FERTIGATION STUDIES USING WICK IRRIGATION SYSTEM

By

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KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR– 679573, MALAPPURAM,

KERALA, INDIA

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PROJECT REPORT

Submitted in partial fulfilment of the requirement for the degree of

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Kerala Agricultural University

Department of Land and Water Resources and Conservation Engineering

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR– 679573, MALAPPURAM,

KERALA, INDIA, 2018

DECLARATION

We hereby declare that this project entitled **“Fertigation studies using wick irrigation system”** is a bonafide record of project work done by us during the course of project and that the report has not previously formed the basis for the award to us any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Place: Tavanur

Date: 31-01-2018

Badush Salim
(2014-02-015)

Dilsha Suresh
(2014-02-018)

Harisankar O.P
(2014-02-045)

CERTIFICATE

Certified that this project entitled **"Fertigation studies using wick irrigation system"** is a record of project work done jointly by **Badush Salim** (2014-02-015)**, Dilsha Suresh** (2014-02-018) and **Harisankar O.P** (2014-02-045) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

Place: Tavanur
Date: 31-01-2018

Dr. Abdul Hakkim, V.M.,
Professor and Head
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Tavanur, Malappuram-679573

Dedicated to our parents, teachers and all our Guiding lights

ACKNOWLEDGEMENT

ACKNOWLEDGEMENT

And so comes the time to look back on the path traversed during the endeavour and to remember the faces and spirits behind the action with a sense of gratitude. Nothing of significance can be accomplished without the acts of assistance, words of encouragement and gestures of help from the other members of the society.

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Badush Salim

Dilsha Suresh

Harisankar O.P

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SYMBOLS AND ABBREVIATIONS

Symbols	Abbreviations
’	Minute
’’	Second
/	Per
^{0}	Degree
^{0}C	Degree Celsius
%	Percentage
Cm	Centimetre(s)
CWRDM	Centre for Water Resources Development and Management
DAP	Days After Planting
et al	and others
Fig.	Figure
g	Gram
ha	Hectare
hr	Hour(s)
i.e.	That is
ICAR	Indian Council of Agricultural Research
K	Potassium
Kg	Kilogram
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
lit	Litre (s)
LWRCE	Land and Water Resources and Conservation Engineering
m	Metres (s)
m^2	Square metre
mm	Millimetre (s)

Mh	million hectares
N	Nitrogen
P	Phosphorus
PFDC	Precision Farming Development Centre
R	Replications
T	Treatments

INTRODUCTION

CHAPTER 1
INTRODUCTION

Water, mankind's most vital and versatile resource is a basic human need and a precious national asset. The slogan, 'Water is life' is truly experienced in water scarce regions. It is essential for agricultural and rural development in order to improve food security and for poverty alleviation. Water, a life sustaining resource, closely linked to the quality of life is getting deteriorated in terms of quality as well as quantity.

Water is one of the critical inputs for sustainability of agriculture, which consumes about 80% of available water, but irrigation efficiency continuous to be only about 30%. The demand for water for agricultural purpose is estimated to increase from 50 M ha m in 1985 to 70 M ha m by 2050. The world water council believes that by the year 2020 we shall need 70% more than water than is available to feed the world. Therefore utmost care in management and foresight is necessary to use water judiciously and economically by various means through conservation, development, storage, distribution, reclamation and reusing the 21st century for sustainable food security in the country as well as in the world.

As far as the Indian agriculture is concerned, irrigation plays a crucial role in the various development projects of the country. The existing methods of surface irrigation are less efficient and we are confronted with many problems regarding soil and water. A major challenge is to develop systems for greater precision in water and plant nutrient control, so as to increase the use efficiencies of soil, water and energy resources and to improve the environment for mankind. Expansion of irrigation facilities is also essential for increasing food production for the alarming Indian population of 1.21 billion at present. With present potential of 114 M ha m of water, only 57 M ha (40%) is under irrigation in India against the total cultivated area of 145 M ha.

Surface irrigation methods, with overall efficiency of 10 to 30% usually cause erosion, salinization and water logging problems. Two important aspects to be considered in this regard are uniform water distribution in the field and accurate amount of water application by permitting accurate delivery control. These requirements are accomplished by adopting the micro irrigation techniques.

At the time when the organic farming is gaining popularity in Kerala, now there are more options for farmers. 'WICK IRRIGATION' is an irrigation technique modified by Kamalam Joseph, a Scientist from CWRDM, Kozhikode with an aim to facilitate farming even when there is scarcity of water. It is a user-friendly irrigation method, which is cheaper and at the same time water efficient. The scientific principle behind this irrigation method is capillary action. Water tends to move toward dry objects using this principle.

Fertigation is the combined application of water and soluble fertilizers along with water through irrigation system. The major advantage of fertigation is saving of water, labour and money. It is a precise application of water soluble fertilizers and other nutrients to the soil at desired concentrations at appropriate time. Hence, ultimately provide a higher yield.

Wick fertigation refers to fertigation through wicks, the method of applying soluble fertilizer through wicks. Scientific studies in the area of wick fertigation are not carried out yet in the State and there are lot of potential for research in this area.

The present study is conducted to evaluate the feasibility of fertilizer application through wick irrigation system with the following objectives.

1. To study the potential of irrigation wick (glass wool) to uptake fertilisers.
2. To standardise the fertigation requirement of tomato through wick irrigation.

REVIEW OF LITERATURE

CHAPTER 2
REVIEW OF LITERATURE

Water is the main constraint for the development of agriculture in many states of India. It therefore becomes necessary to adopt efficient irrigation methods that are economically viable, technically feasible and socially acceptable.

In India efforts were made to introduce micro irrigation system at farmer's level around 1980. Micro irrigation conserves irrigation water easily, doubling the commanded area of a water resource with yield increase up to 50 per cent. Judicious use of irrigation water is equally important to increase the productivity. This can be achieved by introducing micro irrigation coupled with other improved water management and fertilizer application methods. The productivity of crops is based on effective utilization of water and fertilizer, along with other agricultural inputs. Fertigation provides flexibility of fertilizer application, which enables three specific nutritional requirements of the crop to be met at different stages of its growth. In comparison with the conventional methods, it appears that fertigation gives higher crop yield with substantial saving in fertilizer usage.

2.1 Micro irrigation

Micro irrigation is the most efficient method to provide water at the required rate near to the root zone of the crop. Drip irrigation is one such hi - tech system, receiving acceptance and adoption, especially in areas of water scarcity.

Haynes (1985) illustrated that the drip or daily irrigation has been developed particularly for conditions of intensive irrigated agricultural and horticultural production and it has gained wide acceptance not only because it conserves water but also it allows more effective management of water or fertilizer applications than do other irrigation techniques.

Nakayama and Bucks (1991) found that high soil metric potential in the root zone is maintained with the help of high frequency water management by drip irrigation. It provides daily requirements of water to a portion of the rhizhosphere of each plant and reduces plant water stress.

Major advantages of micro irrigation include the slow delivery of water immediately above or below the surface of the soil which helps in minimizing water loss due to runoff, evaporation and wind and moreover it reduces the weed growth. Increased water use efficiency of drip irrigation results in better quality crop yield, which is uniform and it is this uniformity which makes it suitable for automation. It causes minimum damage to the soil structure and it also permits the usage in undulating areas and slow permeable soil. The mould spots, staining and deterioration experienced with overspray from sprinkler irrigation can be eliminated with the use of micro irrigation. It also reduces the foliar disease incidence compared overhead irrigation methods (Hochmuth and Smajestrla, 2003).

The low volume requirements of drip irrigation favours water application in water scarce areas. An AC (Alternating Current) or battery powered controller is enough to manage a drip system. Above all, it requires less labour and energy. However, precipitation, salt accumulation and clogging stands are demerits of this system of irrigation (Wilson and Bauer, 2005).

2.1.1 Impact of micro irrigation on crop growth and yield

Singh *et al.* (2000) made an attempt to study the effect of drip irrigation compared to conventional irrigation on growth and yield of Apricot to work out its irrigation requirement. Drip irrigation at 80 per cent evapotranspiration of water gave significantly higher growth and fruit yield of 8.6 tonnes per hectare compared to the surface irrigation. Plastic mulch plus drip irrigation further raised the fruit yield to 10.9 tonnes per hectare. Drip irrigation besides saving 98 per cent irrigation resulted in 3.3 metric tonnes per hectare higher fruit yield.

Ashokaraja and Kumar (2001) conducted studies on micro irrigation which proved that drip irrigation to be an effective tool for conserving water resources. The studies revealed that 40 to 70 per cent water saving was achieved by drip irrigation compared to surface irrigation and in some crops in specific location yield increased as high as 100 per cent.

The response of potato under drip irrigation and plastic mulching was studied by Jain *et al.* (2001). The highest water use efficiency was found to be 3.24 t/ha- cm for the treatment irrigated with drip system at 80 per cent level with mulch as compared to 2.17 t/ha-cm control treatment.

Narayanamoorthy (2001) illustrated the benefits of micro-irrigation in terms of water saving and productivity gains were substantial in comparison to the same crops cultivated under flood method of irrigation. Apart from being beneficial to the farmers, irrigation development also helps to increase the employment opportunities and wage rate of the agricultural landless labourers, both being are essential to reduce the poverty among the landless labour households.

The water requirement, yield and economics of drip irrigation in litchi were studied by Singh *et al*. (2001) at farmer's field in Uttar Pradesh. It was found that good quality marketable yield of litchi varied from 12.5 to 16 metric tonnes per hectare for drip system. The total volume of water applied was 282 mm for drip irrigation during four months of system operation. The benefit cost ratio of drip irrigated litchi was found to be 3.91 and for surface irrigated litchi it was 3.05.

The response to urea fertilizer with drip irrigation and compared with conventional furrow irrigation for two years. Application of nitrogen through the drip irrigation in ten equal splits at eight days interval saved 20- 40 per cent nitrogen compared to the furrow irrigation when it was applied in two equal split. Similarly, higher fruit yield of 3.7 to 12.5 per cent was obtained with 31 to 37 per cent saving of water by the drip system. Water use efficiency in drip irrigation, nitrogen level was 68 and 77 per cent on an average higher over surface irrigation in 1995 and 1996, respectively. At a nitrogen application rate of 120 kg/ha, maximum tomato fruit yield of 27.4 and 35.2 tonnes per hectare in two years was recorded (Singhandhube *et al.*, 2003).

Bozkurt and Mansuroglu (2009) conducted studies to investigate the effects of drip irrigation methods and different irrigation levels onquality, yield and water use characteristics of lettuce cultivated in solar green house. The result obtained revealed that the highest yield was obtained from subsurface drip irrigation at 10cm drip line depth and 100 per cent of Class A Pan Evaporation rate treatment. The water use efficiency and irrigation use efficiency increased as with reduction in the irrigation.

Singh (2009) conducted studies on drip irrigation resulted in significant increase in production and water use efficiency of potato. At Udaipur it was reported that besides saving in water, the yield of potato tubers was high and weed growth was least in drip irrigation compared to surface irrigation.

2.1.2 Wick irrigation

Organic vegetable cultivation is gaining importance in the event of over-use of pesticides and fertilisers in commercial vegetable farming. The Kerala Government is giving great importance to the production of organic vegetables by providing the needed technological and input services. Individual households and housing complexes are coming forward to produce vegetables for family requirement. Raising vegetables in the grow bags on the terraces of buildings is gaining popularity. However, the greatest problem faced is with regard to timely application of water especially in the container grown plants. The limited rooting media of the containers demands frequent replenishment of water. The usual practice of watering is pot irrigation or hose irrigation, which has its own limitations. Moreover, once the family has to go out, the plants will get dried if not watered. Improper irrigation water management leads to a number of physiological disorders and diseases. Water stress can occur from too much as well as from too little water. Stress caused by too little water reduces yield with the level of reduction depending on when stress occurs in relation to crop development. Quality of the produce may also be affected. Over irrigation may stress the crop through reduced soil aeration and cause similar consequences. A major effect of excess water is the reduction of nitrogen levels within the root zone to less than favourable levels. Further, there is lack of adequate knowledge on actual water requirement of crops at varying growth phases.

With the objective of solving the above mentioned problems, experiments were carried out in the Centre for Water Resources development and Management during the past many years. As a result, a user-friendly irrigation method 'wick irrigation' was developed which is cheap and at the same time water efficient. The scientific principle behind this irrigation method is capillary action. Water tends to move toward dry objects using this principle.

Wick irrigation is a latest technique modified by Kamalam Joseph, a Scientist from CWRDM, Kozhikode with an aim to facilitate farming when there is scarcity of water. Wick irrigation (termed as *'thiri nana'*) reduces water consumption for agriculture to a great extent. It is specifically designed for terrace cultivation of vegetables cultivated in grow bags. A specially designed wick is used to take up water from the supply source at a rate necessary to maintain adequate moisture in the plant root zone. The major component of wick irrigation is the wick, which carries water from source to the rooting medium as per the requirement to keep it wet. Different materials were tried for wick such as cotton, silk wool, glass wool etc.

Son *et al.* (2001) and Lee *et al.* (2010) reported the possibility of covering the substrate in wick irrigation, which can reduce surface evaporation.

The major advantageous of wick irrigation system are:

- Low cost irrigation technique
- In wick irrigation the wetting will be in the lower part of growing media and the surface will remain dry hence evaporation loss is negligible.
- In surface irrigation, as water flows down, the part of dissolved nutrient also flow down, which decreases the efficiency of fertiliser application, whereas in wick irrigation such loss is eliminated.
- By adopting wick irrigation, an environment most conductive for water absorption is developed through adequate aeration of root zone.
- Since plastic bottles are used for irrigation, there is great scope of reuse of plastic bottles.
- No energy consumption is needed in irrigation.
- Less, unskilled labour is sufficient to carry out the irrigation.

According to Andriolo *et al.* (2004) wick irrigation needs less man power and it is independent of electricity for operation, as the management is simplified compared with other irrigation system, it is cost effective in operation.

Son *et al.* (2006) reported that wick irrigation system operates in a closed cycle without runoff, permitting appropriate plant nutrition and creating alternative improve production uniformity i.e., this irrigation system is water and nutrient use efficient.

Laviola *et al.* (2007) concluded from their studies that temperature control of root system in wick irrigation makes it suitable for the cultivation of ornamental plants.

Oh and Son (2008) and Teerarzezi*et al.* (2012) suggested that the wick irrigation can be used for the production of vegetables and aromatic plants.

Studies conducted by Kang *et al.* (2009) revealed the optimum wick width, wick length and suitable water depth for wick contact for effective working of the wick in the system and they also found that the wick length in wick irrigation improves the rate of distribution.

2.1.2.1 Comparison of the wick irrigation with other irrigation methods

Wick irrigation is a low cost technology when compared to the material and installation cost of drip and sprinkler systems and the high labour cost of surface irrigation. No electricity cost is involved in wick irrigation.

In wick irrigation, the wetting will be mostly in the lower part of the growing medium (root zone) and the surface will always remain dry. The surface soil acts as mulch and hence the evaporation loss is almost nil in this case. In the other irrigation methods, water moves from the top to down, and hence the top soil will always be wet which enhances the unproductive evaporation loss which will vary depending on the temperature, humidity and wind velocity. It was earlier reported that sub-irrigation systems which supply water from below the root zone are more efficient watering techniques (Elliot 1992, Dole *et al.* 1994 and Morvant *et al*. 2001).

In surface irrigation method, water flows down during each irrigation and a portion of the dissolved nutrients also will flow down with the leachate. The runoff of water, fertilizer, and pesticides resulting from these irrigation methods are a potential risk to the quality of the environment. In wick irrigation, such loss will be nil, instead, nutrients if added to the irrigation water in the bottle in the dissolved form will be carried to the root zone of the plants for the plants to absorb. Pipe sub irrigation systems were reported to be more efficient in terms of nutrient use (Kent and Reed 1996).

By adopting wick irrigation, an environment most conducive for water absorption is developed through adequate aeration of the root zone, which is not possible in case of surface (alternate wetting and drying created) or drip methods (wetting zone is wetted) of irrigation. This method can be adopted by the rich and the poor, young and old and so many innovations can be brought out in future. Thus gender equity, social equity, age equity and financial equity can be ensured.

Maintaining greenery on the roof will help to increase amount of oxygen in the air and at the same time reduce the indoor temperature by 6-8 degree. In the long run, it will keep the building cool and protect it from direct sun, which will add to the life of the roof. If done scientifically, the urban roof top farming will revolutionise the vegetable production in the urban areas. Roof top gardening will help to relieve stress and strain especially with the easy irrigation technique and hence good for physical and mental health.

2.1.3 Fertigation

The major advantages of fertigation with micro irrigation are saving of water, labour and time. It also provides uniform distribution of fertilizer and cause least damage to crop and soil. This also offers an opportunity for precise application of water soluble fertilizers and other nutrients to the soil at desired concentrations and appropriate times and all these ultimately provide a higher yield (Kumar, 1992).

The irrigation system should be designed such that it should operate efficiently and should supply nutrient solution at constant rate and pressure from the main flow line. It also should ensure for efficient and uniform distribution of plant nutrients. The fertilizers selected should be completely soluble without leaving any residues. (Gowda, 1996).

The absorption and utilization of nutrients are affected by several factors such as plant species, water availability and media of growth, its pH, solar radiation, temperature and humidity in the green house. Hence for getting sustained productivity of crops under green house, care in proper management of the media and appropriate fertigation programme are essential. Excessive or imbalanced application of nutrients would result in an improper plant growth (Mortvedt, 1997).

Fertigation is the technique of applying nutrients to the soil through micro irrigation system. The system permits application of various fertilizer formulations directly at the active root zone. Fertigation system is becoming more popular because of its advantages like, higher fertilizer use efficiency, increased availability of nutrient content to the plant, saving of fertilizer to the range of 20 – 40 per cent, regular supply of crop nutrients at right proportions and right time, saves labour and energy and facilitates the application of chemicals other than fertilizers for specific purposes (Khan *et al*., 1999).

The drip irrigation systems require good management and are generally costly. At the same time it reduces water application rate and increases the nutrient use efficiencies. Loss of nutrients from the root zone was reduced in the fertigation system (Loccascio, 2000).

Manickasundaram (2005) reported that the fertilizers supplied under traditional methods of irrigation are not effectively used by the crops unlike in fertigation where water and fertilizers are efficiently used by the plant. Studies conducted in various commercial, horticultural and high value crops revealed that adoption of this technology improves the yield and quality of crops. It is also highly beneficial for the farming community in reducing the cost of production. Furthermore sustainability of the soil health is achieved for better productivity and reduced environmental hazards.

2.1.3.1 Advantages of fertigation

Fertigation allows applying the nutrients precisely and uniformly into the wetted root zone, where the concentration of active roots is more and this in turn increases the application efficiency of the fertilizer, which results in reduction in the amount of fertilizer applied. This not only reduces the production costs but also lessens the potential of groundwater pollution caused by the leaching of fertilizer. Fertigation allows adapting the amount and concentration of the applied nutrients in order to meet the actual requirement of nutrients of the crop throughout the growing season. The other advantages of fertigation include the following:

- Quick and convenient.
- Eliminates manual application.
- High efficiency and saving of fertilizer up to 20 – 40%.
- Remarkably increases the efficiency of application thereby allowing a reduction in the quantity of fertilizer applied.
- Saving of energy time and labour.
- Fertilizer application may be done for the plants according to their requirement during various growth stages.
- Minimise the loss of nutrients.
- Nutrients can be applied even if the soil or crop condition does not permit the entry into the field for conventional method of application.
- Major and minor nutrients which are compatible can be applied together in one solution through irrigation.
- Supply of nutrients can be regulated and monitored more carefully.
- Light soils can be brought under cultivation.
- Less fertilizer leaching (Imas, 1999)

2.1.3.2 Factors to be considered for an effective fertigation

Effective fertigation requires consideration of many factors like plant growth characteristics which include fertilizer requirements and rooting patterns, fertilizer chemistry including mixing compatibility, precipitation, clogging and corrosion, soil chemistry like mobility and solubility of the nutrients and the water quality factors including pH, salt and sodium hazards and toxic ions.

2.1.3.3 Effect of fertilizers on fertigation

Fertigation can be used for the application of macronutrients as well as micronutrients. Fertilizers are available as liquid fertilizers or solid water soluble fertilizers. Liquid fertilizers are solutions which contain one or more plant nutrients in liquid form. Solid fertilizers are 100% water soluble fertilizers and are also referred to as speciality fertilizers. These fertilizers contain two or more major nutrients as well as micronutrients. Soluble fertilizers completely dissolve in water leaving no precipitate.

Nitrogen

Nitrogen is the nutrient most commonly used in fertigation with micro irrigation and overhead sprinkling systems. In general, all nitrogenous fertilizers cause few clogging and precipitation problems with the expectation of ammonium sulphate, which may cause precipitation of calcium sulphate in hard, calcium-rich water. Urea is well suited for injection in micro-irrigation. It is highly soluble and dissolves in non-ironic form so that it does not react with other substances in the water. Also urea doses not cause much precipitation problems.

Phosphorous

Application of phosphorous to irrigation water may cause precipitation of phosphate salts. The precipitation of in soluble di-calcium phosphate and di-magnesium phosphate compounds in irrigation pipes and water emitters is likely in water with a pH (Bester *et al*, 1974) and low pH respectively. Reducing the pH of irrigation water is significantly reducing the risk of calcium phosphate compounds precipitation. Thus phosphoric acid appears more suitable for fertigation.

Potassium

Potassium in general seems to cause fewer problems of clogging in drip irrigation systems. Common potassium sources are potassium sulphate, potassium chloride and potassium nitrate, which are readily soluble in water. These fertilizers move readily in soil and some of the potassium ions are exchanged on the clay complex and readily leached away.

Hegde *et al.* (1986) reported that the higher requirement of N, P, and K was during the period from 10 days after flowering. The application of nutrients through drip irrigation makes the nutrients readily available for the plants in the root zone.

Goya *et al.* (1988) studied the nitrogen fertigation (as urea) at 150, 300 or 500 kg ha^{-1} via11 irrigations or at 500 kg ha^{-1} as side dressing on two dates had positive effect on fruit width, weight and number.

Marchesi and cattivelli (1988) found that plant height, stem thickness, plant weight or total dry matter between plants of *capsicum annuum* cv. Sansone F1 seedlings were increased by fertigation using the compound product ideronova (21:7:14:2 of N:P:K:Mg) as compared to unfertilized plants.

Clark *et al.* (1991) reported that improved water and fertilizer management by using tensiometer and fertigation with micro irrigation for market tomatoes in sandy soils can result in reduced water and fertilizer application as compared to those associated with current irrigation methods.

Cook and Sanders (1991) reported that fertigation improves nutrient use efficiency besides water use efficiency.

Locascio and Smajstria (1992) observed that the marketable yield of large fruits of tomato and total marketable yield were 30 and 10 per cent higher respectively with 60 per cent of N and K applied with drip irrigation than with all fertilizer applied pre- plant. Yields for the daily and weekly fertigation treatments were similar.

Malik *et al.* (1994) studied the effect of urea application through drip irrigation system to pea showed that highest green pod yield (95.5 and 98.1 q ha^{-1}) Was recorded where fertilizer was applied in split doses through drips, the magnitude of yield response to fertilizer was applied in split doses through drips, the magnitude of yield response to fertilizer application was also maximum in the treatment. The urea applied through drip was found to be more uniformly distributed throughout the soil depth up to 0.90 m.

Storlie *et al.* (1995) studied the effects of fertilizer rates and application frequency on drip fertigated *Capsicum annuum* in southern New Jersy. Yield and fruit quality were greatest with 71.82 kg N, 31.36 kg P and 56.54 kg K $acre^{-1}$ in sandy loam soil. Average marketable fruit weight increased with increasing fertilizer rate.

Raghuramulu (1996) conducted studies on fertigation in coffee at Central Research Station, Balehonur and revealed that the application of 120:90:120 kg N PK/ha through drip irrigation resulted in production of maximum number of bearing nodes, flower buds or bunch, fruit set, number of fruits per branch and yield of clean coffee, compared to soil application of 160:120:160 kg NPK/ha in four split doses.

Srinivasa (1999) reported that the application of 150g of nitrogen and potassium through fertigation in banana was found to be significantly superior and on part with 200g of nitrogen and potassium as it resulted in getting higher plant height and bunch yield compared to all other treatments. Application of soluble fertilizers through drip irrigation could bring about substantial savings (20-25 per cent) in fertilizer use.

Shingure *et al.* (2000) found that fertigation is supplying fertilizers along with irrigation is one of the most effective of convenient method of supplying nutrients water according to the specific requirement of the crop to maintain optimum soil fertility and to increase the quality of the produce.

Asokaraja (2002) conducted fertigation studies on sugarcane with soluble fertilizers. The results indicated that highest yield of sugar cane was recorded under drip fertigation with water soluble fertilizer as 75% NPK recommended dose, when compared to control surface irrigation and soil application of normal fertilizers at 100% NPK dose.

Anon *et al.* (2004) reported that the nutrient requirement of hybrid chilli as 120:80:80 kg ha^{-1} and stated that the full dose of phosphorus and potassium were applied as basal and nitrogen was applied in four splits up to 90 DAP.

Nikam *et al.* (2004) noticed that fertigation with recommended dose of fertilizer (100:50:50 kg NPK ha^{-1}) at two days intervals upto 105 days resulted in significantly higher yield of green chilli of 9.30 and 9.06 t ha^{-1}, during first and second year of the crop.

Karthikeyan *et al.*(2006) noted that the increase in the yield of tomato, over 40 per cent by 100 per cent of recommended N through drip plus P and K as soil applied, and an increase of 24.1 per cent by 70 per cent N and 80 per cent P and K through drip fertigation. It showed that there is increase of 19.2, 5.9 and 4.2 per cent increase in yield by 100 per cent NPK as soil applied surface irrigation, 70 per cent recommended NPK through drip fertigation and 100 per cent N through drip plus P and K as soil applied respectively.

Hongal and Nooli (2007) reported that supply of moisture and nutrients enable to attain higher growth rate and increased yield. Fertigation through drip ensures every plant to be irrigated and receives its requirement of nutrients. It offers an opportunity for precise application of fertilizer in restricted volume of wetted soil zone and there by increases fertilizer use efficiency.

MATERIALS AND METHODS

CHAPTER 3

MATERIALS AND METHODS

A study was conducted to evaluate the potential of irrigation wick (glass wool) to uptake fertiliser and to standardise the fertigation requirement of tomato crop through wick irrigation. Materials used for study and the methodology adopted for achieving the objectives are discussed below.

3.1 Location of the study

The experiment was conducted in the experimental plot of PFDC, Tavanur located at KCAET, Tavanur situated at 10º 53´ 33"N latitude and 76º E longitudes. Agro-climatically, the area falls within the border line of Northern zone, Central zone and Kole land of Kerala. The area receives rainfall mainly from the South West monsoon and to certain extends from the North East monsoon.

The climatological data of the experimental area is shown below.

Mean maximum temperature: 32.5^{o} C

Mean minimum temperature: 22^{0} C

Average relative humidity : 83%

Average annual rainfall : 2500 mm

Mean evaporation : 6 mm / day

Mean solar radiation : 85 W/ m^2/ day

3.2 Period of study

The study was conducted during the period from October 2017 to January 2018. Wick irrigation system was installed inside the rainshelter during the month of October 2017 to January 2018.Performance of the system was evaluated on fertilizer uptake using tomato crop.

3.3 Experimental procedure

The experiment was conducted inside a rainshelter having an area of 50 m^2. The crop tomato (*Akshaya*) was raised in the rainshelter during the period from September 2017 to January 2018. All the cultural practices were done according to the Package of Practices recommendations of KAU.

3.4 Experimental details

The details about the crop, variety and experiment are shown in Table 3.1.

Table 3.1 Experimental details

Location	Kelappaji College of Agricultural Engineering and Technology, Tavanur.
Crop	Tomato (*Solanumlycopersicum*)crop belongs tothe family*Solanaceae*.
Variety	*Akshaya*
Spacing	60×60 cm between the plants
Area	50 m²
Protected structure /condition	Rain shelter
Treatment	9
Replications	3

3.5 Field experiment

3.5.1 Feasibility studies

A preliminary study was conducted to check whether the fertigation through wick is possible or not. For this purpose wick was inserted in a grow bag planted with amaranthus. A mixture of water and fertilizer was poured into the 2 litre bottle. It was observed that there is considerable reduction in the water fertilizer mixture in the bottle after 2-3 days, comparable to the reduction occurred in case of water alone. From the feasibility study it was concluded that fertigation is possible and effective through wick irrigation system.

3.5.2 Nursery preparation

Tomato seedlings were raised using protrays having 98 cells of size 4 cm in diameter and 4.5 cm depth which were filled with the growing media composed of vermi compost, soil and coco peat in equal proportion. Sowing was done by placing each seeds in a hole at a depth 0.5cm and was covered by thin layer of growing medium. The trays were watered lightly and placed in a sheltered place. Seeds were treated with *Trichoderma* solution to avoid soil borne diseases. Seeds germinated in 4 - 6 days and the seedlings were ready for transplanting 21days after sowing. Plate 3.1 shows the germination of seedlings.

Plate 3.1 Nursery preparation

3.5.3 Grow bag filling

Potting mixture comprising of sand, soil and cow dung in the ratio of 1:1:1 was mixed thoroughly after sprinkling water for the grow bag filling. At the bottom of the bag, a hole of 25 mm was made to insert the wick. The grow bag was filled up to one third volume and made into the round shape. Wick was then inserted into the bag through the bottom of the hole in such a way that one third length of the wick is projected outside the bag as shown in Plate 3.2.There after bag was filled up to desired depth.

3.5.4 Installation of wick irrigation system

Two litre capacity bottles were used for the installation of wick fertigation system. Two holes of 25 mm size were drilled on the bottle, one hole is at 3-3.5 above the bottom for inserting the wick and other hole near to the neck of the bottle for filling water. Bottle cap was tightened and the bottle was placed horizontally in between two bricks in such a way that the holes are facing up as shown in Plate 3.2.

The filled grow bags along with wicks were placed on the brick and the wick was inserted into the hole provided at the lower portion of the bottle as shown in Plate3.3. The bottle was then filled with water.

Plate 3.2 Fixing wick inside the grow bag

Plate 3.3 Installation of wick irrigation system

3.5.5 Transplanting

The seedlings prepared in the nursery were transplanted into the grow bags. Grow bags were laid out with at a spacing of 60 x 60 cm with a total number of 27 grow bags. Transplanting in to the grow bags are shown in Plate 3.5.

Plate 3.4 Placing of wick inside the grow bag and bottle

Plate 3.5 Transplanting

3.5.6 Training of tomato plants

Training of plants was done by using the plastic twine. Separate plastic twine was provided for each plant and to each branch so that branches do not break up. Tying of plants to the plastic twine started from fourth week after transplanting and tying was done at weekly intervals along with pruning operation. Training of tomato plants is shown in Plate 3.6.

Plate 3.6 Crop stand in rainshelter after training of plants

3.5.7 Weeding

Weeds interfere with the growth of the crop by absorbing water and nutrients. Therefore periodical removal of the weeds was essential to maintain an optimum growth rate for the crops. Manual weeding was done at 20 days interval.

3.5.8 Plant protection measures

Plant protection measures using recommended dose of chemicals were adopted to prevent the incidence of pest and disease attacks. Various pesticides used were *Trichoderma* for seed treatment (10 g/kg) and Indofil-M-45 (3 g/l) for the management of various fungal diseases. Plate 3.7 shows the spraying of pesticide.

Plate 3.7 Spraying of pesticides

3.5.9 Harvesting

Harvesting of tomato fruits started at 70 days after transplanting and continued until150 days after transplanting. The ripened fruits were harvested daily on the basis of colour.

3.6 Fertigation

Fertigation treatments involved in the study were based on KAU recommended dose of fertiliser of 70:40:25.Nine different combinations of treatments comprising of three different levels of nitrogen (80%, 100%, and 120% of KAU recommended dose of fertiliser) and potassium (80%, 100%, and 120% of KAU recommended dose of fertiliser) were used in the study and are shown in Table 3.2. Phosphorus (Rajphos fertilizer) was applied as the basal dose. Tenth combination was the control, in which Fertilizers were applied manually and irrigation was given through wick.

Table 3.2 Fertigation levels with different treatments

Nitrogen– Urea (g per plant)		Potassium- Murate of potash (g per plant)		
		80%	100%	120%
	80%	T1 (N: 4.7 & K:1.2)	T2 (N: 4.7 & K: 1.5)	T3 (N: 4.7 & K: 1.8)
	100%	T4 (N: 5.9 & K: 1.2)	T5 (N: 5.9 & K: 1.5)	T6 (N: 5.9 & P: 1.8)
	120%	T7 (N : 7.0 & K: 1.2)	T8 (N: 7.0 & K: 1.5)	T9 (N: 7.0 & K: 1.8)

The different treatments used for the study are as given below

T1 – 80% Nitrogen and 80% potassium.

T2 –80% Nitrogen and 100% Potassium.

T3 –80% Nitrogen and 120% potassium.

T4 –100% Nitrogen and 80% Potassium.

T5 –100% Nitrogen and 100% Potassium.

T6 –100% Nitrogen and 120% Potassium.

T7- 120% Nitrogen and 80% potassium.

T8- 120% Nitrogen and 100% Potassium.

T9 -120% Nitrogen and 120% Potassium.

T10- Control (100% Nitrogen and 100% Potassium).

Each treatment was replicated three times (R1, R2, and R3). The desired fertilizer requirement for each treatment was supplied as three equal split doses. The first split was given 10 days after the transplantation. The second was given 30 days after transplantation. Last split was given 60 days after transplantation.

3.7 Observation recorded

Observations on growth yield and fruit quality parameters were recorded at various stages of crop growth and harvest from each labelled plants inside rainshelter.

3.7.1 Growth parameters

3.7.1.1 Plant height (cm)

Height of the plant was measured from ground level to tip of top most leaf. Readings were recorded for each treatment from the transplanted date at an interval of 30 days. The height of plants was recorded by using meter scale from the base to its growing tip of the main stem and the mean value was expressed in centimetres.

3.7.1.2 Stem girth (cm)

Girth of the plant is measured at 2.5cm above ground level at 30 days of interval. Average girth was calculated.

3.7.1.3 Number of branches

Total number of branches was counted from each treatment for different interval.

3.7.2 Reproductive parameters

3.7.2.1 Time taken for flower initiation

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

3.7.2.2 Time taken for 50% flowering

The time by which 50% of the plants got its flowers from date of transplanting was observed. The number of days for each treatment was recorded.

3.7.2.3 Time taken to first harvesting

The number of days taken from flowering to harvest was recorded from the each treatment and expressed as days taken for first harvest of fruit.

3.7.3 Yield parameters

3.7.3.1 Number of fruits per plant

The total number of fruit harvested was recorded from each treatment at weekly intervals was recorded till the end of the cropping period.

3.7.3.2 Average fruit weight (g)

Average weight of fruits was recorded under each treatment at every harvest using digital electronic balance and mean was expressed in grams.

3.7.3.3 Average fruit diameter (cm)

The fruit diameter was recorded from each treatment by measuring diameter of individual fruits using measuring tape.

3.7.3.4 Yield per plant (kg)

The weight of fruits per plant in each harvest was recorded till the final harvest and total yield of fruits per plant was recorded in kilograms.

3.7.3.5 Total yield (kg)

Total yield was calculated by recording the yield from the net plot under each treatment and was expressed in kilograms.

3.8 Nutrient content

The initial nutrient content in the soil before planting and final nutrient content after harvesting were noted.

3.9 Nutrient use efficiency

Nutrient use efficiency was calculated as:

$$\text{NUE} = \frac{\text{Yield } (\frac{\text{Kg}}{\text{ha}})}{\text{Total amount of nutrients } (\frac{\text{Kg}}{\text{ha}})}$$

3.10 Performance of wick

Wick used for this study was glass wool. The water up taking capacity along with fertilizer was noted in different interval.

RESULTS AND DISCUSSION

CHAPTER 4

RESULTS AND DISCUSSION

The results obtained from the present study based on the observation taken from the field are discussed in this chapter. The study was conducted during the period from October 2017 to January 2018 at PFDC Tavanur.

4.1 Growth parameters

4.1.1 Plant height (cm)

The plant height of tomato differed significantly due to growing environment in all stages of crop growth *viz.*30, 60, and 90 days after transplanting (DAT).

4.1.1.1 One month after transplanting

Plant height measured one month after transplanting are given in Table 4.1 and Fig. 4.1.

Table 4.1 Plant height one month after transplanting

Treatments	Plant height (cm)
T1	38.3
T2	35.6
T3	32
T4	40.1
T5	29.1
T6	36
T7	38
T8	37
T9	39
T10	43

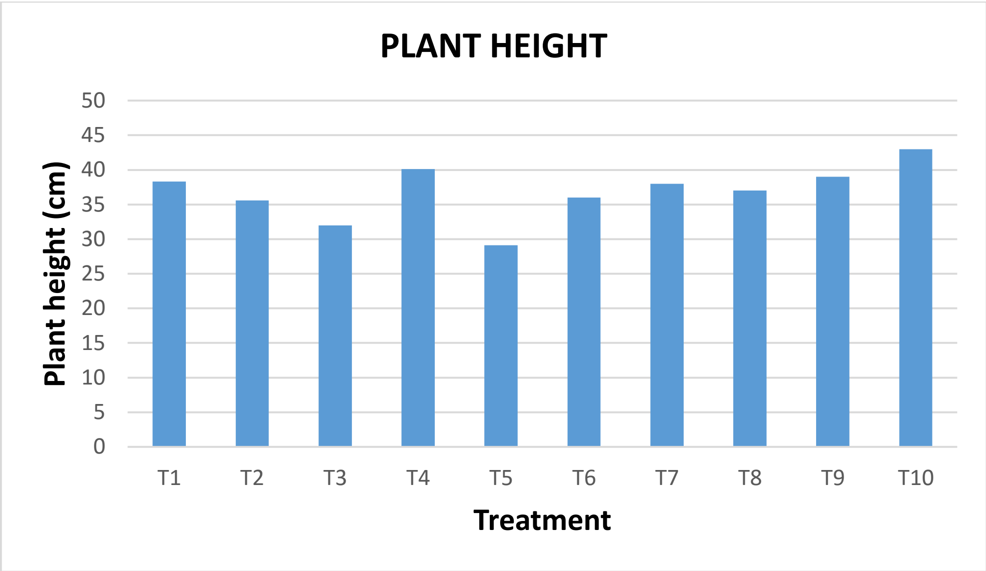

Fig. 4.1 Plant height one month after transplanting

One month after transplanting, maximum plant height was obtained from the treatment T10 (43cm). Followed by the treatment T4 (40.1 cm). The minimum plant height was obtained from the treatment T5 (29.1cm)

4.1.1.2 Two months after transplanting

Plant height measured two months after transplanting are given in Table 4.2 and Fig. 4.2.

Table 4.2 Plant height two months after transplanting

Treatments	Plant height (cm)
T1	85
T2	88
T3	86.3
T4	91.2
T5	87.4
T6	79.8
T7	83
T8	80
T9	91
T10	95

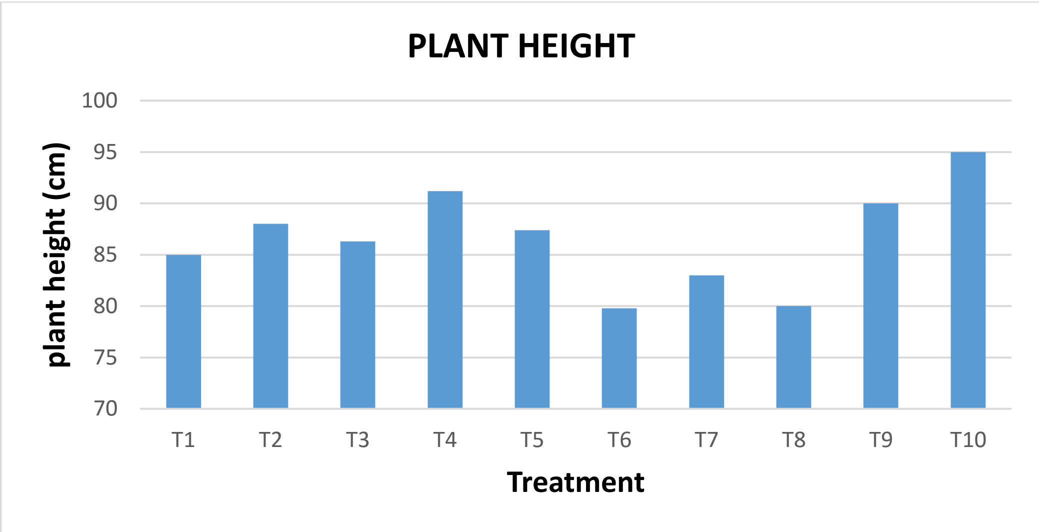

Fig. 4.2 Plant height two months after transplanting

Two months after transplanting, maximum height was obtained from the treatment T10 (95cm). Followed by the treatment T4 (91.2cm). The minimum plant height was obtained from the treatment T6 (79.8).

4.1.1.3 Three month after transplanting

Plant height measured three months after transplanting are given in Table 4.3 and Fig. 4.3.

Table 4.3 Plant height three months after transplanting

Treatments	Plant height (cm)
T1	121
T2	117
T3	117.6
T4	124
T5	120
T6	118
T7	123.9
T8	120
T9	123
T10	127

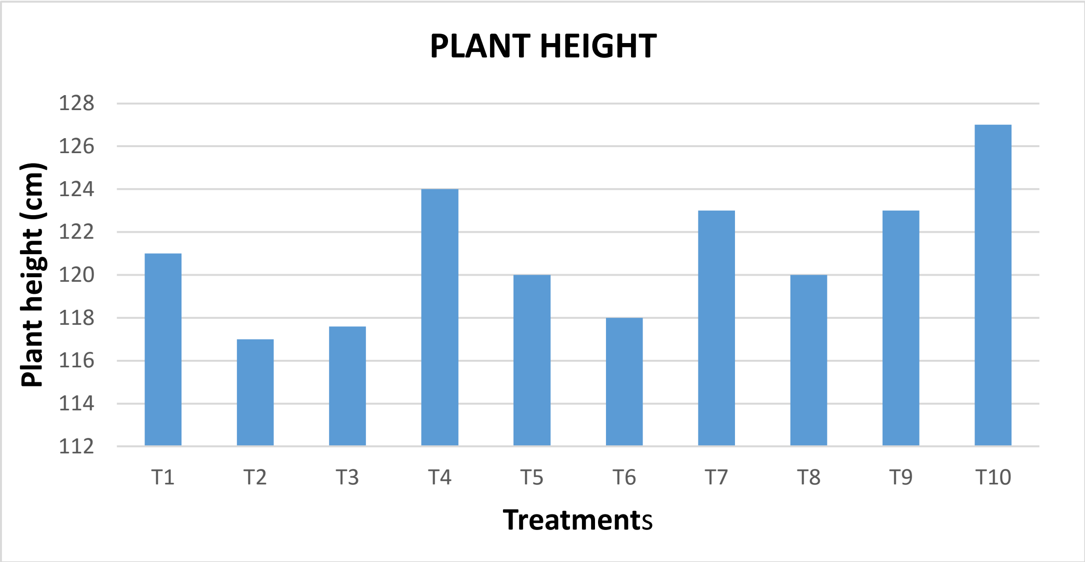

Fig. 4.3 Plant height three months after transplanting

Three month after transplanting, maximum plant height was obtained from the treatment T10 (127cm). Followed by the treatment T4 (124cm). The minimum plant height was obtained from the treatment T2 (117cm).

4.1.2 Stem girth

Stem girth of plants under each treatment were measured at one month, two months and three months after transplanting.

4.1.2.1 One month after transplanting

Stem girth measured one month after transplanting are given in Table 4.4 and Fig. 4.4.

One month after transplanting, maximum stem girth was obtained from the treatment T10 (1.7cm). Followed by the treatment T4 (1.3cm). The minimum stem girth was obtained from the treatment T3 (1.1cm).

Table 4.4 Stem girth one month after transplanting

Treatment	Stem girth (cm)
T1	1.5
T2	1.4
T3	1.1
T4	1.3
T5	1.3
T6	1.4
T7	1.2
T8	1.3
T9	1.5
T10	1.7

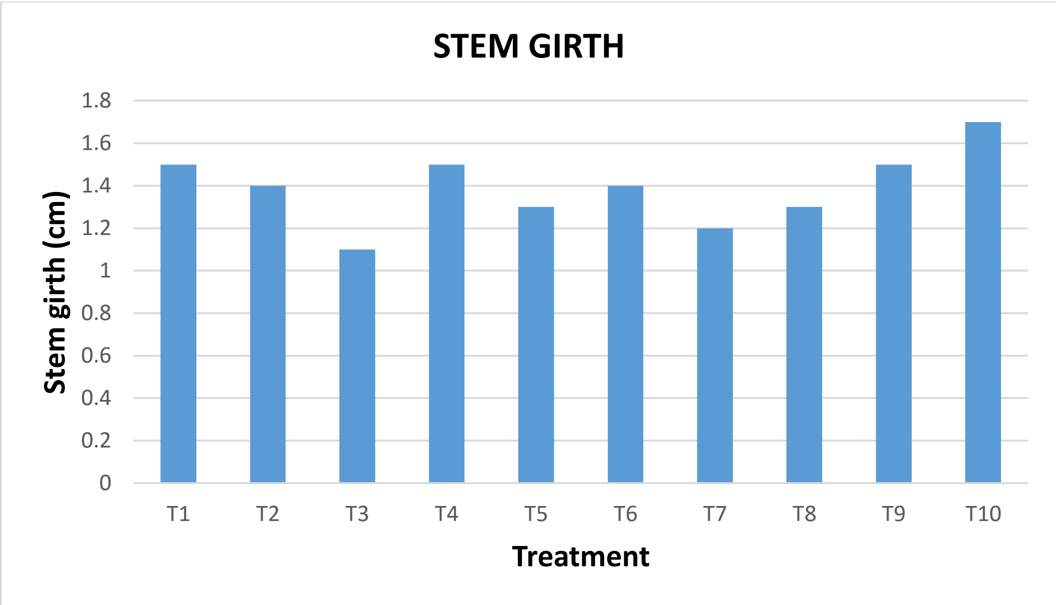

Fig. 4.4 Stem girth one month after transplanting

4.1.2.2 Two months after transplanting

Stem girth measured two months after transplanting are given in Table 4.5 and Fig. 4.5.

Table 4.5 Stem girth two months after transplanting

Treatments	Stem girth (cm)
T1	3
T2	3.1
T3	2.9
T4	3.3
T5	2.8
T6	3.1
T7	3.2
T8	3.2
T9	3.2
T10	3.5

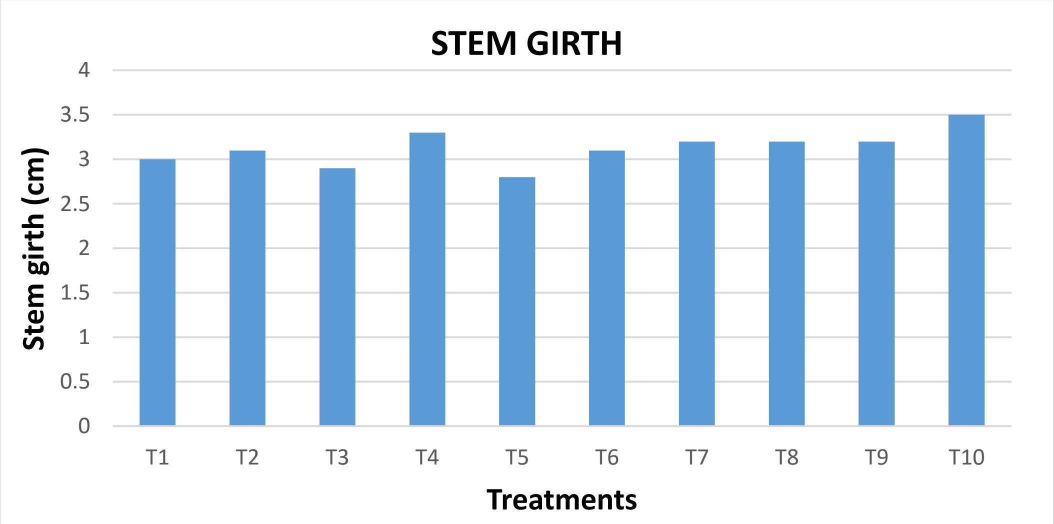

Fig. 4.5 Stem girth two months after transplanting

Two months after transplanting, maximum stem girth was obtained from the treatment T10 (3.5cm). Followed by the treatment T4 (3.3cm). The minimum stem girth was obtained from the treatment T5 (2.8cm).

4.1.2.3 Three month after transplanting

Stem girth measured three months after transplanting are given in Table 4.6 and Fig.4.6.

Table 4.6 Stem girth three months after transplanting

Treatments	Stem girth
T1	6.3
T2	6.1
T3	5.5
T4	6.7
T5	5.7
T6	5.3
T7	5.2
T8	5.9
T9	6.2
T10	6.9

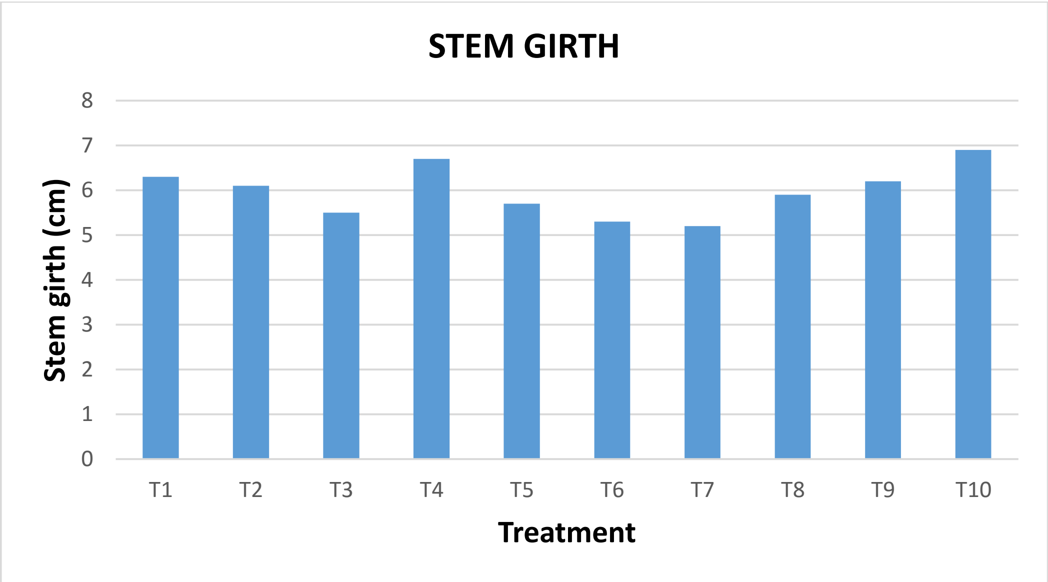

Fig. 4.6 Stem girth three months after transplanting

Three months after transplanting, maximum stem girth was obtained from the treatment T10 (6.9cm). Followed by the treatment T4 (6.7cm). The minimum stem girth was obtained from the treatment T7 (5.2cm).

4.1.3 Number of branches

The number of branches of tomato plants under each treatment was recorded at one month, two month, and three month.

4.1.3.1 One month after transplanting

The number of branches recorded one month after transplanting are given in Table 4.7 and Fig. 4.7.

One month after transplanting. Maximum number of branches was observed in the treatment T10 (14). Followed by the treatment T4 (10). The minimum number of branches was observed in the treatment T7 (5).

Table 4.7 Number of branches one month after transplanting

Treatments	Number of branches
T1	7
T2	8
T3	8
T4	10
T5	9
T6	9
T7	5
T8	10
T9	12
T10	14

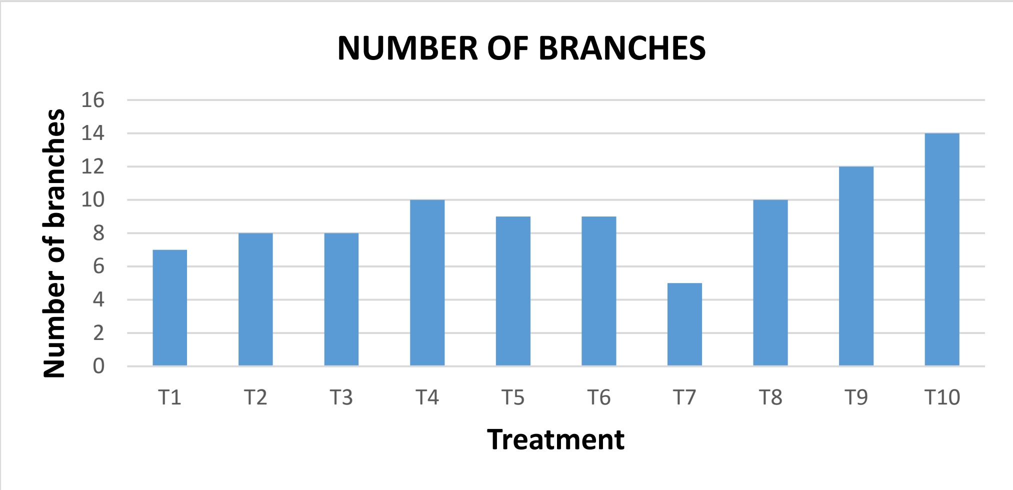

Fig. 4.7 Number of branches one month after transplanting

4.1.3.2 Number of branches two months after transplanting

The number of branches recorded two months after transplanting are given in Table 4.8 and Fig. 4.8.

Table 4.8 Number of branches two months after transplanting

Treatments	Number of branches
T1	15
T2	18
T3	16
T4	19
T5	16
T6	17
T7	13
T8	19
T9	17
T10	22

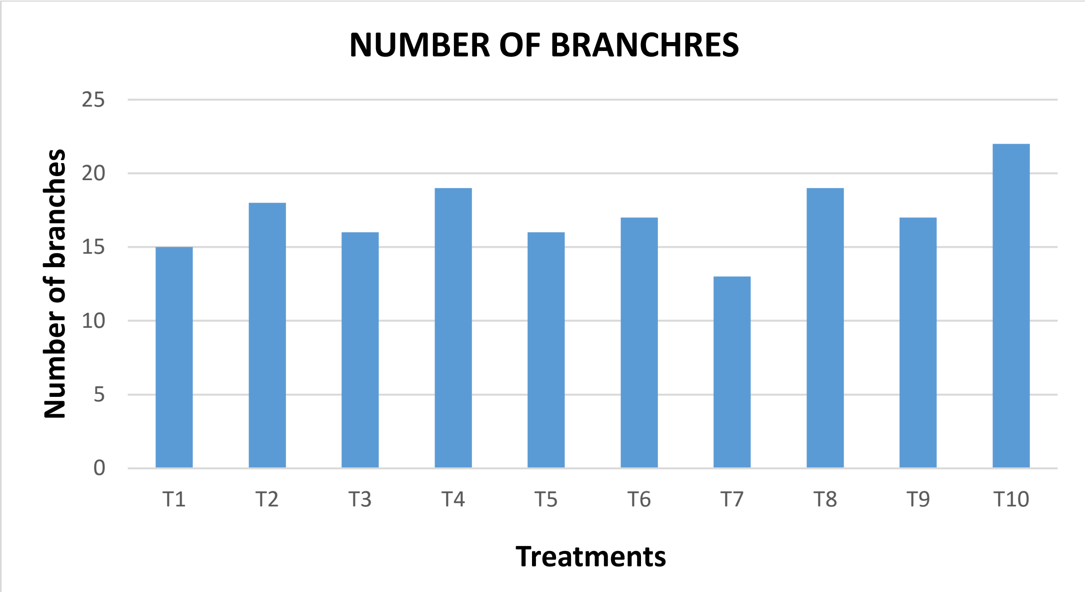

Fig. 4.8 Number of branches two months after transplanting

Two months after transplanting. Maximum number of branches was observed in the treatment T10 (22). Followed by the treatment T4 (19). The minimum number of branches was observed in the treatment T7 (13).

4.1.3.3 Three month after transplanting

The number of branches recorded three month after transplanting are given in Table 4.9 and Fig. 4.9

Table 4.9 Number of branches three months after transplanting

Treatments	Number of branches
T1	29
T2	24
T3	26
T4	30
T5	25
T6	29
T7	23
T8	29
T9	28
T10	32

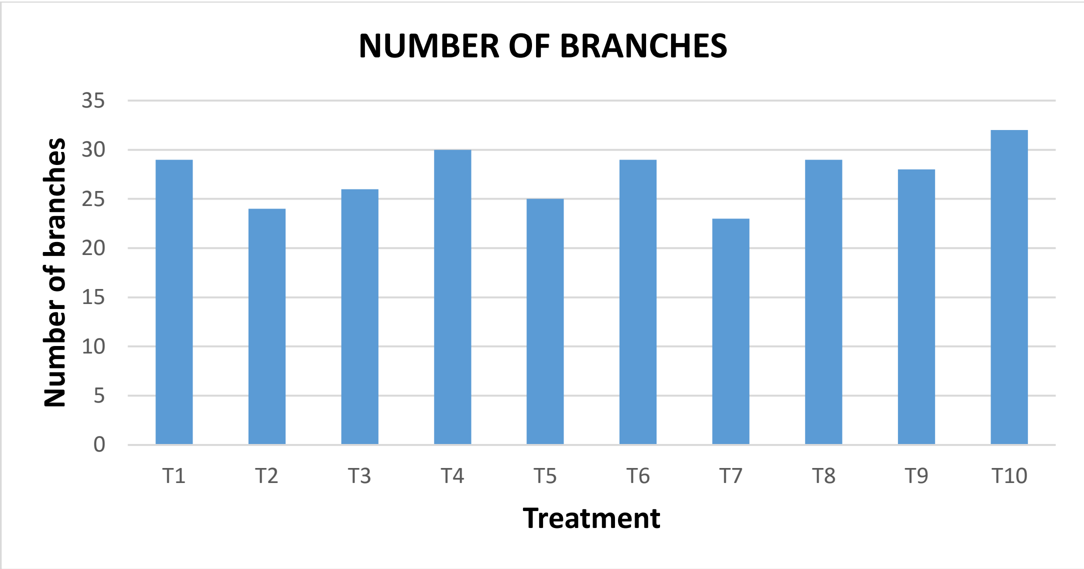

Fig. 4.9 Number of branches three months after transplanting

Three months after transplanting. Maximum number of branches was observed in the treatment T10 (32). Followed by the treatment T4 (30). The minimum number of branches was observed in the treatment T7 (23).

4.2 Reproductive parameters

4.2.1 Time taken for flower initiation

Compared to the other treatments early flower initiation was noted in treatment T10 (30 days DAP). The second early flowering was noted in treatment T4, T6 and T9 (31 days). Treatment T6 was taken more time for first flowering.

4.2.2 Time taken for 50 % flowering

The growing environment significantly influenced the average number of days required for 50 % flowering. Maximum photosynthesis activity inside the rainshelter and faster growth might have resulted in the early initiation of flowers and 50% flowering. Nearly 50 % flowering was noted in treatment T10 (49 days).

4.2.3 Time taken to first harvest

The time taken to first harvest was minimum for the treatment T10 (71 days). Followed by the treatment T4 (76 days). The time taken to first harvest was maximum for the treatment T8 (82 days).

Table 4.10 Time taken for various reproductive attributes of tomato

Treatments	Time taken for flower initiation (days)	Time taken for 50 per cent flower initiation (days)	Time taken for first harvest (days)
T1	35	58	79
T2	36	60	78
T3	39	56	80
T4	34	55	76
T5	37	59	79
T6	36	56	75
T7	34	55	76
T8	34	56	82
T9	35	54	80
T10	30	49	71

4.3 Yield parameters

4.3.1 Number of fruits per plant

The number of fruits harvested from each treatment was found to be highly remarkable under different treatments. The average numbers of fruits harvested from various treatments are given in Table 4.11 and the same is shown graphically in Fig. 4.10.

From the Table 4.11 & Fig.4.10 it is found that highest number of fruits were obtained from the treatment T10 (70). Followed by the treatment T4 (61). The lowest number of fruits were obtained from the treatment T3 (48).

Table 4.11 Number of fruits per plant

Treatments	Number of fruits per plant
T1	59
T2	56
T3	48
T4	61
T5	55
T6	60
T7	49
T8	57
T9	61
T10	70

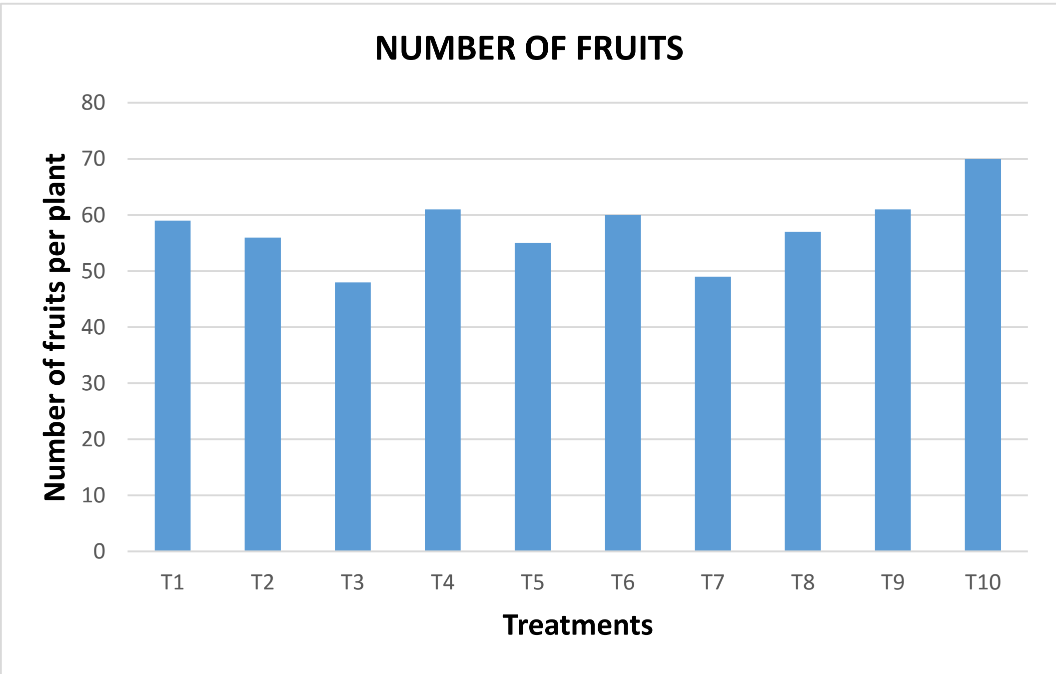

Fig. 4.10 Number of fruits per plant

4.3.2 Average fruit weight (g)

The average individual fruit weight obtained from each treatment was noted and are shown in Table 4.12 and Fig. 4.11.

Table 4.12 Average fruit weight (g)

Treatments	Average fruit weight (g)
T1	375
T2	430
T3	350
T4	455
T5	410.5
T6	388
T7	250
T8	298
T9	420
T10	750

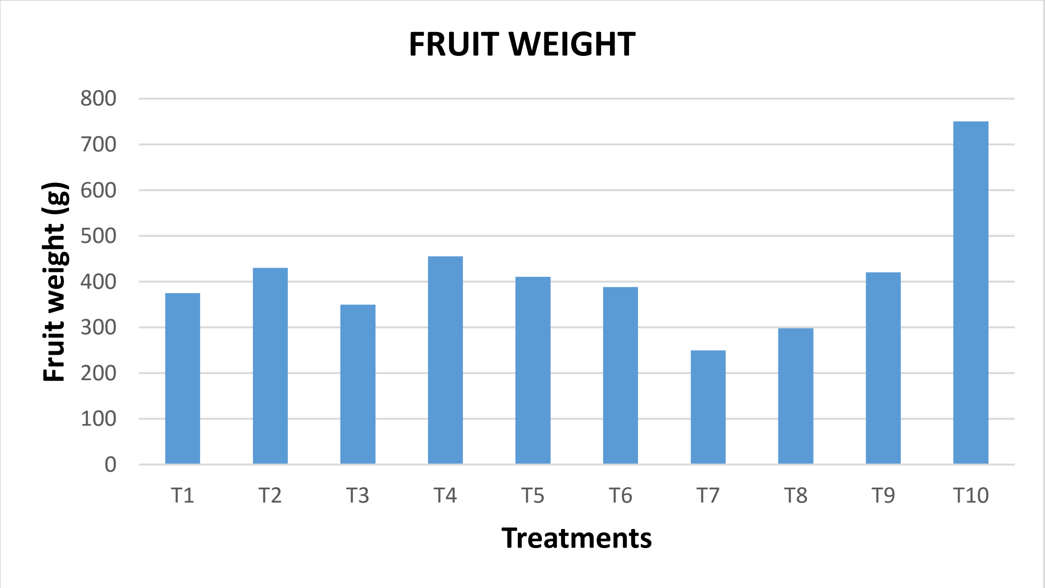

Fig. 4.11 Average fruit weight (g)

From the Table 4.12 & Fig.4.11 it is found that highest average fruit weight was obtained from the treatment T10 (750g). Followed by the treatment T4 (455g). The lowest average fruit weight was obtained from the treatment T7 (250g).

4.3.3 Average fruit diameter (cm)

Average diameters of the fruits harvested from various treatments are shown in Table 4.13 and Fig 4.12.

Table 4.13 Average fruit diameter

Treatments	Average fruit diameter (cm)
T1	5.0
T2	4.7
T3	4.9
T4	5.3
T5	4.8
T6	4.9
T7	4.0
T8	4.7
T9	5.1
T10	6.5

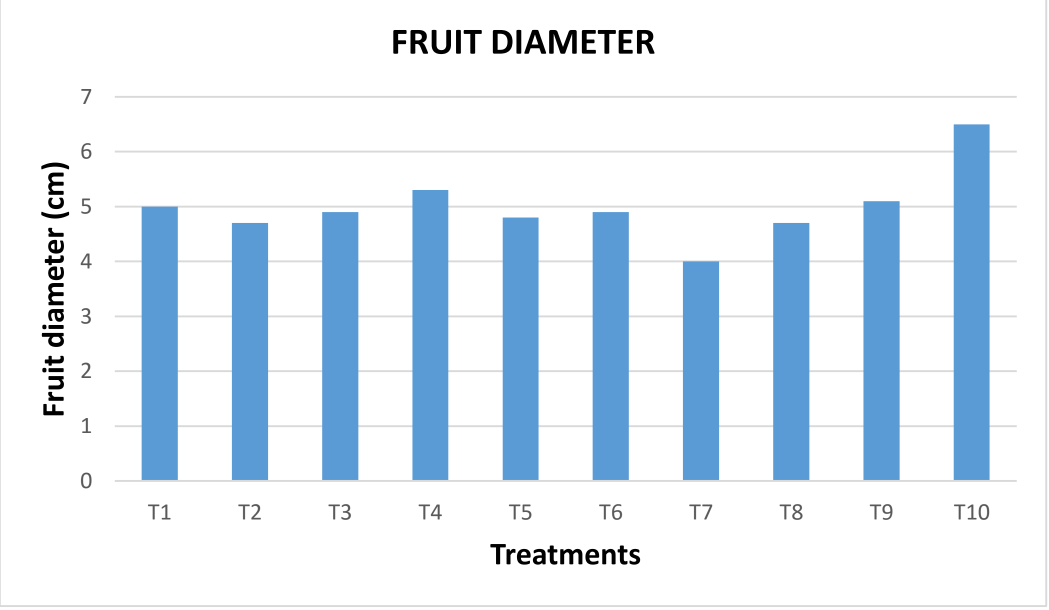

Fig 4.12 Average fruit diameter (cm)

From the Table 4.13 & Fig.4.12 it is found that highest average fruit diameter obtained from the treatment T10 (6.5cm). Followed by the treatment T4 (5.3cm). The lowest yield per plant was obtained from the treatment T7 (4.0cm).

4.3.4 Yield per plant

Harvesting was started from two months after transplanting. The yield response was notable under different treatments. The average yields obtained from various treatments are given in Table 4.14 and the same is shown in Fig. 4.13.

Table 4.14 Yield per plant

Treatment	Yield (Kg) per plant
T1	0.375
T2	0.430
T3	0.350
T4	0.455
T5	0.4105
T6	0.388
T7	0.250
T8	0.298
T9	0.420
T10	0.750

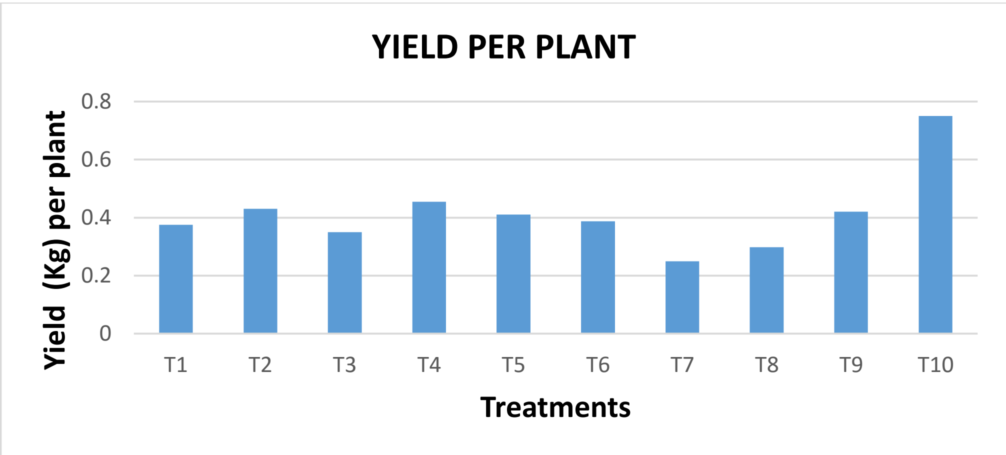

Fig. 4.13 Yield (kg) per plant

From the Table 4.14 & Fig.4.13 it is found that highest yield per plant was obtained from the treatment T10 (0.750 kg). Followed by the treatment T4 (0.455 kg). The lowest yield per plant was obtained from the treatment T7 (0.250 kg).

4.3.5 Total yield

The total yield from each treatment was calculated. The crop yield obtained from different treatments were different. Treatment T10 was found to be the best treatment and the yield from T10 was 0.750 kg. Treatment T4 gave the second best yield (0.450 kg). The least yield was obtained from treatment T7 (0.250 kg) and the total yield from the plot was 4.2 kg.

4.4 Nutrient content

The initial soil nutrient content before planting and the final nutrient content in the soil after harvesting are shown in Table 4.15 and Table 4.16 respectively. From the first tables it was evident that nutrients present in the soil after harvest were almost same as that before planting. After harvesting the crop the soil nutrient content in the soil was quite high for all the treatments when compared to the control. This indicates that wick can absorb the nutrients through the water solution but it would take much more time to reach the soil. May be this reason for the high residual nutrient content. For the control using manual fertilizer application, the nutrient content in the soil was less after harvesting the crop, which indicates that soil could directly absorb the nutrient faster than fertigation using wick.

Table 4.15 Initial soil nutrient content before planting

Sample	N%	P (Kg/ha)	K(kg/ha)
T1R1	1.46	71.76	608.16
T1R2	1.44	65.15	402.08
T1R3	-	-	760.48
T2R1	0.83	36.33	439.04
T2R2	2.27	-	327
T2R3	1.52	78.9	673.12
T3R1	-	79.2	570
T3R2	1.44	73.5	583.5
T3R3	1.66	66.05	649.6
T4R1	1.78	-	579.04
T4R2	1.58	-	395.36
T4R3	1.23	67.86	582.4
T5R1	1.46	99.98	733.6
T5R2	1.74	69.66	766.08
T5R3	1.92	76.56	684.44
T6R1	2.31	91.58	807.52
T6R2	1.66	89.78	833.28
T6R3	1.40	81.67	708.96
T7R1	2.47	99.68	800.8
T7R2	1.97	113.80	543.2
T7R3	1.46	42.03	436.8
T8R1	1.11	56.15	523.04
T8R2	1.13	-	676.48
T8R3	2.21	83.77	752.69
T9R1	0.95	-	663.04
T9R2	1.25	-	659.68
T9R3	-	-	724.64
T10R1	1.9	88.0	410.0
T10R2	.99	82.5	655
T10R3	1.15	68	760

4.16 Final nutrient content in the soil after harvesting

Sample	N (%)	P (kg/ha)	K (kg/ha)
T1R1	1.17	135	939.08
T1R2	1.15	118	1009
T1R3	1.4	119	788
T2R1	1.5	112	804.16
T2R2	1.22	119.2	954.2
T2R3	1.24	29.4	635
T3R1	1.4	119	788
T3R2	1.2	112	786.0
T3R3	1.31	142.6	853.9
T4R1	1.28	145.5	670
T4R2	1.6	104.7	820.6
T4R3	1.6	111	900
T5R1	1.4	74	1000
T5R2	1.66	126.4	1041
T5R3	1.54	116	878.08
T6R1	1.62	83.7	873.6
T6R2	1.93	168	890.4
T6R3	1.26	104.4	1137
T7R1	1.32	137	723
T7R2	1.36	135	826
T7R3	1.6	119	696.69
T8R1	1.38	118.1	994.5
T8R2	1.32	126.2	780.6
T8R3	1.34	138.4	889
T9R1	1.9	131	777
T9R2	1.51	137	993.4
T9R3	1.57	117.8	860
T10R1	0.9	70.8	408.01
T10R2	1.0	80.01	605
T10R3	0.88	60	700

4.7 Nutrient use efficiency

The nutrient use efficiency worked out for different treatments are shown in the Table 4.17.

Table 4.17 Nutrient use efficiency

Treatments	Nutrient use efficiency
T1	27
T2	29.28
T3	24.13
T4	30.13
T5	26.6
T6	24.7
T7	15.43
T8	18
T9	25
T10	49

The nutrient efficiency was higher in the treatment T10 (49). All the growth parameters like plant height, plant girth, number of branches and yield parameters like fruit number, fruit diameter, and fruit weight were higher in the treatment T10 (control). Thus T10 was found to be the best treatment from the ten treatments. In the present study the lowest nutrient efficiency was recorded in treatment T7 (15.43).

4.7 Performance of wick

The experiment was conducted for three months. Wick used for the purpose was glass wool. The water uptake capacity of this wick along with the fertilizer was satisfactory. During the initial stages of plant growth (first month) the water uptake through wick was 0.286 to 0.333 lit/plant/day. During the second month the water uptake was 0.5 to 0.666 lit/plant/day and during the last month the water uptake was 1.0 to 1.33 lit/plant/day. The only problem noted was the penetration of roots through the wick, which did not affect the plant growth and yield.

4.4 STAGES OF PLANT GROWTH

Plate 4.1 Sowing

Plate 4.2 Germination

Plate 4.3 Budding

Plate 4.4 Flowering

Plate 4.5 Fruiting

4.5 YIELD FORM DIFFERENT STAGES

Plate 4.6 First harvest

Plate 4.7 Second harvest

Plate 4.8 Third harvest

SUMMARY AND CONCLUSION

CHAPTER 5

SUMMARY AND CONCLUSION

Crop yield can be increased by providing irrigation at right time intervals in correct proportions. For any crop, to get maximum yield, scheduled fertilizer application is highly inevitable. Wick fertigation is a method of fertilizer application in which fertilizer is incorporated with the irrigation water and applied through wick irrigation systems, so that the fertilizer solution is distributed evenly throughout the crop root zone. Fertigation through wick allow farmers to deliver adequate nutrient quantity and concentration with irrigation water into the active plant root area throughout the growing season, thereby saving labour, money and time.

The study was conducted evaluate the performance of fertigation using wick irrigation system. Field evaluation of wick fertigation system was conducted by growing tomato crop inside a rainshelter located at PFDC, Tavanur during the period from October 2017 to January 2018.

The results of the study showed notable differences in the yield and growth parameters of tomato crops under various fertigation treatments. The growth parameters like plant height, stem girth, number of branches and yield parameters like fruit number, fruit diameter and fruit weight were recorded under ten different treatments to evaluate the performance of wick fertigation system and to find out the most effective treatment for tomato. The results obtained from the experiments conducted under the present study can be summarized as follows.

- Maximum height of the plant was obtained from the treatment T10 (control). Plant height measured one month, two months and three months after transplanting were 40.1, 91.2 and 127 cm respectively. Whereas the time the plant height obtained from T4 were 40.1, 91.2 and 124 cm respectively.
- Stem girth recorded one month, two month and three month after transplanting were maximum for the treatment T10 (control) and were 1.7,

3.5 and 6.9 cm respectively, whereas, treatment T4 recorded the values of 1.3, 3.3 and 6.7 cm for the same observation.

- The number of branches observed for control was 14, 22 and 32 which is the maximum value when compared with T4.
- The first flower initiation took lesser time in treatment T10 which was occurred 30 days after transplanting. But treatment T4 took 34 days for first flower initiation.
- The time taken to 50 % flowering was 49 days in T10, whereas it was 55 days in case of T4.
- Treatment T10 took 71 days for the first harvesting, whereas treatment T6and treatment T4 took 75 and 76 days respectively.
- The average number of fruits harvested from the T10 was 70 and T4 was 61.
- Average fruit diameter recorded for the control was 6.1 cm but for treatment T4 it was 5.3 cm.
- The yield response was highly remarkable under different treatments. 0.750kg per plant was obtained from the treatment T10and the total yield from the plot was 4.2 kg.
- The nutrient efficiency was higher in the treatment T10 and it was observed as 83.33 simultaneously the recorded value for the treatment T4 was 64.

From this study it is evident that there was significant difference in the total yield of tomato harvested from the treatment T10 (irrigation through wick and fertilizer application manually) and T4 (highest yield under wick fertigation) during the entire growing season. Hence it can be concluded from the study that manual application of fertilizer is more efficient than fertigation using wicks.

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APPENDICES

APPENDIX 1

Calculation of amount of fertilizer required

According to the POP recommendations *Akshaya* variety tomato plant requires,

152kg urea, 200kg Rajphose and 50kg Murate of potash per hectare.

Number of tomato plants per hectare = 10000/spacing

= 10000/ (0.6×0.6)

= 27778 plants.

Amount of urea required for one plant =152/27778

=0.0054kg.

Amount of rajphose required for one plant =200/27778

=0.0071kg.

Amount of murate of potash required for one plant = 50/27778

= 0.0017kg.

APPENDIX 2

Calculation of nutrient use efficiency

Nutrient use efficiency (NUE) = total yield/amount of nutrients given

For T1, NUE = 375/ (4.7+1.2+8)

= 27

For T2, NUE = 430/ (4.7+1.5+8)

= 29.28

For T3 NUE =350/ (4.7+1.8+8)

= 24.13

For T4, NUE =455 / (5.9+1.2+8)

= 30.13

For T5, NUE = 410.5 / (5.9+1.5+8)

= 26.6

For T6, NUE = 388/ (5.9+1.8+8)

= 24.7

For T7, NUE = 250/ (7.0+1.2+8)

= 15.43

For T8, NUE = 298/ (7.0+1.5+8)

= 18

For T9, NUE = 420/ (7.0+1.8+8)

= 25

For T10, NUE = 750/ (5.9+1.8+8)

= 49

FERTIGATION STUDIES USING WICK IRRIGATION SYSTEM

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ABSTRACT OF THE THESIS

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ABSTRACT

At the time when the organic farming is gaining popularity in Kerala, there are more options for farmers. 'WICK IRRIGATION' is an irrigation technique modified by Kamalam Joseph, a scientist from CWRDM in Kozhikode with an aim to facilitate farming even when there is scarcity of water. It is a user-friendly irrigation method, which is cheaper and at the same time water efficient. The scientific principle behind this irrigation method is capillary action. Water tends to move towards dry objects using this principle.

Fertigation is a combined application of water and soluble fertilizer along with water through irrigation system. The major advantages of fertigation are saving of water, labour and money. It is a precise application of water soluble fertilizers and other nutrients to the soil at desired concentrations at appropriate time. Hence, ultimately provide a higher yield.

The present study was undertaken to study the fertigation using wick irrigation system. The experiment was conducted in the experimental plot of PFDC, Tavanur located at KCAET. A comparative evaluation was carried out between biometric observations, yield parameters and nutrient content of the two sets of crop grown inside the rainshelter, one set with fertigation using wick by varying concentrations and combinations and the other one with manual fertilizer application. The major crop growth parameters like height of the plant, stem girth, number of branches, days to first flowering, days to 50 per cent flowering, days to first harvest were observed. Yield parameters viz. size of the fruit, fruit diameter, and number of fruits harvested per plant and yield per plant were recorded during the study. The nutrient content of the soil before planting and after harvesting under each treatment were noted. Values of all growth and yield parameters were found to be better for the crop with the manual fertilizer application compared to the fertigation using wick. Hence it can be concluded that manual fertilizer application can ensure better yield for tomato variety *Akshaya* using wick irrigation system.