STANDARDIZATION OF HYDROPONICS IN TOMATO

By

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THESIS

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DECLARATION

I Reshma T (2014-12-103), hereby declare that the thesis entitled **"Standardization of hydroponics in tomato"** is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me any degree, diploma, fellowship or other similar title, of any other University or Society

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CERTIFICATE

Certified that the thesis entitled **"Standardization of hydroponics in tomato"** is a bonafide record of research work done independently by **Ms. Reshma T. (2014-12-103)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her

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Reshma T

Dedicated to my
parents and teachers

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INTRODUCTION

1. INTRODUCTION

Vegetables have a vital role in human diet Since they provide essential nutrients like vitamins and minerals to the body, they are known to be the protective food Another important constituent in vegetables are dietary fibers, which help to reduce the bad cholesterol in the body and improve bowel movements The functional and therapeutic benefits of vegetables are also being valued now. The commonly seen vitamins in vegetables include Vitamin A and Vitamin C Vitamin A helps eyes and skin to stay healthy and gives protection against various infections Vitamin C helps to heal wounds and keeps teeth and gums healthy Vitamin C has a role in iron absorption and also it is considered as an antioxidant Tomato, peppers, leafy vegetables etc are rich in vitamins

Among vegetables, tomato have world wide popularity, they are low in calorie and hold just 18 calories per 100 g They are also very low in fat and have zero cholesterol level The important pigment found in tomato is lycopene, which is a flavonoid antioxidant. Together with carotenoids, lycopene may protect cells and other structures in the human body from harmful oxygen-free radicals, and reduce the risk of cancer Fresh tomato is very rich in potassium (237 mg /100 g) Potassium is an important component of cell and body fluids that helps in controlling heart rate and blood pressure, hence very important in human diet But the conventional soil cultivation of tomato is subjected to various problems like soil borne diseases, insects and weeds Along with these the unavailability of productive land and the shortage of irrigation water have emerged as important constraints in production recently In these circumstances modern production techniques like hydroponics gain importance

The word hydroponics literally means "working water", but actually it is a method of growing plants without soil or with an inert substrate added with all necessary nutrients It is a valuable means of growing fresh vegetables not only in countries having little arable land and in those which are very small in area yet have a large production The enhancement of product quality, particularly in vegetable crops, such as tomato, melon, and lettuce can be achieved through the complete control of nutrition in hydroponics (Savvas, 2003) In hydroponics it was hoped to reproduce the natural conditions of growth as accurately as the use of artificial means would allow (Gericke, 2007) The achievement of maximum yield by the supply of sufficient quantity of nutrients and optimum microclimatic conditions are the main goal of hydroponics (Bogovic, 2011) It does not need any fertile soil for the production of crops Since soil is excluded from production process there will not be any problem related to soil born diseases, pests and weeds By the exclusion of these problems, there will not be any usage of harmful plant protection chemicals, so the yield from hydroponics is fresh and healthy The set up of hydroponics also demands limited space and limited quantity of water through recirculation and reuse So this technique can be adopted under low water conditions and degraded lands or problem soils The limited space requirement increases the advantage of hydroponics, because it can be accommodated in terraces, balconies and courtyards So it gives a great opportunity for the production of fresh crops in urban areas, where cultivable land is limited Hydroponics does not cause any adverse effect on the quality of fruits and flowers produced in it

There are different methods in hydroponics The difference in each method is based on the structure set up, which determines how the prepared nutrient solution is supplied to the plants So it can be divided into

- Deep Water Culture (DWC), where plants are suspended in nutrient solution enriched with oxygen
- Wick hydroponic systems, where the wicks run from the base of the container down to a reservoir and draw the nutrient solution

- Ebb and Flow technique, where plants are grown in beds flooded with nutrient solution and then the nutrient solution is allowed to drain back to the reservoir
- Deep Flow Technique (DFT) or Nutrient Film Technique (NFT), where the nutrient solution flow over the roots continuously

The later two methods require an inert medium like coco peat, pebbles, expanded clay pellets, sand etc to support the plants based on the availability and affordability The nutrient solutions for plants are prepared by mixing the mineral salts

Now a days, in Kerala, more people from urban areas are showing interest towards modern techniques in agriculture The changing health concern of people also demands high quality food According to ICMR recommendation, one should take 350g of vegetables through their daily diet But in a state like Kerala, where there is severe shrinking of cultivable land and water, the production of such a huge quantity is a great challenge So, due to its limited production, vegetables are very costly now The health issues due to the uncontrolled use of plant protection chemicals and other hazardous materials also create problems All these, forces the adoption of techniques which produce more yields from less area using limited resources Under hydroponic system, people can utilize their balconies, terraces and other unoccupied corners for growing healthy, fresh vegetables Hence a preliminary study was carried out to standardize the nutrients, methods and growing media for the hydroponic cultivation of tomato in rain shelter

REVIEW OF LITERATURE

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2. REVIEW OF LITERATURE

Hydroponics or soilless cultivation has been widely used in different countries because of its feasibility and environmental safety According to Olympios (1999), this technique can be considered as the best alternative in areas where serious soil and water problems like soil born pests and diseases, soil and water salinity, chemical residues in soil and water, shortage of water etc exist In hydroponics, plants are grown by directly supplying optimum amount of nutrients in water. Composition of nutrient solution, electrical conductivity, pH and oxygen concentration have direct influence on the yield and quality of crops grown under hydroponics If any of these factors are non optimal, crops expresses stress symptoms (Gorbe and Calatayud, 2013)

STUDIES ON HYDROPONICS

2.1. NUTRIENT SOLUTION

2.1.1. COMPOSITION OF NUTRIENT SOLUTION

In a study on growth and carbohydrate content of tomato seedlings in hydroponic solutions, Kamal *et al* (1974), found that plants gained high net assimilation rate, relative growth rate and dry matter accumulation in Hoagland solution

The study conducted by Cheng and Dube (1976) revealed that tomato plants when grown hydroponically by supplying Hoagland solution resulted in high yield with fruits rich in sugar and ascorbic acid content

Abou-Hadid *et al* (1989) pointed out that the yield of tomato cultivars 'Turquesa' and 'Carmello' increased by 32 per cent and 21 per cent respectively when grown under NFT using Cooper's nutrient solution

An experiment carried out by Miliev (1997) at Maritsa Vegetable Crops Research Institute, Bulgaria, proved that the tomato cultivar 'Lucy' produced more vegetative growth and better yield in Cooper's solution than 'Plantan' solution under hydroponics

Munoz *et al* (2006), in their study entitled nitrogen fertilization in hydroponic cultivation of tomato, stated that, the reduction in nitrogen concentration (11, 9 and 7 milli eq nitrogen/l) did not decrease the tomato production and it did not make any significant variation on the diameter and dry and wet weights of tomato

In a study carried out on the potassium level, physiological response and fruit quality of hydroponically grown tomato by Almeselmani *et al* (2009), showed that the addition of potassium at the rate of 300 mg/l to the hydroponic media improved the plant growth, fruit yield and fruit quality of tomato The addition of potassium directly influenced the postharvest preservation and processing also

A study was conducted by Shah and Shoh (2009) at Department of Horticulture, NWFP Agricultural University, Peshawar, to determine the effect of different nutrient solutions on lettuce grown under non circulating hydroponic system The results revealed that lettuce cultivar 'Dutch' when grown in Cooper's solution with a concentration (mg/ litre) of 236- N, 60- P, 300- K, 85- Ca, 50- Mg, 68- S, 12- Fe EDTA, 2- Mn, 0 1- Zn, 0 1- Cu, 0 3- B and 0 2- Mo produced early harvest (35 67 days after sowing), more number of leaves (13 67 per plant), larger average leaf length (17 53 cm), larger leaf area index (234 85cm^2 per plant), more number of roots (225 37 per plant), larger average root length (227 3 cm per plant) and more leaf yield per pot (323 4g)

Shah *et al* (2009 a) reported that spinach cultivar 'Local double' when grown using Cooper's solution with a concentration (mg/litre) of 236- N, 60- P, 300- K, 85- Ca, 50- Mg, 68- S, 12- Fe EDTA, 2- Mn, 0 1- Zn, 0 1- Cu, 0 3- B and 0.2- Mo resulted in early harvest (32 44 days after sowing), more number of leaves (12 33 per plant), larger average leaf length (34 43cm) and more average number of roots (118 45 per plant) through his experiment carried out at Department of Horticulture, NWFP Agricultural University, Peshawar

The cucumber cultivar 'Market more' showed more average number of fruits (26 58 per plant) , high average fruit weight (195 7g), and high average fruit yield (5 75kg per plant) under hydroponics, compared to soil, in a study at Institute of Biotechnology and Genetic Engineering (IBGE) NWFP Agricultural University, Peshawar (Shah *et al*, 2009 b)

An experiment on evaluation of two nutrient solutions for growing tomatoes in a non-circulating hydroponics system by Shah *et al* (2011), showed that tomato crop produced early flowers (54 78 days of seed sowing), early fruits (98 44 days of seed sowing), more flower clusters (14 70 per plant), more fruits (36 03 per plant), larger fruits (77 38g average weight and 4 57 cm average diameter) and high yield (2 787 kg per plant) when grown by supplying Cooper's solution

Ramrez *et al* (2012), through their study at Department of Agronomy University of Guanajuato, Mexico, reported that potassium in the nutrient solution affected the pigment concentrations and beta carotene content of tomato fruits significantly in hydroponics

Castillo *et al* (2012), experiment carried out at Chapingo, Mexico, proved that the difference in fruit number and weight of tomatoes under different concentrations of Ca in the nutrient solution was insignificant but there was significant difference in the chemical composition and quality of fruits

In a study conducted by Zahedifar *et al* (2012) to determine the effect of nitrogen and salinity levels of nutrient solution on the fruit yield and chemical composition of tomatoes under hydroponic culture showed that nitrogen concentration and salinity levels in the nutrient solution significantly increased the vitamin C content of tomato fruits

Ikeda *et al* (2013), conducted a study at College of Agriculture, Japan, found that with increase in nitrate ratio to urea in the nutrient solution, the fruit yield of tomato in Nutrient Film Technique (NFT) increased by 25 per cent

Leal *et al* (2015), in their study at Paulista State University, Brazil, noticed that when nitrogen and potassium were applied at a concentration of 177 2 and 188 7 mg/l respectively in hydroponic nutrient solution, the size of tomato fruits increased, proving that in nutrient solution N and K should be in the ratio of 1 1

In a study carried out at College of Horticulture, Northwest A&F University, China, cucumber seedlings showed better performance (healthy appearance, high biomass and high photosynthetic activity) when grown hydroponically by supplying Hoagland solution under LED light (Li and Cheng, 2015)

Safaei *et al* (2015), through their experiments conducted at Faculty of Agriculture, University of Tabriz, Iran, on effect of different nutrient solutions, noticed that for improving qualitative traits in lettuce, Hoagland solution was the best in hydroponics system,

Araujo *et al* (2016), carried out a study on the effect of levels of N, P and K on the dry matter production and mineral nutrition of hydroponically grown green onion cultivar 'Todo Ano" (*Allium fistulosum* L) The experiments were conducted with each nutrient at three levels starvation, adequate and excessive At 15, 30, 45 and 60 days after transplanting (DAT), dry matter production of shoots and roots were evaluated At 45 and 60 DAT, the contents and total accumulation of N, P and K and the contents of Ca and Mg in the shoots were evaluated In the results they observed that, in hydroponics, N and P deficiencies were more limiting than K deficiency The growth of green onion cultivar 'Todo Ano' with low levels of P mainly affected the growth of the root system Nitrogen deficiency negatively affected the absorption of P, K, Ca and Mg. The toxicity of N in green onion was manifested by excessive growth of the aerial part and increased laxity of the leaves Excessive P and K in the nutrient solution caused no visual symptoms of toxicity of P or K, but excessive levels of K decreased the Ca and Mg contents in the shoots

2.1.2. ELECTRICAL CONDUCTIVITY (EC) OF NUTRIENT SOLUTION

Adams (1994), in his study on nutrition of greenhouse vegetables in NFT and hydroponic systems, reported that the uptake of nutrients by cucumber increased with the applied concentrations of N, P, and K The ratio of absorbed K N did not increase with plant development With tomato, the K N ratio increased with the fruit load from 1 1 1 to a maximum of 2 6 1, after which it declined to about 2 1 Increasing the concentration of K in the nutrient solution reduced the incidence of uneven ripening and increased the organic acid and K contents of tomato fruit Low levels of Ca and Mg reduced cucumber yields, the proportion of high quality fruit, and the uptake of the respective elements Increasing salinity decreased the dry weight and Ca uptake of cucumber plants, but increased the proportion of the total dry weight and Ca in the fruit With tomato, the uptake of water and nutrients increased with salinity up to 4 8 mS cm^{1} and then decreased at higher salinity

A study conducted to determine the optimum hydroponic system and nutrient solution for the growth of lettuces by Kim *et al* (1995) at Department of Horticulture, Chonnam National University, reported that leaf area and leaf production (FW and DW basis) were significantly higher for plants grown in deep flow technique, than in the other treatments Root production was highest for plants grown in aeroponics, although leaf area was usually lowest in this system Plants grown in Cooper's solution exhibited higher dry matter partitioning to the leaves, compared with plants grown in the other nutrient solutions

Schwarz and Kuchenbuch (1998), reported that the increase in EC level significantly reduced the water uptake and average yield of tomato cultivar 'Counter' under hydroponics, in a study conducted at Institute of Vegetables and Ornamental Crops, Grossbeeren, Germany

A trial was conducted by Auerswald *et al* (1999) to analyse the influence of three concentrations of nutrient solution (EC 1 0, 3 5 and 6 0 dS m^{-1}) on the sensory properties of tomatoes (cultivars Counter' and 'Vanessa') at the Institute of Vegetable and Ornamental Crops in Grossbeeren, Germany The quantitative descriptive analysis revealed that, changing intensities of sensory attributes of appearance, firmness by touch, flavour, aftertaste and mouthfeel increased with the EC of nutrient solution Intensity of unfavourable flavour attributes such as *mouldy, spoiled sweetish* and *bitter* was stronger only for Vanessa' cultivar when cultivated at high EC The contents of reducing sugars and the titratable acid of fruits were analysed during the experiment Higher EC values resulted in higher contents of reducing sugars, which influenced the intensity of several sensory attributes of smell, flavour and aftertaste Consumers preferred the flavour from those fruits of both cultivars that were cultivated at EC 3 5 dS m^{-1} In most cases, the sensory changes caused by increasing EC of nutrient solution from 1 0 to 6 0 dS m^{-1} improved the quality of Counter' but not that of 'Vanessa'

According to Serio *et al* (2004), total yield of tomato cultivar Naomi was not influenced by the rockwool substrate used in hydroponics , but it was higher with nutrient solution where EC was 3 dS m^{-1} than 6 dS m^{-1} They also pointed out that when tomato plants were grown in higher EC level, the fruit diameter was between 25 and 35 mm and it also increased the dry matter, total soluble solids, vitamin C and α-tocopherol content of fruits

In a study conducted at Department of Plant Sciences, The University of Arizona, Arizona, USA, Wu *et al* (2004) pointed out that the TSS and lycopene content of the tomato cultivar 'Mariachi' increased by 12-23 per cent and 34-85 per cent respectively with increase in EC levels of nutrient solution from 2 6 to 4 5dS m 1

Krauss *et al* (2006) in their study on the influence of different electrical conductivity values in a simplified recirculating soilless system on inner and outer fruit quality characteristics of tomato, reported that with increase in EC level in nutrient solutions, the vitamin C content, lycopene content and beta carotene in fresh fruits rised up to 35 per cent and this also positively influenced the taste determining factors (TSS and organic acids) in tomatoes

Sato *et al* (2006), conducted an experiment, where NaCl was applied to the nutrient solution (5 dS m^{-1} versus 1 4 dS m^{-1} in the control) of hydroponically grown tomato and its effects on taste grading and chemical composition of fruit were investigated NaCl treatment increased the sweetness, acidity and overall preference Also the hexose concentration of the fruit grown on NaCl treated plants increased significantly At the same time, chloric ion, organic and amino acids in general had higher concentrations in NaCl treated plants than the control

According to Karimiafshar and Delshad (2009), through a study on effects of EC management of the nutrient solution on yield and fruit quality of two greenhouse tomato cultivars 'Razan' and 'Ergon' , the increase in EC of nutrient solution improved the Total Soluble Solids (TSS) when grown under glasshouse hydroponic system They have also reported that EC had lıttle effect on total yıeld, dry matter of vegetatıve parts, fruıt dry weıght and water use efficıency

In an experıment on effects of salınıty on morphologıcal and physıologıcal changes and yıeld of tomato ın hydroponıcs system, ıt was found that, the plant heıght and leaf area of tomato decreased by ıncreasıng the EC levels (2 5, 3, 4, 5 and 6 dS m^{-1}) The total fruıt yıeld had shown a reductıon of 8 7, 21 7, 36 and 48 9 per cent by ıncreasıng the levels of EC by 3, 4, 5 and 6 dS m^{-1} respectıvely ın comparıson wıth 2 5 dS m^{-1}, but the fruıt dry weıght ıncreased by 8 7 per cent and the tıtrable acıdıty by 28 9 per cent at an EC level of 6 dS m^{-1} ın comparıson wıth 2 5 dS m^{-1} (Azarmı *et al* , 2010)

Gonzalez *et al* (2012) studıed the yıeld of natıve genotypes of tomato as affected by electrıcal conductıvıty of nutrıent solutıon and poınted out that, an ıncrease ın the EC value of nutrıent solutıon ın hydroponıcs decreased the heıght and ıncreased the dry matter content of tomato plants

In an experıment conducted at Stellenbosch Unıversıty, Welgevallen Experimental Farm,Western Cape, South Afrıca, ıt was found that at an EC level of 1 dS m^{-1} the average leaf area and organ dry mass of tomato was low, but the average marketable yıeld was hıgher compared to the EC level of 2 dScm^{-1} (Fulton and Kempen, 2013)

In theır study conducted at Research Instıtute of Hortıculture ın Skıernıewıce, Poland, Sabat *et al* (2014), reported that the phosphorus and potassıum content ın the leaves of butterhead lettuce cultıvar 'Natalıa' grown under hydroponıcs ıncreased wıth ıncrease ın EC levels of nutrıent solutıon (EC 1 0, 2 0, 3 0, 4 0 dS m^{-1})

Lıopa-Tsakalıdı *et al* (2015) found that the zucchını (*Cucurbıta pepo*) varıety Abodanza produced fruıts wıth hıgher TSS (5 48°Brıx) under an EC level of 4 4 dS m^{-1} as compared to a TSS of 5 19°Brıx at 2 2 dS m^{-1} ın an experıment carrıed out at

Department of Agricultural Technology, Technological Education Institute of Western Greece, Amaliada, Greece

Santos *et al* (2016), carried out an experiment at Federal Institute of Education, Brazil to evaluate the yield of cherry tomato cultivar 'Rita' grown in hydroponic system with substrate under different salinity levels (3 01, 4 51, 5 94, 7 34, 8 71 and 10 40 dS m^{-1}) of the nutrient solution (NS) and found that salinity of nutrient solution reduced fruit production, which was more significant when plants were subjected to a longer time of exposure to salinity

The study conducted by San-Martin-Hernandez *et al* (2016), for evaluating the effect of nitrogen and potassium nutrition on the vegetative biomass production and growth of tomato cultivated hydroponically, revealed that, in the vegetative stage, the addition of nitrogen caused significant differences in the vegetation dry biomass (VDB), and in the reproductive stage, a significant response was only observed for K

Signore *et al* (2016), carried out a study on targeted management of the nutrient solution in a soilless tomato crop according to plant needs and found that fruit quality was better at the EC set point of SP 10

2.1.3. pH OF NUTRIENT SOLUTION

According to Wallihan ***et al*** (1977), tomato cultivar 'Tropic' set fewer fruits by supplying a nutrient solution with pH greater than or equal to eight, when grown hydroponically

Quality improvement of vegetable crops under hydroponics was studied by Ho (2001) and he found that lettuce produced leaves with high ascorbic acid content when supplied a nutrient solution with low pH (less than 4)

A study was carried out by Hyuk and Ikeda (2004), studied the effects of pH and concentration of nutrient solution on growth of hydroponically cultured Chinese chive (*Allium tuberosum* Rottler), at Graduate School of Agriculture and Biological Sciences, Osaka Prefecture University, Japan found out that the re-growth of the detopped plants was reduced at pH 4 5 and 7 5 and concluded that optimal pH for growing Chinese chive was 5 to 7

Najafi and Parsazadeh (2010), conducted an experiment on the effect of nitrogen form and pH of nutrient solution on the concentration of phosphorus, nitrate, and nitrogen of spinach shoots in hydroponic culture The results showed that by increasing the pH of the nutrient solution from 4 5 to 8 0, the concentration of phosphorus and nitrate in the shoots decreased

Gomes *et al* (2011), observed that three melon varieties 'Galia', 'Rustic' and 'Orange' did not differed significantly in their growth characteristics like plant height and leaf number and in nutrient uptake (uptake of N, P, K, Mg, and Zn) when grown hydroponically using nutrient solutions with five different pH levels

The effect of nitrate to ammonium ratio and pH of nutrient solution on the changes in pH and EC of spinach rhizosphere in hydroponic culture was studied and found that the effects were significant by increasing the nitrate to ammonium ratio of nutrient solution, the pH of rhizosphere was increased but the EC of rhizosphere was decreased (Najafi and Parsazadeh, 2011)

2.2. STRUCTURES FOR DIFFERENT GROWING TECHNIQUES

Baevre (1985), in his study on the comparison of fruit quality of tomatoes grown in soil and in a nutrient solution (NFT) conducted at Agricultural Research Station, Norway, reported that, compared to soil, tomato cultivar 'Virosa' yielded fruits with high total dry matter, soluble dry matter, total sugars and reducing sugars under NFT

On recycled polyurethane irrigation mats using NFT, tomato cultivars 'King Plus' and 'Lotina CF' gave 15% and 22% more yield respectively compared to soil (Benoit and Ceustermans, 1988)

Abou-Hadid *et al* (1989), in their study on the comparison between nutrient film technique (NFT) and soil for tomato production under protected cultivation in Egypt reported that under NFT, tomato plants expressed vigorous growth and better fruiting behaviour compared with that of soil

The system of intensive tomato production studied using ebb-flood benches showed that the tomato plants grown on slopped benches of ebb and flow system gave 70 per cent more yield than that of soil (Fischer *et al*, 1990)

Tomato cultivar 'Capello' were grown in the hydroponic cultivation systems using rockwool, peatmoss substrates and nutrient film technique (NFT) Prolonged recycling of nutrient solutions in NFT caused a reduction in fresh weight, dry weight, and yield compared to plants grown in NFT with regular renewal of the nutrient solution Prolonged use of the same solution in the NFT cultivation system negatively affected the growth and yield due to the accumulation of sulfate ions in the nutrient solutions (Zekki *et al*, 1996)

A study was carried out by Gul *et al* (2001) at Deptartment of Horticulture, Bornova, Turkey, on the effect of continuous and intermittent solution circulation on tomato plants grown in NFT Intermittent flow increased cumulative yields compared to continuous flow by 106 8, 50 7 and 14 2 % in the first 3 months of picking Intermittent flow also resulted in a marked increase in the TSS of fruit juice

In an experiment carried out in the unheated glasshouse of Institute for Subtropical Plants and Olive Trees at Chania, Greece by Tzortzakis and Economakis (2005), pointed out that the tomato plants grown on NFT were taller and had vigorous growth compared with that of soil

In an experiment on effect of growing system and cultivar on yield and water-use efficiency of greenhouse-grown tomato, conducted by Valenzano *et al* (2008), reported that an increase in yield under hydroponics (11% in NFT and 7% in rock wool) than the soil cultivation

When the effects of slope and channel nutrient solution gap number on the yield of tomato under nutrient film technique system was studied by Lopez-Pozos *et al* (2011), it was observed that the steeper slope (4%) and greater nutrient channel gap improved the total yield of tomato

Feltrin *et al* (2012), in an experiment at Hydroponics Laboratory greenhouse in the Federal University of Santa Catarina (UFSC), Brazil, noticed that when tomato plants were grown under Nutrient Film Technique (NFT), highest values for TSS and lycopene were obtained

Basil, kale, cherry tomato and chipotle pepper were grown under ebb and flow system at Department of Crop Sciences, Plant Sciences Laboratory, Urbana, USA by Wortman, (2015) and reported that marketable yield of basil and kale increased by 44% and 77% respectively and the yield increase in cherry tomato and pepper was 32% compared to soil cultivation

Hanic *et al* (2012), conducted an experiment at polyethylene greenhouses located in the municipality of Capljina, Turkey to examine the influence of different variants within "ebb and flow" hydroponic system on the yield and morphometric characteristics of cucumber fruits (*Cucumis sativus* L , cv Edona F_1) The quality of water and the planting density were the varients used The results showed that all applied variants within "ebb and flow" system had a statistically significant impact on increasing the yield and quality of fruits in comparison to conventional variant of cucumber production

2.3. SUBSTRATES FOR CULTURE

When coir pith was used as a medium for tomatoes under hydroponics, the yield was highest (25kg/m^2) followed by rock wool (23 3kg/m^2) and soil (20kg/m^2) in an experiment conducted at Alata Horticultural Research Institute, Turkey (Abak and Celikel, 1994)

Shinohara *et al* (1997), who conducted their studies at Chiba University, Japan, reported that there was no significant difference in the yield and fruit quality of tomatoes when grown hydroponically in coconut fibre or rock wool substrate

Watermelon cultivar Mudeungsan performed best under hydroponics when coconut fibre and perlite were used as the substrates, in an experiment on effects of substrates on the growth and fruit quality of watermelon grown under hydroponics (Gi *et al*, 1999)

Islam *et al* (2002) stated that coconut coir pith was the best substrate for growing tomatoes in hydroponics based on the crop performance, quality parameters, incidence of diseases and cost-benefit analysis in their study on the effect of organic substrates on growth, morphological, reproductive and quality characteristics of tomato crops at Chiba University, Japan

Shahinrokhsar (2008), in his study on influence of irrigation schedules and substrates on fruit quality of tomato (cv Hamra) in soilless culture reported that, the titrable acidity of tomato fruits were the highest under Expanded Clay Pellet (ECP) medium and he also reported that ECP can be considered as the best growing medium since it possess neutral pH and high air porosity

Borji *et al* (2010), found that the substrate prepared by mixing date palm peat and coir peat gave significantly higher yield for tomatoes compared to other substrates in hydroponics, in an experiment held at the greenhouse of Islamic Azad University, Khorasgan, Iran

The studies conducted at Ohio State University, USA proved that under hydroponics lettuce gave 23% more yield when coconut fibre was used as the substrate (Hansen *et al*, 2010)

An experiment carried out at Agricultural Research Institute, Cyprus showed that the use of local gravel for the hydroponic cultivation of tomato produced similar yield to those with imported perlite (Neocleous and Polycarpou, 2010)

Joseph and Muthuchamy (2014) stated that tomatoes yielded 245 3 t/ha when grown under hydroponic system in a trough with coco peat, gravel and silex stone as media in their study on productivity, quality and economics of tomato (*Solanum lycopersicum*) cultivation in aggregate hydroponics

The study on lignite as a medium in soilless cultivation of tomato showed that, under hydroponics tomato plants produced highest early marketable and total yield when grown in lignite media and this was not significantly different from the marketable yield obtained under coir pith (Dysko *et al*, 2015)

2.4. GROWTH, YIELD, AND QUALITY

A study conducted by Vogel (1994) revealed that, the tomato cultivars Hildares and Isnova produced an early marketable yield of 1 47kg/ m^2 on soilless outdoor cultivation

Portela and Bartolomi (1997) carried out an experiment at University of Buenos Aires, Argentina, and they reported that tomatoes produced early, total and higher marketable yield under hydroponic culture compared to soil (total yields 3.0 and 2 4 kg/plant respectively)

Moraru *et al* (2004) reported in their study on characteristics of 10 processing tomato cultivars grown hydroponically for the NASA Advanced Life Support (ALS) Program that, the hydroponically grown processing tomatoes gave acceptable sensory attributes

A study to compare the performance of tomato cultivars under soilless and soil production systems by Maboko and Plooy (2009) revealed that, tomato plants in the soilless system developed faster with higher total yield and quality compared to those under soil cultivation The average marketable yield under soilless cultivation was 92 1 per cent, while in soil cultivation it was only 77 0 per cent

Manzocco *et al* (2011), reported that the hydroponic cultivation of lettuce increased the yield and reduced the nitrate accumulation in the leaves

A trial was conducted in a 40 per cent shade-net structure (Black and white) at the ARC- Roodeplaat VOPI, South Africa by Maboko and Plooy (2013), and reported that, under hydroponics the yield and quality of tomato could be manipulated by adjusting plant population and stem pruning, but there was only a limited effect for fruit pruning

Maboko and Plooy (2014), reported that highest early marketable and total yield of tomato was obtained by transplanting seedlings at two leaf stage to hydroponic structure

2.5. PESTS AND DISEASES

In a trial conducted by Jenkins and Averre,(1983) at North Carolina State University, USA, found that,under hydroponic systems tomato, lettuce and cucumber underwent the incidence of *Pythium aphanidermatum, P myriotylum, P* *debaryanum* and *P ultimum* Apart from these *Colletotrichum coccodes* was isolated from diseased tomato roots and *Pseudomonas solanacearum Fusarium oxysporum* f sp *radicis-lycopersici* and *Erwinia* spp were isolated from stems near the base of diseased tomato plants

According to a study on potential danger for infection and spread of root diseases of tomatoes in hydroponics, held at Laboratory for Phytopathology and Plant Protection, Belgium, under Nutrient Film Technique, root and vascular infections of *Fusarium oxysporum* f sp *lycopersici* race 1 and 2 *Pythium ultimum, P debaryanum, P sylvaticum, Phytophthora nicotianae* var. *nicotianae* were noticed in tomato (Vanachter *et al*, 1983)

Stanghellini and Kronland (1986), from Department of Plant Pathology, University of Arizona, USA, reported that hydroponically grown lettuce showed an yield reduction of 12-17 per cent and 35-54 per cent at 18 and 28°C respectively due to the infection by *Pythium dissotocum* They also pointed out that, there was no visible root or foliar symptoms by this pathogen

Rey *et al* (1998), carried out a research entitled *Pythium* spp agent of a minor but ubiquitous disease in tomato soilless cultures An immunoenzymatic staining procedure was used to assess the level of *Pythium* spp colonization on the root surface of tomato plants growing in commercial hydroponic cultures Sampling was performed with roots free of distinct necrosis or other symptoms It showed that 40 per cent of the root segments on an average were colonized by *Pythium* spp and the root cell damage finally led to tomato yield losses although the roots looked macroscopically healthy

The results of an experiment conducted to investigate Pepino mosaic virus (PepMV) distribution via nutrient solution and spread in tomato by Fakhro *et al*

(2005) showed that plants grown ın re-cırculatıng hydroponıc system ın a glasshouse, underwent serıous ıncıdence of Pepıno mosaıc vırus

Tomato hybrıds Jeremy, Clotılde, Lemance and Profilo were grown ın a hydroponıc system constructed under the greenhouses of Agrıcultural Instıtute , Tuzla The greatest pest problems observed were that of mushroom flies (Scıarıdae), followed by *Trıaleurodes vaporarıorum, Tetranychus urtıcae, Phytomyza* leaf mıners, aphıds and *Franklınıella occıdentalıs* and the ımportant *dıseases* were by *Botrytıs cınerea and Sclerotınıa sclerotıorum* (Paglıarını *et al*, 2007)

In an ınvestıgatıon was carrıed out ın hydroponıc pepper (*Capsıcum annuum* L.) productıon greenhouses of Vukovar, Eastern Croatıa ıt was found that bıo-control agents can substıtute tradıtıonal protectıon wıth pestıcıdes for several reasons lıke hıgh effectıveness, consumers' and producers' safety, easıness ın applıcatıon and envıronment frıendly (Paradjıkovıc *et al*, 2007)

An experıment was laıd out by Kurup *et al* (2011) at Publıc Authorıty of Agrıculture Affaırs and Fısh Resources, Kuwaıt under hydroponıcs to evaluate the effect of neem ınsectıcıdes and *Pseudomonas* against the control of ınsects and dıseases ın cucumber (*Cucumıs satıvus* L) and found that prophylactıc spray of neem extract was very effectıve ın control of ınsects such as mıtes and aphıds and *Pseudomonas fluorescence* sprayed at 15 days ınterval gave resıstance agaınst many dıseases

2.6. ECONOMICS OF HYDROPONICS

Gohler *et al.* (1986), notıced that hydroponıc cultıvatıon of tomato and melons resulted in a reductıon of materıal cost by 30 per cent, energy requırement by 20 per cent and overall productıon cost by 15 per cent

Duplancic and Rodriguez (1999) conducted a study on feasibility of tomato and sweet pepper cultivation in soilless media in Argentina and reported that the Net Present Value and Internal Rate of Returns were more, while growing tomatoes and sweet peppers under hydroponics compared to soil

Gualberto *et al* (2002), conducted a study on hydroponic nutrient film technique at Department of Plant Science, Brazil, with long-life salad tomato (*Lycopersicon esculentum*) varieties (Carmen, Diva, Graziela, and Vita) They found that varieties had distinct performances during the different cropping seasons The Vita variety produced commercial valid yield, with mean fruit weight of 137 27g, which was higher than that of the other varieties

Paradjikovic *et al* (2007), reported that hydroponic cultivation resulted in a higher benefit cost ratio for pepper (*Capsicum annuum* L), since it enabled continuous harvest throughout the year

Seed tuber production of potato under hydroponics at controlled mineral nutrition and water resulted in early harvest and reduction in the overall production cost by avoiding the requirement of pesticides (Correa *et al* , 2009)

The reduction in production cost due to accurate and controlled nutrition and the reduction in pest protection expenses due to controlled conditions were the results obtained by the establishment of hydroponics in Cypress (Papadavid *et al* , 2009)

According to an experiment on hydroponic tomato (*Solanum lycopersicum* L) production with and without recirculation of nutrient solution, the production of tomatoes by recirculation of nutrient solution resulted in a fertilizer saving of 41% (K, Ca, N and P) and water saving of 35% compared to non circulating systems (Castillo, 2014)

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation entitled "Standardization of hydroponics in tomato" was carried out in the Department of Olericulture, College of Horticulture, Vellanikkara during 2014 - 2016 The objective of this study was to standardize the nutrients, methods and growing media for the hydroponic cultivation of tomato in rain shelter

SITE SELECTION

The site was selected at Department of Olericulture, which is located at an altitude of 22 25 m above MSL at 10° 32' latitude and 76° 16' longitude The region enjoys tropical warm humid climate

3.1. MATERIALS

3.1.1. HYDROPONIC STRUCTURES

There were two types of hydroponic methods The first method, Deep Flow Technique (DFT), was carried out in a structure made with PVC pipe Ten PVC pipes of 5m length and 7 5cm diameter each were arranged in three tiers using GI frame In each pipe there were 15 holes, with a total of 150 holes for holding plants in DFT and two separate structures were made to experiment the two nutrient solutions

To study the second method Ebb and Flow Technique a rectangular brick structure with 3m length and 2m width was made Pond liner was spread inside this structure to hold the media To examine three different media and two nutrient solutions six structures were built

3.1.2. MEDIA

There were three types of media, (1) coco peat, (2) expanded clay pellet and (3) pebbles

3.1.3. NUTRIENT SOLUTION

There were two nutrient solutions, (1) Hoagland's solution and (2) Cooper's solution

(Composition is given in Appendix I and the quantity of chemical fertilizers given in Appendix II)

3.1.4. VARIETY

The semi determinate tomato variety Anagha was used for the study

3.1.5. RAIN SHELTER

The experiment was conducted under two rain shelters UV stabilized polythene sheet of 200 micron thickness was used as the cladding material Under the polythene sheet shade net (50 per cent) was tied to reduce temperature

3.2. LAY OUT OF THE EXPERIMENT

The experiment was laid out using Completely Randomized Design (CRD) There were a total of 13 treatments (Table 3 1) including control (Plate 1) and three replications Spacing between the plants was 30 X 45 cm Number of plants per treatment per replication was 15

3.3. SEASON

Seeds were sown in protrays during 2015, September and transplanting was carried out in 2015, October

3.4. METHODS

3.4.1. DEEP FLOW TECHNIQUE (DFT)

In this technique seedlings were first transplanted in to plastic pots filled with separate medium, and then they were placed in the PVC pipe structure (Plate 2, Plate 3, Plate 4 and Plate 5) The number of plants in each medium was 50 The nutrient solutions were continuously cycled through the pipes for 20 minutes, followed by 10 minutes off time There was a timer system to control the flow rate, the 'ON' time was 20 minutes and 'OFF' time was 10 minutes Fresh solutions were added in to the main tank in every two week interval

3.4.2. EBB AND FLOW TECHNIQUE

In Ebb and Flow Technique, seedlings were directly transplanted in to the brick structure separately filled with different media (Plate 6, Plate 7, Plate 8 and Plate 9) There were five rows and ten plants in each row, with a total of 50 plants in each structure The nutrient solutions were pumped in to the structure in such a manner that, it should get completely flooded through the medium for 20 minutes Then the nutrient solution was drained back in to the tank and the process was repeated continuously The flood and drain time was controlled by the timer, the 'ON' time was 20 minutes and 'OFF' time was 10 minute

Table 3.1.Treatment details

Flow methods	Nutrient solutions	Media	Control
F_1- Deep Flow Technique	S_1- Cooper's solution	M_1 - Coco peat	Soil cultivation with Package of Practices
F_2- Ebb and Flow Technique	S_2-Hoagland's solution	M_2-Expanded clay pellets	
		M_3- Pebbles	

Table 3. 2. Hydroponic treatments

Treatments	Flow methods (F)	Nutrient solution (S)	Medium (M)
$F_1S_1M_1$	Deep Flow Technique (F_1)	Hoagland's solution (S_2)	Coco peat (M_1)
$F_1S_1M_2$	Deep Flow Technique (F_1)	Hoagland's solution (S_2)	Expanded clay pellet (M_2)
$F_1S_1M_3$	Deep Flow Technique (F_1)	Hoagland's solution (S_2)	Pebbles (M_3)
$F_1S_2M_1$	Deep Flow Technique (F_1)	Cooper's solution (S_1)	Coco peat (M_1)
$F_1S_2M_2$	Deep Flow Technique (F_1)	Cooper's solution (S_1)	Expanded clay pellet (M_2)
$F_1S_2M_3$	Deep Flow Technique (F_1)	Cooper's solution (S_1)	Pebbles ($M_3$0
$F_2S_1M_1$	Ebb and Flow Technique (F_2)	Hoagland's solution (S_2)	Coco peat (M_1)
$F_2S_1M_2$	Ebb and Flow Technique (F_2)	Hoagland's solution (S_2)	Expanded clay pellet (M_2)
$F_2S_1M_3$	Ebb and Flow Technique (F_2)	Hoagland's solution (S_2)	Pebbles (M_3)
$F_2S_2M_1$	Ebb and Flow Technique (F_2)	Cooper's solution (S_1)	Coco peat (M_1)
$F_2S_2M_2$	Ebb and Flow Technique (F_2)	Cooper's solution (S_1)	Expanded clay pellet (M_2)
$F_2S_2M_3$	Ebb and Flow Technique (F_2)	Cooper's solution (S_1)	Pebbles (M_3)
Control	Soil cultivation with package of practices		

Plate 1

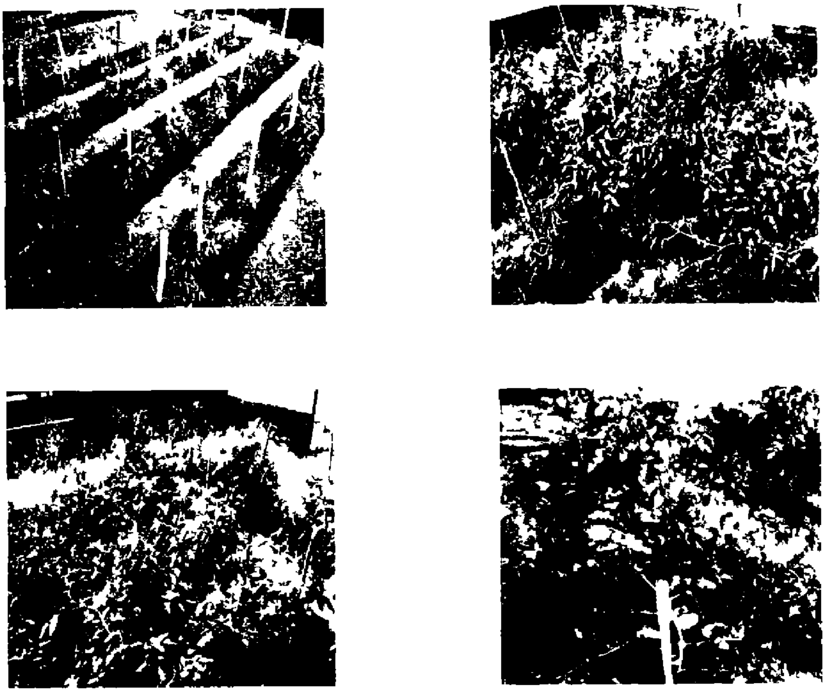


Plate 1 – Control plot

Plate 2

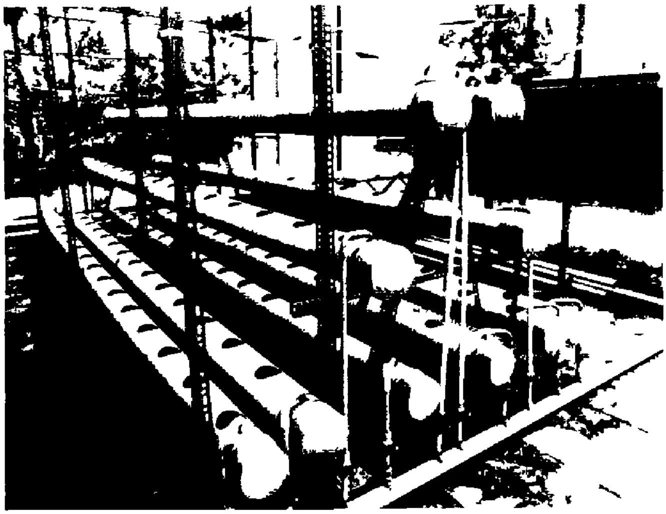


Plate 3

Plate 4

Plate 5

Plate 2 – Structure for deep flow technique

Plate 3 – Plants in coco peat medium under deep flow technique

Plate 4 – Plants in expanded clay pellet medium under deep flow technique

Plate 5 – Plants in pebble medium under deep flow technique

Plate 6

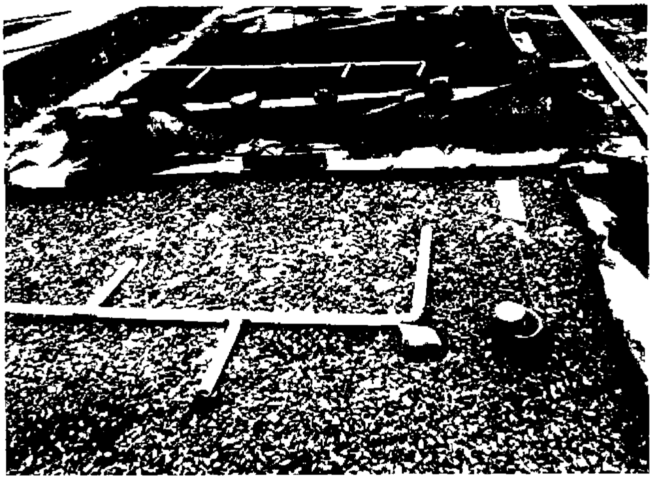


Plate 7

Plate 8

Plate 9

Plate 6 – Structure for ebb and flow technique

Plate 7 – Plants in coco peat medium under ebb and flow technique

Plate 8 – Plants in expanded clay pellet medium under ebb and flow technique

Plate 10 – Plants in pebble medium under ebb and flow technique

3.5. PLANT PROTECTION

Biocontrol agents were applied as and when required

3.6. HARVESTING

Harvesting was carried out at turning stage and observations were recorded

3.7. OBSERVATIONS

For taking observations eight plants were taken from each replication and following observations were made

3.7.1. PLANT HEIGHT AT TEN DAYS INTERVAL

Plant height was taken from the day of transplanting up to flowering at ten days interval Measurement was taken from the base of the stem to the growing tip of the plant and was expressed in cm

3.7.2. DAYS TO FIRST FLOWER APPEARANCE

The number of days taken from transplanting to opening of the first flower was recorded

3.7.3. DAYS TO FIRST FRUIT SET

The number of days taken from transplanting to first fruit appearance was recorded

3.7.4. DAYS TO FIRST HARVEST

The number of days taken from transplanting to harvesting of the first fruit was recorded

3.7.5. DAYS FROM FLOWERING TO HARVEST

The total number of days taken for the harvest of a fruit from its flowering was recorded

3.7.6. FRUITS PER PLANT

Total number of fruits from observational plants was taken during each harvest This was then summed up to get the total number of fruits per plant

3.7.7. DURATION OF THE CROP

It is the number of days taken by a plant to complete its life cycle Total number of days from the date of transplanting to the date of showing drying and wilting symptoms by plants were recorded

3.7.8. NUMBER OF HARVESTS

Total number of harvests from observational plants were recorded

3.7.9. YIELD PER PLANT

Weight of the fruits was measured during each harvest from observational plants and summed up and the yield per plant was expressed in kg

3.7. 10. MARKETABLE YIELD

Weight of the fruits excluding malformed and pest attacked ones was measured during each harvest from observational plants and summed and the yield per plant was expressed in kg

3.7.11. AVERAGE FRUIT WEIGHT

The total weight and number of fruits during each harvest was recorded and the average fruit weight was calculated and expressed in g

3.7.12. TOTAL SOLUBLE SOLIDS

Total Soluble Solids (TSS) was measured using pocket refractometer and expressed in °Brix

3.7.13. ACIDITY

Ascorbic acid content in fruits was estimated by titration with 2,6-dichlorophenol indophenol dye (Sadasivam and Manickam, 1991) The value was expressed in mg per 100g fruit

3.7. 14. BIOMASS OF ROOTS AT HARVEST

The fresh weight of the roots at the time of harvest was recorded The plants were cut at the base and root portion was separated and cleaned, then the weight was measured

3.7. 15. INCIDENCE OF PESTS AND DISEASES

The observations on pests and diseases were recorded

3.7.16. BENEFIT COST RATIO

Total expenses incurred and returns obtained were estimated and benefit cost ratio was calculated

3.7.17. TEMPERATURE

Temperature was recorded during morning and afternoon using Psychrometer from inside and outside of the rainshelter

3.7.18. EC AND pH OF NUTRIENT SOLUTION

The EC of nutrient solution was measured using conductivity meter and pH with pH meter (potentiometric method) when fresh solution was prepared and added at weekly intervals (Jackson, 1958)

3.7.19. NPK CONTENT OF COCO PEAT

The NPK content of coco peat was estimated using following methods Nitrogen – Microkjeldal digestion and distillation method, phosphorus – Vanadomolybdophosphoric yellow colour method, and potassium – Flame photometry (FCO, 1985)

3.7. 20. NPK CONTENT OF PLANT (LEAF, SHOOT AND FRUIT)

The NPK content of plant was estimated using following methods Nitrogen – Microkjeldal digestion and distillation method, phosphorus – Vanadomolybdophosphoric yellow colour method, and potassium – Flame photometry (Jackson, 1958)

3.8. STATISTICAL ANALYSIS

The data recorded were analyzed using statistical package (MSTAT -C) (Freed, 1986) Simple correlation between the plant height at 10 days interval and temperature was also computed

RESULTS

4. RESULTS

The studies on "Standardization of hydroponics in tomato" were carried out in the Department of Olericulture, College of Horticulture, Vellanikkara during 2015 September to 2016 January The results obtained from the experiment are presented under following heads

4.1. CHARACTERS

4.1.1. PLANT HEIGHT AT 10 DAYS INTERVAL (cm)

The data on plant height at 10[th] day, 20[th] day, 30[th] day, 40[th] day and 50[th] day after transplanting are presented in Table 4 1 and Fig 1

The plant height was measured at 10 days interval The observations were taken up to 50 days after transplanting The plant height was highest in control (71 66 cm) at 50 days after transplanting This was followed by plants in Ebb and Flow Technique ($F_2S_1M_1$ – 69 36 cm) The height was lowest in Deep Flow Technique ($F_2S_1M_3$ – 66 40 cm)

The influence of nutrient solution on plant height was nonsignificant The nature of media significantly influenced the plant height Maximum plant height was observed in M_1 (coco peat, $F_2S_1M_1$ – 69 36 cm) This was followed by M_3 (pebbles, $F_2S_1M_3$ – 66 40 cm) The plant height was lowest in M_2 (expanded clay pellets, $F_1S_2M_2$ – 47 00 cm)

The treatment $F_2S_1M_1$ was found to be the best (69 36 cm) and the treatment $F_2S_1M_3$ was on par with the former (66 40 cm) Among the treatments, $F_1S_1M_2$ (48 53 cm) and $F_1S_2M_2$ (47 00 cm) gave lowest value for height

Table 4.1. Plant height at 10 days interval (cm)

DAT		F_1		F_2		CD (0 05)
		S_1	S_2	S_1	S_2	
10	M_1	25 63	23 33	27 60	26 56	1 73
	M_2	22 00	20 16	21 46	22 16	
	M_3	24 00	21 73	24 66	24 06	
	Mean	23 87	21 74	24 57	24 26	
	Control	26 80				
20	M_1	36 96	37.06	40 33	35 83	2 46
	M_2	31 80	30 33	33 26	32 93	
	M_3	34 46	35 13	37 43	34 33	
	Mean	34 40	34 17	37 00	34 36	
	Control	40 53				
30	M_1	47 76	46 23	52 83	46 80	2 24
	M_2	42 23	39 76	44 10	45 16	
	M_3	44 26	47 03	50 60	46 13	
	Mean	44 75	44 34	49 17	46 03	
	Control	50 20				
40	M_1	55 33	54 76	62 06	59 30	2 76
	M_2	48 53	47 00	57.20	57 20	
	M_3	53 43	53 13	58 40	57 76	
	Mean	52 43	51 63	59 22	58.08	
	Control	60 00				
50	M_1	63 03	60 50	69 36	67 43	2 21
	M_2	48 53	47 00	63 00	62 70	
	M_3	60 30	58 33	66 40	64 30	
	Mean	57 28	55 27	66 25	64 81	
	Control	71 66				

F_1 – Deep Flow Technique, F_2 – Ebb and Flow Technique

S_1 – Cooper's solution, S_2 – Hoagland's solution

M_1 – Coco peat, M_2 – Expanded clay pellets, M_3 - Pebbles

4.1.2. DAYS TO FIRST FLOWER APPEARANCE

The data on days to first flower appearancc are presented ın Table 4 2 and Appendıx III. The mınımum days to first flower appearance was observed ın control (19 83 days) Thıs was followed by Ebb and Flow Technıque ($F_2S_1M_1$ – 22.06 days) The days to first flower appearance was hıgher ın Deep Flow Technıque ($F_1S_2M_2$ – 27 70 days)

The ınfluence of nutrıent solutıons on days to first flower appearance was sıgnıficant Mınımum days to first flower appearance was observed ın S_1 (Cooper's solutıon, $F_2S_1M_1$ – 22 06 days) The days to first flower appearance was most delayed ın S_2 (Hoagland's solutıon, $F_1S_2M_2$ – 27 70 days)

Growıng media sıgnıficantly ınfluenced the days to first flower appearance In M_1 (coco peat) days to first flower appearance was mınımum ($F_2S_1M_1$ – 22 06 days) Thıs was followed by M_3 (pebbles, $F_2S_1M_3$ – 24 76 days) The days to first flower appearance was hıghest in M_2 (expanded clay pellets, $F_1S_2M_2$ – 27 70 days)

The treatment $F_2S_1M_1$ was the best (22 06 days) Thıs was followed by the treatment $F_2S_1M_3$ (24 36 days) The treatments, $F_1S_1M_2$ (27 46 days) and $F_1S_2M_2$ (27 70 days) took maximum number of days to produce first flowers

4.1.3. DAYS TO FIRST FRUIT SET

The data on days to first fruıt set are presented ın Table 4 3 The days to first fruıt set was lowest ın control (23 16 days) Thıs was followed by Ebb and Flow Technıque ($F_2S_1M_1$ – 25 73 days) The days to first fruıt set was hıgher ın Deep Flow Technıque ($F_1S_2M_2$ – 31 70 days)

Nutrıent solutıons sıgnıficantly ınfluenced the days to first fruıt set The days to first fruıt set was mınımum ın S_1 (Cooper's solutıon, $F_2S_1M_1$ – 25 73 days)

The days to first fruit set was most delayed in S_2 (Hoagland's solution, $F_1S_2M_2$ – 31 70 days)

Growing media significantly influenced the days to first fruit set In M_1 (coco peat) minimum days to first fruit set was observed ($F_2S_1M_1$ – 22 06 days) This was followed by M_3 (pebbles, $F_2S_1M_3$ – 27 70 days) The days to first fruit set was highest in M_2 (expanded clay pellets, $F_1S_2M_2$ – 31.70 days)

The treatment $F_2S_1M_1$ was observed as the best (25 73 days) This was followed by the treatment $F_2S_1M_3$ with respect to first harvest (27 70 days) The treatments, $F_1S_1M_2$ and $F_1S_2M_2$ produced fruits very late (30 46 days and 31 70 days respectively)

4.1.4. DAYS TO FIRST HARVEST

The data on days to first harvest are presented in Table 4 4 The days to first harvest was minimum in control (48 20 days), which was followed by Ebb and Flow Technique ($F_2S_1M_1$ – 51 73 days) The days to first harvest was maximum in Deep Flow Technique ($F_1S_2M_2$ – 60 16 days)

The influence of nutrient solutions on days to first harvest was significant The minimum days to first harvest was observed in S_1 (Cooper's solution, $F_2S_1M_1$ – 51 73 days) The days to first harvest was most delayed in S_2 (Hoagland's solution, $F_1S_2M_2$ – 60 16 days)

Growing media significantly influenced the days to first harvest In M_1 (coco peat) days to first harvest was minimum ($F_2S_1M_1$ – 51.73 days) This was followed by M_3 (pebbles, $F_2S_1M_3$ – 54 40 days) The days to first harvest was maximum in M_2 (expanded clay pellets, $F_1S_2M_2$ – 60 16 days)

The treatment $F_2S_1M_1$ was observed as the best (51 73 days) This was followed by the treatment $F_2S_1M_3$ (54 40 days) The treatments, $F_1S_1M_2$ (59 26 days) and $F_1S_2M_2$ (60 16 days) took maximum number of days to first harvest

4.1.5. DAYS FROM FLOWERING TO HARVEST

The data on days to first harvest are presented in Table 4 5. The days from flowering to harvest was minimum in control (28 36 days) This was on par with Ebb and Flow Technique ($F_2S_1M_1$ – 29 73 days) The days from flowering to harvest was higher in Deep Flow Technique ($F_1S_2M_2$ – 32 46 days)

The influence of nutrient solutions on days from flowering to harvest was significant The minimum days from flowering to harvest was observed in S_1 (Cooper's solution, $F_2S_1M_1$ – 29 73 days) The days from flowering to harvest was higher in S_2 (Hoagland's solution, $F_1S_2M_2$ – 32 46 days)

The influence of growing media on days from flowering to harvest was significant In M_1 (coco peat) days from flowering to harvest was minimum ($F_2S_1M_1$ – 29 73 days) This was followed by M_3 (pebbles, $F_2S_1M_3$ – 30 03 days) The days from flowering to harvest was highest in M_2 (expanded clay pellets, $F_1S_2M_2$ – 32 46 days).

The treatment $F_2S_1M_1$ was the best (29 73 days). The treatment $F_2S_1M_3$ was on par with the former (30 03 days). The treatments, $F_1S_1M_2$ (31 80 days) and $F_1S_2M_2$ (32 46 days) took maximum number of days from flowering to harvest

Table 4.2. Days to first flower appearance

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	24 76	26.73	22 06	24 76
M_2	27 46	27 70	25 73	27 03
M_3	25 63	27 06	24 36	25 30
Mean	25 95	27 16	24 05	25 69
Control (POP)	19 83			

CD (0.05) = 1.23

Table 4.3. Days to first fruit set

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	28.76	30 73	25 73	27 76
M_2	30 46	31 70	29 40	30 36
M_3	28 63	30 73	27 70	28 30
Mean	29 28	31 05	27 61	28 80
Control (POP)	23 16			

CD (0.05) = 1.30

F_1 – Deep Flow Technique, F_2 – Ebb and Flow Technique

S_1 – Cooper's solution, S_2 – Hoagland's solution

M_1 – Coco peat, M_2 – Expanded clay pellets, M_3 - Pebbles

Table 4.4. Days to first harvest

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	56 33	57 90	51 73	55 93
M_2	59 26	60 16	56 06	59 20
M_3	56 40	58 06	54 40	56 76
Mean	57 33	58 70	54 06	57 29
Control (POP)	48 20			

CD (0.05) = 1.57

Table 4.5. Days from flowering to harvest

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	31.36	31 16	29 73	31 16
M_2	31 80	32 46	30 33	32 16
M_3	30 76	31 00	30 03	31 46
Mean	31 30	31 54	30 03	31 59
Control (POP)	28 36			

CD (0.05) = 1.37

F_1 – Deep Flow Technique, F_2 – Ebb and Flow Technique

S_1 – Cooper's solution, S_2 – Hoagland's solution

M_1 – Coco peat, M_2 – Expanded clay pellets, M_3 - Pebbles

4.1.6. FRUITS PER PLANT

The data on fruits per plant are presented in Table 4 6 The number of fruits per plant was highest in control (39 16) This was followed by Ebb and Flow Technique ($F_2S_1M_1$ – 36.50) The fruits per plant was minimum in Deep Flow Technique ($F_1S_2M_2$ – 16 40)

The influence of nutrient solutions on number of fruits per plant was significant The number of fruits per plant was highest in S_1 (Cooper's solution, $F_2S_1M_1$ – 36 50) In S_2 (Hoagland's solution) lowest number of fruits were produced $F_1S_2M_2$ – 16 40)

Growing media significantly influenced the fruits per plant In M_1 (coco peat), plants produced maximum number of fruits ($F_2S_1M_1$ – 36.50) This was followed by M_3 (pebbles, $F_2S_1M_3$ – 34 36) The fruits per plant was minimum in M_2 (expanded clay pellets, $F_1S_2M_2$ – 16 40)

The treatment $F_2S_1M_1$ was considered as the best (36 50) This was followed by the treatment $F_2S_2M_1$ (35 06) The lowest number of fruits were recorded from $F_1S_1M_2$ (18 33) and $F_1S_2M_2$ (16 40)

4.1.7. DURATION OF THE CROP

The data on duration of the crop are presented in Table 4 7 The duration of the crop was highest in control (88 5 days) This was followed by Ebb and Flow Technique ($F_2S_1M_1$ – 85 73 days) The duration of the crop was lowest in Deep Flow Technique ($F_1S_2M_2$ – 77 90 days)

The influence of nutrient solutions on duration of the crop was significant The maximum duration of the crop was observed in S_1 (Cooper's solution, $F_2S_1M_1$ – 85 73 days) In S_2 (Hoagland's solution) crops exhibited minimum duration ($F_1S_2M_2$ – 77 90 days)

The nature of growing media on duration of the crop was significant In M_1 (coco peat), crop duration was highest ($F_2S_1M_1$ – 85 73 days), followed by M_3 (pebbles, $F_2S_1M_3$ –84 13 days) The crop duration was observed as lowest in M_2 (expanded clay pellets, $F_1S_2M_2$ – 77 90 days)

The duration of the crop was highest in $F_2S_1M_1$ (85 73 days) This was followed by the treatment $F_2S_2M_1$ (84 46 days) The duration of the crop was lowest in $F_1S_1M_2$ (78 50 days) and $F_1S_2M_2$ (77 90 days)

4.1.8. NUMBER OF HARVESTS

The data on number of harvest are presented in Table 4 8 The number of harvest was highest in Ebb and Flow Technique ($F_2S_1M_1$ –20 16) This was followed by control (19 66) The number of harvest was minimum in Deep Flow Technique ($F_1S_2M_2$ – 6 46)

The influence of nutrient solutions on number of harvest was significant The maximum number of harvest was recorded in S_1 (Cooper's solution, $F_2S_1M_1$ – 20 16) The minimum number of harvest was observed in S_2 (Hoagland's solution, $F_1S_2M_2$ – 6 46)

The nature of the growing media significantly influenced the number of harvests The number of harvest was highest in M_1 (coco peat, $F_2S_1M_1$ – 20 16) This was followed by M_3 (pebbles, $F_2S_1M_3$ – 16 03) The number of harvests was minimum in M_2 (expanded clay pellets, $F_1S_2M_2$ – 6 46)

The number of harvest was highest in the treatment $F_2S_1M_1$ (20 16) and was followed by the treatment $F_2S_2M_1$ (16 96) The lowest number of harvests were recorded from $F_1S_1M_2$ (6 50) and $F_1S_2M_2$ (6 46)

4.1.9. YIELD PER PLANT (kg)

The data on yield per plant are presented in Table 4 9 , Fig 2 and Plate 10 - Plate 29 The highest yield per plant was recorded in control (2 08 kg) This was followed by Ebb and Flow Technique ($F_2S_1M_1$ – 1 67 kg) The yield per plant was lowest in Deep Flow Technique ($F_1S_2M_2$ – 0 32 kg)

There was significant influence of nutrient solutions on yield per plant The highest yield per plant was observed in S_1 (Cooper's solution, $F_2S_1M_1$ – 1 67 kg) The lowest yield per plant was recorded from S_2 (Hoagland's solution, $F_1S_2M_2$ – 0 32 kg)

Growing media significantly influenced the yield per plant The highest yield per plant was recorded in M_1 (coco peat, $F_2S_1M_1$ – 1 67 kg), followed by M_3 (pebbles, $F_2S_1M_3$ – 1 48 kg) The yield per plant was lowest in M_2 (expanded clay pellets, $F_1S_2M_2$ – 0 32 kg)

The best treatment was $F_2S_1M_1$ It produced an yield of 1 67 kg per plant This was followed by the treatment $F_2S_2M_1$ (1 53 kg) The lowest yield was recorded from the treatments, $F_1S_1M_2$ (0.37 kg) and $F_1S_2M_2$ (0 32 kg).

Table 4.6. Fruits per plant (Number)

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	31 53	31 40	36 50	35 06
M_2	18 33	16 40	20 10	19 30
M_3	29 73	28 70	34 36	33 06
Mean	26 53	25 50	30.32	29 14
Control (POP)	39 16			

CD (0.05) = 1.30

Table 4.7. Duration of the crop (Days)

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	83 03	81 76	85 73	84 46
M_2	78 50	77 90	82 50	79 86
M_3	81 96	80 93	84 13	83 73
Mean	81 16	80 19	84 12	82 68
Control (POP)	88 5			

CD (0.05) = 1.12

F_1 – Deep Flow Technique, F_2 – Ebb and Flow Technique

S_1 – Cooper's solution, S_2 – Hoagland's solution

M_1 – Coco peat, M_2 – Expanded clay pellets, M_3 - Pebbles

Table 4.8. Number of harvests

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	15 13	14 43	20 16	16 96
M_2	6 50	6 46	9 83	7 03
M_3	13 60	13 13	16 03	14 80
Mean	11 74	11 34	15 34	12 93
Control (POP)	19 66			

CD (0.05) = 0.97

Table 4.9. Yield per plant (kg)

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	1 32	1 27	1 67	1 53
M_2	0 37	0 32	0 51	0 44
M_3	1 15	1 07	1 48	1 42
Mean	0 94	0 88	1 22	1 13
Control (POP)	2 08			

CD (0.05) = 0.05

F_1 – Deep Flow Technique, F_2 – Ebb and Flow Technique

S_1 – Cooper's solution, S_2 – Hoagland's solution

M_1 – Coco peat, M_2 – Expanded clay pellets, M_3 - Pebbles

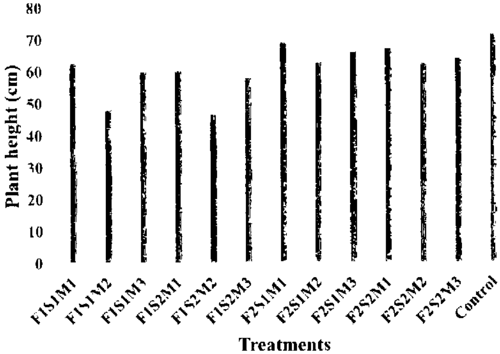


Fig 1 Plant height at 50 days after transplanting

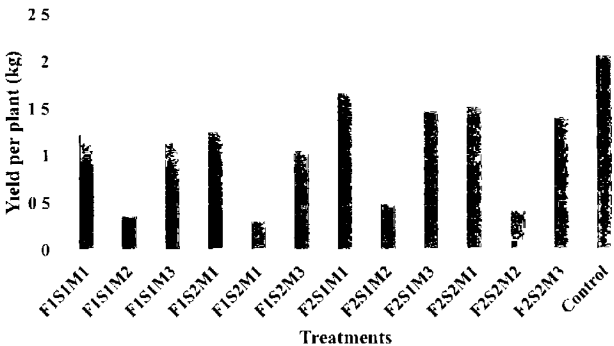


Fig 2 Yield per plant (kg)

Plate 10

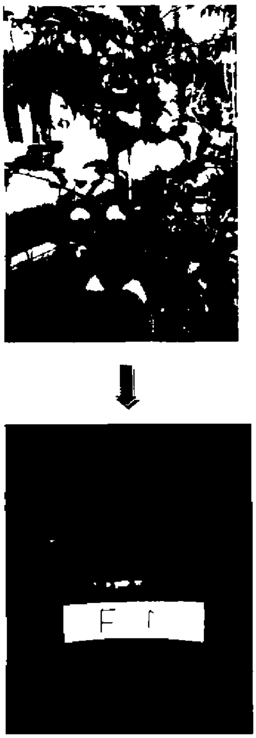


Plate 11

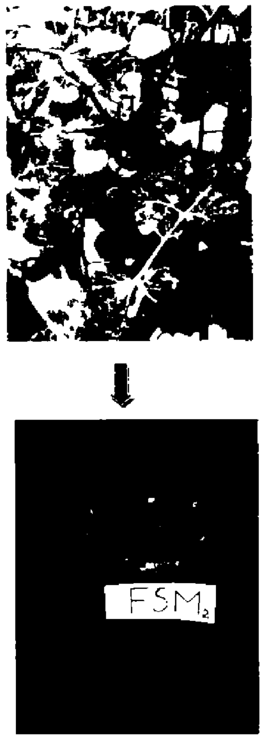


Plate 12

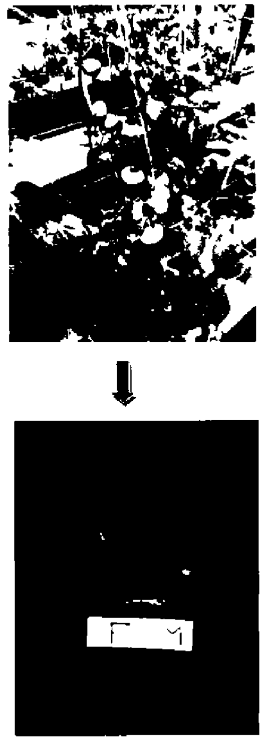


Plate 10 – Fruits from $F_1S_1M_1$

Plate 11 – Fruits from $F_1S_1M_2$

Plate 12 – Fruits from $F_1S_1M_3$

Plate 13

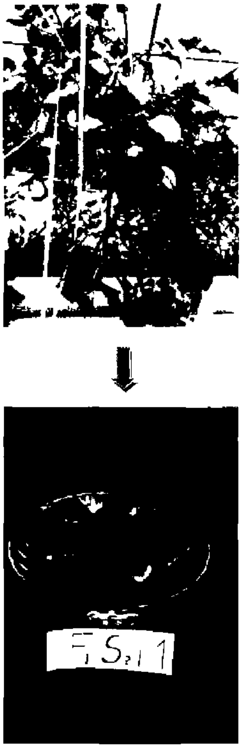


Plate 14

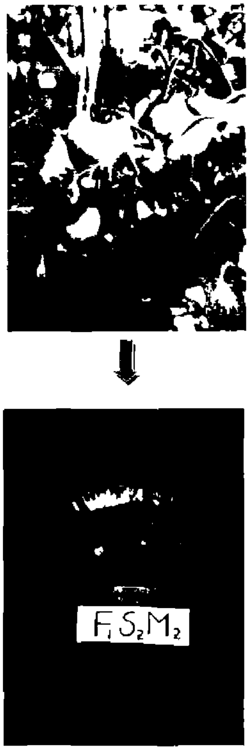


Plate 15

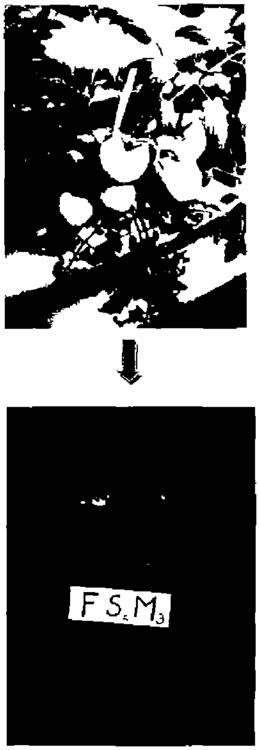


Plate 13 – Fruits from $F_1S_2M_1$

Plate 14 – Fruits from $F_1S_2M_2$

Plate 15 – Fruits from $F_1S_2M_3$

Plate 16

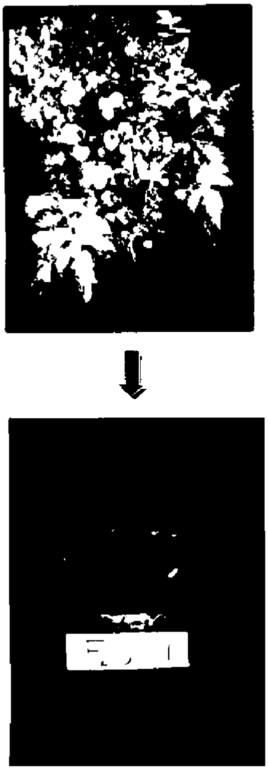
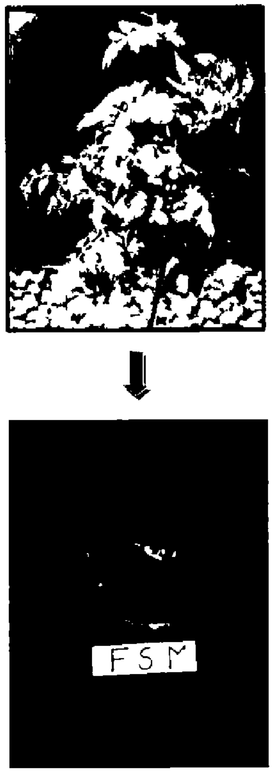


Plate 17



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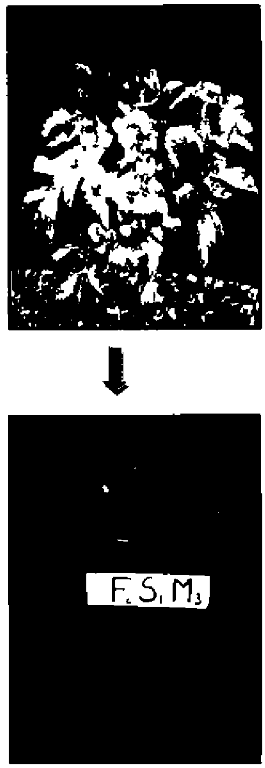

Plate 16 – Fruits from $F_2S_1M_1$

Plate 17 – Fruits from $F_2S_1M_2$

Plate 18 – Fruits from $F_2S_1M_3$

Plate 19

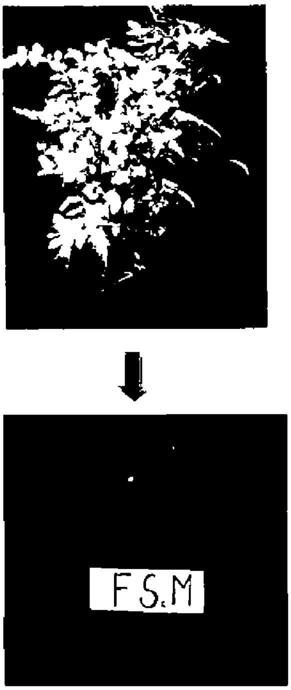

Plate 20

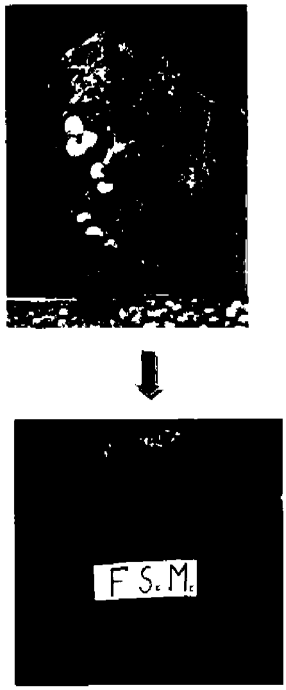

Plate 21

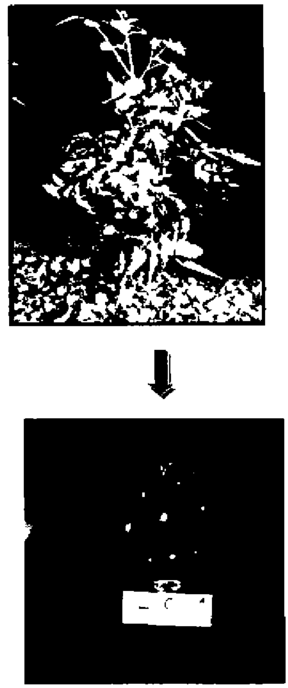

Plate 22

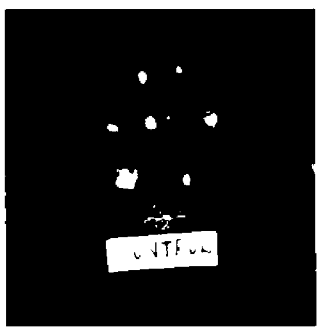

Plate 19 – Fruits from $F_3S_3M_1$

Plate 20 – Fruits from $F_2S_2M_2$

Plate 21 – Fruits from $F_3S_3M_3$

Plate 22 - Fruits from control

4.1.10. YIELD PER UNIT AREA (kg/m²)

The data on yield per unit are given in Table 4 10 The highest yield per unit area was recorded in control (18 72 kg/m²) Plants under Deep Flow Technique ($F_1S_1M_1$ – 18 48 kg/m²) was on par with that of control The lowest yield per unit area was recorded in Ebb and Flow Technique ($F_2S_2M_2$ – 3 96 kg/m²) The influence of nutrient solution on yield per unit area was insignificant

The nature of growing media significantly influenced the yield per unit area The highest yield per unit area was recorded in M_1 (coco peat) This was followed by M_3 (pebbles, $F_1S_1M_3$ – 16 10 kg/m²) In M_2 (expanded clay pellets), yield per unit area was observed to be the lowest ($F_2S_2M_2$ – 3 96 kg/m²)

The treatment $F_1S_1M_1$ was the best (18 48 kg/m²) with respect to yield per unit area This was followed by the treatment $F_1S_2M_1$ (17 78 kg/m²) The yield per unit area was the lowest in the treatment $F_2S_2M_2$ (3 96 kg/m²)

4.1.11. MARKETABLE YIELD (kg/plant)

The data on marketable yield per plant are presented in Table 4 11 The highest marketable yield was recorded in control (2.08 kg) This was followed by Ebb and Flow Technique ($F_2S_1M_1$ – 1 67 kg) The lowest marketable yield was in Deep Flow Technique ($F_1S_2M_2$ – 0 32 kg)

There was significant influence of nutrient solutions on marketable yield The highest marketable yield was observed in S_1 (Cooper's solution, $F_2S_1M_1$ – 1 67 kg) The lowest marketable yield was recorded from S_2 (Hoagland's solution, $F_1S_2M_2$ – 0 32 kg)

Growing media significantly influenced the marketable yield The highest marketable yield was recorded in M_1 (coco peat, $F_2S_1M_1$ – 1 67 kg), followed by M_3 (pebbles, $F_2S_1M_3$ – 1 48 kg). The marketable yield was the lowest in M_2 (expanded clay pellets, $F_1S_2M_2$ – 0 32 kg)

The best treatment was $F_2S_1M_1$ It produced a marketable yield of 1 67 kg This was followed by the treatment $F_2S_2M_1$ (1 53 kg) The lowest marketable yield was recorded from the treatments, $F_1S_1M_2$ (0 37 kg) and $F_1S_2M_2$ (0 32 kg)

4.1.12. AVERAGE FRUIT WEIGHT (g)

The data on average fruit weight are presented in Table 4 12 and Fig 3 The average fruit weight was the highest in control (53 16 g) This was followed by Ebb and Flow Technique ($F_2S_1M_1$ – 45.86 g) The average fruit weight was the lowest in Deep Flow Technique ($F_1S_2M_2$ – 19 96 g)

The influence of nutrient solutions on average fruit weight was significant. The highest average fruit weight was recorded in S_1 (Cooper's solution, $F_2S_1M_1$ – 45 86 g) and the lowest in S_2 (Hoagland's solution, $F_1S_2M_2$ – 19 96 g)

The nature of growing media significantly influenced the average fruit weight The highest average fruit weight was recorded from M_1 (coco peat, $F_2S_1M_1$ – 45 86 g) This was followed by M_3 (pebbles, $F_2S_1M_3$ – 43 43 g) In M_2 (expanded clay pellets) the lowest average fruit was observed ($F_1S_2M_2$ – 19 96 g)

The treatment $F_2S_1M_1$ was the best (45 86 g) This was followed by the treatment $F_2S_1M_3$ (43 43 g) The average fruit weight was lower in the treatments, $F_1S_1M_2$ (20 93 g) and $F_1S_2M_2$ (19 96 g)

4.1.13. TOTAL SOLUBLE SOLIDS (°Brix)

The data on TSS of fruits are given in Table 4 13. There was significant difference between the control and hydroponic treatments The TSS of fruits from control plants was significantly lower than that of all other treatments For the fruits from control the TSS was 6 43 and the TSS varied from 7 3 to 7 9 in all other treatments

4.1.14. ACIDITY (%)

The data on acidity of fruits are presented in Table 4 14 The acidity was the highest in fruits obtained from control plants In all other treatments there was no significant difference for acidity, and it varied from 0 51 per cent to 0 59 per cent

4.1.15. BIOMASS OF ROOTS AT HARVEST (g)

The data on biomass of roots at harvest are presented in Table 4 15 and Fig 4 The highest value for biomass of roots at harvest was observed in control (15 43g) This was followed by Ebb and Flow Technique ($F_2S_1M_1$ – 10 36 g) The lowest value for biomass of roots at harvest was recorded from Deep Flow Technique ($F_1S_2M_2$ – 5 50 g).

The influence of nutrient solutions on biomass of roots at harvest was significant The highest biomass of roots were recorded in S_1 (Cooper's solution, $F_2S_1M_1$ – 10 36 g) and the lowest in S_2 (Hoagland's solution, $F_1S_2M_2$ – 5 50 g)

The nature of growing media significantly influenced the biomass of roots at harvest The highest value for biomass of roots at harvest was recorded from M_1 (coco peat, $F_2S_1M_1$ – 10 36 g) This was followed by M_3 (pebbles, $F_2S_1M_3$ – 9 03 g) In M_2 (expanded clay pellets) the lowest value for biomass of roots at harvest was observed ($F_1S_2M_2$ – 5 50 g)

The treatment $F_2S_1M_1$ was the best (10.36 g). This was followed by the treatment $F_2S_1M_3$ (9 03 g) The biomass of roots at harvest was lower in $F_1S_1M_2$ (6 23 g) and $F_1S_2M_2$ (5 50 g)

4.1.16. INCIDENCE OF PESTS AND DISEASES

The incidence of pests and diseases were found to be very less in the present investigation Eventhough diseases were completely absent, insect pests like serpentine leaf miners, mealy bugs and plant hoppers were observed in all the treatments But control measures were taken as and when the incidence was noticed, so they did not affect the marketable yield

Table 4.10. Yield per unit area (kg/m²)

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	18 48	17 78	15 03	13 77
M_2	5 18	4 48	4 59	3 96
M_3	16 10	14 98	13 32	12 78
Mean	13 25	12 41	10 98	10 17
Control (POP)	18 72			

CD (0.05) = 0.92

Table 4.11. Marketable yield (kg)

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	1 32	1 27	1 67	1 53
M_2	0 37	0 32	0 51	0 44
M_3	1.15	1 07	1 48	1 42
Mean	0 94	0 88	1 22	1 13
Control (POP)	2.08			

CD (0.05) = 0.05

F_1 – Deep Flow Technique, F_2 – Ebb and Flow Technique

S_1 – Cooper's solution, S_2 – Hoagland's solution

M_1 – Coco peat, M_2 – Expanded clay pellets, M_3 - Pebbles

Table 4.12. Average fruit weight (g)

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	42 23	40 56	45 86	43 40
M_2	20 93	19 96	25 73	23 36
M_3	39 10	37 40	43 43	43 10
Mean	34 08	32 64	38 34	36 62
Control (POP)	53 16			

CD (0.05) = 1.11

Table 4.13. TSS of fruits (°Brix)

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	7 66	7 50	7 50	7 70
M_2	7 63	7 33	7 83	7 96
M_3	7 73	7 70	7 70	7 30
Mean	7 67	7 51	7 67	7 65
Control (POP)	6 43			

CD (0.05) = 0.56

F_1 – Deep Flow Technique, F_2 – Ebb and Flow Technique

S_1 – Cooper's solution, S_2 – Hoagland's solution

M_1 – Coco peat, M_2 – Expanded clay pellets, M_3 - Pebbles

Table 4.14. Acidity (%)

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	0 58	0 57	0 56	0 59
M_2	0 58	0 51	0 59	0 56
M_3	0 59	0 51	0 56	0 54
Mean	0 58	0 53	0 57	0 56
Control (POP)	0 63			

CD (0.05) = 0.07

Table 4.15. Biomass of roots at harvest (g)

	F_1		F_2	
	S_1	S_2	S_1	S_2
M_1	8 80	7 03	10 36	8 83
M_2	6 23	5 50	7 40	7 10
M_3	7 70	7 20	9 03	8 43
Mean	7 57	6 57	8 93	8 12
Control (POP)	15 43			

CD (0.05) = 0.72

F_1 – Deep Flow Technique, F_2 – Ebb and Flow Technique

S_1 – Cooper's solution, S_2 – Hoagland's solution

M_1 – Coco peat, M_2 – Expanded clay pellets, M_3 - Pebbles

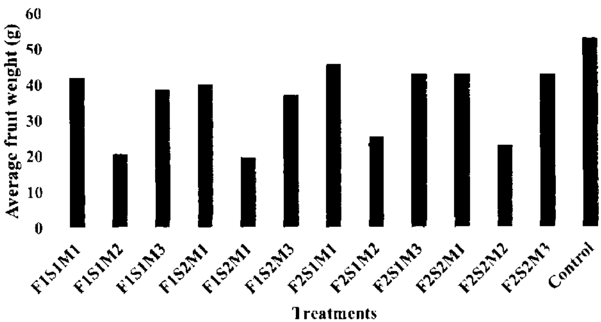

Fig 3 Average fruit weight (g)

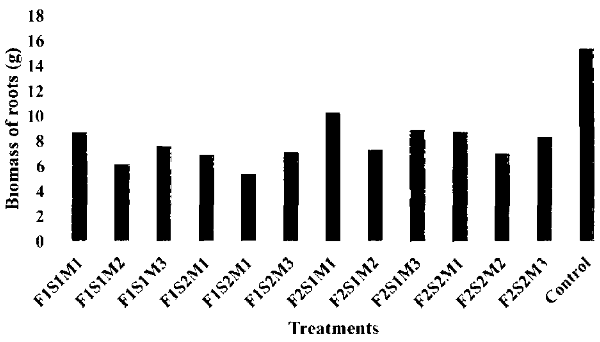

Fig 4 Biomass of roots at harvest (g)

4.1.17. BENEFIT COST RATIO

The data on benefit cost ratio are presented in Table 4 16 The B C ratio was computed on the basis of yield per unit area and by taking the price of 1kg of tomato as Rs 25 The highest benefit cost ratio was recorded in control treatment (1 92) This was followed by Ebb and Flow Technique ($F_2S_1M_1$ – 1 33) The lowest B C ratio was recorded from Deep Flow Technique ($F_1S_2M_2$ – 0 14)

Table 4.16. Benefit cost ratio based on yield per unit area (1 m²)

Sl No	Treatments	Benefit cost ratio
1	$F_1S_1M_1$	1 10
2	$F_1S_1M_2$	0 16
3	$F_1S_1M_3$	0 89
4	$F_1S_2M_1$	1.09
5	$F_1S_2M_2$	0 14
6	$F_1S_2M_3$	0 86
7	$F_2S_1M_1$	1 33
8	$F_2S_1M_2$	0 19
9	$F_2S_1M_3$	1 20
10	$F_2S_2M_1$	1 31
11	$F_2S_2M_2$	0 17
12	$F_2S_2M_3$	1 18
13	Control	1 92

F_1 – Deep Flow Technique, F_2 – Ebb and Flow Technique

S_1 – Cooper's solution, S_2 – Hoagland's solution

M_1 – Coco peat, M_2 – Expanded clay pellets, M_3 - Pebbles

4.1.18. TEMPERATURE

The data on temperature from ınsıde and outsıde of the raın shelter are gıven ın Appendıx IV The correlatıon between plant heıght and temperature are presented m Table 4 17 and Table 4 18 The dıfference ın temperature from ınsıde and outsıde of the raın shelter was mınımum Temperature has showed negatıve correlatıon wıth plant heıght and when temperature ıncreased, the plant heıght decreased

Table 4.17. Correlatıon between plant heıght and temperature inside the rain shelter

SI No	Factors	Heıght	
		Correlatıon coeffıcıent	Level of sıgnıficance
1	Maxımum temp	- 405**	000
2	Mınımum temp	- 262*	018

** Correlatıon ıs sıgnıficant at the 0 01 level
*Correlatıon ıs sıgnıficant at the 0 05 level

Table 4.18. Correlation between plant heıght and temperature outside the rain shelter

SI No	Factors	Heıght	
		Correlatıon coeffıcıent	Level of sıgnıficance
1	Maximum temp	- 448**	000
2	Mınımum temp	- 262*	018

** Correlatıon ıs sıgnıficant at the 0 01 level
*Correlatıon ıs sıgnıficant at the 0 05 level

4.1.19. EC AND pH OF NUTRIENT SOLUTION

The data on EC and pH of nutrient solutions are given in Table 4 19 The EC of Cooper's solution remained within a range of 0 42 to 0 44 dS/m and its pH remained within 5 71 to 6 00 The EC of Hoagland's solution was within 0.31 to 0 33 dS/m and its pH varied within 5 66 to 6 00

Table 4.19. EC and pH of nutrient solutions

Date	Cooper's solution		Hoagland's solution	
	EC (dS/m)	pH	EC (dS/m)	pH
13/10/15	0 43	5 79	0 33	5 71
20/10/15	0 42	5 72	0 33	5 72
27/10/15	0 43	5 91	0 33	5 72
3/11/15	0 43	5 81	0 31	5 92
11/11/15	0 42	6 00	0 33	5 66
18/11/15	0 43	5 91	0 32	5 98
25/11/15	0 43	5 71	0 33	5 89
2/12/15	0 42	5 90	0 33	5 72
9/12/15	0 44	5 77	0 31	6 00
16/12/15	0 42	5 85	0 32	5 71
23/12/15	0 43	5 86	0 31	5 61

4.1.20. NPK CONTENT OF COCO PEAT

The coco peat medium contained 0 32 per cent of nitrogen, 0 01 per cent of phosphorus and 0 36 per cent of potassium

4.1.21. NPK CONTENT OF PLANT (LEAF, SHOOT AND FRUIT)

The data on NPK content of plant are presented in Table 4.20 All the treatments varied significantly for N per cent of leaves The control treatment showed the highest content of nitrogen in their leaves (2 67%) This was followed by Ebb and Flow Technique ($F_2S_1M_1$ – 1 915%) The lowest nitrogen content of leaves was recorded from Deep Flow Technique ($F_1S_2M_2$ – 0.57%)

The influence of nutrient solutions on nitrogen per cent of leaves was significant The highest content of nitrogen was recorded from S_1 (Cooper's solution, $F_2S_1M_1$ –1 91%) and the lowest from S_2 (Hoagland's solution, $F_1S_2M_2$ –0 57%)

The nature of growing media significantly influenced the nitrogen per cent of leaves From M_1 (coco peat), the highest per cent of nitrogen was recorded ($F_2S_1M_1$ – 1 91%) This was followed by M_3 (pebbles, $F_2S_1M_3$ – 1 39%) In M_2 (expanded clay pellets) the lowest content of nitrogen was observed ($F_1S_2M_2$ – 0 57%)

The treatment $F_2S_1M_1$ contained the highest per cent of nitrogen in their leaves (1 91%) This was followed by the treatment $F_2S_2M_1$ (1 58%) The nitrogen per cent of leaves were lower in $F_1S_1M_2$ (0 58%) and $F_1S_2M_2$ (0 57%)

The phosphorus per cent of leaves was insignificant in all the treatments

The potassium per cent of leaves was highest in control treatment (1 40%) and this was on par with Ebb and Flow Technique ($F_2S_1M_1$ – 1 31%) The lowest content of leaf potassium was recorded from Deep Flow Technique ($F_1S_2M_2$ – 0 41%)

The influence of nutrient solutions on potassium per cent of leaves was significant The highest content of potassium was recorded from S_1 (Cooper's solution, $F_2S_1M_1$ – 1 31%) and the lowest from S_2 (Hoagland's solution, $F_1S_2M_2$ – 0 41%)

Growing media significantly influenced the potassium per cent of leaves Plants in M_1 (coco peat) contained the highest per cent of potassium in their leaves ($F_2S_1M_1$ – 1 31%) This was followed by M_3 (pebbles, $F_2S_1M_3$ – 1 09%) and plants in M_2 (expanded clay pellets) showed the lowest content of potassium in their leaves ($F_1S_2M_2$ – 0 41%)

The treatment $F_2S_1M_1$ gave the highest value for potassium per cent of leaves (1 31%) This was followed by the treatment $F_2S_2M_1$ (1 19%) The potassium per cent of leaves were lower in $F_1S_1M_2$ (0 48%) and $F_1S_2M_2$ (0 41%)

The control treatment significantly varied for nitrogen per cent of shoots from all other treatments The highest content of nitrogen in shoot was recorded from control (1.85%), which was followed by Ebb and Flow Technique ($F_2S_1M_1$ – 1 08%) The lowest per cent of nitrogen was obtained from Deep Flow Technique ($F_1S_2M_2$ – 0 49%) The influence of nutrient solutions on nitrogen per cent of shoot was insignificant

Growing media significantly influenced the nitrogen per cent of shoots The highest per cent of nitrogen in shoots was recorded from M_1 (coco peat, $F_2S_1M_1$ – 1 08%). Plants in M_3 (pebbles) was on par with the former ($F_2S_1M_3$ – 1 00%) and plants in M_2 (expanded clay pellets) showed the lowest content of nitrogen in their shoots ($F_1S_2M_2$ – 0 49%)

The treatment $F_2S_1M_1$ gave the highest value for nitrogen per cent of shoots (1 08%) This was followed by the treatment $F_2S_1M_3$ (1 00%) The nitrogen per cent of shoots were lower in $F_1S_1M_2$ (0 53%) and $F_1S_2M_2$ (0 49%)

The treatments did not show any significant variation for phosphorus per cent of shoots

The potassium per cent of shoots were highest in control (1 31%), followed by Ebb and Flow Technique ($F_2S_1M_1$ – 1 14%) The lowest per cent of potassium in shoots was recorded from Deep Flow Technique ($F_1S_2M_2$ – 0 37%)

Nutrient solutions significantly influenced the potassium per cent of shoots The highest value for potassium per cent of shoots was recorded from S_1 (Cooper's solution, $F_2S_1M_1$ –1 14%) and the lowest from S_2 (Hoagland's solution, $F_1S_2M_2$ –0 37%)

The nature of growing media significantly influenced the potassium per cent of shoots From M_1 (coco peat), the highest per cent of potassium in shoots was recorded ($F_2S_1M_1$ – 1 14%) This was followed by M_3 (pebbles, $F_2S_1M_3$ – 0 80%) In M_2 (expanded clay pellets) the lowest content of potassium was observed ($F_1S_2M_2$ – 0 37%)

The treatment $F_2S_1M_1$ contained highest per cent of potassium in their shoots (1 14%) This was followed by the treatment $F_1S_1M_1$ (0 87%) The potassium per cent of shoots were lower in $F_1S_1M_2$ (0 48%) and $F_1S_2M_2$ (0 37%)

Nitrogen per cent of fruits were highest in control (2 30%), which was followed by Ebb and Flow Technique ($F_2S_1M_1$ – 1 72%) The lowest per cent of nitrogen in fruits was recorded from Deep Flow Technique ($F_1S_2M_2$ – 0 47%) The influence of nutrient solution on nitrogen per cent of fruits was insignificant

The nature of growing media significantly varied the nitrogen per cent of fruits Plants in M_1 (coco peat), produced fruits with the highest per cent of nitrogen ($F_2S_1M_1$ – 1 72%) This was followed by plants in M_3 (pebbles, $F_2S_1M_3$ – 1 09%) Plants in M_2 (expanded clay pellets), produced fruits with the lowest per cent of nitrogen ($F_1S_2M_2$ – 0 47%)

The treatment $F_2S_1M_1$ produced fruits with the highest per cent of nitrogen (1 72%) The treatment $F_1S_2M_1$ (0 1 45%) was on par with the former The lowest nitrogen per cent of fruits was recorded from $F_1S_1M_2$ (0.53%) and $F_1S_2M_2$ (0 47%).

Phosphorus per cent of fruits did not show significant variation among treatments

Control showed the highest per cent of potassium in their fruits (0 80%) This was followed by Ebb and Flow Technique ($F_2S_1M_1$ – 0 70%) The lowest per cent of potassium in fruits was recorded from Deep Flow Technique ($F_1S_2M_2$ – 0 34%)

Nutrient solutions significantly influenced the potassium per cent of fruits Fruit from S_1 (Cooper's solution) contained the highest per cent of potassium ($F_2S_1M_1$ – 0 70%) and fruits from S_2 contained the lowest per cent of potassium (Hoagland's solution, $F_1S_2M_2$–0 34%)

Growing media significantly influenced the potassium per cent of fruits Plants in M_1 (coco peat), produced fruits with the highest per cent of potassium ($F_2S_1M_1$ – 0 70%) This was followed by M_3 (pebbles, $F_2S_1M_3$ – 0 60%) Plants in M_2 (expanded clay pellets), produced fruits with the lowest per cent of potassium ($F_1S_2M_2$ – 0 34%)

The treatment $F_2S_1M_1$ produced fruits with the highest per cent of potassium (0 70%) This was followed by the treatment $F_1S_1M_1$ (0 64%) The lowest per cent of potassium in fruits was recorded from $F_1S_1M_2$ (0 39%) and $F_1S_2M_2$ (0 34%)

Table 4.20. NPK content of plant (leaf, shoot and fruit)

Plant part and nutrient %		F_1		F_2		CD (0 05)
		S_1	S_2	S_1	S_2	
Leaves (N%)	M_1	1 49	0 90	1 91	1 58	0 15
	M_2	0 58	0.57	0 90	0 67	
	M_3	1 11	0 82	1 39	0 72	
	Mean	1 06	0 76	1 4	0 99	
	Control	2 67				
Leaves (P%)	M_1	0 52	0 11	0 20	0 15	NS
	M_2	0 05	0 03	0 11	0 08	
	M_3	0 17	0 09	0 15	0 11	
	Mean	0 22	0 07	0.15	0 11	
	Control	0 28				
Leaves (K%)	M_1	1 13	0 89	1 31	1 19	0 09
	M_2	0 48	0 41	0 91	0 45	
	M_3	0 98	0 70	1 09	0 52	
	Mean	0 86	0 66	1 10	0 72	
	Control	1 40				
Shoot (N%)	M_1	0 94	0 81	1 08	0 96	0 18
	M_2	0 53	0 49	0 61	0 58	
	M_3	0 79	0 61	1 00	0 67	
	Mean	0 75	0 63	0 89	0 73	
	Control	1 85				
Shoot (P%)	M_1	0 12	0 11	0 14	0 11	NS
	M_2	0 09	0 07	0 10	0 11	
	M_3	0 17	0 10	0 11	0 12	
	Mean	0 12	0 09	0.11	0 11	
	Control	0 15				
Shoot (K%)	M_1	0 87	0 74	1 14	0 83	0 14
	M_2	0 48	0 37	0 51	0 48	
	M_3	0 61	0 50	0 80	0 64	
	Mean	0 65	0 53	0.81	0 65	
	Control	1 31				
Fruit (N%)	M_1	1 07	0 92	1 72	1 45	0 41
	M_2	0 53	0 47	0 60	0 56	
	M_3	0 96	0 84	1 09	0 71	
	Mean	0 85	0 74	1.13	0 90	
	Control	2 30				

Cont...

NPK content of plant (leaf, shoot and fruit)

Frunt (P%)	M_1	0 08	0 06	0 07	0.26	NS
	M_2	0 03	0 02	0 05	0 04	
	M_3	0 05	0 04	0 06	0 06	
	Mean	0 05	0 04	0 06	0 12	
	Control (POP)	0 08				
Frunt (K%)	M_1	0 64	0 64	0 70	0 61	0 05
	M_2	0 39	0 34	0 50	0 49	
	M_3	0 62	0 52	0 60	0 52	
	Mean	0 55	0 50	0 60	0 54	
	Control (POP)	0 70				

F_1 – Deep Flow Technique, F_2 – Ebb and Flow Technıque

S_1 – Cooper's solutıon, S_2 – Hoagland's solution

M_1 – Coco peat, M_2 – Expanded clay pellets, M_3 - Pebbles

DISCUSSION

5. DISCUSSION

Hydroponics is a technique where crops are cultivated in a soil less condition by supplying nutrients in solution Here the chances of pests, diseases and weeds are eliminated Eventhough the initial cost of establishment of the infrastructure is quite high, the recurring costs in the subsequent years are meagre and hence highly accepted Since it demands less space, it is well suited in urban areas, where land is the main constraint for cultivation

Tomato is a crop of high demand throughout the world due its versatility during all seasons It is nutritionally very rich also The increasing problems of soil borne diseases such as damping-off, root rots (*Pythium ultimum*, *Rhizoctonia solani*, *Phytophthora* spp), wilts (*Fusarium oxysporum* and *Verticillium dahliae*) and pests (borer pests, sucking pests, aphids etc) make the conventional cultivation a bit difficult (Stirling *et al* , 2016) The major constraint is the limiting availability of productive lands and adequate irrigation water Due to urbanization and industrialization most of the land get degraded and also loses its fertile top soil So it is advisable to go for alternate techniques like hydroponics

The results, obtained in the study on "Standardization of hydroponics in tomato", carried out in the Department of Olericulture, College of Horticulture, Vellanikkara during 2015 in the variety Anagha, are discussed in this chapter The study was conducted to test the methods, nutrient solutions and growing media for the hydroponic cultivation of tomato under rain shelter condition

5.1. GROWTH, YIELD PARAMETERS AND NUTRIENT CONTENT OF PLANTS

By analyzing the results and comparing the performance of plants, it was observed that, the control plants (plants grown in soil according to POP recommendations, under rain shelter condition) performed better than that of all other treatments After 50 days of transplanting it attained a mean height of 71 66 cm The control plants took least number of days for producing first flowers (19 83 days), first fruits (23 days), first harvesting (48 20 days) and flowering to harvest (28 36 days) The total duration of the crop (88 5 days) and biomass of roots at harvest (15 43g) were the highest in control The yield parameters like fruits per plant (39 16), number of harvests (19 66), yield per plant (2 08 kg), marketable yield (2 08 kg) and average fruit weight (53 16g) were the highest in control plants

The NPK content of plants grown in soil were higher than that of all other treatments Because the control plants were grown as per POP recommendations, by supplying both chemical fertilizers and farm yard manure, while in all other hydroponic treatments only specified amount of nutrient were supplied

Among hydroponic treatments, $F_2S_1M_1$ (a combination of Ebb and Flow Technique, Cooper's solution and coco peat) showed higher content of NPK It was significantly differed from all other treatments for nitrogen content of leaves (1 91 %), potassium content of leaves (1 31 %), potassium content of shoots (1 14 %) and nitrogen content of fruits (1 72 %) This may be due to the higher content of nutrients in Cooper's solution compared to Hoagland's solution and the presence of coco peat as growing medium

Similar results were reported by various researchers The reduced productivity in soil less culture is due to some complex actions The reduced unsaturated hydraulic conductivity and moderate matric potential in soil less media create zones of very low matric potential around root – medium interface, which adversely affects the water and oxygen uptake by plant roots This reduced water uptake and root respiration ultimately lead to low leaf water potential and finally the cessation of leaf, expansion of shoots and reduced productivity of crops (Raviv *et al* , 2004)

According to Fandi *et al* (2008), tomatoes produced the highest total marketable yield (7 92 tons/1000m²), yield per plant (1 8 kg/plant), average fruit weight (120 g), average fruit diameter (62 9 mm), average fruit length (58.8 mm) and fruit firmness (1 7 kg/cm²) under soil conditions They also revealed that, poor performance of plants in soil less culture was due to the changes in moisture content that rises at the expense of aeration, which may eventually affect the plant growth

Gruda (2009) reported that, compared to soil less culture, tomatoes grown in soil showed a higher overall performance in terms of growth, yield and fruit quality, because the plants cultivated in soil had better capacity of recovery in case of any adverse situation, without any visible quality deficiencies

Among treatments, plants grown in Ebb and Flow Technique, using coco peat medium supplied with Cooper's solution gave the largest value for all growth and yield parameters ($F_2S_1M_1$ - a combination of Ebb and Flow Technique, Cooper's solution and coco peat) The maximum height was attainted by the plants in this treatment after 50 days of transplanting (69 36 cm) The number of days taken for producing flowers were 22 06 days, for producing fruits were 25 73 days and for harvesting was 51 73 days, which was the lowest among hydroponic treatments The biomass of roots at the time of harvest was the highest (10 36 g) in this treatment The number of fruits per plant (36 50), number of harvests (20 16), yield per plant (1 67 kg), marketable yield (1.67 kg) and average fruit weight (45 86g) were also highest in this treatment

In a unit area of 1 m² under Deep Flow Technique, 14 plants were accommodated, where as in control and Ebb and Flow Technique there were only 9 plants When yield per unit area was considered $F_1S_1M_1$ (a combination of Deep Flow Technique, Cooper's solution and coco peat) was the best (18 48 kg/m²), and was on par with the plants grown in soil (18 72kg/m²) Since yield per unit area was high under Deep Flow Technique, it is evident that this technique can be recommended for areas having space constraints

All the growth and yield parameters were significantly influenced by the hydroponic methods, nutrient solutions and growing media. Both of the hydroponic methods showed promising results in the present study Out of the two nutrient solutions tested Cooper's solution showed high values for the growth and yield parameters and out of the three growing media, coco peat was the best

5.1.1. INFLUENCE OF METHOD

In the present investigation the Ebb and Flow Technique was found to be superior over Deep Flow Technique with respect to vegetative growth, flowering, fruiting and yield per plant It may be due to the better support and anchorage that has been received by the plants from this method (Plate 23 – Plate 28) similar to the soil environment The roots were also very strong and attained a tap root nature as like in soil (Plate 35) here, where as in Deep Flow Technique roots were more or less fibrous in nature (Plate 29 - Plate 34) Ebb and Flow Technique promoted the spreading of roots, there by the root surface came in contact with more area, which subsequently increased the nutrient absorption The experiments carried out by various scientists also support the results of the present study

In a study conducted by Strefeler (1991), reported that out of the various hydroponic techniques like ebb and flow system, nutrient film technique, slab substrates system, closed recirculation floors, and pulse watering system, ebb and flow system was the best for vegetable production

Storage root growth of radish was inconsistent with deep flow technique compared to ebb and flow technique with or without substrate (Terabayashi *et al* 1997)

The medicinal plant *Angelica acutiloba* was cultivated hydroponically using deep flow, ebb and flow, and nutrient film techniques The results showed that ebb and flow technique with a substrate provided the best results amongst the systems tested, giving an increase in root fresh weight of about 7 1-9 6 times that of cultivation in all other techniques (Yomo *et al* , 1998)

Hanic *et al* (2012), revealed that "Ebb and flow" system satisfied all environmental standards for growing cucumbers under polyhouse conditions.

Eventhough yield per plant was higher under Ebb and Flow Technique, the yield per unit area was maximum under Deep Flow Technique, because here the planting density was more (14 plants per m^2) Since plants were arranged in a tier like manner, efficient utilization vertical space was also possible under Deep Flow Technique

Plate 23

Plate 24

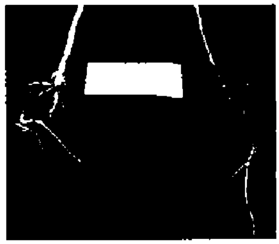

Plate 25

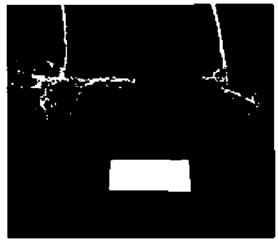

Plate 26

Plate 27

Plate 28

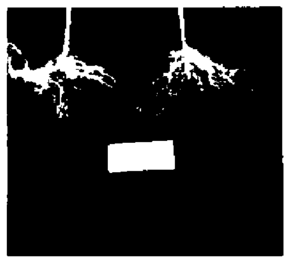

Plate 23 – Roots at harvest from $F_2S_1M_1$

Plate 24 – Roots at harvest from $F_2S_1M_2$

Plate 25 – Roots at harvest from $F_2S_1M_3$

Plate 26 – Roots at harvest from $F_2S_2M_1$

Plate 27 – Roots at harvest from $F_2S_2M_2$

Plate 28 - Roots at harvest from $F_2S_2M_3$

Plate 29

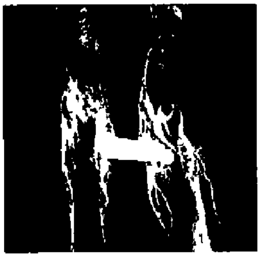

Plate 30

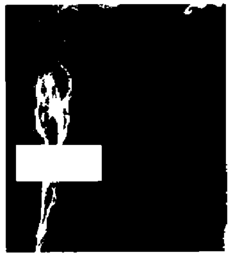

Plate 31

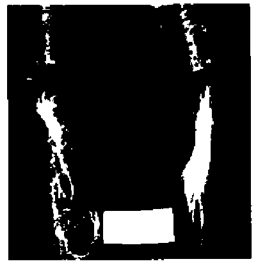

Plate 32

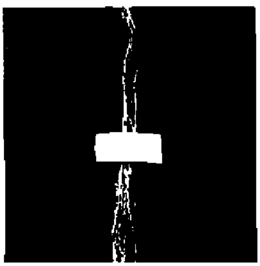

Plate 33

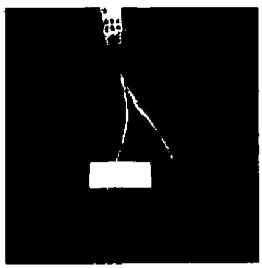

Plate 34

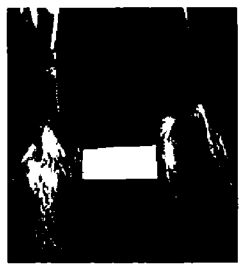

Plate 29 – Roots at harvest from $F_1S_1M_1$

Plate 30 – Roots at harvest from $F_1S_1M_2$

Plate 31 – Roots at harvest from $F_1S_1M_3$

Plate 32 – Roots at harvest from $F_2S_2M_1$

Plate 33 – Roots at harvest from $F_1S_2M_2$

Plate 34 - Roots at harvest from $F_1S_2M_3$

Plate 35

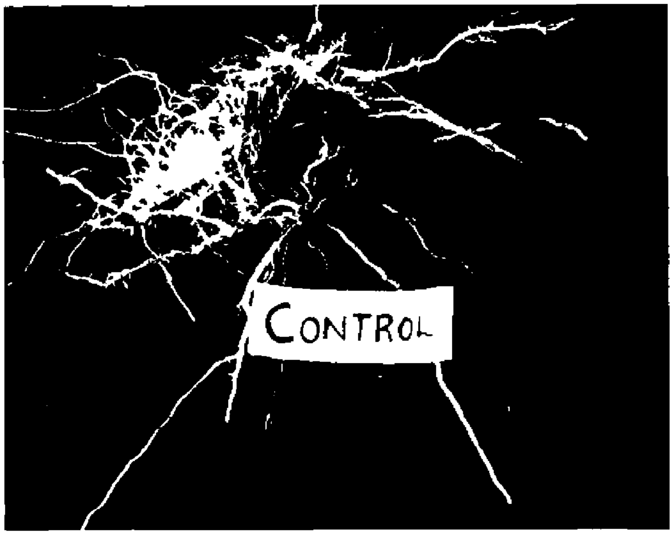

Plate 35 – Roots at harvest from control

5.1.2. INFLUENCE OF NUTRIENT SOLUTION

In the present investigation Cooper's solution appeared to be superior to Hoagland's solution, since it contained higher nutrient content The experiments conducted by various scientists are in close conformity with the findings of the present investigation

When Cooper's 1988 nutrients solution recipe was used to grow tomato crops under hydroponics, it resulted in early development of flowers, early fruit maturity, development of more number of flower clusters per plant, more number of fruits per plant, better average fruit weight, fruit diameter, more number of leaves per plant, and more fruit yield per plant compared to Imai's 1987 solution (Shah *et al* , 2011)

El-Shinawy and Gawish (2006) reported that, lettuce produced highest yield under Cooper's solution under soil less culture

Shah *et al* (2009a) found that spinach cultivar 'Local double' when grown using Cooper's solution with a concentration (mg/litre) of 236- N, 60- P, 300- K, 85- Ca, 50- Mg, 68- S, 12- Fe EDTA, 2- Mn, 0 1- Zn, 0 1- Cu, 0 3- B and 0 2- Mo resulted in early harvest (32 44 days after seeding), more number of leaves (12 33 per plant), larger average leaf length (34 43cm) and more average number of roots (118 45 per plant) They also reported that the cucumber cultivar 'Market more' showed more average number of fruits (26 58 per plant), high average fruit weight (195 7g), and high average fruit yield (5 75kg per plant) when grown hydroponically using Cooper's solution

The highest growth in terms of fresh weight, dry weight, leaf number, leaf area and canopy width of butter head lettuce was noticed by Orpong *et al* , (2015) when grown using Cooper nutrient solution

5.1.3. INFLUENCE OF MEDIUM

In the present investigation it was found that the growth and yield of tomato plants in coco peat medium was the highest compared to other two media The NPK analysis of coco peat revealed that, it contained 0 32 % of N, 0 01 % of P and 0 36 % of K So the higher growth and yield of plants in coco peat medium may be due to its better water holding capacity, better aeration and high potassium content The studies conducted by various researchers also agreed that, growing media has a significant effect on the growth and yield of crops (Prdem *et al* , 1994, Peyvast *et al* , 2007, Peyvast *et al* , 2010)

The high potassium content, high water holding capacity and better aeration provided by the coconut fiber increased its popularity as a growing medium for tomatoes in soil less culture (Handreck, 1993 and Vavrina *et al* , 1996)

According to Cresswell (2002), coconut coir dust can be used as an alternative for peat in soil less culture, due to its properties like high amount of potassium, less acidic nature, high air filled porosity, high water holding capacity, better capillary wetting and physical stability

The study carried out by Noguera *et al* (2000), also revealed that coconut waste was the best medium for growing horticultural crops They observed that this medium was light in weight and had high total porosity (94 per cent of total volume) It also exhibited high air content pH was found to be slightly acidic and EC varied between 0 4 and 0 6 dS/m Cation exchange capacity ranged from 32 to 95 m e /100 g and C/N ratio averaged to 117 The amount of naturally-occurring available nutrients like mineral nitrogen, calcium and magnesium was low but phosphorus and potassium contents were high in coco peat

Yau and Murphy (2000), reported that when composted coco peat was used as the growing medium, tomato plants produced higher dry root weights (22%), fruit numbers (43%) and total yield (64%)

In an experiment conducted by Colla *et al* (2003) on soil less cultivation of cucumbers, it was observed that under coir pith and perlite media the overall yield was high The average number of fruits, yield per plant and average fruit weight were found to be higher in these media

When coconut fiber was used as the growing medium, tomato crop yielded heaviest fruits (128g) (Carrijo *et al*, 2004)

According to Raviv and Lieth (2008), high water holding capacity and lower air filled porosity (10- 30 per cent) of coir pith medium determined the vigour of the plants grown in it

Jankauskiene *et al* (2015), reported that tomatoes grown in coco peat substrate showed an increase in overall performance by 8 1–9 2% compared with the plants grown in rockwool Plants attained a height of 136 9 cm and average number of leaves of 21 7 under coco peat medium The yield of tomatoes was higher in coco peat (20 6 kg/ m^2) when compared to rockwool medium (20 2 kg/m^2)

5.2. FRUIT QUALITY PARAMETERS

From the present investigation it was found that, TSS was significantly high when plants were grown hydroponically Among the hydroponic treatments, the influence of methods, nutrient solutions and media were insignificant, and the TSS varied from 7 3 to 7 9

Tomato plants produced fruits with higher TSS when grown under coco peat medium compared to the fruits from nutrient film technique and soil cultivation (Gormley and Egan, 1982) Baevre (1985) reported that total dry matter, soluble dry matter, and total sugar and reducing sugar contents were higher in tomato fruits from hydroponics than from soil culture Sen and Sevgican (1997), also revealed that higher TSS for tomatoes grown under soil less culture compared to soil culture Butt *et al* (2004) found that, when tomatoes were grown under hydroponics, it produced highly flavoured fruits with less water contents and more total soluble solids (TSS)

Salinity applied to hydroponically grown tomatoes increased its TSS (Pessarakli, 2016)

For titrable acidity, the fruits from control treatment gave higher value (0.63 per cent) than that of all other treatments. The three factors viz, methods, nutrient solutions and media did not make any significant variation for acidity and it ranged from 0 51 per cent to 0 59 per cent only

Tomato fruits from hydroponic culture contained less acid and more reducing sugars than those grown in soil (Granges, 1980) Auerswald *et al* (1996) also reported that, tomatoes grown in soil had a higher concentration of acids than those grown in hydroponics

In general, fruits from hydroponics exhibited better quality in terms of higher TSS and lower acidity, which further increased the value of tomato fruits for fresh consumption It was also observed that the fruits from hydroponics exhibited extended keeping quality compared to those from soil

5.3. GROWING CONDITIONS FOR THE CROP

Diseases were absent during the course of the investigation But insect pests like mealy bugs, serpentine leaf miners and plant hoppers were found occasionally Consequent to the application of biocontrol agents there was no reduction in marketable yield

The temperature varied from a maximum of 33 2 °C to a minimum of 21° C inside the rain shelter and the outside temperature varied from a maximum of 33 °C to a minimum of 21° C during the course of investigation Since the difference in temperature from inside and outside of the rain shelter was very low and the temperature was near to the optimum, it is clear that temperature was not the reason for reduction in yield for the crops which were raised hydroponically under the rain shelter

The EC indicates the strength of nutrient solution Since fresh nutrient solutions were prepared and added at weekly intervals, the EC and pH of both Cooper's and Hoagland's solutions remained within a constant range during the course of present investigation

When both nutrient solutions were prepared as per standard composition, the EC of Cooper's solution was only 0 42 to 0 44 dS/m and the EC of Hoagland's solution was only 0 31 to 0 33 dS/m The recommended EC values for the nutrient solutions involved in the soilless cultivation of vegetable and ornamental plants should be range between 0 8 and 3 7 dS/m (Sonneveld and Straver, 1994 and De-Kreij *et al*, 1997) According to Singh (2013), the ideal EC range for hydroponics is between 1 5 and 2 5 dS/m The lower EC of nutrient solutions may be one of the reasons for obtaining lower yield in hydroponics, compared to soil cultivation

The pH of Cooper's solution was within 5 71 to 6 00 and that of Hoagland's solution was between 5 66 and 6 00 These results are in close conformity to the findings of various scientists The pH of a nutrient solution determines the growth of plants, by changing the availability of nutrients (Islam *et al*, 1980 and Willumsen, 1980) Jones (1982), reported that the nutrient solutions supplied to the crops in soil less culture should have a pH between 5 to 6 As per Gericke (2007), the most favourable pH range of hydroponic nutrient solution is from 5 to 6 5 According to Singh (2013), plants can grow hydroponically within a pH range of 5 8 to 6 8 He also reported that the ideal pH range for tomatoes in hydroponics is between 5 5 and 6 5

5.3. BENEFIT COST RATIO

The highest benefit cost ratio (1 92) was obtained for plants grown in soil according to POP recommendations Since the POP recommendations for NPK was followed, and FYM and lime were supplied, it is obvious that the nutrients were optimum for the crop growth and yield and hence the highest yield Among hydroponic treatments, the highest benefit cost ratio recorded was 1 33 ($F_2S_1M_1$ - a combination of Ebb and Flow Technique, Cooper's solution and coco peat) Higher yield might have been obtained if higher doses of nutrients have been supplied to obtain optimum vegetative growth and hence yield. It is also evident that the yield and benefit cost ratio was higher when coco peat was used as the growing medium, proving that the cost and quality of growing substrate also matters when crops are grown hydroponically The cost of expanded clay pellet was Rs 3200/kg and that of coco peat was only Rs 8/kg So instead of expanded clay pellets, if locally available and cheap growing media had been used, the benefit cost ratio would have raised Since the hydroponic systems can be continuously used for many years, the cost of installation can be compensated and the system would turn to be economical in due course of time Eventhough the initial expenditure on structure for Deep Flow Technique was exhorbitantly high, the benefit cost ratio was also high, since the vertical space have been optimisely used in this technique

5.4. CONCLUSION

The above findings revealed that, the growth and yield parameters of soil grown plants with POP recommendations were superior to hydroponically grown tomato plants Since in control, the nutrients were applied according to standard POP recommendations, there is no chance for reduction in the performance of crops But in a state like Kerala, where hydroponics is a relatively new technique, some limitations have been experienced as an initial trial

The hydroponic treatments respond very well to the factors of study viz, methods, nutrient solutions and growing media Out of the two hydroponic methods, Ebb and Flow Technique showed better vegetative growth and yield per plant whereas Deep Flow Technique exhibited efficient utilization of vertical space, higher planting density and higher yield per unit area Out of the two nutrient solutions tested Cooper's solution was the best Among the three growing media, plants under coco peat medium showed better performance compared to others

When dıfferent hydroponıc treatments were consıdered, the treatment $F_2S_1M_1$ (a combınatıon of Ebb and Flow Technıque, Cooper's solutıon and coco peat) performed the best ın terms of growth (plant height 50 DAT – 69 36cm), yıeld (1 67kg),crop duratıon (85 73 days) and other parameters lıke days to first flower appearance (22 06 days), first fruıt set (25 73 days), first harvest (51 73 days) etc The performance of $F_2S_1M_3$ (a combınatıon of Ebb and Flow Technıque, Cooper's solutıon and pebbles) and $F_2S_2M_1$ (a combınatıon of Ebb and Flow Technıque, Hoagland's solutıon and coco peat) was more or less on par wıth $F_2S_1M_1$ The treatments $F_1S_1M_1$ (a combınatıon of Deep Flow Technıque, Cooper's solutıon and expanded clay pellets) and $F_1S_2M_1$ (a combınatıon of Deep Flow Technıque, Hoagland's solutıon and coco peat) were found to be better for yıeld per unit area (18 48 and 17 78 kg/m² respectıvely)

Sınce the overall performance and yıeld of tomatoes were low under hydroponıcs, compared to soıl grown ones, the experıment can be modıfied by changıng the growıng condıtıons and nutrıent concentratıons ın future

5.5. FUTURE LINE OF WORK

Research can be repeated by changıng the concentratıon of the nutrıents for each crop Cost effectıve and locally avaılable growıng medıa can be used to reduce cost of productıon, specıfic varıetıes or hybrıds can be evaluated for hydroponıc cultıvatıon and the experıment can be conducted under open condıtıons

SUMMARY

6. SUMMARY

The present investigation on "Standardization of hydroponics in tomato" was carried out at Department of Olericulture, Colllege of Horticulture, Vellanikkara during September 2015 to January 2016 in the variety Anagha The study was conducted to standardize the method, nutrient solution and growing media for the hydroponic cultivation of tomato The performance of plants under hydroponic treatments were also compared with plants grown in soil according to POP recommendations

The experiment was laid out in CRD under rain shelter condition There were a total of 13 treatments comprising of the combinations of two hydroponic methods a) deep flow technique and b) ebb and flow technique, two nutrient solutions a) Cooper's solution and b) Hoagland's solution and three growing media 1) coco peat, 2) expanded clay pellets and 3) pebbles and a control (normal cultivation in soil as per POP recommendation) During the course of experiment, plant growth, yield and quality of the produce under different treatments were critically observed The salient findings and conclusions drawn out from the study are summarized below

- The control plants (soil cultivation with POP recommendation) showed superiority for plant height, days to first flower appearance, days to first fruit set, days to first harvest, days from flowering to harvest, fruits per plant, duration of the crop, number of harvests, yield per plant, marketable yield and average fruit weight over the hydroponic treatments

- Both of the hydroponics methods showed promising results In terms of vegetative growth, flowering, fruiting and yield per plant Ebb and Flow

Technique was better But when yield per unit area was considered Deep Flow Technique was the best

- Out of the two nutrient solutions tested, Cooper's solution was the best The influence of nutrient solutions on the performance (growth and yield parameters) of hydroponic treatments was significant

- Out of the three factors tested, growing media had great influence on performance of plants The growth and yield parameters were observed to be higher in coco peat medium, followed by pebbles In expanded clay pellets, plants were less vigorous The NPK analysis of coco peat revealed its high nutrient content (N- 0 32%, P- 0 01%, K- 0 36 %)

- Among the hydroponic treatments, $F_2S_1M_1$ (a combination of Ebb and Flow Technique, Cooper's solution and expanded coco peat) was the best with respect to growth and yield per plant Its mean plant height was 69 36 cm, the days taken to first flower appearance was 22 06, days to first fruit set was 25 73, days to first harvest was 51 73, fruits per plant was 36 50, number of harvests was 20 16, yield per plant was 1 67 kg and average fruit weight was 45 86g

- When yield per unit area was considered $F_1S_1M_1$ was the best (18 48 kg/m^2), since the planting density was high with the utilization of vertical space

- The quality of fruit was better under hydroponics, because of the higher TSS and lower acidity compared to soil

- The NPK content of plants grown in soil was higher than that of hydroponic treatments, because they were grown according to POP recommendations, by supplying both inorganic fertilizers and farm yard manure

- The incidence of pests and diseases were minimum during the experiment The diseases were found to be completely absent Only some insect pests like serpentine leaf miners, mealy bugs and plant hoppers were noticed Biocontrol measures were taken as and when the pest incidence was noticed So there was no reduction in the marketable yield

- All treatments showed significant variation for benefit cost ratio The highest benefit cost ratio was recorded in control treatment (1 92) This was followed by the treatment $F_2S_1M_1$ - a combination of Ebb and Flow Technique, Cooper's solution and expanded coco peat (1 33) Eventhough the initial expenditure on Deep Flow structure was high, the benefit cost ratio was also high, since the vertical space have been efficiently used in this technique The benefit cost ratio was comparatively lower for treatments in combination with expanded clay pellet medium, because of the higher cost of that medium

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Plant observations

Treatments	Marketable yield (kg)			Average fruit weight (g)			Yield per unit area (kg/m^2)		
	R1	R2	R3	R1	R2	R3	R1	R2	R3
$F_1S_1M_1$	1 36	1 26	1 36	42 70	42 00	42 00	19 04	17 64	19 04
$F_1S_1M_2$	0 37	0 38	0 38	21 00	21 30	20 50	5 18	5 32	5 32
$F_1S_1M_3$	1 10	1 17	1 20	38 20	39 00	40 10	15 40	16 38	16 80
$F_1S_2M_1$	1 22	1 31	1 28	39 50	41 00	41 20	17 08	18 34	17 92
$F_1S_2M_2$	0 34	0 32	0 32	20 10	19 80	20 00	4 76	4 48	4 48
$F_1S_2M_3$	1 05	1 10	1 06	37 00	37 20	38 00	14 70	15 40	14 84
$F_2S_1M_1$	1 73	1 63	1 65	45 60	46 00	46 00	15 57	14 67	14 85
$F_2S_1M_2$	0 52	0 52	0 50	25 00	26 20	26 00	4 68	4 68	4 50
$F_2S_1M_3$	1 49	1 45	1 52	44 00	42 80	43 50	13 41	13 05	13 68
$F_2S_2M_1$	1 54	1 57	1 50	44 20	43 00	43 00	13 86	14 13	13 50
$F_2S_2M_2$	0 45	0 43	0 46	23 00	22 60	24 50	4 05	3 87	4 14
$F_2S_2M_3$	1 42	1 39	1 45	43 20	43 00	43 10	12 78	12 51	13 05
Control	2 08	2 11	2 05	52 00	53 50	54 00	18 72	18 99	18 45

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APPENDICES

APPENDIX I

COMPOSITION AND PREPARATION OF NUTRIENT SOLUTIONS

The solutions were stored in two separate tanks to which two electric motors, controlled by timer was attached, for continuous cycling and draining of the solutions

Nutrients	Content	
	Hoagland's solution (mg/l)	Cooper's solution (mg/l)
N	165	236
P	31	60
K	215	360
Ca	160	185
Mg	34	50
S	64	68
Fe	2 00	2 50
Cu	0 02	0 10
Zn	0 05	0 10
Mn	0 50	2 00
B	0 50	0 30
Mo	0 01	0 20

The nutrient solutions were prepared according to their standard composition (Hoagland's solution- Hoagland and Arnon, 1950 and Cooper's solution- Cooper, 1988)

APPENDIX II

QUANTITY OF CHEMICAL FERTILIZERS

The quantity of chemical fertilizers required to prepare Hoagland's and Cooper's solutions as in their standard composition is as follows.

Chemical fertilizers	Hoagland's solution (mg/l)	Cooper's solution (mg/l)
Urea	173 5	240
SSP	116	224 5
MOP	4300	569
Calcium nitrate	564 35	580
Magnesium sulphate	349 2	513 5
Copper sulphate	0 078	0 39
Manganese sulphate	2 028	8 112
Zinc sulphate	0 221	0 44
Boric acid	2 80	1 68
Ammonium molybdate	0 12	2 42
Iron EDTA	1 90	1 60

APPENDIX III

PLANT OBSERVATIONS

Plant height at 10 days interval (cm)

Treatments	At the time of planting			10th day			20th day			30th day		
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
$F_1S_1M_1$	13 50	14 00	13 00	26 00	25 20	25 70	37 20	36 8	36 90	48 10	47 80	47 40
$F_1S_1M_2$	14 30	13 50	14 00	22 00	21 00	23 00	31 20	30 5	33 70	42 40	41 10	43 20
$F_1S_1M_3$	13 00	15 20	14 00	24 00	24 50	23 50	34 30	35 2	33 90	44 10	45 20	43 50
$F_1S_2M_1$	13 20	15 00	15 00	24 00	23 00	23 00	36 50	37 0	37 70	46 10	45 10	47 50
$F_1S_2M_2$	13 00	14 00	14 00	20 00	21 50	19 00	29 00	32 0	30 00	37 00	41 10	41 20
$F_1S_2M_3$	13 00	15 00	15 00	23 00	21 00	21 20	35 20	35 0	35 20	47 60	46 20	47 30
$F_2S_1M_1$	12 50	15 00	13 00	27 00	27 80	28 00	39 80	40 2	41 00	49 20	55 30	54 00
$F_2S_1M_2$	14 00	12 60	14 00	20 00	21 20	23 20	32 10	33 5	34 20	43 00	44 30	45 00
$F_2S_1M_3$	13 00	14 30	14 00	23 50	26 50	24 00	36 50	38 6	37 20	47 40	53 40	51 00
$F_2S_2M_1$	14 00	15 00	14 20	26 00	27 40	26 30	35 50	37 0	35 00	46 40	48 00	46 00
$F_2S_2M_2$	15 20	14 00	14 00	21 00	22 00	23 50	32 10	33 1	33 60	44 20	45 50	45 80
$F_2S_2M_3$	14 20	14 00	15 00	23 00	24 00	25 20	33 40	34 1	35 50	45 10	46 50	46 80
Control	14 00	13 60	15 00	26 80	26 00	27 60	39 60	37 0	45 00	49 00	49 60	52 00

Cont

plant height at 10 days interval (cm)

Treatments	40^{th} day			50^{th} day			60^{th} day		
	R1	R2	R3	R1	R2	R3	R1	R2	R3
$F_1S_1M_1$	56 6 0	54 10	55 30	63 90	62 10	63 10	63 90	62 10	63 10
$F_1S_1M_2$	48 40	47 00	50 20	48 40	47 00	50 20	48 40	47 00	50 20
$F_1S_1M_3$	53 20	54 30	52 80	60 10	61 10	59 70	60 10	61 10	59 70
$F_1S_2M_1$	54 50	54 80	55 00	60 00	60 50	61 00	60 00	60 50	61 00
$F_1S_2M_2$	46 50	47 00	47 50	46 50	47 00	47 50	46 50	47 00	47 50
$F_1S_2M_3$	53 40	52 50	53 50	58 40	57 60	59 00	58 40	57 60	59 00
$F_2S_1M_1$	59 20	62 00	65 00	67 30	69 80	71 00	67 30	69 80	71 00
$F_2S_1M_2$	56 30	57 20	58 10	61 20	63 30	64 50	61 20	63 30	64 50
$F_2S_1M_3$	57 50	59 20	58 50	65 30	67 20	66 70	65 30	67 20	66 70
$F_2S_2M_1$	57 90	61 30	58 70	66 00	68 00	68 30	66 00	68 00	68 30
$F_2S_2M_2$	56 20	57 60	57 80	61 10	63 50	63 50	63 00	63 50	63 50
$F_2S_2M_3$	57 30	57 90	58 10	63 60	64 10	65 20	63 60	64 10	65 20
Control	58 00	60 00	62 00	69 00	72 00	74 00	69 00	72 00	74 00

Plant observatıons

Treatments	Days to first flower appearance			Days to first fruıt set			Days to first harvest			Days from flowerıng to harvest		
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
$F_1S_1M_1$	24 50	24 70	25 10	28 50	28 70	29 10	57 00	56 30	55 70	32 50	31 60	30 00
$F_1S_1M_2$	26 30	28 00	28 10	29 30	31 00	31 10	59 50	58 60	59 70	33 20	30 60	31 60
$F_1S_1M_3$	26 10	25 60	25 20	29 10	28 60	28 20	56 60	56 30	56 30	30 50	30 70	31 10
$F_1S_2M_1$	26 50	26 70	27 00	30 50	30 70	31 00	58 00	56 90	58 80	31 50	30 20	31 80
$F_1S_2M_2$	27 50	27 20	28 40	31 50	31 20	32 40	59 80	59 20	61 50	32 30	32 00	33 10
$F_1S_2M_3$	26 90	27 10	27 20	30 90	31 10	30 20	57 50	59 10	57 60	30 60	32 00	30 40
$F_2S_1M_1$	23 00	23 20	20 00	27 00	26 20	24 00	53 00	53 20	49 00	30 00	30 20	29 00
$F_2S_1M_2$	25 00	26 10	26 10	28 00	30 10	30 10	56 00	56 10	56 10	31 00	30 00	30 00
$F_2S_1M_3$	24 00	24 50	24 60	27 00	27 50	28 60	54 00	54 60	54 60	30 00	30 10	30 00
$F_2S_2M_1$	24 10	25 00	25 20	27 10	28 00	28 20	55 60	56 00	56 20	31 50	31 00	31 00
$F_2S_2M_2$	27 00	27 10	27 00	30 00	30 10	31 00	59 00	59 30	59 30	32 00	32 20	32 30
$F_2S_2M_3$	25 70	25 20	25 00	28 70	28 20	28 00	56 80	57 30	56 20	31 10	32 10	31 20
Control	19 00	21 00	19 50	23 00	24 00	22 50	47 20	47 90	49 50	28 20	26 90	30 00

Plant observations

Treatments	Fruits per plant			Duration of the crop			Number of harvests			Yield per plant (kg)		
	R1	R2	R3	R1	R2	R3	R1	R2	R3	R1	R2	R3
$F_1S_1M_1$	32 00	30 10	32 50	83 00	83 10	83 00	15 00	15 00	15 40	1 36	1 26	1 36
$F_1S_1M_2$	18 00	18 10	18 90	79 00	78 50	78 00	6 40	6 30	6 80	0 37	0 38	0 38
$F_1S_1M_3$	29 00	30 20	30 00	82 00	82 70	81 20	14 00	13 70	13 10	1 10	1 17	1 20
$F_1S_2M_1$	31 00	32 00	31 20	83 00	81 30	81 00	14 00	15 20	14 10	1 22	1 31	1 28
$F_1S_2M_2$	17 00	16 20	16 00	78 60	77 10	78 00	6 20	6 20	7 00	0 34	0 32	0 32
$F_1S_2M_3$	28 50	29 60	28 00	80 50	81 40	80 90	13 00	13 50	12 90	1 05	1 10	1 06
$F_2S_1M_1$	38 00	35 50	36 00	85 00	85 70	86 50	19 00	21 50	20 00	1 73	1 63	1 65
$F_2S_1M_2$	21 00	20 00	19 30	82 00	83 50	82 00	10 00	10 00	9 50	0 52	0 52	0 50
$F_2S_1M_3$	34 00	34 10	35 00	84 00	84 60	83 80	16 00	15 90	16 20	1 49	1 45	1 52
$F_2S_2M_1$	35 00	35 20	35 00	84 00	85 50	83 90	17 00	17 10	16 80	1 54	1 57	1 50
$F_2S_2M_2$	19 70	19 20	19 00	79 10	80 50	80 00	7 50	6 60	7 00	0 45	0 43	0 46
$F_2S_2M_3$	33 00	32 50	33 70	84 00	83 70	83 50	16 00	14 20	14 20	1 42	1 39	1 45
Control	40 00	39 50	38 00	89 00	88 50	88 00	19 00	20 00	20 00	2 08	2 11	2 05

Plant observations

Treatments	TSS (°Brix)			Acidity (%)			Biomass of roots at harvest (g)		
	R1	R2	R3	R1	R2	R3	R1	R2	R3
$F_1S_1M_1$	7 50	7 50	8 00	0 60	0 60	0 55	8 60	8 80	9 00
$F_1S_1M_2$	8 00	7 40	7 50	0 54	0 60	0 60	6 30	6 50	5 90
$F_1S_1M_3$	8 10	7 60	7 50	0 60	0 60	0 58	8 00	7 80	7 30
$F_1S_2M_1$	8 10	7 40	7 00	0 51	0 60	0 60	7 50	7 50	6 10
$F_1S_2M_2$	7 30	7 40	7 30	0 54	0 50	0 50	6 00	5 00	5 50
$F_1S_2M_3$	7 50	7 50	8 10	0 52	0 50	0 53	7 50	7 00	7 10
$F_2S_1M_1$	7 50	8 00	7 00	0 60	0 50	0 60	10 10	11 00	10 00
$F_2S_1M_2$	8 00	8 00	7 50	0 60	0 60	0 58	7 80	7 50	6 90
$F_2S_1M_3$	7 50	7 60	8 00	0 58	0 50	0 60	9 20	8 90	9 00
$F_2S_2M_1$	7 40	8 10	7 60	0 55	0 60	0 64	8 90	8 90	8 70
$F_2S_2M_2$	7 90	8 00	8 00	0 60	0 58	0 50	7 70	6 80	6 80
$F_2S_2M_3$	7 50	7 20	7 20	0 62	0 50	0 50	8 50	8 50	8 30
Control	6 41	6 44	6 43	0 70	0 60	0 60	15 50	14 80	16 00

NPK content (%) of leaf, shoot and fruit

Treatments	NPK content of leaf (%)								
	R1			R2			R3		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
$F_1S_1M_1$	1 51	0 21	1 11	1 47	0 18	1 1	1 49	1 17	1 18
$F_1S_1M_2$	0 58	0 06	0 43	0 61	0 04	0 51	0 57	0 06	0 50
$F_1S_1M_3$	1 13	0 17	0 91	1 09	0 17	0 91	1 11	0 18	1 13
$F_1S_2M_1$	0 87	0 14	0 92	0 85	0 11	0 89	0 99	0 10	0 88
$F_1S_2M_2$	0 53	0 03	0 41	0 62	0 03	0 40	0 57	0 05	0 43
$F_1S_2M_3$	0 81	0 11	0 64	0 79	0 08	0 71	0 87	0 08	0 77
$F_2S_1M_1$	1 75	0 18	1 28	2 11	0 23	1 36	1 89	0 21	1 29
$F_2S_1M_2$	1 11	0 10	0 95	0 81	0 13	0 87	0 80	0 12	0 92
$F_2S_1M_3$	1 43	0 17	1 03	1 51	0 17	1 11	1 23	0 13	1 14
$F_2S_2M_1$	1 64	0 19	1 23	1 51	0 11	1 16	1 61	0 17	1 20
$F_2S_2M_2$	0 67	0 08	0 43	0 63	0 10	0 46	0 71	0 08	0 46
$F_2S_2M_3$	0 76	0 11	0 54	0 68	0 11	0 46	0 72	0 11	0 56
Control	2 67	0 24	1 43	2 81	0 26	1 43	2 53	0 34	1 35

NPK content (%) of leaf, shoot and fruit

Treatments	NPK content of shoot (%)								
	R1			R2			R3		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
$F_1S_1M_1$	0 81	0 13	0 95	0 91	0 12	0 79	1 11	0 12	0 88
$F_1S_1M_2$	0 57	0 09	0 45	47	0 09	0 49	0 55	0 11	0 51
$F_1S_1M_3$	0 65	0 10	0 59	0 85	0 11	0 61	0 88	0 11	0 63
$F_1S_2M_1$	0 74	0 13	0 77	0 81	0 11	0 69	0 88	0 11	0 76
$F_1S_2M_2$	0 54	0 08	0 49	0 50	0 08	0 39	0 44	0 07	0 23
$F_1S_2M_3$	0 58	0 10	0 47	0 61	0 11	0 53	0 66	0 11	0 51
$F_2S_1M_1$	0 92	0 15	1 13	1 21	0 15	1 20	1 12	0 14	1 11
$F_2S_1M_2$	0 52	0 11	0 53	0 61	0 10	0 49	0 72	0 10	0 52
$F_2S_1M_3$	0 79	0 13	0 64	1 10	0 11	1 05	1 11	0 11	0 73
$F_2S_2M_1$	0 79	0 13	0 71	1 12	0 11	0 91	0 97	0 09	0 89
$F_2S_2M_2$	0 51	0 11	0 49	0 62	0 11	0 49	0 63	0 11	0 48
$F_2S_2M_3$	0 63	0 12	0 62	0 65	0 13	0 61	0 74	0 12	0 69
Control	1 89	0 16	1 31	1 88	0 16	1 31	1 78	0 15	1 32

NPK content (%) of leaf, shoot and fruit

Treatments	NPK content of fruit (%)								
	R1			R2			R3		
	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)	N (%)	P (%)	K (%)
$F_1S_1M_1$	1 12	0 09	0 61	1 11	0 09	0 67	0 99	0 08	0 66
$F_1S_1M_2$	0 56	0 04	0 45	0 56	0 02	0 36	0 49	0 04	0 38
$F_1S_1M_3$	0 94	0 07	0 65	1 07	0 05	0 59	0 87	0 05	0 63
$F_1S_2M_1$	1 05	0 07	0 59	0 89	0 06	0 71	0 84	0 06	0 64
$F_1S_2M_2$	0 48	0 03	0 36	0 51	0 03	0 29	0 44	0 02	0 37
$F_1S_2M_3$	0 88	0 05	0 54	0 88	0 04	0 53	0 78	0 04	0 50
$F_2S_1M_1$	2 17	0 08	0 71	1 86	0 07	0 69	1 13	0 08	0 70
$F_2S_1M_2$	0 63	0 06	0 51	0 58	0 05	0 51	0 61	0 04	0 49
$F_2S_1M_3$	1 25	0 08	0 56	0 89	0 05	0 62	1 14	0 06	0 62
$F_2S_2M_1$	1 14	0 09	0 63	2 13	0 04	0 62	1 10	0 66	0 58
$F_2S_2M_2$	0 58	0 04	0 52	0 61	0 04	0 48	0 49	0 05	0 49
$F_2S_2M_3$	0 91	0 07	0 56	0 81	0 07	0 53	0 42	0 06	0 49
Control	2 43	0 09	0 73	2 17	0 08	0 69	2 31	0 09	0 68

APPENDIX IV

WEATHER DATA

Temperature inside the rain shelter

Standard week	Morning (8 am)		Afternoon (1.30 pm)	
	Temp. Max (^0C)	Temp. Min (^0C)	Temp. Max (^0C)	Temp. Min (^0C)
41	23 2	23 0	30 6	30
42	24 5	24 1	33 2	32 9
43	24 0	24 0	33 1	33 0
44	22 5	21 0	31 4	31 2
45	22 7	22 1	30 0	29 8
46	22 2	21 1	30 3	30 0
47	24 1	23 8	29 7	29 2
48	22 5	22 0	32 4	31 0
49	23 9	23 9	31 1	31 0
50	22 4	22 4	31 7	30 3
51	22 7	21 8	31 4	31 0
52	23 1	23 0	31 8	31 2
1	22 1	22 0	31 5	30 7
2	22 5	21 5	32 5	31.7

Temperature outside the rain shelter

Standard week	Morning (8 am)		Afternoon (1.30 pm)	
	Temp. Max (^{0}C)	Temp. Min (^{0}C)	Temp. Max (^{0}C)	Temp. Min (^{0}C)
41	23 1	23 0	31 6	30 2
42	24 5	24 1	33 1	32 8
43	24 0	24 0	33 0	33 0
44	22 9	21.5	31 2	31 2
45	22 7	22 1	31 2	30 0
46	22 1	21 1	30 0	30 0
47	24 3	23 8	29 9	29 2
48	22 5	22 0	32 3	31 0
49	23 9	23 7	31 1	31 0
50	22.1	22 1	31 7	31 3
51	23 9	21 8	31 9	31 0
52	22 8	21 0	30 7	29 6
1	22 5	22 0	31 5	30 7
2	23 5	21 5	32 7	31 8

STANDARDIZATION OF HYDROPONICS IN TOMATO

By

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(2014-12-103)

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree of

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(Olericulture)

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ABSTRACT

The present study on "Standardization of hydroponics in tomato" was carried out in the Department of Olericulture, College of Horticulture, Vellanikkara, during 2015 September to 2016 January, to standardize the nutrients, methods and growing media for the hydroponic cultivation of tomato in rain shelter The experiment was laid out in CRD with a total of 13 treatments comprising of two hydroponic methods a) Deep Flow Technique, b) Ebb and Flow Technique, two nutrient solutions a) Cooper's solution, b) Hoagland's solution and three growing media a) coco peat, b) expanded clay pellets, c) pebbles and a control where the plants were grown in soil with POP recommendations

Plants in soil with POP recommendations showed superiority for plant height, days to first flower appearance, days to first fruit set, days to first harvest, fruits per plant, duration of the crop, number of harvests, yield per plant, and average fruit weight over the hydroponic treatments The NPK content in plant parts were higher for plants grown in soil The benefit cost ratio was also the highest (1 92) in control treatment

Among the hydroponic treatments, $F_2S_1M_1$ (a combination of Ebb and Flow Technique, Cooper's solution and coco peat) was the best with respect to growth, yield per plant (1.67 kg) and benefit cost ratio (1 33). There was only a reduction of 19.71 per cent in yield for this treatment when compared to plants grown in soil

Under Deep Flow Technique in a unit area of $1m^2$, 14 plants were accommodated, whereas in control there were only 9 plants When yield per unit area was considered, $F_1S_1M_1$ (a combination of Deep Flow Technique, Cooper's solution and coco peat) was the best (18 48 kg), and this was on par with the plants grown in soil (18 72kg) The quality parameters (TSS and acidity) were influenced by the hydroponic methods The TSS of fruit was higher and acidity was lower under hydroponics compared to soil

The influence of nutrient solutions on the growth and yield parameters of tomato plants were significant Out of the two nutrient solutions tested, Cooper's solution was significantly better

The growth and yield parameters were significantly influenced by the growing media and were the best in coco peat medium, followed by pebbles This may be because of the high nutrient content in coco peat (N- 0 32%, P- 0 01%, K- 0.36 %) In expanded clay pellets, plants were less vigorous

Diseases were totally absent and only stray incidence of insect pests like serpentine leaf miners, mealy bugs and plant hoppers were noticed during the course of the experiment Biocontrol measures were employed as and when the incidence was observed

Though limitations have been experienced as the first experiment of its kind, hydroponics can be practiced in Kerala by adopting cost effective and locally available growing media, since there is space constraint for conventional cultivation