquid media for 2 weeks with a curative effect of 50.0%. The preventive effect was 87.0% after 5 µg/ml carbendazim was added to the liquid media for 2 weeks with a curative effective of 34.4%. It was observed that tomato wilt disease could be well controlled by low toxicity and systemic fungicides added in a hydroponic system at their appropriate concentration.

Kratky *et al.* (2005) reported that Low density, plant-holding trays conveniently float on nutrient solution in hydroponic systems, but they do not provide an air space to the plant root zone. A study was conducted to determine the effect of air space between the tank cover and the nutrient solution on production of lettuce using three non-aerated hydroponic methods that were non-circulated also. 'Red Sails' leaf lettuce (*Lactuca sativa* L.) was grown in

5-cm net pots supported by expanded polystyrene bead board tank covers where the board was supported by the tank frame and remained fixed. The board floated on the nutrient solution initially and sank to a 5-cm depth when the solution was depleted. Tanks were 8.9-cm high and contained 7.6 cm of non-circulating nutrient solution. No additional nutrient solution was added. Lettuce was harvested when only 1.3 cm of nutrient solution remained in the tank. Average fresh head weight of lettuce was maximum (220 g) during a period of one year with seven crops, when the board remained fixed.. Lettuce production was 19% lower compared to this when the boards were floated on the nutrient solution. When the boards were initially floated on the nutrient solution and then rested on a 5-cm high support during the latter stage of growth, reduction in fresh head weights observed was only 7% compared to fixed board. They arrived at a conclusion that, an air space with high relative humidity, between the nutrient solution and the expanded polystyrene bead board tank cover, encouraged the growth rate of lettuce.

Aslam *et al.* (2016) conducted the study on development of different Hydroponics techniques for terrace cultivation of vegetable crops. They used three systems for the cultivation of Amaranthus crop , such as floating system , drip system and ebb and flow system. Out of these floating system showed the better performance and good crop yield. It was observed that morphological parameters like plant girth , height, number of leaves and node to node distance showed better performance in floating system compared to the other two systems.

2.2 NUTRIENT FILM TECHNIQUE

Trotman *et al.* (1993) conducted a study on hydroponics system for growing peanuts in green house to determine the effect hydroponic growing system of pod and foliage yield. Experiments were conducted with plant nutrients supplied in a modified Evan's solution using nutrient film technique. The findings indicated that use of screens was feasible which will not retard pod development.

2.3 COMPARISON BETWEEN HYDROPONIC AND AEROPONIC TECHNIQUES

Ritter *et al.* (2001) carried out a study to compare hydroponic and aeroponic cultivation system for the production of potato mini-tubers in greenhouse beds. Plants in the aeroponic system showed increased vegetative growth, delayed tuber formation and an extended vegetative cycle of about seven months after transplanting. Therefore in 1999, two production cycles were obtained with the hydroponic system, but only one with the aeroponic system. However, the tuber yield per plant was almost 70% higher in the aeroponic system compared to hydroponic system. Number of tubers were also 2.5 fold more in the aeroponic system. Total production was reduced by 33% in the aeroponic system.

Frederic F Souret *et al.* (2008) conducted a study on development of saffron (*Crocus sativus* L.) plants and the production of commercial saffron and saffron constituents were compared in three culture systems: aeroponics, hydroponics, and soil. On a dry weight, but not fresh weight basis, corm growth was increased in aeroponics and hydroponics, compared with growth in soil. Root length in aeroponics and hydroponics was reduced as compared with root length in soil, but shoot development was not significantly affected. Flowering was poor in all three culture systems, probably due to the small-sized (2.6 cm) bulbs used in propagating the plants. The production of stigmas and the concentration of the main constituents of saffron in the stigmas was similar in all three culture systems, suggesting saffron bulbs grown aeroponically and hydroponically may be used as a practical and renewable source of pharmacological compounds extracted from saffron.

2.4 AEROPONICS

Neil Reese *et al.* (2005) has conducted an experiment in which genetically modified corn has been grown in an aeroponics system. The technology allows for completed containment of allow effluents and by-products of biopharma crops to remain inside a closed-loop facility. According to Reese it was a historical feat to grow corn in an aeroponic apparatus for bio massing. Reese harvested full ears of corn, while containing the corn pollen and spent effluent water and preventing them from entering the environment. Containment of these by-products ensures the environment remains safe from GMO contamination.

Chiipanthenga *et al.* (2012) worked to find out the potential of aeroponic technique in the production of quality potato seed. The production of potato seed under conventional system has not been effective in avoiding or reducing the build up of pathogens and has consequently led to reduced quality potato seed and low crop yields. Plants once cleaned through meristem culture and induction of tuberization under aeroponics system, produced high quality potato seed tubers rapidly that are free from contamination of pathogens. They reported that quality mini-tubers could be produced from potato cultivated under aeroponics system, in a short time using tissue culture.

Jia Qi *et al.* (2012) developed an aeroponic system in which a microcontroller was used to control spraying system. The microcontroller automatically started and stopped spraying according to humidity and moisture level inside the system. The system detected humidity level by using an analogue capacitive humidity sensor placed inside the aeroponic chamber.

Heinrich Lieth *et al.* (2015) conducted a study to evaluate different concentrations of the nutrient solution applied during the day (D) and night (N) to aeroponically grown lettuce *(Lactuca sativa* L.) with assessing the effect on growth, leaf photosynthesis, and nitrate accumulation in leaves. Two different treatments in the nighttime solution concentration (D25/N75, EC: 1.8 dS m^{-1}; and D25/N50, EC: 1.2 dS m^{-1}), a day nutrient solution of EC 0.6 dS m^{-1}, plus a day and night treatment with constant EC (D50/N50, EC: 1.2 dS m^{-1}) were applied. Plant growth, leaf photosynthesis, and leaf nutrient content were evaluated after 3 wk of growth. Mean shoot weight was 106.3 g with no differences among treatments. Root biomass was lower with D25/N75 (0.14 vs. 0.85 g in the other treatments). The maximum rate of leaf photosynthesis was 66% lower with D25/N75 than in the other treatments. Nitrogen, P, K, Ca, and Mg were lower in leaf tissue in the treatments with different solution concentrations where leaf $NO3^-$ content was reduced by approximately 75%. Switching nutrient solution concentration between day and night is a viable practice to reduce $NO3^-$ in lettuce leaves with no detriment to leaf production.

2.5 PHYSIO-CHEMICAL PROPERTIES OF GROWING MEDIA

Sahin *et al.* (2001) studied the physico-chemical properties of some organic (peat moss, peat, saw dust) and inorganic (perlite, pumice, creek sand) substrates. pH, electrical conductivity, cation exchange capacity, carbonates, organic matter, particle size distribution, bulk density, water retention characteristics and pore size distribution of substrates were determined. The water retention values were highest in peat: saw dust (60.0%), perlite: creek sand (40.1%) and saw dust: perlite (57.2%). Highest values of macro pores (>100µm) were for saw dust (56.9%), pumice (60.2%), 56% for peat: saw dust, 52.6% for saw dust: perlite. Lowest bulk density was for peat moss (0.086g/cc) and the highest for peat moss: perlite (0.099g/cc) respectively. pH values of substrates varied from 5.1(peat moss and peat) to 7.6 (pumice). The highest EC, CEC, Carbonates and organic matter level were for 1.065 ds/m (peat) 206.4 cmol/kg (peat moss), 0.75% (pumice) and 95% (peat moss) respectively.

Nowak *et al.*(2010) conducted a study on the changes of physical properties in rockwool and glasswool slabs during hydroponic cultivation of roses. Roses cv. 'Trixx' were grown in 4 different slabs of mineral wool (100 cm length, 15 cm width and 7.5 cm height), which were placed on specially constructed racks in a greenhouse. The cultivation method using bent shoots was used. The studied growth media were: rockwool slabs –Master and Pargro which had a horizontal fibrous structure, Bomat slabs with a homogeneous structure and glasswool Cultilene slabs with a homogeneous structure. The physical properties of mineral wool slabs were obtained from 15 cm long and 15 cm width samples. The samples were taken from slabs before cultivation, and periodically from a greenhouse during the 2.5 year growing period (6, 12, 18, 24 and 30 months after planting). The bulk density increased and total porosity decreased in the Master and Cultilene slabs as early as after six months of cultivation. Other changes in the remaining slabs were not evident until the end of the cultivation stage. The air-water properties depended on the cultivation time and were very different at -4 cm H_2O. More stable values of air-water properties were observed at -10 cm H_2O. Usually in the beginning of the cultivation period, water content was lower – especially at the -10 to -50 cm H_2O range of water potential.

Hossain *et al*. (2012) carried out a study on the effect of salt stress on physiological response of tomato fruit grown in hydroponic culture system. Fruit growth rate, water status, cuticle permeability and induction of blossom-end rot (BER) of tomato fruit were considered for this study. Salt stress was applied by using Ca salt treatment and it plays an important role on all parameters studied in this experiment. Fruit growth rate, predawn water potential, osmotic potential and cuticle permeability were significantly lower in treated plants than in control plants. On the other hand, tissue turgor of control and treated fruit showed almost similar values 12 days after flowering (DAF). This result indicated that turgor was osmotically regulated in fruit under stress condition. Fruit growth rate was found to decline from 12 DAF and eventually ceased when BER externally appeared on fruit surface at the age of 19 DAF in this experiment. The reduction of growth rate coincided with the reduction of water potential in fruit tissue due to salt stress. Although BER externally appeared at 19 DAF anatomical investigation showed that intercellular air space becomes discoloured at least one week before external symptoms appeared on fruit tip. Different levels of permeability indicated that the deposition of cuticular wax on fruit surface was enhanced by the salt stress condition in tomato fruit. Since, BER was found to appear on fruit tip under high calcium concentration in solution it can be concluded that calcium deficiency was not the only the cause of BER in tomato, rather salt stress might alter metabolic activity in developing tomato fruit.

Emmanuel *et al*. (2015) studied soilless media and containers for bell pepper production in protected culture. Bell pepper plants were grown in box, bag, and pot containers and coconut coir, pine bark, and potting mix soilless media in a 50-mesh net house. Media chemical and physical analysis, plant height, total marketable yield, and root dry biomass were determined. The combination of potting mix with bags, pots, or boxes increased bell pepper total marketable fruit weight, number, and plant height compared to pine bark and coconut coir.

2.6 Effect of pH and EC of nutrient solution

Kalam *et al*. (2009) developed the use of silicate minerals, which buffer pH, and a nutri-culture system using quartz porphyry (QP). Nutrient solutions were allowed to pass from the lower to the upper side of the packing layer by pumping into the system. The pH of the nutrient solution not using QP changed rapidly with the addition of pH buffer. However, the nutrient pH using QP without addition of buffer remained stable at 5.6–6.1. With cultivation of komatsuna (*Brassica rapa* L. nothovar) in the Nutrient film technique system, the fresh weight of leaves and roots and the length of plants were significantly higher in treatments compared to control. Therefore, this nutrient system has potential applications in hydroponics.

Daniela. *et al.* (2013) carried out a study on effect of nitrogen form and nutrient solution pH on growth and mineral composition of self-grafted and grafted tomatoes. Three greenhouse experiments were carried out to determine the effect of the nitrogen form and the nutrient solution pH on growth, yield, leaf gas exchange, carbohydrate, N-compound concentrations and mineral composition of tomato cv. Moneymaker (*Solanum lycopersicum* L.) self-grafted and grafted onto 'Maxifort' (S. lycopersicum L.×S. habrochaites S. Knapp and D. M. Spooner) grown in hydroponics. Exp.1 included five pH levels in the nutrient solution (3.5, 4.5, 5.5, 6.5, and 7.5) while in the Exps. 2 and 3 four different ratios of NO_3^- to NH_4^+ (100:0, 70:30, 30:70, and 0:100) were used. The Exps. 1 and 2 were performed in a short period of time (about 20 days) while Exp. 3 was a long-term experiment. No significant differences among treatments were observed in shoot and root dry biomass of tomato in the pH experiment (Exp. 1), whereas shoot dry biomass, Ca and Mg concentrations decreased sharply when N was exclusively provided as NH4+ (Exp. 2). When averaged over the pH level of the nutrient solution, the highest Ca, Fe, Zn, and Cu concentrations were recorded in grafted than self-grafted plants (Exp. 1), whereas in Exp. 2 shoot and root biomass values recorded in grafted plants were significantly higher than those observed for self-grafted plants, by 20%, and 24%, respectively. In the long-term experiment, the plant growth and yield decreased in response to an increase of NH4+ in the nutrient solution. The decrease in marketable yield with decreasing NO3− NH4+ ratio resulted mainly from the increase of blossom-end rot, which reduced the number of marketable fruits per plant. The adverse effects of an increased supply in NH4+ have been associated to a fall in Ca and Mg levels in plant tissues. The carbohydrate concentrations, amino acids and proteins increased under NH4+ in comparison to NO3− based nutrition. Moreover, NH4+ toxicity was associated with reduced rates of net photosynthesis. Their results also demonstrated that grafting 'Moneymaker' into 'Maxifort' did not mitigate the negative effects of ammonium nutrition on tomato productivity.

Mello *et al.* (2014) conducted a study on nitrogen metabolism and fresh weight production of crambe under different nitrate doses and pH values in nutrient SolutionIn the first experiment, crambe plants were submitted to crescent NO3 -N doses (0.2; 2.0; and 4.0 mM) in hydroponic system located in a greenhouse. The second-experiment was conducted with crambe plants cultivated under different pH values (5.0; 5.5; 6.0; and 6.5) also in nutrient solution at the same conditions. In both experiments the harvest was performed at the end of vegetative stage. Plants under pH 5.5 showed a high flux of NO3 -N reduction and assimilation. The results-obtained also indicated a key role of stem in NO3 -N storage in crambe, probably as part of vacuolar pool. A significant increase in fresh weight of stem and leaves was obtained in plants submitted to 2 mM NO3 -N and under pH 6.5. These results indicated a possible way to reduce the utilization of high NO3 -N doses for crambe production and the necessity of soil adjustment, aiming the use of the culture for ruminant feed.

Choi *et al.* (2014) investigated the effect of concentration of nutrient solution on the growth and yield of roses during the juvenile period and more than 1 year after transplanting using coir substrate in open soilless culture. Concentration of nutrient solution was four different EC levels (0.6, 1.0, 1.4, and 1.8 dS•m-1). Until 22 days after transplanting, even high concentration of nutrient solution supplied to the substrate, there was no difference in EC of the extracts. After that, they were sharply increased with higher concentration of nutrient solution. Number of shoots were increased with increasing nutrient concentration, but there was no significant difference among treatment except EC 0.6 dS•m-1 since 3rd growth cycle. Long-term cultivation of roses for more than a year using coir substrate, EC and inorganic ions in extracts of substrate was slightly higher in EC 0.6 and 1.0 dS m-1, and was severely higher above EC 1.4 dS•m-1. In high temperature period, yield was decreased with increase of nutrient concentration. In low temperature period, The highest yield was obtained from EC 1.0 dS•m-1 and yield was decreased in EC 1.8 dS•m-1 compared to the other treatments. They suggested that the suitable nutrient concentration was EC 1.8 dS•m-1 until 90 days and then EC 1.4 dS•m-1 until 165 days after transplanting which was more higher than conventional nutrient concentration. For long-term cultivation of roses for more than a year, suitable nutrient concentration was EC 0.6~ 1.0 dS•m- 1

Wortman *et al.* (2015) evaluated the crop physiological response to nutrient solution electrical conductivity and pH in an ebb-and-flow hydroponic system. Crops grown in the high EC–low pH solution approached a greater final height, but relative growth rate was not different from the low EC– high pH solution. Leaf chlorophyll content, estimated from leaf greenness, was up to 37% lower in the low EC–high pH solution. Yield loss in tomato and pepper was less severe (<32%), but still significant. Observed yield reductions were greater than previous comparisons of floating-raft aquaponic and hydroponic systems, which demonstrates the importance of root to nutrient solution contact area and fertigation frequency when using low EC–high pH nutrient solution (e.g., aquaculture effluent). Differences may also suggested that there were components of aquaponic solution not tested in this mechanistic study (e.g., organic metabolites and alternative nutrient forms or ratios) that may contribute to crop growth and yield in aquaponics.

2.7 Effect of micro and macro nutrient

Sanchez *et al.* (2000) conducted a study of conifer nitrogen nutrition using hydroponic cultures. Nitrogen (N) optimization of a nutrient solution for ornamental conifers was obtained with two different experiments in hydroponic cultures: First, by using three different NO_3^-/NH_4^+ ratios (60/40, 55/45, and 40/60 in percentages of the total N supplied); and, secondly by testing three total N levels (3.7; 4.7 and 5.5 mmol L^{-1}). Best growth was obtained with a NO_3^-/NH_4^+ ratio of 55/ 45 and a total N level of 3.7 mmol L^{-1}. With these experiments, reference levels of foliar concentrations of the macronutrients N, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and the biochemical indices, such as chlorophyll and starch levels, were obtained with the treatments corresponding to the plants with the higher growth. In the course of a growth cycle, a substrate assay with two different pot mixes (moss peat plus perlite and black peat plus sepiolite 60/40 -% v/v-) was carried out by using the best N ratios and doses in nutrient solutions as obtained in hydroponics. The results indicated that the same N fertilization in fertigation systems changes depending on the different physicochemical properties of the substrates used; in this case, depending on the different physical properties of the two substrates

Drazic *et al.*(2004) conducted a study on cadmium toxicity: the effect on macro- and micro-nutrient contents in soybean seedlings. The effect of Cd (10, 100, and 200 μM) on tissue contents of macronutrients (N, P, K, Ca, Mg) and micronutrients (Fe, Zn, Cu, Mn) was investigated in hydroponically grown soybean (*Glycine max*) seedlings. Concentration changes of analysed elements observed against increasing Cd accumulation indicated that acute Cd-phytotoxic effect monitored through chlorophyll content was not a consequence of nutrient deficiency.

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Jarrahi *et al.* (2013) studied the effect of bicarbonate of irrigation water on absorption of some of micro elements and leaf chlorophyll of some citrus rootstocks in hydroponic culture. To analyze the effect of four irrigation water bicarbonate levels (0, 3, 6 and 9 mmol/l) on leaf chlorophyll and absorption of Iron, Zinc and Manganese of 3 citrus rootstocks including Carrizo citrange, Swingle citrumelo and Sour orange under hydroponic culture, this study has been done. Experiment has been conducted as factorial in completely randomized design including 2 factors and 6 replications in eastern Mazandaran. At control level, Carrizo citrange and Sour orange had the highest and lowest concentration of leaf Fe, Zn, Mn and chlorophyll, respectively and Swingle citrumelo have been placed between these two rootstocks in this case. Fe highest concentration belonged to sodium bicarbonate level 9 and the lowest was observed at sodium bicarbonate level 0 (control). In Citrumelo and Sour orange, the highest leaf Zn concentration belonged to control. The lowest leaf Zn concentration in all 3 rootstocks was observed at level 6 of sodium bicarbonate. The highest leaf Mn concentration was seen at level 3 of bicarbonate in Citrumelo and in Sour orange at all levels of bicarbonate had the lowest leaf Mn concentration. Maximum Fe and Mn contents were for Citrumelo and Sour orange and maximum Zn content was observed in Sour orange. The minimum Fe, Zn and Mn content belonged to Citrange. Maximum leaf Fe and Zn content among 4 different bicarbonate levels belonged to control. Leaf Fe and Zn content, reduced along with increasing of bicarbonate amount. Maximum chlorophyll level in Citrange and Sour orange was observed at control level. In contrast, in Citrumelo, level 6 of bicarbonate showed the highest chlorophyll among the other levels. Sour orange at all levels of bicarbonate showed lowest chlorophyll compare to other rootstocks.

Hyun *et al.* (2014) took up studies on real-time control of hydroponic macronutrients for closed growing system. Recirculating hydroponic system based on EC-control is not efficient in managing the composition of individual ions in the solution, thereby resulting in a high increase in total concentration of the nutrients and an imbalance of the nutrient salts. This study developed and evaluated a computer-controlled system with an array of ion- selective electrodes (ISEs) and four diaphragm pumps for direct measurement and individual control of macronutrients in recirculating hydroponic solutions. The ability of three PVC membrane-based ISEs for simultaneous determination of NO_3, K+, and Ca_2+ ions in the closed soilless system was evaluated. The results showed that the NO3-K-Ca ISEs exhibited satisfactory performance in measuring nutrient concentrations in hydroponic solution. The target concentrations were prepared as expected by using the automated nutrient management system, showing linear relationships with high determination coefficient of >0.9 between the ISE- dosing methods and standard analyzers.

Keller *et al.* (2014) studied the effect of silicon on wheat seedlings (*Triticum turgidum* L.) grown in hydroponics and exposed to 0 to 30 lM Cu. The hydroponic study was set up to investigate the influence of Si on Cu tolerance in durum wheat grown in 0, 0.7, 7.0 and 30 lM Cu without and with 1.0 mM Si, and to identify the mechanisms involved in mitigation of Cu toxicity. Si supply alleviated Cu toxicity in durum wheat at 30 lM Cu, while Cu significantly increased Si concentration in roots. Root length, photosynthetic pigments concentrations, macroelements, and organic anions (malate, acetate and aconitate) in roots, were also increased. This study provides evidences for Simediated alleviation of Cu toxicity in durum wheat. It also showed that Si supplementation to plants exposed to increasing levels of Cu in solution induces non-simultaneous changes in physiological parameters.

Ariana *et al.* (2015) reported the responses of jack-bean and sorghum to Cd supply and Cd accumulation by these species grown in hydroponic culture. The plants were subjected to 0, 15, 30, or 60 µmol Cd L−1 in the nutrient solution, and gas exchange, plant growth and Cd accumulation were measured at 25 days after starting Cd treatments. The Cd supply severely reduced growth of shoots and roots in both species. In jack-bean, Cd decreased photosynthesis by 56–86%, stomatal conductance by 59–85% and transpiration by 48–80%. The concentrations and amounts of Cd accumulated in the plant tissues were proportional to the metal supply in the nutrient solution. Sorghum was more tolerant than jack-bean to Cd toxicity, but the latter showed a greater metal concentration and accumulation in the shoot.

Chitdeshwari *et al.* (2015) concluded that Zinc is an essential micronutrient for growth and yield of various agricultural crops which in turn is needed for human nutrition as well. Zinc deficiency is a critical nutritional problem in crops and is responsible for low yield and poor quality. A solution culture experiment was conducted to evaluate twenty greengram genotypes for their Zn efficiency under zinc sufficient (2.50 mg Zn L-1) and deficient (0.0 mg Zn L-1) conditions using Hoagland's Nutrient Solution. The plants were grown hydroponically and harvested after 30 days of transplanting. Zinc efficiency in the selected genotypes ranged from 73 % to 111 % and the genotypes differed significantly in Zn efficiency. Based on higher Zn efficiency, the genotypes, Pusa Vishal, K 851 and CO 7 were Zn efficient while CO 912, CO 6, ADT 3 and Local variety were Zn inefficient Green gram genotypes.

Kong *et al.* (2015) reported the potential of producing Salicornia bigelovii hydroponically as a vegetable at moderate NaCl salinity. It is a halophyte that is capable of growing under high salinity. To evaluate the potential of producing S. bigelovii hydroponically as a vegetable at moderate NaCl concentrations, plants were grown in nutrient solutions with 6, 8, and 10 mm NaCl, and with 200 mm NaCl as a control. Results showed that plants had a reduced main stem length, canopy width, stem diameter, and root system length in 6 to 10 mm NaCl compared with those in 200 mm. Also, fresh weight increase, fresh and dry weights of individual plants, marketable yield, and water use efficiency of the plants grown in solutions with 6 to 10 mm NaCl were significantly lower than those grown in 200 mm. Associated with the reduced growth attributes, remarkable decreases in sodium uptake by the plants were also obtained in 6 to 10 vs. 200 mm NaCl. The results suggest that S. bigelovii is not a good candidate for hydroponic production as a vegetable at moderate NaCl salinity resulting from reduced growth attributes, which are possibly associated with decreased sodium uptake.

2.8 EFFECTS OF GROWING MEDIA ON PLANT GROWTH PARAMETERS.

Logendra *et al.* (2001) conducted an experiment using mini- rockwool blocks as growing media for limited-cluster tomato production. Rockwool is an excellent growing medium for the hydroponic production of tomato; however, the standard size rockwool blocks [4 × 4 ×2.5 inches (10 × 10 × 6.3 cm) or 3 × 3× 2.5 inches (7.5 × 7.5 × 6.3 cm)] are expensive. The following experiments were conducted with less expensive minirock wool blocks (MRBs), on rayon polyester material (RPM) as a bench top liner, to reduce the production cost of tomatoes (*Lycopersicon esculentum*) grown in a limited cluster, ebb and flood hydroponic cultivation system. Fruit yield for single-cluster plants growing in MRBs [2 × 2 × 1.6 inches (5 × 5 × 4 cm) and 1.6 × 1.6 × 1.6 inches (4 × 4 × 4 cm)] was not significantly different from plants grown in larger sized blocks (3× 3 × 2.5 inches). When the bench top was lined with RPM, roots penetrated the RPM, and an extensive root mat developed between the RPM and the bench top. The fruit yield from plants on RPM was significantly increased compared to plants without RPM due to increase in fruit size and fruit number. RPM also significantly reduced the incidence of blossom-end rot. In a second experiment, single and double-cluster plants were grown on RPM. Fruit yield for double cluster plants was 40% greater than for single-cluster plants due to an increase in fruit number, although the fruits were smaller in size. As in the first experiment, fruit yield for all plants grown in MRBs was not significantly different from plants grown in the larger sized blocks. MRBs and a RPM bench liner are an effective combination in the production of limited-cluster hydroponic tomatoes.

Christoulaki *et al.* (2012) carried out a study on the lettuce plants grown in sawdust (Saw) and/or perlite (Per) mixtures (sawdust; Saw:Per 75:25%; Saw:Per 50:50%; Saw:Per 25:75%; Perlite) and in Nutrient Film Technique (NFT), in an unheated greenhouse. Plants grown in NFT were taller with greater leaf area resulting in greater fresh weight. Sawdust addition reduced leaf length, leaf area and as a consequence the fresh weight but not the leaf number. However, leaf dry weight increased as sawdust content increased into the substrate. Leaf chlorophyll reduced but leaf fluoresces increased in perlite and NFT. High sawdust content (75% or 100%) reduced photosynthetic rates and stomatal conductance. Nutrient uptake [potassium (K), sodium (Na), phosphorus (P)] was the greatest in NFT treatment, while perlite and Saw:Per 25:75% increased elemental uptake (up to 74%) comparing with the remaining treatments. Leaf elemental analysis fluctuated among treatments. Thus, low content (i.e. 25%) of sawdust in perlite could improve inorganic substrate media properties.

Paul *et al.* (2013) carried out a study to analyze the effects of different hydroponics systems and growing media on the vegetative growth, yield and cut flower quality of gypsophila (*Gypsophila paniculata* L.). The study investigated the potential of growing gypsophila using different hydroponics systems. The experiments were laid out in a split-plot design. Three hydroponics systems were used as the main plots, i.e. elevated tray, ground lay bed and bag culture systems. The sub-plots were allocated to three different aggregate/medium components, i.e., sawdust, river sand and vermiculite. Throughout the production period, plants grown using river sand had the lowest plant height. The highest plant height (52.9 cm) was obtained from plants grown in vermiculite at 12 weeks after transplanting (WAT). Plant height of gypsophila plants grown using sawdust at 12 WAT was almost double that of those grown using sand. There was a significant ($P < 0.05$) reduction in number of shoots/plant in gypsophila grown in sand medium in all three hydroponics systems. The highest number of shoots/plant was obtained from plants grown in sawdust in all hydroponics systems. The highest cut flower stem length (67.0 cm) was obtained from plants grown in sawdust in the bag culture hydroponics system, while the lowest cut flower stem length (25.0 cm) was observed in plants grown in sand in the elevated tray hydroponics system. The highest number of branches/plant was observed in plants grown in the bag culture hydroponics system when compared to the elevated tray and ground lay bed hydroponics systems. For the hydroponics culture of gypsophila, sawdust should be used as growing medium. To induce highest vegetative growth, flower yield and quality, the plants should be grown using bag culture hydroponics system.

Marinou *et al.* (2013) conducted experiments to evaluate the use of sawdust, coco soil and pumice in hydroponically grown strawberry. Strawberry plants were grown hydroponically in different ratio of sawdust (Saw-100), coco soil (Coc-100) and/or pumice (Pum-100) mixtures. Leaf number doubled in plants grown in Saw- 100 while runners (stolons) number increased up to 70% in plants grown in Coc- 100 compared with the control treatment (Pum-100). Fruit number increased (up to 50%) in plants grown in Pum-100. Leaf stomatal conductance, photosynthetic rate and internal concentration of CO_2 differentiated according to the plant vegetative or reproductive stage and/or substrate medium. Leaf and stem fresh weight as well as leaf area was increased (up to 32, 24 and 44%, respectively) in case of Coc-100 compared with the Saw-100 or Pum-100. Plant yield was doubled when pum-Saw (50-50) was used compared with the Saw-100, which was due to the reduced fruit number produced rather than the difference in fruit fresh weight. Substrate affected fruit quality parameters. The present findings highlighted the putative use of organic medium i.e. Sawdust on top of the widely used coco soil as substrate medium in strawberry culture.

2.9 EFFECT OF TEMPERATURE ON GROWTH

Nxawe *et al.* (2009) conducted an experiment on the effect of regulated irrigation water temperature on hydroponics production of Spinach (Spinacia oleracea). The effects of different temperature regimes of irrigation water on the growth rate of *Spinacia oleracea* L. were determined in the greenhouse for 8 weeks. The spinach seedlings were irrigated with water heated to various temperatures (24, 26 and 28°C) via pumps connected to 4 sets of water tanks each maintained at the experimental temperatures using Dolphin aquarium heaters. Unheated water from the tap supplied from the fourth tank served as control. All the plants were supplied with a mixture of Ocean HYDROGRO and Ocean HORTICAL nutrient solutions containing all essential elements. After 8 weeks of growth, results showed that leaf length (mm), leaf number and total fresh and dry weights (g per plant) was higher in plants grown at elevated temperatures compared with the control plants with optimum growth being recorded at 28°C. These results suggest that controlled production of spinach during winter seasons is possible by irrigation with heated water in a greenhouse.

Nxawe *et al.* (2010) carried out an experiment on the possible effects of regulating hydroponic water temperature on plant growth, accumulation of nutrients and other metabolites. Water temperature can affect many physiological processes during plant growth and development. Temperatures below or above optimum levels may influence plant metabolic activities positively or negatively. This may include accumulation of different metabolites such as phenolic compounds, reactive oxygen species (ROS), nutrient uptake, chlorophyll pigment formation, the photosynthesis process and finally the growth and development of the plant. The optimum temperature of the growth medium can contribute to improving and optimizing the earlier mentioned plant physiological processes. Information on how the temperature of hydroponic solution influences certain flowering plant production in glasshouses during the winter period is limited. This paper suggested the possible benefits of regulating temperatures of the hydroponic solution with the aim of optimizing production of flower in the glasshouse during winter periods.

Martin *et al.* (2013) carried out a study to analyze the effect of arbuscular mycorrhiza and temperature control on the plant growth, yield, and mineral content of tomato plants grown hydroponically. Tomato seedlings, therefore, were treated with a mycorrhizal inoculant (MycorootTM) at transplanting to potentially enhance nutrient uptake by the plant. Then seedlings were transferred to either a temperature-controlled (TC) or a nontemperature- controlled (NTC) tunnel and maintained using the recommended (100%) or a reduced (75% and 50%) nutrient concentration. Plants grown in the NTC tunnel had significantly poor plant growth, lower fruit mineral concentration, and lower yield compared with fruit from plants in the TC tunnel. Leaves from plants in the NTC tunnel had higher microelement concentrations than those in the TC tunnel. Highest yields were obtained from plants fertigated with 75% of the recommended nutrient concentration, and not from the 100% nutrient concentration. Application of arbuscular mycorrhizal fungi (AMF) neither enhanced plant growth, nor yield, nor fruit mineral nutrient concentrations. However, temperature control positively affected the fruit Mn and Zn concentration in the TC tunnel following AMF application.

Maryam *et al.* (2014) conducted a study for low and high temperature stress effect on the growth characteristics of tomato in hydroponic culture with selenium (Se) and nano- selenium (N-Se) amendment. Se was applied at 0 μ M(control), 2.5 μM (Se1), 5 μM (Se2) and 8 μM (Se3). Similarly, N-Se was applied at 1 μM (N-Se1), 4 μM(N-Se2), 8 μM (N-Se3) and 12 μM (N-Se4). All plants were exposed to optimal temperature (25/17 ± 2◦Cday/night = T1), then to high (24 h at 40◦C = T2) and low (24 h at 10◦C = T3) temperature stress, then placed at optimal conditions for 10 days. Se, when applied at 2.5 _M, promoted plant growth after both high and low temperature stress were applied. More specifically, shoot dry weight and diameter increased in T2, shoot fresh weight, dry weight and diameter increased in T3, and root fresh weight, dry weight and root volume increased in T2 and T3. N-Se had no effect on plant growth. In T3, Se increased the chlorophyll content of leaves by 19.2% while N-Se improved it by 27.5%. Root volume increased 33.3% after treatment with Se in T2 and by 60% in T3. Se and N-Se increased relative water content after T2 and T3 stress. Thus, Se and N-Se can improve selected tomato plant growth parameters after a short-term pulse of high and/or low temperature stress.

Masaru *et al.* (2015) investigated effects of root-zone temperatures on growth and components of hydroponically grown red leaf lettuce (*Lactuca sativa* L. cv.

Red Wave) under a controlled cultivation system at 20˚C. Compared with ambient root-zone temperature exposure, a 7-day low temperature exposure reduced leaf area, stem size, fresh weight, and water content of lettuce. However, root-zone heating treatments produced no significant changes in growth parameters compared with ambient conditions. Leaves under low root-zone temperature contained higher anthocyanin, phenols, sugar, and nitrate concentrations than leaves under other temperatures. Root oxygen consumption declined with low temperature root exposure, but not with root heating. Leaves of plants under low root zone temperature showed hydrogen peroxide production, accompanied by lipid peroxidation. Therefore, low temperature root treatment was suggested to induce oxidative stress responses in leaves, activating antioxidative secondary metabolic pathways.

Masaru *et al. (*2015) investigated the effect of root-zone temperatures (20˚C, 25˚C, 29˚C, and 33˚C) on carrot growth and components using a hydroponic system. High root-zone temperatures for 14 days reduced shoot and root growth and water content. In contrast, total phenolic compounds and soluble-solid content increased in tap roots under high- temperature treatment. Root oxygen consumption was up regulated after 7 days under high-temperature treatment. These results suggest that high root-zone temperatures induce drought-like stress responses that modulate carrot biomass and components. High root-zone temperature treatments administered to hydroponically grown crops may be a valuable tool for improving and increasing the quality and value of crops.

Sumarni *et al.* (2013) conducted an experiment to find out the temperature distribution in an aeroponics system. Two treatments were applied, i.e., application of root zone cooling at 10 °C and no cooling as control. The temperature distribution inside the aeroponics chamber was analysed using the CFD. The size of the aeroponics chamber used was 1.5 m length, 1.0m width and 1.0m height. The outer wall of the aeroponics chamber was made of plywood material of 12 mm thick. The inside part of the wall was insulated with Styrofoam of 2.0cm thickness. This set up performed a good temperature distribution. The result of validation showed that air temperature simulated by using CFD agreed well with that of air temperature measured inside the aeroponics chamber.

Ritter *et al.* (2013) evaluated and compared different methods and cultivars for the production of quality prebasic seed in potato. Two cultivation systems, aeroponics and greenhouse beds with a peat moss substrate, and three potato cultivars with different vegetative cycle, Agria, Monalisa and Zorba, were assayed. Plants in the aeroponic system showed increased growth and their vegetative cycle extended between 12 and 36 % compared to the plants cultivated in greenhouse beds. Flowering and tuberization dates, Absolute Growth Rates (AGR) during the period of 60 days after planting (DAP) and height presented a wide variation between cultivars. Zorba showed earlier flowering and tuberization, lower AGR and reached a minor height at 60 DAP. Instead the late season cultivar Agria showed later flowering and tuberization, presented higher AGR and reached an increased height at 60 DAP. The total tuber yield per plant was between 34 and 87 % higher in the aeroponic system, with a marked difference for the earlier cultivars Zorba and Monalisa. Tuber numbers increased between 60 and 80 %. Mini-tuber production in aeroponics showed a better size distribution, with a reduction in the percentage of tubers smaller than 12 mm of between 33 and 86 %. In this soil-less culture system average tuber weight increased in Zorba and Monalisa over 60 % but was lower for Agria.

Barak *et al.* (1996) conducted a study to examine whether nutrient uptake rates could be calculated for aeroponic systems by difference using measurements of concentrations and volumes of input and efflux solutions. Data were collected from an experiment with cranberry plants (*Vaccinium macrocarpon* Ait. cv. Stevens) cultured aeroponically with nutrient solutions containing various concentrations of ammonium-N and isotopically labelled nitrate-N. Validation of the calculated uptake rates was sought by: (1) evaluating charge balance of the solutions and total ion uptake (including proton efflux) and (2) comparison with N-isotope measurements. Charge balance and proton efflux calculations required use of chemical modelling of the solutions to determine speciation of dissolved phosphate and acid-neutralizing capacity (ANC). The results showed that charge balance requirements were acceptably satisfied for individual solution analyses and for total ion uptake when proton efflux was included. Relative rates of nitrate/ammonium uptake determined by difference were in agreement with those determined by isotopic techniques. Additional information was easily obtained from this experimental technique, including evidence of diurnal variation in nutrient uptake, correlation between ammonium uptake and proton efflux, and the relationship between ion concentration and uptake. Use of aeroponic systems for non-destructive measurement of water and ion uptake rates for numerous other species and nutrients appears promising.

Austin *et al*. (2010) studied the effects of root-zone (RZ) CO_2 on crisp head-type lettuce (*Lactuca sativa* L. cv. 'Wintergreen') were measured in an aeroponic system under photosynthetic photon flux of 650 µmol m^{-2} s^{-1}, 12 h photoperiod at 36°C/30°C and 28°C/22°C (day/night), with three enriched RZ CO_2 levels (2000 ppm, 10,000 ppm and 50,000 ppm). Leaf growth was monitored after elevated RZ CO_2 had been supplied for one week. Leaf areas with elevated RZ CO_2 were greater than ambient controls at both temperatures, while shoot and root weights were also higher. Increasing temperature reduced biomass overall, but the relative response to RZ CO_2 was greater. Elevated RZ CO_2 stimulated photosynthetic CO_2 assimilation, with greater increase at higher temperatures. Elevated RZ CO_2 decreased stomatal conductance at both temperatures, reducing transpiration water loss.

Sengupta *et al.* (2012) explains that with the advent of civilization, open field/soil-based agriculture is facing some major challenges; most importantly decrease in per capita land availability. 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. In soil-less culture, plants are raised without soil. Improved space and water conserving methods of food production under soil-less culture have shown some promising results all over the World.

CHAPTER 3

MATERIALS AND METHODS

Soil-less gardening offers many advantages to the home gardener. Since a medium is used, there are no weeds to remove, and soil-borne pests and diseases are minimized, if not eliminated completely.The technology Hydroponics and Aeroponics plays very crucial role in 21 St century in soilless culture in commercial food production. In this technology natural media is helpful to grow the plants. The main principle involving the use of sprayers, nebulizers, foggers to create a fine mist of solution of deliver nutrients to plants roots. Plant roots are suspended above a reservoir of nutrient solution or inside a channel connected to a reservoir. Plants will grow under optimal conditions like nutrient, temperature, aeration, and pH. In this technique oxygen is influenced into the nutrient solution, allowing the roots to absorb nutrients quicker and more easily. This facilitates stimulating the rapid growth, preventing algae
formation and resulting high yields.

The big advantage to these techniques is the ability to automate the entire system with a timer. Automation reduces the actual time it takes to maintain plant growth requirements. Automation also provides flexibility to the gardener as one can go for long periods of time without having to worry about watering the plants.

Hydroponics is an indoor horticulture. It is best to adapt hydroponics in areas where the soil is not suitable for plant growth like Antarctica and Space colonies. Hydroponics is incredible amount of water; it uses as little as 1/20 the amount of as a regular farm to produce same amount of food. Nutrient solutions may be re-used in other areas such as potted plants and turf management. Growing medium can be reused and recycled. Culture and technique requires less space. When removing the crops, it can be packed and sold. When alive to retain its freshness for a longer time.Advantages are excellent aeration is the main advantage of Aeroponics. These techniques have been given special attention from NASA; since a mist is easier to handle than a liquid in a zero gravity environment. A comparative evaluation of simple Hydroponics and Aeroponics systems for terrace cultivation of Amaranthus was done and materials used and the methods employed are discussed in the following subheadings.

3.1 LOCATION OF THE STUDY AREA

The site is situated at Tavanur on the cross point of 10.85°N lattitude and 75.98°E longitude The study was undertaken in the terrace of auditorium building at KCAET, Tavanur. This area had a small portion roofed temporarily with asbestos sheet. The systems were placed in the area of 4.5×2.1 m^2. The selected area had adequate amount of sunlight and air circulation.

3.2 CLIMATE OF THE STUDY AREA

The average rainfall of the area is in between 2500 to 2900mm. The maximum temperature of the study area was 33°C and the minimum temperature was 21°C.

3.3 CROP SPECIES

The study compared the effects of one hydroponics system and three aeroponics system on the growth and yield of Amaranthus (*Amaranthusspp)* variety coimbatore 1(co 1) which needs 25°C for its optimum growth.

3.4 DESIGN AND DEVELOPMENT OF HYDROPONIC AND AEROPONICS SYSTEMS

One Hydroponic and three different Aeroponics system were compared at the same site for the same crop.

3.4.1 Floating system

3.4.1.1 Description

Basically this system is based on deep water culture method. The system uses a shallow depth plastic tray or tub. The nutrient solution was filled ¾th of the tray and a thermocol sheet was paced above the tray. The plants were planted in small grow cups which were placed on the thermocol sheet in suitable sized hole (equal to the diameter of the cup not small or large). An aerator was provided in the tub to agitate the system to ensure enough oxygen supply. The materials used for the fabrication of the floating system are listed in the Table 3.1

Table 3.1 Materials used for the Floating system

Materials	Dimension/Specification	Quantity
Plastic tray	301	1
Thermocol	51cm×37cm×3cm	1
Grow cups	8cmØ, 7cm height	4
Aerator	2.5 W, 30l/min	1
Oasis	-	1
Nutrients salts	-	40g
water	-	261

. Fig 3.1 Gives the view of the experimental set up for floating system

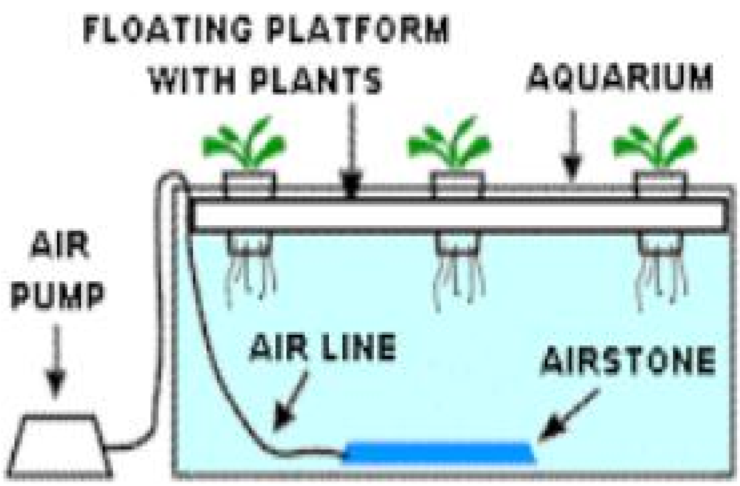


Fig 3.1 Layout of the floating system

3.4.1.2 Floating system-Field set up

For preparing floating system set up, a tray of size 55cm×40cm×17cm and 30 l capacity was taken. It was filled with 20 l of salt solution prepared in such a proportion so that 1g of salt is dissolved in 1 l of water. On the surface of the solution a thermocol sheet of size of 55cm×40cm×3cm was placed. The sheet was provided with four holes of diameter 15cm same as that of top diameter of the grow cups. Inter hole spacing was maintained as 9.5cm row to row and 18 cm plant to plant. The plants were planted in the small grow cups and then it was fixed in the thermocol sheet in the holes provided.

3.4.1.3 Crop raising

Amaranthus seedlings were raised in a seed bed prepared with a combination of soil and cow dung. They were transplanted after 2 weeks. The seedlings had 8cm height and 4-5 leaves. Each of the plants were placed in the grow cups and to hold the plants in position and coir pith was filled as the top layer for extra support.

3.4.2 Re-circulating system

3.4.2.1 Description

This system is basically consists of deep depth plastic trough and tank, The solution was filled ¾ th of the tank .The nutrient solution is pumped from the tank through the lateral pipe line provided at the bottom of the plant in the trough , the fogger attached to the pipe will emit the nutrient solution in the form of mist, this mist provide moisture atmospheric condition around the root system of the plants and can be easily absorbed . The nutrient solution is returned back to the tank. It is a continuously working process for 24hrs. A pump was provided on the tank which will pump the nutrient solution to the plant. The materials used for the fabrication of the recirculating system are listed in the Table 3.2.

Table 3.2 Materials used for the construction of Re-circulating system

Materials	**Dimension/Specification**	**Quantity**
Trough	60 l	1
Tank	50 l	1
Thermocol	64×33.5×2.5 cm	1
pipes	¾inch	2m
fogger		4
Submersible pump	40W 3200l/min	1
Coirpith	-	1kg
End plug	0.5mm	1

The experiment setup is given in fig-3.2

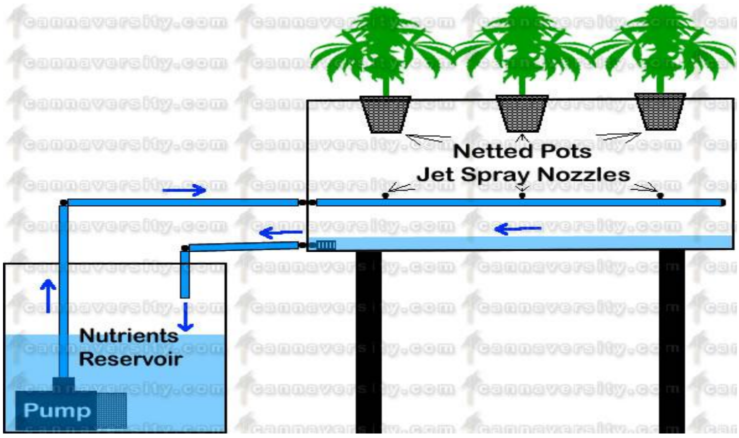


Fig 3.2 Layout of the field recirculating system

3.4.2.2 Re-circulating field set up

A trough of 60 l capacity and tank of 50 l capacity were taken. The tank was filled with 30 l of salt solution prepared in such a proportion, so that 1g of salt is dissolved in 1 l of water. Inflow pipe from the tank was connected to the side of the trough and outflow pipe was connected to the bottom hole in the trough to tank for recirculation process. Low pressure foggers (3 nos) were attached on the pipes for providing fine mist around the plants . On the surface of the trough a thermocol sheet of size 64×33.5×2.5 cm in was placed, The sheet was provided with nine holes of diameter 12cm same as that of top diameter of the grow cups. Inter hole spacing was maintained as 9 cm row to row and 18cm plant to plant. The plants were planted in the small grow cups and then it was fixed in the thermocol sheet in the holes provided. The pictorial of the structure as shown on the given plates 3.1

Plate 3.1 image of recirculating system

3.4.2.3 Crop raising

Seedling of size 7cm height and 9 plants were selected for transplanting.

3.4.3 SIMPLE MISTING TIME

3.4.3.1 Description

This method employs with trough and fogger attached on a pipe using clamp wich is fabricated by mild steel. And plants are planted on the small grow cups in the holes provided on the thermocol above the bucket. Nutrient sump has a pump working to lift solution to the pipe line and nozzles are working in the pipes to deliver the spray. The returning solution falls in the same tank. Timer controls the working of pump and supply is at certain intervals. This is a burst of nutrient solution, misting for a certain time at different cycles.By using this technique, which does not change during the life of the crop, the misting cycle never causes the plant's roots to dry out. The cycle timings have to be set based on observation. The materials used for the simple misting system is given in table 3.3

Table 3.3 Materials used for the construction of Simple misting time

Materials	Specification / Dimension	Quantity
Pvc pipe	¾ inch	1.5m
Bent joint	¾ inch	3
T joint	¾ inch	1
Trough	50 l	1
Coir pith	-	1kg
Foggers		4
Submersible pump	40 W, 3200l/min	1
Timer	200-250VAC Frequency 50/60 hz	1
Thermocol	54.5×2.5×44 cm	1

The experimental set up is given in Fig-3.3

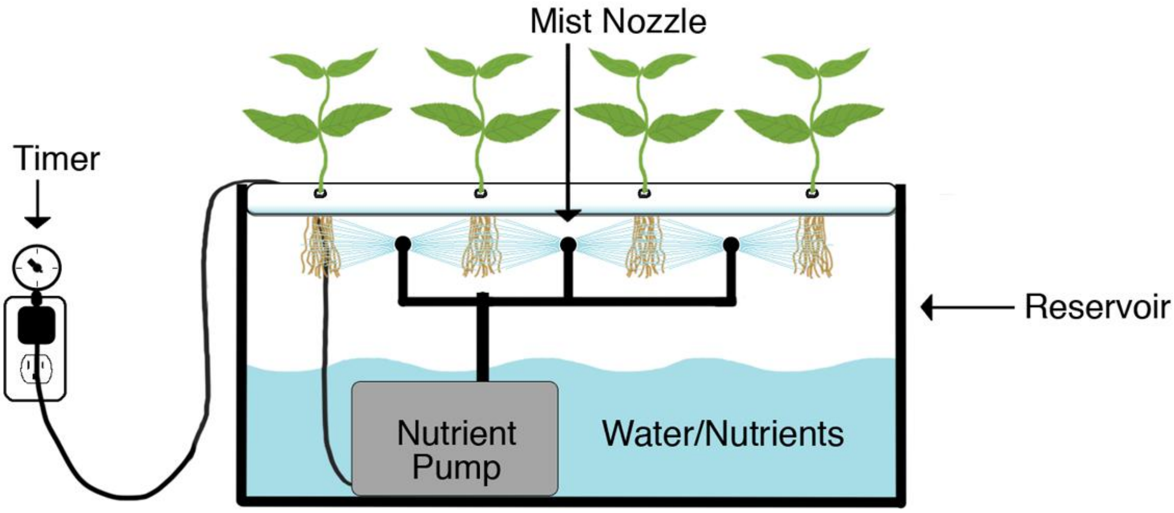


Fig 3.3 layout of the simple misting time

3.4.3.2 Simple misting time - Field Set up

For constructing simple misting time system set up,A bucket of 50 l capacity was taken. It was filled with a 30 l of salt solution prepared in such a proportion so that 1g of salt is dissolved in 1 l of water. The foggers were attached on the pipes with T Joints and they were supported on the clamps fabricated by using mild steel.3 nos of low pressurized foggers were used. On the surface of the bucket a thermocol of size of 54.5×2.5×44cm was placed. The sheet was provided with nine holes of diameter 8cm same as that of the top diameter of the grow cups. Inter hole spacing was maintained as 9.5cm row to row and 18cm plant to plant. The plants were planted in the small grow cups and then it was fixed in the thermocol sheet in the holes provided.

Table 3.4 On-Off time schedules of the simple misting time

TIME	ON/OFF
4 AM - 6 AM	ON
6 AM - 8 AM	OFF
8 AM - 11 AM	ON
11 AM - 12 PM	OFF
12 PM - 4 PM	ON
4 PM - 5 PM	OFF
5 PM - 8 PM	ON
8 PM - 10 PM	OFF
10 PM - 12 PM	ON
12 AM - 4 AM	OFF

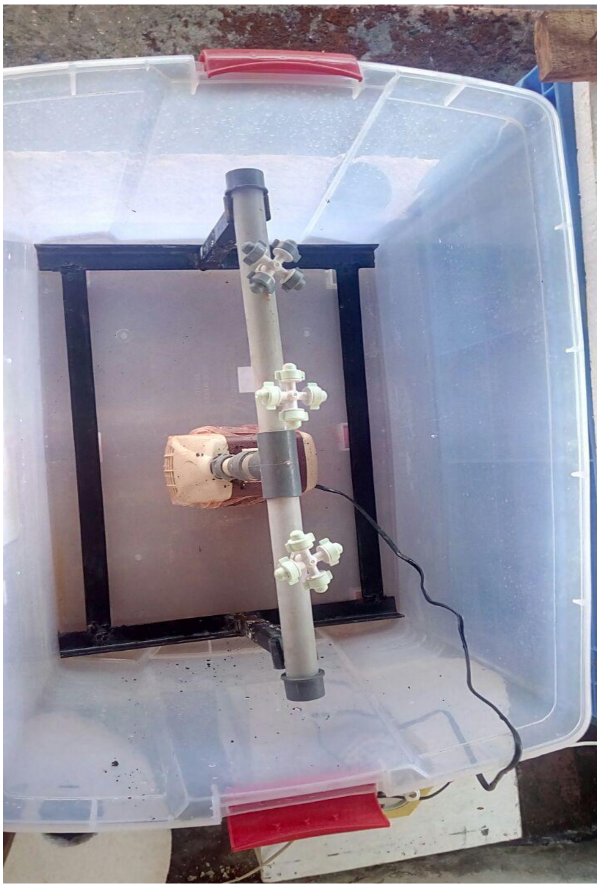


Plate 3.2 image of simple misting system

3.4.3.3 Crop raising

Seedlings of size 8cm height and 9 plants were selected for transplanted.

3.4.4 SIMPLIFIED SYSTEM WITHOUT EMITTERS

3.4.4.1 Description

In this system, the pump is submersed in the nutrient solution in the bottom of the 70l bucket. The tubing (or hose) has several small holes drilled into it. The tubing is positioned to coil around the bucket from bottom to top, and is plugged at the top end.The roots will be getting good coverage with the hydroponic nutrient solution. An submersible pump works well for this. The materials used for the simplified system without emitters is given in Table 3.4

Table 3.5 Materials used for the construction of Simplified system without emitter

Materials	Specification/ Dimension	Quanti ty
Hose/pipe	¾ inch	3m
Long bucket	70 l	1
Coirpith	-	1kg
Vaccum clips	-	10
Submersible pump	40 W, 3200l/min	1
Thermocol	45mm	1

The experimental set up is given in Fig-3.4

Fig 3.3 image of simplified system without emitter

3.4.4.2 Simplified system without emitter Field-set up

For preparing simplified system without emitter set up, A bucket of 70 l capacity was taken . it was filled with 40 l of salt solution prepared in such a proportion that 1g of salt is dissolved in 1 l of water , The hose were positioned to coil around the bucket from bottom to top, and is plugged at the top end. The hose was provided with several holes drilled on it at a diameter of 2mm at regular interval. And the hose is connected to the pump placed at the bottom inside the bucket. On the surface of the bucket a thermo col sheet of size 45Ø was placed. The sheet was provided with four holes of diameter 12 cm same as that of top diameter of the grow cups. Inter hole spacing was maintained as 9.5cm in row to row and 18cm plant to plant. The plants were planted in the small grow cups and then it was fixed in the thermo col sheet in the hole provided.

Plate 3.3 image of simplified system without emiters

3.4.4.3 Crop raising

Seedlings of size 8cm height and 9 plants were selected for transplanting.

3.5 Nutrient solution

Nutrient solution is the major part of the Aeroponics and Hydroponics techniques which decides its successes. These techniques has no meaning without nutrient solution. It is important to follow the dilution rate recommended. Stock solution is the concentrated solution of mixed nutrients which is diluted with water to make the nutrient. The macro nutrients (N, P, K, Mg, Ca, S) and micro nutrients (B, Zn, Fe, Mn, Cu) were properly mixed separately. Both were in salt form. Compositions of nutrients in the diluted solution supplied to each of the systems are given in Table 3.4

Table 3.6 Inflow Nutrient solution concentration

Element		concentration in ppm	
		A	B
N	(NO3-)	159.935	0.001
K2O		0.000	1.086
P2O5		0.000	0.818
Mg		0.755	124.542
Ca		1.000	0.000
S		0.000	164.621
Fe		0.020	0.000
Zn		0.000	0.001
B		0.000	0.005
Cu		0.000	0.001
Mo		0.000	0.001
Na		0.050	0.000
Si		0.000	0.000
Cl		0.000	0.000
Mn		0.000	0.005
N	(NH4+)	0.000	0.000

3.6 FIELD EXPERIMENT

System performance was analysed on the basis of the factors such as temperature , relative humidity etc. The readings were taken 2 weeks . it was measured by using humidity meter. Then after amaranthus performance was analysed on the basis of morphological parameters. Readings were taken week. pH measurements of the solution were noted once in four days .

The plants are transplanted three times due to stunted behaviour. The transplanted dates are 28 Nov to 13 Dec , 14 Dec to 21 Dec , 22 Dec to 16 Jan. Readings are also noted durings each transplantations. They are included in the next chapter. The measuring factors as follows, they are ;

3.6.1 pH Measurements

pH is a measure of whether the solution is alkaline or acidic. The pH scale runs from 0-14. A lower value indicates acidity; a higher value indicates alkalinity. Fresh water is neutral at a pH of 7. Sample solution is taken in small beakers and the meter is inserted in the solution. When the meter shows a constant reading, that reading was taken into account.

3.6.2 Morphological measurements

The tagged best plant in each system was monitored to measure the growth and yield parameters.

3.6.2.1 Crop height

The height of crop was measured from the base level to the every 7 days.

3.6.2.2 Number of leaves

Number of leaves per plant in each system was noted at 7 days interval.

3.6.2.3 Node to node distance

The distance between the two consecutive nodes was measured in each plant.

After these readings, system performances are noted by measuring the Temperature and humidity of the systems for finding the problem associated with growth factor .

3.6.3 EVALUATION OF SYSTEM PERFORMANCE

3.6.3.2 Temperature measurement

Temperature inside the four systems are noted. Optimum temperature for the Hydroponic and Aeroponics system should be 25 °c . The readings noted from the each system are included in the next chapter.

3.6.3.3 Humidity measurement

Optimum humidity for these techniques should be 50 to 80%. The humidity inside the four systems are noted.

CHAPTER 4

RESULTS AND DISCUSSION

Results obtained from the system performance studies and field trials on the comparative evaluation of Hydroponic and Aeroponic techniques for terrace cultivation of Amaranthus were analyzed and the details are discussed under various headings in this chapter.

4.1 EXPERIMENT SET UP

Based on the procedures explained in section 3.4 four different systems viz Floating system, Recirculating system, Simple misting system and simplified system without emitters were designed and developed. The systems were installed in the roofed area of the terrace of the auditorium building and evaluated for the crop Amaranthus during the months from November 2016 to January 2017. The overall view of the designed systems is shown in plate 4.1. Design features of each system are as specified below in Table 4.1

Table 4.1 System Components

Floating system	**Recirculating system**	**Simple misting time system**	**Simplified system without emitter system**
Plastic tray (30 l)	Bucket (60 l)	Trough(50l)	Trough(70l)
Thermocol (51cm×37cm×3cm)	Fogger	Fogger	PVC pipe (¾ inch)
Grow cups 8cmØ, 7cm height	Submersible pump (40 W, 3200 l/min)	Submersible pump (40 W, 3200 l/min)	Submersible pump (40 W, 3200 l/min)
Aerator	Tank (50 l)	Timer (200-250	Thermocol

(2.5 W, 30l/min)		VAC frequency)	45 mmØ

4.2 EVALUATION OF THE SYSTEMS FOR AMARANTHUS CROP

4.2.1. CASE 1

pH variation of nutrient solution during crop growth period.

The variation of pH value of nutrient solution using nutrient (19 :19 :19) mix during the crop growth period was observed every 3 days interval from November 28 to December 13 for about 2 weeks and results from 3 days after transplanting are presented in Fig 4.1

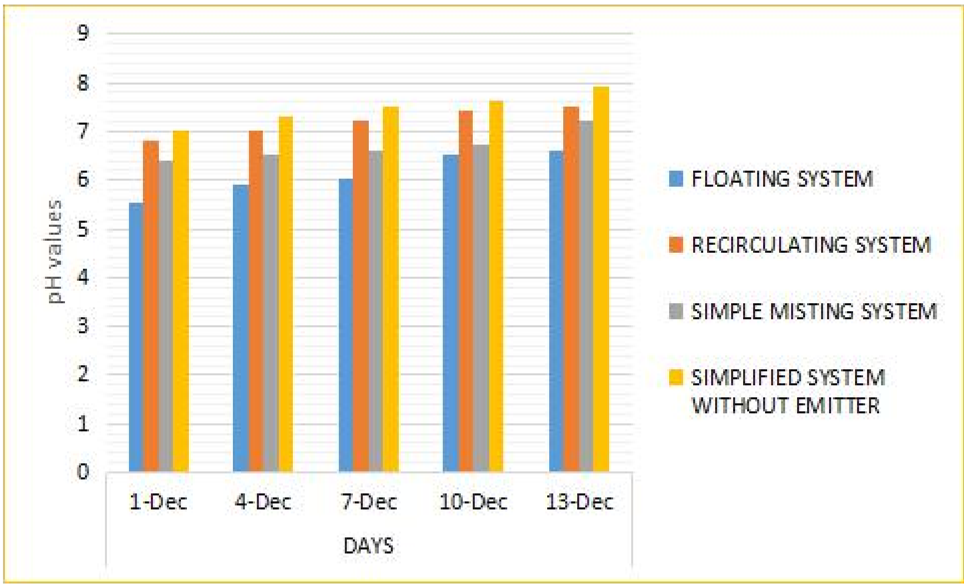


Fig 4.1 Variation of pH of nutrient solution during crop season

From the above graph ,it was understood that though the same solution (19:19:19) was used to start the experiment in all systems, within the growing period itself, pH showed variations in the four systems. In the initial growing period, during the first three days simplified system exhibited more variation in pH than the other systems. Floating system, recirculating system and simple misting system showed only minor variations. Floating system maintained optimal pH for plant growth ie, 6.2 to 6.5. After 7 days the solution was replaced only once. Thus the Floating system is ascertained to be the ideal system to maintain the pH. But in the case of other systems it varies invariably. The simplified system shows the maximum variation .

4.2.3 Biometric observations for amaranthus

The observations on plant growth were taken at every 4 days interval after planting from Nov 28 to Dec 13. After December 13 plants growth seemed to be stunted. But the observations on morphological parameters were made on this selected plant between these intervals. The results are presented in the following figures and tables

Fig 4.2 shows the variation in plant height during crop growth period.

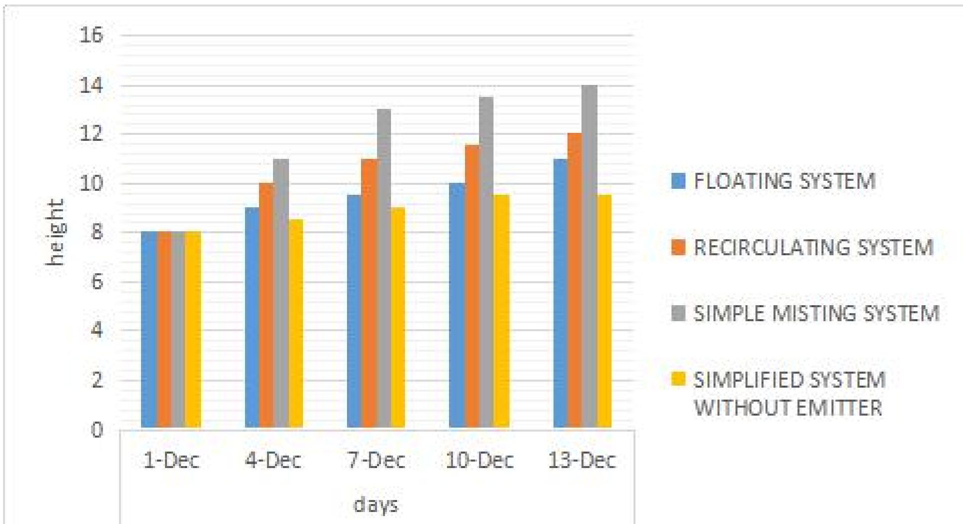


Fig 4.2. Variation of Plant height during crop growth period

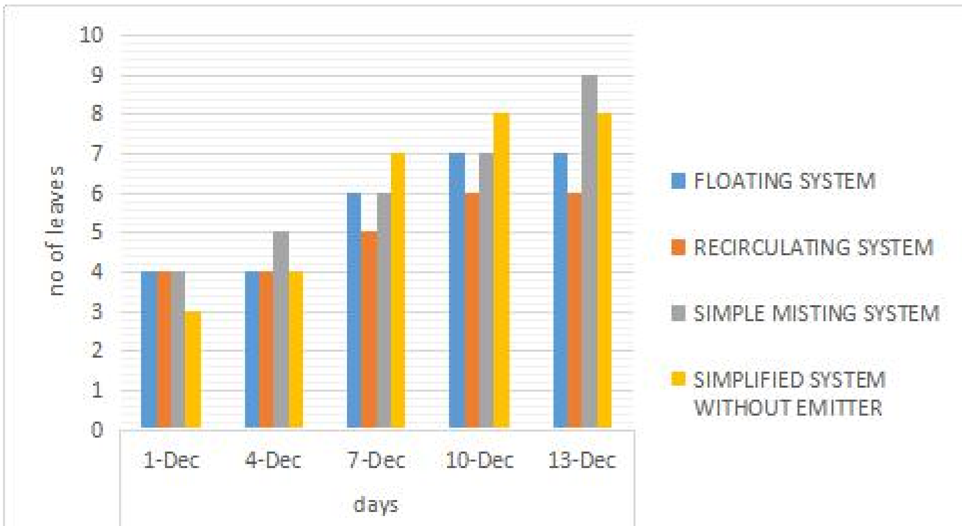


Fig 4.3 Variation of Number of leaves during crop growth period

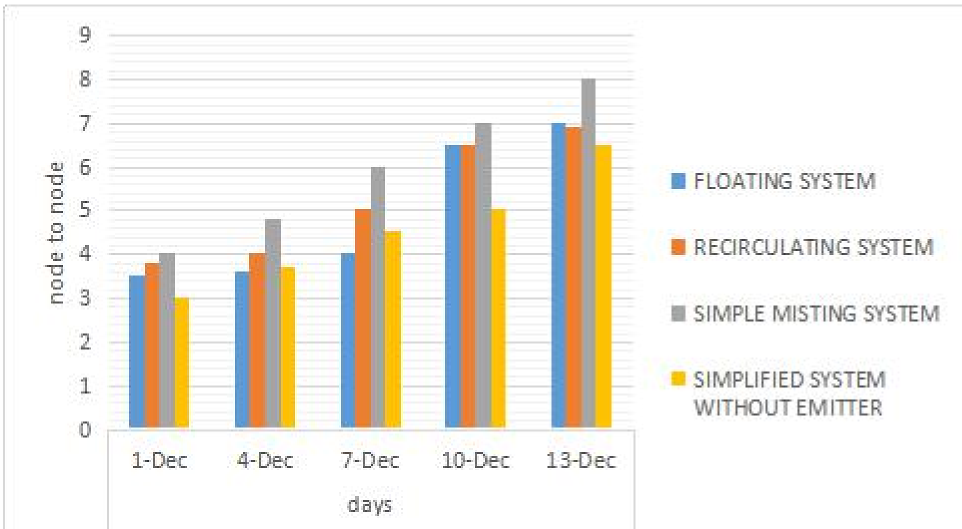


Fig 4.3. Variation of node to node distance during crop growth period

The plant height variations were almost similar in Simple misting system and Recirculating system. The growth was prominent in simple misting system compared to the other systems two weeks after planting. There was a steady increase in height for the simple misting system. Variation in the no of leaves as seen in the graph shows that simple misting system is having more leaves during 13th December compared to other systems. Node to node distance were almost similar in simple misting system and recirculating systems during last days of observation.

After two weeks, the plant growth seemed to be stunted and some of the plants wilted off. The lack of micro nutrient supplies in the nutrient solution and the temperature developing inside the chambers may be the reason for crop failure. Also use of foggers and perforated pipes in the aeroponic systems caused high pressure spray which might have damaged the roots of seedlings.

4.3 CASE 2

In this case, Urea alone was used as nutrient for Amaranthus to see whether the plants could pick up in this nutrient solution as is done in Aquaponic systems. Instead of applying macro and micro nutrient mixes, urea alone was dissolved and this solution was sprayed to plant roots through the systems.

4.3.1 pH variation of nutrient solution during crop growth period.

The variation of pH value of nutrient solution with Urea alone as nutrient during the crop growth period was observed every 3 days interval from Dec 14 to Dec 26 for about 2 weeks and results from 3 days after transplanting are presented in chart.

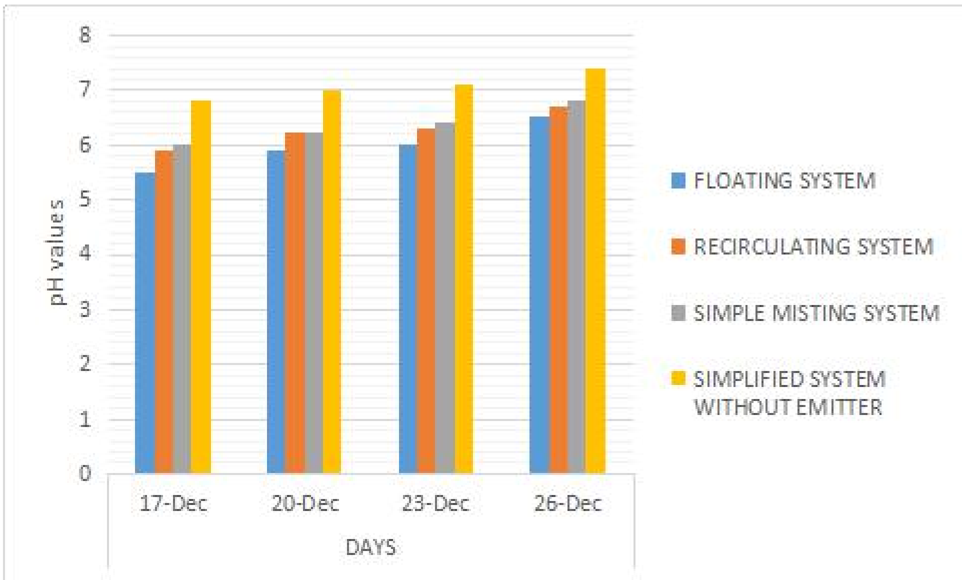


Fig 4.4 Variation of p H of nutrient solution –Case II

During the initial period, recirculating system and simple misting system have pH above the optimum level, simplified system has pH below optimum level and floating system has pH which is nearer to optimum value. Towards the last period of observation, floating system has maintained the pH value compared to the other systems. For maintaining the pH value of solution, the nutrient solution was replaced once .

4.5 Biometric observation

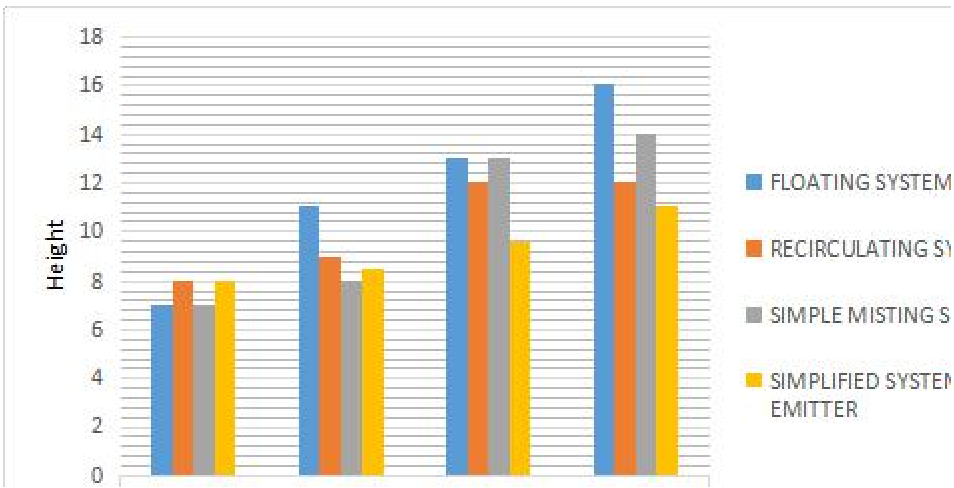
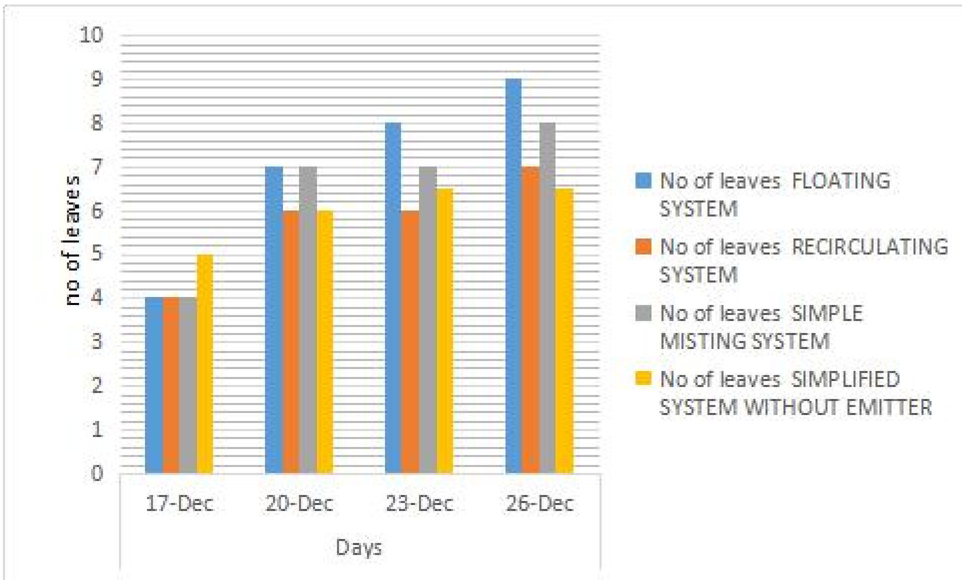
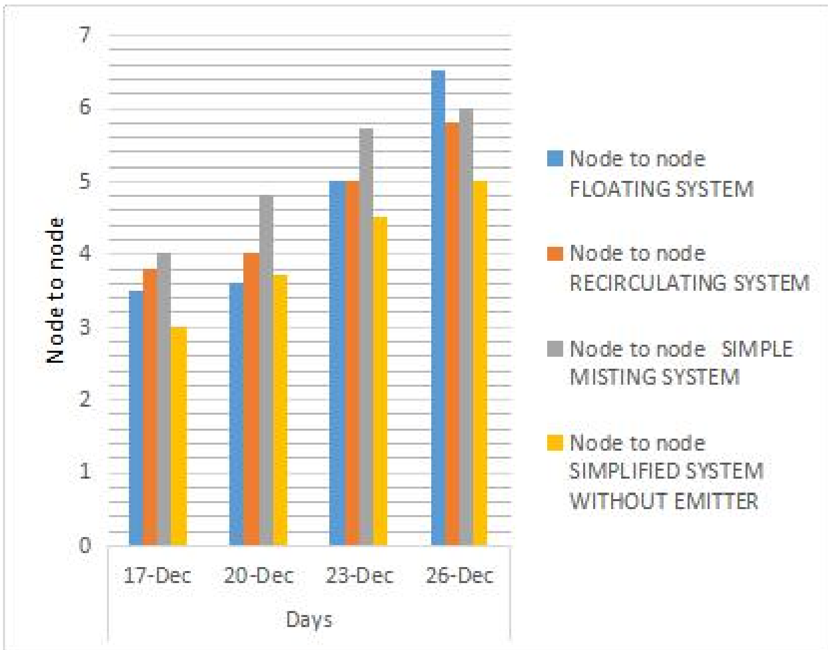


Fig 4.5. Variation of plant height during crop growth period



4.6 Variation of no of leaves during crop period



4.7. Variation of node to node during crop period

From the graphs, during the first stage of observation, the height of the plant, no of leaves and node to node distance were almost similar in each system After that as the growth of plant proceeds , the above parameters observed from each system were different. During 17 to 21 of Dec , the height of the plant , no of leaves and node to node distance were seen maximum in floating system compared to the other systems Poor growth was observed in simplified system without emitters. After this period of observation, growth of plants was again stunted, so another transplantation was done. Here excess of ammonia was found to be produced while reacting with water.

Since this ammonia produced is toxic it may have killed the seedlings.

4.6 CASE 3

In this case all the micro and macro nutrients were applied separately by mixing non reacting salts in two tanks in measured amounts.

4.6.1 pH variation of nutrient solution during crop growth

The nutrient used contained all micro and macro nutrients in Tank A and Tank B concept. pH variation of nutrient solution during crop growth period was observed every 3 days interval from Dec 26 to Jan 16 for about 3 weeks and results from 3 days after transplanting are presented in chart.

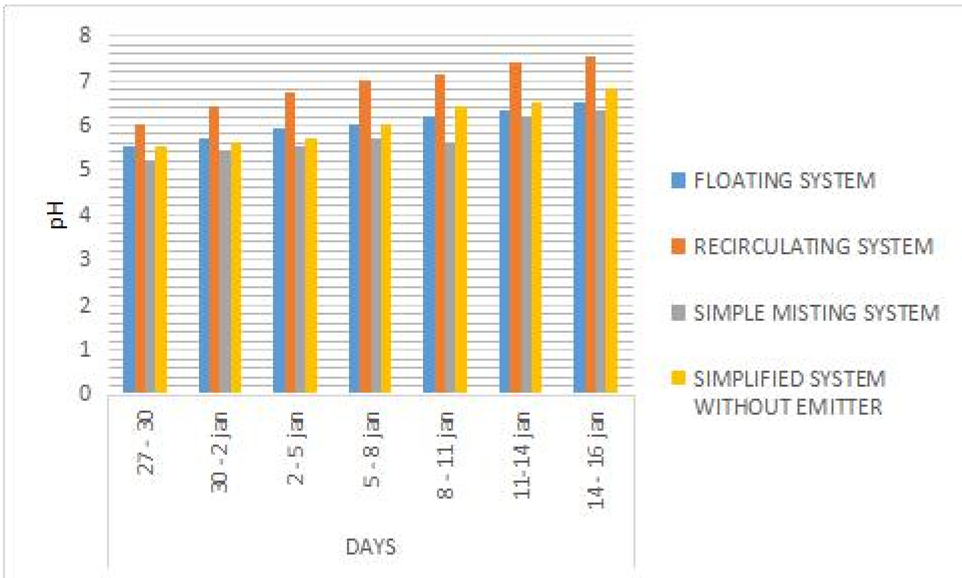


Fig 4.8. Variation of pH of nutrient solution during crop growth period

From the above graph we can see that during growing stage , the pH of solution is almost below optimum level for all systems. Then pH of the recirculating system is predominantly increased than the normal compared to the other systems. It has been observed that pH of the solution is at the optimum level and other systems are having nearer to optimum level .The solution was changed twice in order to maintain the pH level. The optimum pH level is 6.3 to 6.5.

4.7 Biometric observation

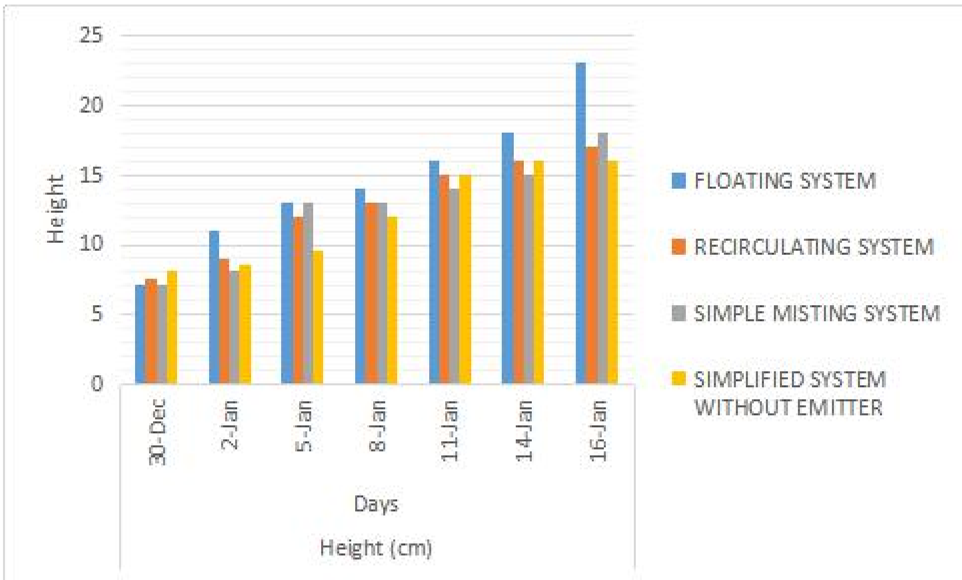


Fig 4.9 Variation of plant height

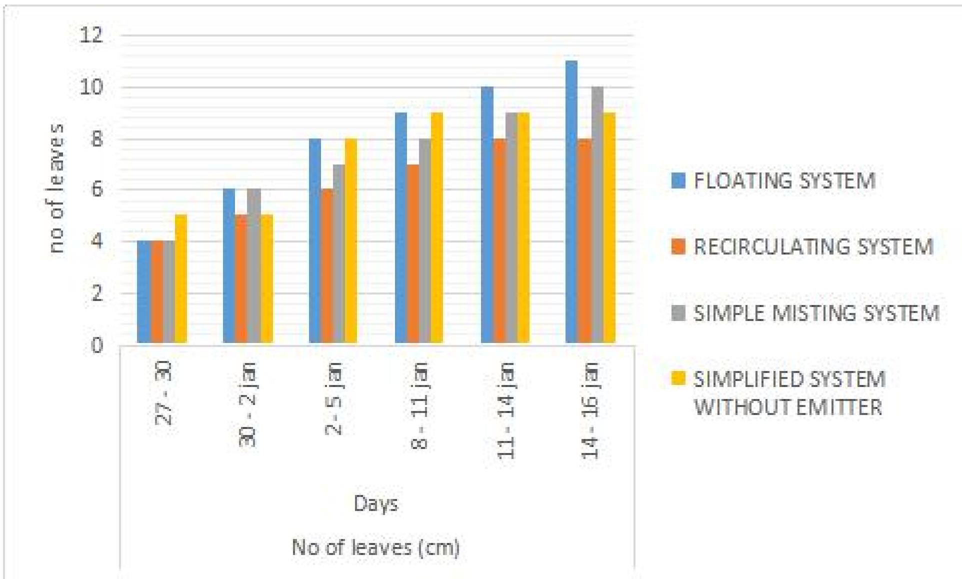


Fig 4.10 Variation of no of leaves

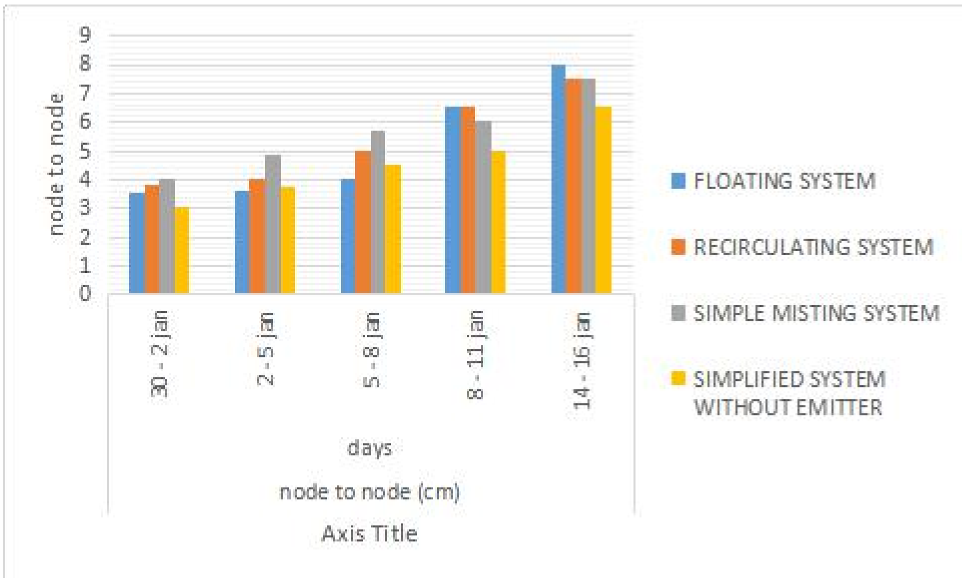


Fig 4.11 Variation of node to node distance

During growing stage, height of the plant, no of leaves, and node to node distance were almost similar. As the growth proceeds during each intervals of observation it was seen that floating system is having maximum values. Lowest growth was observed in simplified system without emitter. After three weeks observation plant growth became stunted and some of them wilted off.

Plate 4.1 Floating system

Plate 4.2 Re-circulating system


Designer
CONTAINERS
ARISTO

Plate 4.3 Simple misting system

Plate 4.4 Simplified system without emiter

4.8 EVALUATION OF SYSTEM PERFORMANCE

Due to the stunted growth of plant in the systems in three cases. It was decided to compare the micro climatic parameters inside the systems with the standard values required for plant growth. For the proper growth of an amaranthus plant it requires an optimum temperature of 25^{o}C and relative humidity of 70% .

The temperature developed inside the system was monitored for 10 days from 16/1/2017 – 26/1/2017

Table 4.2 Temperature(^{o}C) variation-simplified system without emitter

TIME	10am	12pm	2pm	4pm	6pm
DAY 1	27	29.2	30.6	28.5	28
DAY 2	29.1	29.4	29	28.7	28.6
DAY 3	28.8	29.1	28.7	28.2	26
DAY 4	27.7	28.3	28.1	27.6	27.1
DAY 5	32	32.4	31.5	30.8	29
DAY 6	32.7	33.3	32.6	32.4	
DAY 7	28.7	29	28.9	28.4	28.3
DAY 8	25.6	26.3	26.1	25.8	25.8
DAY	26.1	27	27	26.4	26.3

9					
DAY 10	26.7	27.5	26.9	26.9	26.7

Table 4.3 Temperature(°C) variation-re-circulating system

TIME	10am	12pm	2pm	4pm	6pm
DAY 1	28	28.8	28.4	27.8	27.7
DAY 2	28.2	28.7	29.1	28.53	28.3
DAY 3	28.67	29.1	29.1	28.6	28.34
DAY 4	28.1	28.6	28.7	28.4	27.9
DAY 5	31.58	31.7	32	31.9	31.1
DAY 6	32.4	33.1	33.47	32.8	32.2
DAY 7	31.3	31.7	31.2	30.7	29
DAY 8	28.7	29.1	29	28.7	28.45
DAY 9	27.8	28	28.3	27.9	27.6
DAY 10	28.4	28.9	28.7	28.3	27.9

Table 4.4 Temperature(°C) variation-simple misting system (ON- 2hr, OFF– 0.5hr)

TIME	10am	12pm	2pm	4pm	6pm
DAY 1	29.4	29.8	29.7	29.5	29.4
DAY 2	29	29.7	30.1	29.4	29.1
DAY 3	28.7	29.3	29.1	28.8	28.4
DAY 4	29.7	30.2	30	29.4	28.9
DAY 5	30	30.2	31.7	30.9	28
DAY 6	30.7	31.72	31.8	31	28
DAY 7	30.2	31.6	32.2	31.8	31.5
DAY 8	29.8	30.5	30.5	30.1	29.76
DAY 9	29.4	29.6	29.8	29.3	28.8
DAY 10	29.6	30.1	29.7	29.3	28.7

The relative humidity (%) inside the systems were measured for 10 days

Table 4.5 Relative humidity (%) variation-simplified system without emitter

TIME	10am	12pm	2pm	4pm	6pm
DAY 1	75.67	45	56	58.37	64
DAY 2	78	55	60	64.56	68.3
DAY 3	85.87	65.53	69.14	72.4	75.1
DAY 4	63.4	57	62.74	68.46	69.1
DAY 5	50.4	41.35	52.71	57.63	65.6
DAY 6	76.1	68.7	73.14	79.4	83.8
DAY 7	85.74	76.5	78.14	83.12	88.12
DAY 8	84.78	76.8	78.23	81	83.21
DAY 9	86.78	78.85	75.12	79.2	81.8
DAY 10	78.32	55.45	59.3	68.2	76.2

Table 4.6 Relative humidity (%) variation-re-circulating system

TIME	10am	12pm	2pm	4pm	6pm
DAY 1	64.66	47	60	57.5	69
DAY 2	67.35	49.52	54.12	67.5	72.3
DAY 3	75.4	59.4	66.56	73.54	76.12
DAY 4	66.89	41.23	54	59.82	66.48
DAY 5	64.63	47.52	59.86	72.45	76.25
DAY 6	69.25	49.89	63.47	68.7	74.18
DAY 7	80.14	64.23	72.5	78.45	83.45
DAY 8	81.23	69.22	75.26	77.45	78.98
DAY 9	74.56	68.2	73.12	75	75.3
DAY 10	83	65.88	73.56	78.45	79.12

Table 4.7 Relative humidity (%) variation-simple misting system

TIME	10am	12pm	2pm	4pm	6pm
DAY 1	72.37	44	54	56	66
DAY 2	75.23	56.71	63.12	66.66	68.45
DAY 3	73.25	50.23	57.45	53.54	58.79
DAY 4	69.89	47.12	58.23	64.78	70.14
DAY 5	71.21	54.23	64.89	72.32	75.22
DAY 6	78.74	58.25	67.12	64.32	72.1
DAY 7	79.78	53.5	62	69.23	75.1
DAY 8	76.85	48.2	57.19	61.36	68.97
DAY 9	71.12	43.52	63.25	68.29	74.73
DAY 10	78.36	57	68.23	74.12	79.82

4.12 VARIATIONS OF AVERAGE TEMPERATURE (˚C)

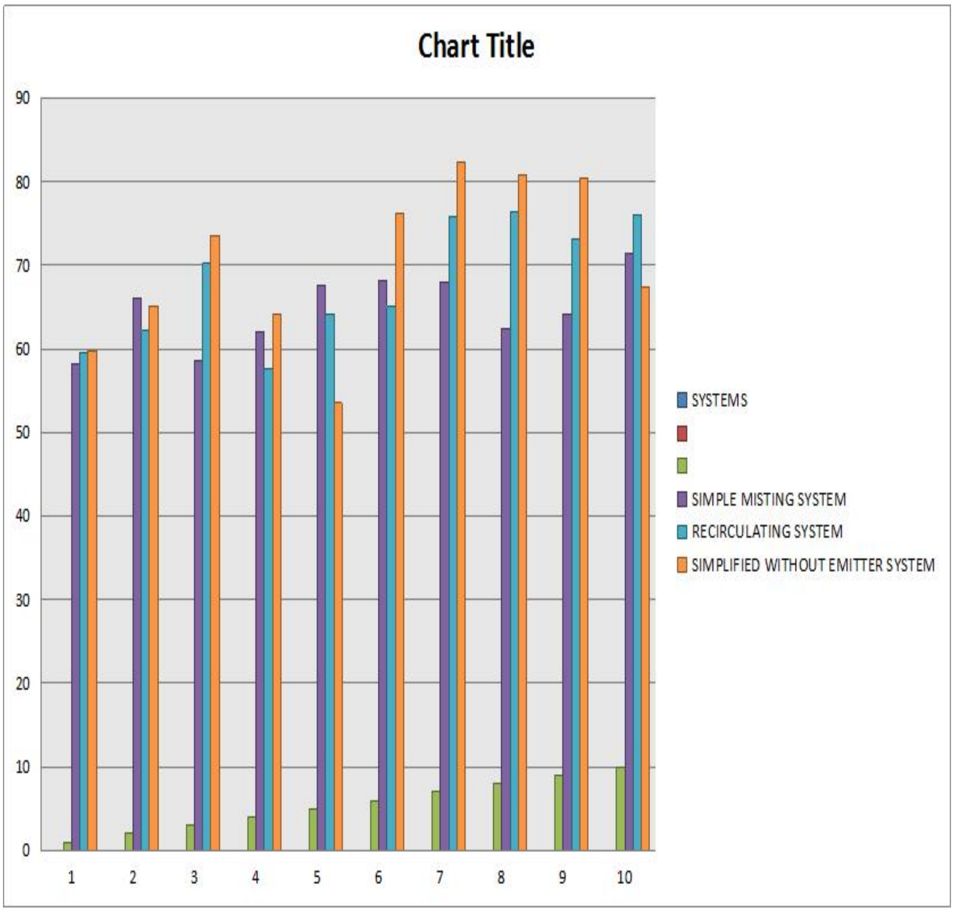


Fig 4.12 variation of average temperature

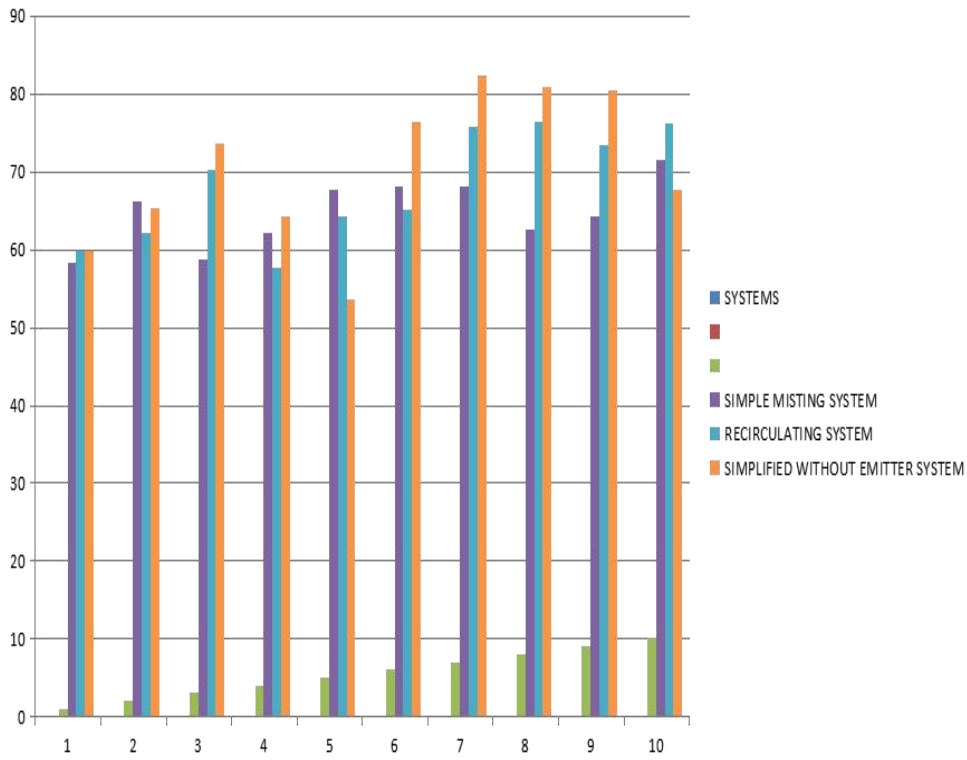


Fig 4.13 variation of average relative humidity

From the study, it was found that Simplified system without emitters was almost maintaining the optimum temperature. In Simple misting system and Recirculating system, the average temperature is almost 30˚C.Therefore the temperature around the root zone increases and, this may have caused damage of roots. From the above data (chart 2), the Simplified system without emitters seemed to obey the optimum humidity range 70%. In Recirculating and Simple misting systems, the humidity is less than the optimum condition. It is seen to be about 68% in both the systems.

From the overall observations of crop performance and micro climatic studies in the selected hydroponic and Aeroponic systems it was found that the Hydroponics system that is floating system and from the aeroponics system that is simple misting system performed well compared to the other systems and can be recommended for terrace cultivation of vegetables after conducting more crop specific studies for long durations.

4.10 Suggestions for future research

- Make the temperature controlled by colouring the insid of troughs black.
- Drop size should be less- Misting or fogging may be a better option in Aeroponics.
- Proper aeration
- Stakes are required for support during high wind.
- Amount of ammonia should be controlled.
- Pressure should be in controlled in the system

CHAPTER 5

SUMMARY AND CONCLUSION

Soil is usually the most available growing medium for plants and provides anchorage, nutrients, air, water etc for successful plant growth. However soil do pose serious limitations for plant growth like presence of disease causing organisms and nematodes, unsuitable soil reaction, unfavorable soil compaction and poor drainage. With the advent of civilization, open field/soil-based agriculture is facing some major challenges mainly due to the decrease in per capita land availability. Due to rapid urbanization and civilization as well as the intricacies caused by global warming, arable land is further going to decrease. Under such circumstances, in the 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. In soil-less culture, plants are raised without soil. Improved space and water conserving methods of food production under soil-less culture like Hydroponics and Aeroponics have shown some promising results all over the world.

In this study, Four different systems viz Hydroponic Floating system, Aeroponic systems like Recirculating system, Simple misting system and Simplified system without emitters were designed and developed. The systems were installed in the roofed area of the terrace of the auditorium building and evaluated for the growth parameters of Amaranthus crop *CO1* variety during the months from November 2016 to January 2017.Evaluation of the system for Amaranthus crop were done using three cases of nutrient formulations .The same nutrient solution (19:19:19) was used to start the experiment in all systems. Within the growing period itself pH values of the nutrient solution exhibited variations in four systems. In all these cases during growing stage height of the plant, no of leaves, and node to node distance were almost similar. As the growth proceeded during each intervals of observation, it was seen that floating system was having maximum values. Lowest growth was observed in simplified system without emitter. After three weeks observation as the plant growth became stunted replanting was done and Urea alone was used as the fertigation solution. As the results were not encouraging, nutrient formulation with all micro and macro nutrients in Tank A-Tank B concept was applied. The growth parameters were observed as floating system shows better growth compare to all systems . Comparison of micro climatic condition in the chambers were done by monitoring the temperature and humidity in order to identify reasons for crop failure. For the proper growth of Amaranthus plant it requires an optimum temperature of 25˚C and humidity of 70%. It was found that Simplified system without emitters is almost obeying the optimum temperature and humidity . In Simple misting system and Recirculating system the average temperature was almost 30˚C. In Recirculating and simple misting system the humidity is less than the optimum condition, about 68% in both the systems.It was found that the supply of complete macro and micro nutrients in separate tanks was ideal for proper plant growth. When comparing the Aeroponic and Hydroponic systems it was found that Floating hydroponic system was giving good plant growth parameters. Among the Aeroponic systems, it was found that Simple misting system gave good plant performance. In the aspect of maintaining the micro- climate inside the aeroponic system, it was found that Simplified system without emitters was ideal for cultivation by maintaining optimum temperature and humidity. More modifications of the operating conditions by painting the inside of troughs with black and use of mist or very fine spray of nutrients instead of high application rate foggers etc have to be tried in order to standardize the results.

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COMPARATIVE EVALUTION OF SIMPLIFIED HYDROPONIC TECHNIQUES FOR VEGETABLE CULTIVATION

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ABSTRACT

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ABSTRACT

COMPARATIVE EVALUTION OF SIMPLIFIED HYDROPONICS TECHNIQUES FOR VEGETABLE CULTIVATION

Four different simplified Hydroponic systems were evaluated for their performance regarding crop growth and micro climatic conditions. The systems used were Floating/Water culture system, Aeroponic systems like Recirculating system, Simple misting system and Simplified system without emitters. The systems were designed, fabricated and installed in the roofed area of the terrace of the auditorium building and evaluated for the growth parameters of Amaranthus crop *CO1* variety during the months from November 2016 to January 2017.Evaluation of the systems were done using three cases of nutrient formulations, Macro nutrients alone as a complex (19:19:19),Urea alone and all macro and micro nutrients in Tank A -Tank B concept. Floating system used water culture principles with the crops planted in grow cups on a thermocol sheet and the roots floating in the nutrient solution in the trough. The second system was a recirculating system with the nutrient solution applied by using foggers around plant roots and the residual nutrient flowing to a separate tank from where it was recirculated. The simple misting system applies the nutrient solution by using foggers attached to the pipe and timer controlled mechanism was used to manage irrigation. The simplified system without emitters used a perforated pipe attached to a pump in a deep trough to spray the nutrient to the roots of plants. The system performance was analyzed on the basis of plant morphological parameters, cost and micro climatic conditions.. Micro climatic parameters like temperature and relative humidity were monitored inside the troughs. It was found that Simplified system without emitters almost obeyed the optimum temperature and humidity ranges. In Simple misting system and Recirculating system the average temperature was almost 30˚C. In Recirculating and simple misting system the humidity was less than the optimum condition, about 68%. It was found that the supply of complete macro and micro nutrients in separate tanks was ideal for proper plant growth. When comparing the Aeroponic and Hydroponic systems it was found that Floating hydroponic system was giving good plant growth parameters. Among the Aeroponic

systems, it was found that Simple misting system with timer controls gave good plant performance. More modifications of the operating conditions by painting the inside of troughs with black and the use of mist or very fine spray of nutrients instead of high application rate foggers etc are to be tried in order to standardize the results.