PERFORMANCE EVALUATION OF COST EFFECTIVE FERTIGATION SYSTEM

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PROJECT REPORT

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DECLARATION

We hereby declare that this project report entitled "**PERFORMANCE EVALUATION OF COST EFFECTIVE FERTIGATION SYSTEM**" is a bonafide record of project work done by us during the course of project work and that the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Place: Tavanur

Date: 20-12-2011

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CERTIFICATE

Certified that this project report entitled **"PERFORMANCE EVALUATION OF COST EFFECTIVE FERTIGATION SYSTEM"** is a record of research work done jointly by Anu Chandran, Neethu,M.V. and Shahnaz Abdul Rahman under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship or other similar title of another University or Society.

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Dedicated to

The Almighty,

Loving Parents

Agricultural Engineers

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SYMBOLS AND ABBREVIATIONS

′	minute
″	second
/	per
^{0}	degree
^{0} C	degree Celsius
%	percentage
AICRP	All India Co-ordinated Research Project
ANOVA	Analysis of Variance
BCR	Benefit Cost Ratio
cm	centimeter (s)
Cv	Manufacturing coefficient of variation
CWRDM	Centre for Water Resources Development and Management
DAP	Days after planting
d.f	degrees of freedom
EU	Uniformity coefficient
et al.	and others
E_{pan}	Pan evaporation
Fig.	Figure
g	gram
ha	hectare

ha m	hectare metre
hr	hour (s)
hp	Horse power
i.e.	that is
ICAR	Indian Council of Agricultural Research
IDE	Irrigation and Drainage Engineering
J	Journal of
k	Kilo
K	Potassium
kg	Kilogram
kg/cm^2	Kilogram per square centimeter
kg/ha m^3	Kilogram per hectare cubic meter
kg/ha cm	Kilogram per hectare centimeter
KAU	Kerala Agricultural University
KCAET	Kelappaji College of Agricultural Engineering and Technology
lph	litre per hour
lit	litre(s)
LDPE	Low density poly ethylene
LWRCE	Land and Water Resources Conservation Engineering
m	meter (s)

m^2	square meter
mm	millimeter (s)
min	minute
Mham	million hectare meter
Mha	million hectares
no.	number
N	Nitrogen
NCPAH	National Committee on Plasticulture Application in Horticulture
P	Phosphprous
PFDC	Precision Farming Development Centre
PVC	Poly Vinyl Chloride
q/ha	quintal per hectare
R	Replications
sec	second
Sci	Science
T	Treatment
TNAU	Tamil Nadu Agricultural University
t/ha	tonnes /hectare
viz.	namely
V	Volt(s)

CHAPTER I

INTRODUCTION

Water, mankind's most vital and versatile resource is a basic human need and a precious national asset. 'Water is life' is truly experienced in water scarce regions. It is essential for broad based agricultural and rural development in order to improve food security and poverty alleviation. Water, a life sustaining resource, closely linked to the quality of life, a renewable resource 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 continues to be only about 40 %. 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 17 % more 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 reuse in 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 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 per cent) is under irrigation in India against the total cultivated area of 145 M ha. Therefore the effective management of water resources is essential to meet the increasing competition for water between agricultural and non-agricultural sectors. Also plans are to be introduced to reduce the present day share of 90 per cent of water used for agriculture to 75 to 80 per cent in the coming decades. This necessitates the scientific management of the available water resources in agricultural sector (source: CWRDM report, 2005).

Achieving higher levels of agricultural growth is a priority on the agenda of many countries including India. Towards this end, use of appropriate technology helps not only to improve productivity, quality and economics of production, but also has a salutary impact on the environment. In the present era all the sectors of economy are demanding large quantities of fresh water. Tremendous amount of pressure lies on agricultural sector to reduce their share of water and at the same time to enhance total production. In India major water sources are rivers, lakes, canals, reservoirs, tanks and ground water. It is estimated that more than 80 per cent of fresh water reservoirs are currently being used for agriculture and remaining water fulfills the individual and domestic requirements.

Surface irrigation method, with an overall efficiency of only 20 to 50 per cent usually causes erosion, salinisation 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 promising drip / micro irrigation techniques.

The micro irrigation system is one of the most efficient methods of water application directly into soil at the root zone of plants. Simca Blass, a water engineer, originated drop by drop application of water to the plants through the drip irrigation system in Israel in the early 1960’s. Now a days this system of irrigation finds its roots in countries like America, Australia, South Africa, Southern Europe etc. In India it was introduced in the early 70’s and during the last few years this system has started gaining momentum. About 4 lakh ha of cultivated lands in India utilize this system of irrigation. Among the states, Maharashtra is the leading state covering 6,04,440 ha under micro irrigation followed by Andhra Pradesh with 5,05,205 ha and Tamil Nadu with 2,26,773 ha (March 2010). It is also expected that the projected area of 10 M ha will be brought under micro irrigation by the year 2020 / 2025 AD. About 55 per cent of the total area of Kerala State with a humid tropical climate is under agriculture. As per the assessment of the Directorate of Economics and Statistics the net irrigated area in the state as on March 2010, is 3.86 lakh ha. and the gross area irrigated is 4.54 lakh ha. The net area irrigated has declined from 3.99 lakh ha during 2008-09 to 3.86 lakh ha in 2009-10. Only 16.34 per cent of the net cropped area is irrigated. The area under micro irrigation in Kerala is as low as 15,885 ha (2010). So there is still ample scope, for this technique of irrigation in Kerala.

Research activities in the field of micro irrigation systems are conducted all over the country through ICAR institutes and State Agriculture Universities, AICRP on application of plastics in agriculture, AICRP on water management, DRIPNET project and Adhoc schemes. The ministry of agriculture through NCPAH, which has 17 precision farming development centers (PFDC) located in different agro climatic conditions has also focused attention to develop regionally differentiated technologies on micro irrigation, besides imparting training to a large number of farmers and department staff. Now the adoption of the micro irrigation system has started in areas having water scarcity, poor quality water and undulating terrain.

Micro irrigation which includes mainly drip and micro sprinklers is an effective tool for conserving water resources. It is an irrigation system with high frequency application of water in and around the root zone of plant system, which consists of a network of pipes along with suitable emitting devices. It permits a small uniform flow of water at a constant discharge, which does not change significantly through out the field. It also permits the irrigation to limit the watering closely to the consumptive use of plants. Thus it minimizes the conventional losses such as deep percolation, runoff and soil evaporation. It also permits the utilization of fertilizer, pesticides and other water-soluble chemicals along with irrigation water for better crop response.

It has been found that the micro irrigation saves fertilizer up to 30 per cent, increases the yield up to 100 per cent with saving of water up to 70 per cent. It also prevents weed growth, saves energy and improves the quality of the produce. Thus the micro irrigation system has to be seen as a holistic approach to address poverty alleviation, horticulture-led diversification of agriculture, enhanced productivity, environmental protection and ecological security, promotion of equity and reduced biotic and abiotic stresses. Now micro irrigation is a means of precision farming too.

But there are constraints in the development of micro irrigation systems. These constraints include lack of credit facilities, skilled human resources, availability of appropriate material and technical know how. Micro irrigation is generally perceived as a technology-driven movement, hence receives resistance from certain quarters. The initial cost of establishing micro irrigation system is as high as Rs 30,000 to 75,000 per ha, hence generally out of reach of resource poor farmers. Micro irrigation is not integrated with total water management system, hence generally viewed in isolation. Lack of information on temporal and spatial variation in soil moisture and on the optimal fraction of soil to be wetted, lack of availability of low cost soluble fertilizers and other agro chemicals and poor institutional support system are also the constraints.

Now these constraints are being solved to some extent. There are lot of schemes that provides financial assistance to the farmers up to the extent of 90 per cent of the capital cost of the system for a hectare or Rs.25,000/-per ha whichever is less for SC/ST, small or marginal and women farmers, and 70 per cent of the cost for other categories of farmers. The cost of incentive is shared in the ratio of 90 per cent by Central and 10 per cent by the State Governments. Moreover even with all these constraints and high initial investment it has also been observed that the pay back period of micro irrigation project is about one year only for most of the crops and benefit cost ratio varies from 2 to 5 (source: CWRDM report., 2005).

Drip irrigation is an efficient method of providing irrigation water directly into the soil at the root zone of plants and it permits to limit the water supply to the consumptive use of the plants. Thus drip irrigation minimizes conventional losses. Globally, the drip irrigated area is about 2.8 M ha, representing 1% of worlds total irrigated area. In India the area coverage under micro irrigation is only 1.6% of total irrigated area.

Scientific methods of cultivation and judicious use of all inputs, including water and fertilizers, is called upon to become cost competitive. Higher efficiency of inputs can be achieved by introducing advanced methods of water and fertilizer application. Also, fertilizers applied under traditional methods of irrigation are not efficiently utilized by the crops. As an alternative, fertigation is gaining popularity all over the world.

Fertigation was first started in the late 1960's in Israel with the development of drip irrigation. It is a coined term to irrigate and give fertilizer along with it. In other words, fertigation is addition of fertilizers to irrigation water and application via drip or similar micro irrigation system. Fertigation provides nitrogen, phosphorous and potassium as well as essential trace elements (Mg, Fe, Zn, Cu, Mo, Mn) directly to the active root zone. This minimizes the loss of expensive nutrients and helps in improving productivity and quality of farm produce.

The adoption of fertigation worldwide has shown favourable results in terms of fertilizer use efficiencies and quality of produce besides the environmental advantages. The choice of selecting various water soluble fertilizers are enormous and therefore, selection of chemicals should be based on the property of avoiding corrosion, softening of plastic pipe network, safety in field use and solubility in water. The present study was done to evaluate the performance of cost effective fertigation system.

OBJECTIVES

- To evaluate the performance of the cost effective fertigation tank developed by KVK Malappuram.
- To compare the cost effective fertigation tank with venturi injector and manual application of fertilizers
- To evaluate the effect of fertigation on the yield and growth parameters of the vegetable (tomato).
- To check the cost effectiveness of the tank.

CHAPTER II

REVIEW OF LITERATURE

Water is the main constraint in 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. Micro irrigation falls under this category especially for wide spaced high value crops and commercial crops. As the scarcity of water is increasing rapidly, adoption of micro irrigation system offers potential for bringing nearly double the area under irrigation with the same quantity of water. Application of pressurized irrigation systems such as drip and sprinkler side by side with precise agronomic practices and soil fertility management are potential tool for improved precision agriculture.

2.1 Micro-irrigation

The term "micro-irrigation" describes a family of irrigation systems that apply water through small devices. These devices deliver water onto the soil surface very near the plant or below the soil surface directly into the plant root zone. Growers, producers and landscapers have adapted micro-irrigation systems to suit their needs for precision water application. Micro-irrigation systems are immensely popular not only in arid regions and urban settings but also in sub humid and humid zones where water supplies are limited or water is expensive. In irrigated agriculture, micro-irrigation is used extensively for row crops, mulched crops, orchards, gardens, greenhouses and nurseries. In urban landscapes, micro-irrigation is widely used with ornamental plantings.

Samra *et al.* (2005) found that micro irrigation systems save irrigation water by 40% and fertilizer by 25%, enhances yield up to 50%, improves water use efficiency by 2 to 4 times with benefit cost ratio of 2.77 (without subsidy) and 3.5 on subsidized cost. Through the good management of micro irrigation systems, the root zone water content can be maintained near field capacity throughout the season providing a level of water and air balance close to optimum for plant growth. In addition, nutrient levels that are applied with water through the system (fertigation) can be controlled precisely.

2.1.1 Advantages of micro-irrigation

Water savings - Conveyance loss is minimal. Evaporation, runoff and deep percolation are reduced as compared to other traditional irrigation systems. A water supply source with limited flow rates such as small water wells or city/rural water can be used.

Energy savings - A smaller power unit is required compared to sprinkler irrigation systems. And every drop of water saved is equivalent to energy saved, in many respects.

Weed and disease reduction - Because of limited wetted area from non-spray type of micro-irrigation, weed growth is inhibited and disease incidences reduced.

Can be automated - Fertilizers and chemicals can be applied with water through the irrigation system. Micro-irrigation systems can be automated which reduces labor requirements.

Improved production on marginal land - On hilly terrain, micro-irrigation systems can operate with no runoff and without interference from the wind. The fields need not be levelled.

Sivnappan *et al.* (1975) conducted an experiment with vegetables and cash crops at TNAU and observed that water used in drip method was only 1/2 to 1/5 of the controlled surface method and at the same time yield was increased to 10-40 per cent for some crops.

Sivnappan (1977) conducted experiments to compare drip irrigation and showed that farmers save up to 80 per cent water, reduces weed growth, improves germination and gives the same or sometimes more yield.

Sheela *et al.* (1988) noticed that average conveyance loss of water in the basin method while irrigating one ha of land was 27.7 per cent where as these losses were found to be considerably less under trickle irrigation system.

Anitha *et al.* (1990) conducted a study to design and develop an automatic drip irrigation system. The study showed that labour cost and operational costs could be reduced by this system thereby achieving a highly economic and efficient irrigation application.

Malavia *et al.* (2001) found that the sprinkler method of irrigation was superior to surface method of irrigation in a field experiment at Junagadh. They observed a higher pod yield of groundnut by 24.3 per cent in summer season.

Singh *et al.* (2005) conducted a study at PAU, Ludhiana, to study the response of cauliflower and hybrid chilli to drip irrigation with its economic feasibility. The results revealed that in hybrid chilli crop, drip irrigation at lowest level of irrigation (0.5 E_{pan}) gave highest yield with highest water-use efficiency and proved to be significantly better than all levels of drip irrigation and check basin method of irrigation.

2.1.2 Potential problems

Micro-irrigation systems normally have greater maintenance requirements. Soil particles, algae, or mineral precipitates can clog the emission devices. Animals, rodents and insects may cause damage to some components. The drip and bubbler irrigation systems need additional equipment for frost protection. Micro-irrigation systems are ideal for high value installations such as orchards, vineyards, greenhouses, and nurseries where traditional irrigation methods may not be practical. However, the investment cost can be high.

To maximize the crop yield, supplying nutrients as such in the soil will not serve, as the whole quantities of applied nutrients are not supplied to the plants and the requirement varies with different zones in the soil. Therefore, it is necessary to analyse the soil nutrient status in various zones and the nutrients application according to the site specific requirement. Soil fertilizer recommendations in modern crop production rely on laboratory analysis of representative soil samples. The accuracy and precision of fertilizer recommendation can be improved by considering the factors influencing nutrient variability. The fertilizer and water management varies with different zones and it plays a vital role in determining the yield and quality of farm produce.

Finding the variability of soil condition within fields, and variable management within fields by zones rather than whole fields would increase profitability by doing the right thing at the right place in the right way. Hence, analyzing the soil nutrient status is must to calculate the optimum fertilizer requirement in different zones of the field and for providing site specific nutrient application.

Hybrid varieties are well known for their higher yield as they express their hybrid vigour for most the desirable characters. Higher yield and intensive cropping make high demands for nutrients from soil. This leads to depletion of soil nutrient reserve. Native soil fertility alone cannot support the expected yield increase. Mineral fertilizers are the preliminary source of nutrients and usually contribute 35 to 50 per cent yield increase.

Some of the reviews of previous works done related to the proposed study are presented in this chapter under the following headings.

2.2 Drip irrigation

Drip irrigation method is to provide water most efficiently at the right rate and practically near the root zone of the crop. Drip irrigation is one such hi - tech system, receiving acceptance and adoption, particularly in areas of water scarcity. Therefore, the efforts now needed are to harness the available quantities of water and put them to efficient use to realize higher productivity per unit of water.

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

Nakayama and Bucks (1991) found that high frequency water management by drip irrigation provides at least daily requirements of water to a portion of the root zone of each plant and maintains a high soil metric potential in the rizhosphere to reduce plant water stress.

2.2.1 Uniformity and moisture distribution pattern under drip irrigation

Water movement and its distribution in the soil depending upon many parameters such as soil type, rate of infiltration, rate of emitter discharge, quantity of water applied, antecedent moisture content, depth to water table and certain climatic factors.

Haynes (1985) studied that under conventional modes of irrigation; generally one dimensional downward water flow takes place from the entire soil surface. In contrast under drip, water is added at discreet points on the soil surface resulting in three dimensional transient infiltration of water through the soil. When emitters are widely spaced the soil is typically wetted in an auxiliary symmetric elliptical shape. In closer emitters the wetted parts of the surface will merge. In very closely spaced emitters, the increased discharge rate from a strip source on the wetting pattern is two dimensional.

Kataria and Michael (1990) found in a study under drip irrigation in tomato that the surface soil layer up to 10 cm depth had the maximum soil moisture content and it decreased with depth. This coincided with the regions having the maximum number of effective roots, resulting in better environment for higher yields.

Singh *et al*. (1990) reported that the wetting front was greater in drip irrigation system compared to surface irrigation. Under drip irrigation, when irrigation was applied at every five days, the wetting front reached 60 to 90 cm soil layer. In case of sprinkler irrigation with the same interval and amount of irrigation water, the wetting front did not exceed 30 to 60 cm.

Goel *et al.* (1993) reported that the lateral movement of water varied between 24.4 and 24.2 percent in 0 to 30 cm depth at 40 cm distance away from the dripper.

Mishra and Pyasi (1993) found more uniformity within a 10 cm radius of the emitter with maximum uniformity at zero distance, while non uniformity increased with distance from the emitter, and also the water front advanced rapidly in the beginning and the rate of advance decreased with time.

Clothier and Green (1994) studied that the root systems under partial soil wetting are dominated by wetting pattern under the drippers.

Bharadwaj *et al.* (1995) carried out a field experiment on a gravelly loam soil with 2 year old apple trees and it revealed that the soil water distribution at 0 - 0.15 and 0.15 - 0.20 m depths was uniform under drip irrigation and registered maximum shoot length and trunk girth.

Merman and Smith (1996) tried three types of irrigation in green houses-overhead, drip and sub irrigation. From their study, they revealed that the fixed overhead systems are characterized by low initial cost, low irrigation uniformity and efficiency, Drip systems were low in initial cost, high in irrigation uniformity and moderate in irrigation efficiency, and although high in initial cost, the subsurface systems were high in irrigation uniformity and efficiency.

Prabhakar and Hebbar (1996) reported that soil moisture depletion was highest from 0 to 15 cm and 15 to 30 cm soil layers. At 30 to 45 cm soil depth, the moisture content remained almost constant and was in the higher range indicating maximum soil moisture use by capsicum up to 30 cm depth. As the distance from the source of emission increased, the soil moisture content was found to decrease, but again, only up to 30 cm depth.

Warrick and Shani (1996) observed that soil variability can affect the flow rate of water from subsurface trickle emitters. It was observed that when the design flow volume increases or the hydraulic conductivity of the soil decreases, the pressure head of the soil next to the emitter increases and which will reduce the flow rate (other factors remaining equal).

Hanson *et al.* (1997) investigated the wetting patterns under drip irrigation under a variety of conditions. The conditions included the wetting patterns in a very fine textured soil, under different irrigation frequencies and at different depths of drip tape. Patterns were also developed for conditions of mild and severe deficit region.

Selvaraj (1997) reported that in drip irrigation the vertical wetting front versus elapsed time described by an experimental equation and the horizontal wetting front versus elapsed time could be represented by second order differential equation.

Bobade (1999) revealed that surface irrigation showed steep decline of available soil moisture from 90 to 24 per cent whereas in drip irrigation system, available soil moisture was consistent through out the irrigation cycle (once in two days) about 87 per cent and it was always nearer to field capacity.

Patil (1999) observed that frequent irrigations under drip irrigation has maintained most of the soil in the root zone in a well aerated condition and at a soil moisture content that does not fluctuate between wet and dry extremes. He also observed that the movement of water in the soil depends on the soil characteristics and the dripper discharge.

Satish and Patil (1999) found that the pattern of wetting front will be different for different soils due to variation in soil texture, permeability, quantity of water applied per irrigation, discharge rate of the emitter and the initial moisture content of the soil. They also indicated that the soil moisture content was higher in different depths of soil as well as at different horizontal distances with increase in quantity of water application.

Sureshkumar (2000) reported that the available soil moisture was almost consistent and nearer to field capacity under drip irrigation system as against wide fluctuation under surface irrigation.

2.2.2 Effect of drip irrigation on yield and water use efficiency of vegetables

Ahluwalia *et al. (*1993) observed that when compared with conventional irrigation systems, drip system yielded on an average 6 and 56 per cent higher and saved upto 57 and 37 per cent irrigation water in tomato and cauliflower crops respectively resulting in a tremendous increase in water use efficiency. They also revealed that at optimum irrigation levels, the drip method resulted in saving of water by 38 per cent with consequent increase of 60.9 per cent in water use efficiency over the surface irrigation method.

Bafna *et al*. (1993) studied that irrigation requirement was found to be 67 ha.cm in surface method and 32 ha.cm in drip method, thereby effecting a saving of 53 per cent of irrigation water by using drip system.

Bankar and Pampattiwar (1995) reported that considerable increase in chilli yield with drip over surface irrigation. Drip irrigation offered maximum water use efficiency, increase in yield, better quality fruits and highest net profit in watermelon.

Chandio and Yaseen (1995) recorded higher water use efficiency was obtained under drip irrigation (1.21 kg/ha.m^3) than under furrow irrigation (0.44 kg/ha.m^3) in chillies.

Hagin and Anat Lowengart (1995) studied that maximization of crop yield, quality and minimization of leaching loss of nutrients below the rooting zone could be achieved by managing fertilizer concentrations in measured quantities of irrigation water using drip irrigation .

Jadav *et al.* (1995) reported that on brinjal the growth parameters, yield attributes, fruit yield and water use efficiency was increased significantly with irrigation scheduled through drip at 0.8 CPE as compared to check basin system of irrigation.

Malik and Kumar (1996) determined that the drip irrigation level of 75 per cent pan evaporation coupled with 25kg N/ha fertigation under drip irrigation was the optimum combination for maximizing water use efficiency and yields of peas grown on a sandy loam soil in Himachal Pradesh.

Parikh *et al.* (1996) reported that the water saving ranged from 10 to 56 per cent in various crops with improved yield of 13 to 60 per cent. Fertigation studies in selected crops showed that about 40 per cent of nitrogenous fertilizers can be saved without detrimental effect to yield and quality. The water use efficiency and fertilizer use efficiency were almost doubled due to fertigation.

Selvaraj *(*1997) revealed that drip irrigation to tapioca at 50 per cent of surface level once in 2 days has registered higher tuber yield of 51.6 t/ha which was comparable with that of surface irrigation together with a water saving up to 50 per cent nitrogen saving up to 33 per cent.

Prabhakar (1999) reported that drip irrigation at 0.5 Epan loss replenishment level has recorded the highest water use efficiency of (42.7 kg ha^{-1} mm^{-1}) when compared with furrow irrigation (24.7 kg ha^{-1} mm^{-1}) in paprika.

Cassel Sharmasankar *et al.* (2001) found that in sugar beet, yield and sugar content were increased under drip irrigation. Also drip irrigation enhanced water and fertilizer use efficiencies.

Veeranna *et al*. (2001) showed that, drip irrigation produced significantly higher dry chilli yield with 42 % higher water use efficiency over furrow method.

Singandhupe *et al*. (2002) reported that in tomato, application of nitrogen through the drip irrigation in ten equal plots at 8 days interval saved 20 to 40 per cent nitrogen as compared to the furrow irrigation when nitrogen was applied in two equal splits (at planting and one month thereafter).

Edna Antony and Singandhupe (2004) studied that with 100 per cent drip irrigation, maximum plant height, no. of branches and yield were recorded in chilli when compared with surface irrigated plants.

Gulshan Mahajan and Singh(2005) studied that the drip irrigation at 0.5 x E_{pan} irrespective of fertigation treatments could save 48.1% of irrigation water and resulted in 51.7% higher fruit yield than recommended practices inside the greenhouse. The net profit and yield/mm of water used were estimated to be the highest for the treatment of drip irrigation at 0.5 x E_{pan} in conjunction with fertigation of 125% of recommended nitrogen among different treatments.

Metin Sezen *et al.,* (2005) found that in bell pepper when irrigation was given through drip at 3-6 days interval (with cumulative pan evaporation value of 18-22 mm and plant pan coefficients as 1) recorded the maximum yield (33,140 kg ha^{-1}) and maximum water use efficiency.

Kadam and Karthikeyan (2006) observed that in tomato, the highest water saving was 50.8 per cent and the highest water use efficiency was 206.6 kg ha^{-1} in case of 100 per cent fertilizer dose by drip irrigation as compared to surface irrigated plot of 70.8 kg ha^{-1}.

2.3 Fertigation

Now a days micro irrigation technique such as the drip and micro sprinkler systems are gaining momentum and popularity among farmers. Conventional methods of applying fertilizer are not compatible with drip irrigation system, because in drip irrigation system water is applied only to a fraction of soil volume. Surface application of dry fertilizer may not ensure optimum placement, requires lot of manpower and is a time consuming process compared to fertigation through drip system.

2.3.1 Advantages of fertigation

Fertigation refers to the combined application of water and soluble fertilizer through an irrigation system. Fertigation gives successful results in terms of yield, saving in fertilizer and improvement in quality of the produce. During the dry season in humid areas, micro irrigation can have a significant effect on quantity and quality of yield, pest control and harvest timing. The salient advantages may be summarised as:

1. Uniform application of fertilizers
2. Placement in root zone
3. Quick and conventional method
4. Saves fertilizer
5. Frequent application is possible
6. Possibility of application in different grades to suit the stage of crop
7. Micro nutrient application along with N, P, K.
8. Saves ground water pollution.

Bester *et al.* (1974) observed satisfactory crop growth with uniform berry size on bunches of grapes for all varieties with fertigation. Berry size were varying in different bunches, in all the varieties, resulting in prinking of small berries in conventional method.

Khan *et al.* (1999) found that application of 100% of the recommended dose of water- soluble fertilizers on potato gave highest tuber yield with maximum net returns compared to conventional method of application of 100% normal fertilizers in soil with furrow irrigation. Providing 100% normal fertilizers through fertigation was highly profitable.

Prabhakar and Hebber (1999) conducted fertigation studies on capsicum revealed 25 per cent and 18 per cent higher fruit yield with fertigation and drip irrigation respectively compared to furrow method of irrigation.

2.3.2 Limitations of Fertigation

Although fertigation offers numerous advantages, it has few limitations as:

1. Corrosion
2. Fertilizer suitability
3. Availability of fertigation equipments and its high cost.

2.3.3 Effect of fertilizers on fertigation

Fertigation can be given for the application of macronutrients as well as micronutrients. Fertilizers are available as liquid fertilizers or solid water-soluble fertilizers. Liquid fertilizers are the 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 usually contain two or more major nutrients as well as micronutrients. Soluble fertilizers completely dissolve in water leaving no precipitate.

2.3.3.1 Nitrogen

Nitrogen is the nutrient most commonly used in fertigation with micro irrigation and overhead sprinkling systems. In general, all nitrogen fertilizers cause few clogging and precipitation problems with the exception 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-ionic form so that it does not react with other substances in the water. Also urea does not cause much precipitation problems.

2.3.3.2 Phosphorous

Bester *et al.* (1974) found that application of phosphorous to irrigation water may cause precipitation of phosphate salts. The precipitation of insoluble dicalcium phosphate and dimagnesium phosphate compounds in irrigation pipes and water emitters is likely in water with a pH 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 irrigation.

2.3.3.3 Potassium

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

Tisdale and Nelson (1966) reported that the traditional fertilizers are applied in bulky, large quantities are going waste due to leaching, evaporation and fixation in the soil .

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.

Goyal *et al*.(1988) studied the nitrogen fertigation (as urea) at 150, 300 or 500 kg ha^{-1} via 11 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 F_1 seedlings were increased by fertigation using the compound product idronova (21:7:14:2 of N:P:K:Mg) as compared to unfertilized plants.

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

Clark *et al. (*1991) intimated that improved water and fertilizer management by using tensiometer and fertigation with micro irrigation of fresh market tomatoes produced on sandy soils can resulted in reduced water and fertilizer applications as compared to those associated with current irrigation methods.

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 fertilizers applied pre-plant. Yields for the daily and weekly fertigation treatments were similar.

Papadopoulos (1992) found that the use of drip irrigation and fertigation saves water and fertilizer and gives better yield and quality.

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 application was also maximum in the treatment. The urea applied through drips was found more uniformly distributed throughout the soil depth up to 0.90 m.

Hagin and Lowengart (1995) reported that maximization of crop yield and quality and minimization of leaching below the rooting volume could be achieved by managing fertilizer concentrations in measured quantities of irrigation water using drip irrigation.

Storlie *et al*. (1995) studied the effects of fertilizer rates and application frequency on drip fertigated *Capsicum annuum* in southern New Jersey. 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 the Central Coffee Research Station, Balehonur, revealed that application of 120:90:120 kg NPK/ha through drip irrigation resulted in production of maximum number of bearing nodes, flower buds/ 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.

Muralidhar (1998) studied three methods of irrigation *viz*., furrow, drip and fertigation each in combination with 80 and 100 per cent water soluble or normal fertilizers were compared on growth and yield of *Capsicum annuum*. Capsicum growth was superior with fertigation as the growth components *viz*., plant height, leaf area, number of leaves, primary and secondary branches were improved by fertigation which eventually resulted in significantly higher dry matter production at all growth stages. Green fruit yield was maximum in capsicum with fertigation as compared to drip and furrow irrigation methods.

Shivashankar (1999) reported that drip fertigation increases yield of capsicum by 25 percent, in addition to economizing 20 per cent fertilizer requirement over the conventional method of application.

Dalvi *et al. (*1999) studied that improved water and fertilizer management by drip fertigation scheduled at every second day frequency with fertigation at 96 per cent of recommended level dose resulted in maximum yield of tomato

Shingure *et al.* (1999) reported that only 50 percent of the applied fertilizer are effectively utilized by the plants and remaining get transmitted to the area beyond the active root zone.

Singh *et al*. (1999) studied that drip fertigation at 180 kg N ha^{-1} provided 40 per cent saving in water and 52 per cent higher yield over check basin method of irrigation, and the WUE was also higher in drip fertigation at 180 kg N ha^{-1} followed by drip fertigation at 135 kg N ha^{-1}.

Srinivasa (1999) showed that the application of 150g of nitrogen and potassium through fertigation in banana was found to be significantly superior and on part with 200 g 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.

Papadopoulos and Leena (2000) found that the fertigation irrespective of the combination of fertilizers was superior to soil application in terms of yield in tomato and egg plant.

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 of water according to the specific requirements of the crop to maintain optimum soil fertility and to increase the quality of the produce.

Veeranna *et al.* (2000) showed that decreasing the fertilizer level by 20 per cent than the recommended level especially under fertigated conditions may not affect the yield level in chilli because of improved fertilizer use efficiency at the lower fertilizer dose. Between furrow and drip methods of irrigation, drip irrigation method produced significantly higher dry chilli yield with 42 per cent higher water use efficiency over furrow method even with the same level and method of normal fertilizer application.

Srinivas *et al.* (2001) observed in industrial tomato that fertigation with various amounts of N, P and K fertilizers increased yield, induced early flowering and significantly improved crop quality and water use efficiency.

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.

Singandhupe *et al*. (2002) recorded that the maximum tomato fruit yield of 27.4 and 35.2 t/ha in two years was recorded at 120 kg N/ ha. Total nitrogen uptake in drip irrigation was 8 to 11 per cent higher than that of furrow irrigation.

Anon *et al.* (2004) reported 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 upto 90 DAP.

Nikam *et al.* (2004) noticed that fertigation of recommended dose of fertilizers (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.

Hartz *et al.* (2005) reported that when 'K' was given as foliar application and fertigation in tomato, the total and marketable yields and fruit color improvement were maximum under fertigation without affecting soluble solid concentration.

Rajput and Neelam Patel (2005) showed that the application of 56.4 cm irrigation water and 3.4 kg ha^{-1} urea per daily fertigation resulted in highest yield (28.74 t ha^{-1}) followed by alternate day fertigation (28.4 t ha^{-1}) in onion.

Solaimalai *et al.* (2005) realized that the fertilizer use efficiency is very low, ranging from 40 to 60 per cent only in manual fertilizer application which needs an immediate attention to increase the efficiency. Fertigation is a recent innovative method, by which fertilizers are applied along with irrigation water through drip system to get higher fertilizer use efficiency besides increased yields.

Soumya *et al*. (2005) stated that the significantly higher marketable fruit yield was recorded with the application of MOP and KNO_3 at 100% recommended dose of NPK through fertigation (94.50 tonnes ha^{-1}) with the higher water-use efficiency of 143.11 kg ha^{-1} mm^{-1} and significantly lower marketable fruit yield was recorded with soil application of urea, SSP and MOP at 75% recommended dose of NPK (70.01 t ha^{-1}).

Bhanu Rekha *et al.* (2006) assessed the functional relationship of bhindi to varying levels of drip fertigation. The experiment was laid under randomized block design with 12 treatments included three levels of drip irrigation (0.5, 0.75 and 1.0 E_{pan}) with three fertigation levels (60, 90 and 120 kg/ha), furrow irrigation with 120 kg/ha, family drip system with 120 kg N/ha and fertigation control (drip irrigation at 1 E_{pan} and 0 kg N/ha). The highest pod yields (4.188 and 4.153 kg/ha during 2003 and 2004 respectively) were recorded with crop irrigated through drip at 1.0 E_{pan} and fertigation with 120 kg N/ha and was 54 and 57 per cent higher over furrow irrigated crop during the respective year of the study.

Karthikeyan *et al.* (2006) noted that the increase in the yield of tomato, over 40 per cent by 100 per cent 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 plus 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 plant 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.

2. 4 Economics

The use of drip fertigation system reduces weed infestation, pest occurrence and enhances water and nitrogen use efficiency. The higher net income per unit water and nutrient consumption and net extra income over conventional method of irrigation for either on hectare basis or on equal water usage are more promising. In soil application of fertilizer although initial investment and maintenance costs are high, returns are equally high as compared to traditional cultivation methods.

Shrestha and Gopalakrishnan (1993) revealed that the yield increase of about 1.7 tonnes of sugar per acre and considerable saving of water up to 12 per cent are major contributing factors to the rapid adoption of drip irrigation on their economics analysis of the factors that affect the choice of drip irrigation.

Narayanan *et al*. (1994) conducted an experiment to evaluate the economic benefits of drip irrigation in sweet pepper and revealed that maximum gross return was obtained with drip irrigation compared to furrow irrigation.

Anonymous *et al*. (1995) showed that the net profit per mm of water used in tomato crop under drip irrigation and conventional system were 278.43 and 66.47 respectively and the water use efficiencies were 123.80 and 27.95 kg/ha-cm respectively

Parikh *et al.* (1996) suggested that the higher net income per unit water consumption and net extra income over conventional method of irrigation was more promising and low inputs reduce the water and soil pollution. The income-expenditure analysis based on three years mean results revealed that the net income per unit water consumption was found higher by 2 to 3 folds in micro irrigated plots in chilly, tomato, cabbage, sugarcane, and banana.

Muralidhar *et al*. (1998) reported that among the methods of water and fertilizer application, fertigation method resulted in higher gross and net returns and hence maximum B-C ratio of 1.48 followed by drip method 1:3.81 and furrow method 1:3.47 in Capsicum.

Dalvi *et al*. (1999) observed the cost economics of micro irrigation system and optimization in tomato to assess minimum input cost by considering the advent of mechanically moved portable drip sets. With every second day irrigation, approximately 50 per cent saving on initial investment of drip set can be achieved as the same set will irrigate double the area.

Khan *et al*. (1999) informed that drip irrigation with 100 per cent water soluble fertilizers in potato recorded higher net profit of Rs. 38, 742 per ha than drip fertigation with 100 per cent normal fertilizers (Rs. 33, 604) and furrow irrigation with 100 per cent normal fertilizers (Rs. 32583).

Asoka Raja *et al.* (2002) recorded that higher discounted benefit cost (9.89) was obtained due to drip irrigation than surface irrigation (5.44) in tomato.

Tumbare *et al.* (2002) reported that 100 per cent recommended NPK fertigation through drip registered the highest benefit cost ratio (2.17) in chilli under the drip irrigation system.

Raskar *et al.* (2003) showed that sprinkler method of irrigation was economically beneficial for potato in terms of net income (Rs. 42,850), benefit cost ratio (2.93), additional income over surface method (Rs. 21,115/ha) and net income per unit of water (Rs. 1,191.60/cm).

Vijaykumar *et al.* (2004) explained the cost economics of the drip fertigation for Bhindi in 1 ha. The net seasonal income were Rs. 23,155, 26,877, 20,996 and 14,370 for nitrogen at 100 per cent, 80 per cent, 60 per cent of recommended level with drip irrigation and 100 per cent of recommended level by manual feeding respectively. The B-C ratios for the treatments were 1.87, 2.01, 1.79 and 1.41 respectively. Application of 80% of N recorded high B-C ratio.

Manjunatha *et al.* (2004) noticed that the maximum fruit yield (26.2 t ha^{-1}) and water production efficiency (69.3 ka/ha.m) were achieved with drip irrigation compared to surface irrigation in chilli. The gross B-C ratio varied between 1.97 (highest) for surface irrigation at 1.2 ET to 1.42 (lowest) for drip irrigation at 0.8 ET. The net profit achieved per mm water used was higher under drip irrigation than surface irrigation.

Singh *et al.* (2005) revealed that the drip fertigation in hybrid chilli gave a net return of Rs. 52,685 ha^{-1} against Rs. 35,418 ha^{-1} in check basin method of irrigation.

CHAPTER III

MATERIALS AND METHODS

A study was conducted to evaluate and compare the performance of the cost effective fertigation tank with venturi and manual application of fertilizers. A field experiment was done to evaluate the performance of the fertigation units with respect to crop yield and uniformity of application. Materials used for the study and the methodology adopted for achieving the objectives are discussed in this chapter.

3.1 Location

The experiment was conducted at KCAET Tavanur situated at 10º 53'33" N latitude and 76º E longitudes. Agroclimatically, 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 ^{0} 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 Nursery Preparation

Tomato variety ANAGHA was chosen for cultivation. Seeds were sown and covered with soil in the greenhouse. Watering was done regularly by using rose can both in morning and evening. The seedlings were ready for transplantation in twenty to twenty five days (Plate 1).

Plate 1 Preparation of nursery with ANAGHA variety of tomato

3.3 Details of field selected for the study

The selected plot for the study was located in the Northern side of the farm which was almost nearer to the Bharathapuzha river basin. The plot was bounded with coconut palms on one side and bananas at the other side and the soil in the selected plot was sandy loam. The total area selected for the study was 5 cents (16 x 12 m). Proper land preparation was done before the installation of the system in the field (Plate 2). The field experiment was conducted during March to June when the irrigation demands would be the highest.

3.4 Land preparation

Primary tillage with rotovator was done. The area was divided into 20 plots of equal size (3.50 x 1.9 m). The experiment comprised of 4 treatments with 5 replications.

3.5 Transplanting

The transplanting was done at a spacing of 60 x 60 cm with 18 plants in each plot (Plate 3). The total plant population was 360. Gap filling was done within a week after transplanting to ensure optimum plant population.

Plate 2 Land Preparation

Plate 3 Transplanting

3.6 Field Installation, Operation and Maintenance of the system

Installation of the irrigation system can be divided into three stages:

1. Fitting of the filter unit
2. Fitting of the fertigation tank and venturi system
3. Laying of the mains and sub mains
4. Laying of laterals with emitters

3.7 Components of the System

3.7.1 Pumping unit

A centrifugal pump operated by 1 hp, 230V electric motor was used to develop sufficient pressure. Suction and delivery pipes of 40 mm diameter were used. A portion of water was by passed to the tank by means of a ball valve arrangement to control the inlet pressure.

3.7.2 Control unit

A gate valve was provided at the delivery line of the main pumping system to control the discharge rate. A dial pressure gauge of 0 to 6 kg/ cm^2 was installed at the outlet port of the filter to note the operating pressure.

3.7.3 Screen Filter

The filter unit was fixed on the delivery side of the water distribution system. The filter size was selected in accordance with the capacity of the system. It consisted of a double perforated cylinder in a metallic container for removing the foreign materials. Nominal size of the filter was 2'' (50 mm) with mesh size of 100 micron (120 meshes). Nominal pressure rating was 1.5 kg/cm^2 and nominal flow rate was 18 m^3/hr.

3.7.4 Ball Valve Assembly

Ball valves, each having diameter of 40 mm was used on the sub mainline to control the flow into each block. The time of operation of these ball valves can be controlled according to the requirement of the irrigation to the individual field.

3.7.5 Pressure gauge

Dial pressure gauges of 0 to 6 kg/cm^2 were used to monitor the inlet and outlet pressures. As the drip irrigation system is expected to work from 0.8 to 1 kg/cm^2, this pressure gauge is sufficient.

3.7.6 Fertigation units

Cost effective fertigation tank and venturi type fertigation system were used.

3.7.6.1 Fertigation tank

A low cost fertigation tank of capacity 25 litre, made up of plastic material locally available in the market, was used which was developed by KVK Malappuram is shown in the Plate 4.

Plate 4 Fertigation tank

3.7.6.2 Venturi fertigation unit

A venturi fertigation unit was used for the study. This system creates a pressure differential that forms a vacuum. As water flows through the tapered venturi orifice, a rapid change in velocity occurs. This velocity change creates a reduced pressure (vacuum), which draws (pulls), the liquid to be injected into the system.

Venturi fertigation unit was connected directly to the main line. The suction tube, with a filter at its end, connected from the centre of venturi was used to draw the fertilizer into the system from an open tank. Injection rates into the system from venturi unit depended upon the flow rate through the main line. A gate valve regulated the flow rates.

Venturi fertigation unit made of engineering plastic provided excellent chemical resistance to the chemicals. This highly efficient and compact differential pressure injection device has 3/4” inlet/outlet connections.

3.7.7 Main line and Laterals

A 40 mm diameter PVC pipe was used as main line. The key component of the drip irrigation system is the lateral which delivers water to the crop root zone. The laterals were Low Density Poly Ethylene (LDPE) having nominal diameter 16 mm. End caps were provided at the end of each lateral which helps in periodic flushing of the laterals. Laying of laterals in field is shown in Plate 5.

3.7.8 Online Drippers

A pressure compensating type dripper supplies water uniformly on long rows and on uneven slopes. They are available in various discharge rates from 2 to 24 lph. These are manufactured with high quality flexible rubber diaphragm or disc inside the emitter that delivers uniform discharge. The discharge rate of emitters used in this study was 4 lph.

3.8 Field study to evaluate the performance of cost effective fertigation tank in tomato

A field experiment was conducted to evaluate the performance of cost effective fertigation tank in the crop tomato and the same was compared with venturi type of fertigation equipment and manual fertilizer application. A field layout with plants is shown in Plate 6.

Plate 5 Installation of components of the system

Plate 6 Field after complete installation of all the components

3.9 Statistical design for the study

The statistical design selected for the study was Randomized Complete Block Design (RCBD) with 4 treatments and 5 replications. The overall size of the experimental plot selected for the study was 16 x 12 m^2 consisting of 20 plots. The area of each plot was 3.50 x 1.90 m with 18 plants in each plot at spacing of 60 x 60 cm. So there were a total of 360 plants. The design was done in such a way that main line was divided into 3 sub-mains, i.e., one for venturi injector, one for fertigation tank and for drip alone. An equal volume of water was supplied through drip to all treatments except control for 15-20 minutes. The treatments were as follows

T_3R_1	**T_3R_2**	**T_4R_1**	**T_1R_1**	**T_1R_2**

T_2R_1	T_2R_2	T_4R_2	T_2R_3	T_2R_4
T_4R_3	T_1R_3	T_3R_3	T_2R_5	T_3R_4
T_4R_4	T_4R_5	T_3R_5	T_1R_4	T_1R_5

Where, **T_1** – drip with venturi injector

T_2 – drip irrigation with manual application of fertilizer

T_3 – drip with cost effective fertigation tank

T_4 – control (manual irrigation with manual fertilizer application)

3.10 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.

3.11 Solubility test of fertilizers

Solubility indicates the relative degree to which a substance dissolves in water. Fertilizer formulations usually contain two or more nutrients and the solubility vary correspondingly. So solubility of fertigation is a critical factor when preparing fertilizer solutions from dry fertilizers. Solubility was found as grams of fertilizer per litre of water and was got by mixing the desired fertilizer in a litre of water till saturation level was reached.

3.12 Fertigation Schedule

Recommended dose of 75:40:25 kg N-P-K/ha need to be applied in the form of urea, super phosphate and muriate of potash. In drip fertigation, N and K were applied through fertigation in 16 equal splits while P in the form of super phosphate (1.125 kg) was applied as basal at the time of transplantation for one treatment. Nitrogen in the form of urea (51g) and potassium in the form of muriate of potash (14g) for one treatment for each split doses.

Manual fertilizer application should be given as

Basal application -- 0.5 N: Full P: 0.5 K

30 days after transplanting – 0.25 N: 0.0 P: 0.5 K

60 days after transplanting – 0.25 N: 0.0 P: 0.0 K

3.13 Parameters recorded

The performance of the system was evaluated under the following sub heads.

1. Yield and number of fruits
2. Biometric observations
    a. Height of the plant
    b. Girth of plant
    c. Number of branches
3. Uniformity coefficient
4. Weed infestation

3.13.1 Yield Parameters

First harvesting was done in the middle of May 2011. Afterwards harvesting was done on alternate days. Total weight and number of fruits were recorded separately for each treatment. Yield data were evaluated to know how evenly the water and nutrients were being distributed in the plot.

3.13.1.1 Number of fruits

Total number of fruits was counted for all treatments.

3.13.1.2 Weight of fruit

Average fruit weight of each treatment were observed

3.13.2 Biometric observations

Biometric observations were taken one, two and three month after planting. Observations on height, girth and number of branches were recorded from randomly selected plants for each plot.

3.13.2.1 Height of the plant

The average height of the randomly selected plants grown under each treatment was taken. The measurement was taken from the ground surface to the shoot tip for the selected plants at monthly interval.

3.13.2.2 Girth of the plant

Girth of the plant was measured at 2.5cm above ground level at monthly interval.

3.13.2.3 Number of branches

Total number of branches was counted for the randomly selected crops in each treatment.

3.13.2.4 Statistical analysis for yield and biometric observations

The results obtained during the experiment were statistically analyzed by analysis of variance using computer software. ANOVA test was performed to find out the significant difference in the treatments. The level of significance used was $p=0.05$. Critical difference in the treatments was also calculated for all the treatments.

3.13.3 Uniformity coefficient

The coefficient of uniformity is a measure of the hydrodynamic behavior of the system. It is an indicator of how equal the application rates resulting from the delivery devices are. In field, water distribution efficiency of the system is closely related to emission uniformity, which in turn determines the application efficiency. An efficient micro irrigation system must apply water uniformly throughout the field.

3.13.3.1 Procedure for evaluating the uniformity coefficient

1. Flush the system piping and emitter laterals thoroughly, starting with larger pipes, then the smaller ones.
2. Clean the screen filters
3. Inspect the required pressure at pump discharge, across main filter and at the inlet to the main line and sub main of the lateral
4. Measure the discharge

3.13.3.2 Computation of Cu value

Add up all measured emitter discharge rates from individual emitter at a particular depth and at a particular pressure and divide the sum by number of measurements to obtain the average discharge rate. The uniformity coefficient was calculated using the following formula,

$$\mathbf{EU=100[1-(1.27\ C_v)/\sqrt{n}]\ q_m/q_a}$$

EU - design emission uniformity (%)

n - number of emitters in the sample

C_v - manufactures' coefficient of variation for line source emitters

q_m - minimum emitter discharge rate for a minimum pressure in the section (lph)

q_a - average or design emitter discharge rate for the section (lph)

C_v - $\sqrt{[(q_1^2+q_2^2+\ldots\ldots+q_n^2) - nq^2]}/q(\sqrt{(n-1)})$

q_1, q_2……q_n = individual emitter discharge rate values (lph)

General criteria for EU values for systems, which have been in operation for one or more seasons are as follows

EU values greater than 90 % - Excellent

EU values between 80 – 90 % - Good

EU values between 70 – 80 % - Fair

EU values less than 70 % - Poor

3.13.4 Weed infestation

Weed growth in each plots were observed. Weed infestation depends on soil moisture content. In drip irrigation, only the root zone area of the crop is wetted hence the chance for weed growth is reduced.

CHAPTER IV

RESULTS AND DISCUSSION

A field study was conducted to determine the performance of cost effective fertigation tank. The experiment was conducted during April to June, 2011. The results obtained from the study are analyzed and presented in this chapter under the following subheads.

`

4.1 Evaluation of fertigation units

The efficiency of fertigation units was evaluated based on the physiological growth parameters such as stem height, stem girth and number of branches and yield parameters such as number of fruits and yield. The performance of fertigation tank was further evaluated in comparison with the venturi system by comparing their uniformity coefficients.

4.1.1 Measurement of growth and yield parameters

The physiological growth parameters such as stem height, stem girth and number of branches and yield parameters such as number of fruits and fruit weight were observed, which are given in Appendix I- III.

4.1.1.1 Fruit yield

Harvesting was started from one month after transplanting. The yield responses were highly remarkable under different treatments. The total yield obtained from treatments is given in Appendix IV. The average yield obtained from various treatments was shown in Table 1 and the same is represented graphically in Fig.1.

Table 1. Average yield from different treatments

Treatments	Yield (t/ha)
T1	18.04
T2	17.49

T3	19.48
T4	14.69

Table 2. ANOVA for average fruit yield

Source	DF	SS	MS	F-Ratio	Table value	Remarks
Blocks	4	3.00	0.75	0.85	3.26	NS
Treatments	3	60.56	20.19	22.95	3.49	*
Error	12	10.56	0.88			
Total	19	74.11				

*represents the value is significant at 5 percent significance level **CD = 1.29**

From the Table 1, it can be seen that the treatment T3 is statistically superior to all other treatments. Highest average yield obtained in T3 (19.48 t/ha) and lowest average yield obtained in T4 (14.69 t/ha).

Plate 7 Tomatoes in the field

4.1.1.2 Number of fruits

The number of fruits harvested from each treatment was found to be highly remarkable under different treatments. The average number of fruits harvested from various treatments was shown in Table 3 and the same is represented graphically in Fig.2.

Table 3. Average number of fruits

Treatments	Number of fruits
T1	368125
T2	407083
T3	374583
T4	469792

Table 4. ANOVA for average number of fruits

Source	DF	SS	MS	F-Ratio	Table value	Remarks
Blocks	4	4758176000	1189544000	1.21	3.26	NS
Treatments	3	32435860000	10811950000	10.98	3.49	*
Error	12	11821120000	985093400			
Total	19	49015160000				

*represents the value is significant at 5 percent significance level **CD = 43253.96**

From the Table 3, it can be seen that highest average number of fruits was obtained in T4 (469792/ha).

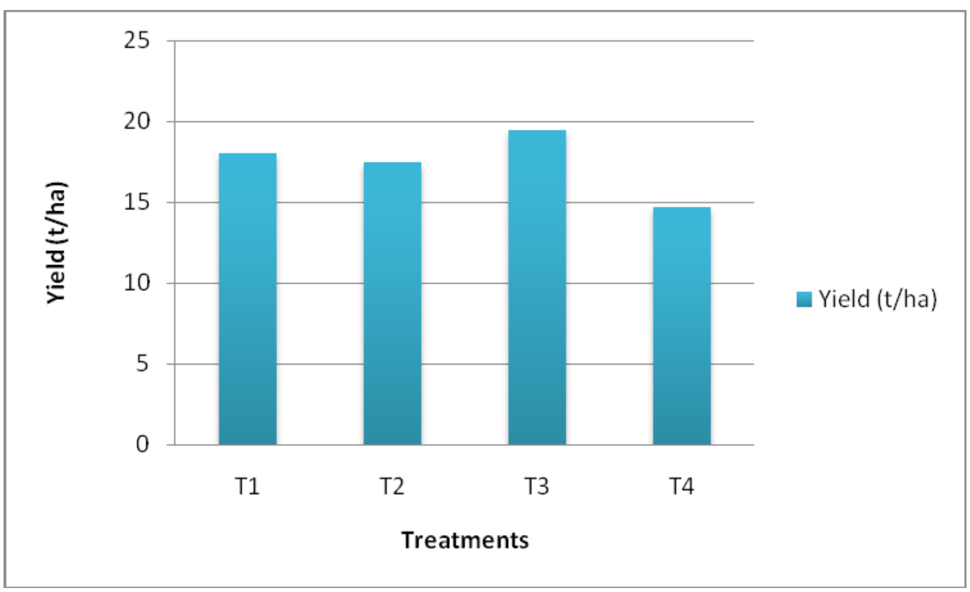

Fig. 1 Average yield from different treatments.

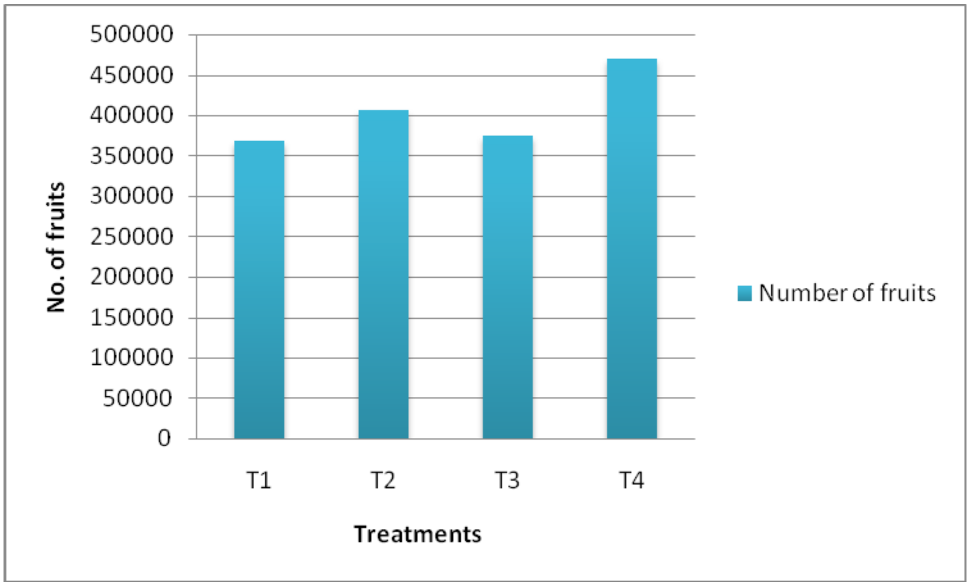

Fig. 2 Average number of fruits from different treatments.

4.1.1.3 Fruit weight

The average individual fruit weight of each treatment was found to be highly remarkable under different treatments and it is shown in Table 5

Table 5. Average fruit weight

Treatments	Average fruit weight (g)
T1	49
T2	43
T3	52
T4	30

From the table, it can be seen that the highest average fruit weight is observed in T3 and lowest for T4.

4.1.1.4 Stem height

The height of the plant was measured at one month, two months and three months after transplanting.

4.1.1.4.1 Stem height one month after transplanting

Stem heights measured one month after transplanting are given in Table 6 and Fig.3.

Table 6. Stem height one month after transplanting

Treatments	Stem height (cm)
T1	44.4
T2	42.6
T3	44
T4	39.9

Table 7. ANOVA for stem height

Source	DF	SS	MS	F-Ratio	Table value	Remarks
Blocks	4	7.80	1.95	0.20	3.26	NS
Treatments	3	62.14	20.71	2.15	3.49	NS
Error	12	115.8	9.65			
Total	19	185.74				

From Table 6, it is found that the highest stem height obtained for T1 and the lowest height obtained for T4.

4.1.1.4.2 Stem height two month after transplanting

Stem heights measured two month after transplanting are given in Table 8 and Fig.3.

Table 8. Stem height two month after transplanting

Treatments	Stem height (cm)
T1	68.8
T2	70.2
T3	73.1
T4	60.8

Table 9. ANOVA for stem height

Source	DF	SS	MS	F-Ratio	Table value	Remarks
Blocks	4	44.3	11.07	0.56	3.26	NS
Treatments	3	415.63	138.54	6.95	3.49	*
Error	12	239.3	19.94			
Total	19	699.23				

*represents the value is significant at 5 percent significance level **CD=6.15**

From table 8, the highest height obtained for the fertigation tanks, which are 73.1 cm and the lowest for control, which is 60.8 cm.

4.1.1.4.3 Stem height three month after transplanting

Stem heights measured three month after transplanting are given in Table 10 and Fig.3.

Table 10. Stem height three month after transplanting

Treatments	Stem height (cm)
T1	135.7
T2	133.9
T3	148.14
T4	132.2

Table 11. ANOVA for stem height

Source	DF	SS	MS	F-Ratio	Table value	Remarks
Blocks	4	302.28	75.51	3.31	3.26	*
Treatments	3	787.75	262.58	11.51	3.49	*
Error	12	273.66	22.8			
Total	19	1363.69				

*represents the value is significant at 5 percent significance level **CD=6.58**

From table 10, it can be seen that the highest stem height obtained is for the T3 which is 148.14 cm and the lowest is for the control.

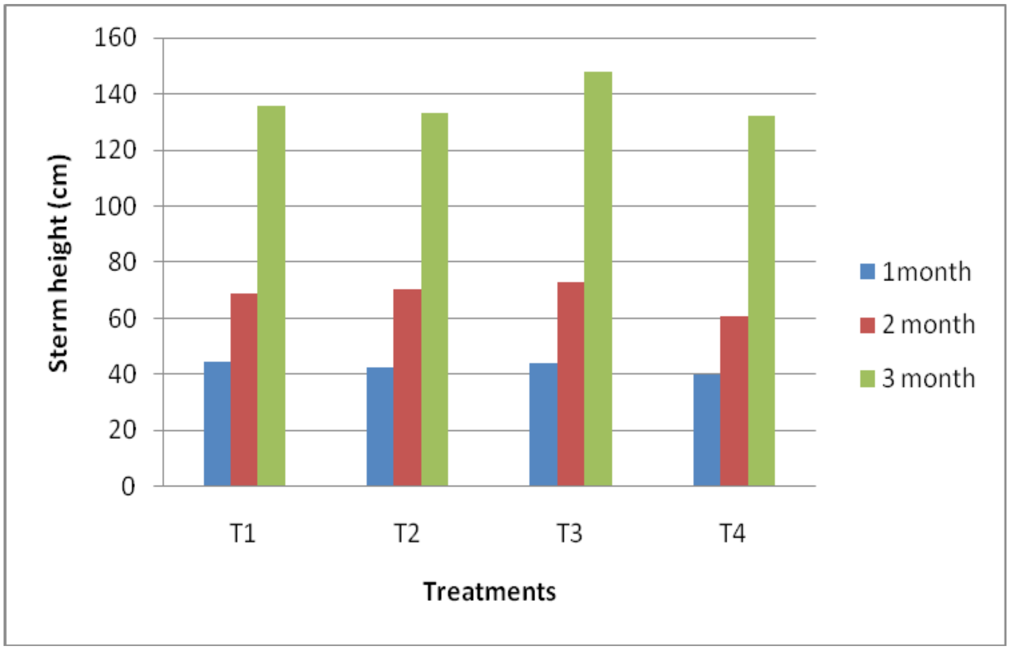

Fig.3 Stem height measurement one month, two month and three month after transplanting from various treatments.

4.1.1.5 Stem girth

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

4.1.1.5.1 Stem girth one month after transplanting

Stem girths measured one month after transplanting are given in Table 12 and Fig.4.

Table 12. Stem girth one month after transplanting

Treatments	Stem girth(cm)
T1	1.54
T2	1.48
T3	1.96
T4	1.72

Table 13. ANOVA for stem girth

Source	DF	SS	MS	F-Ratio	Table value	Remarks
Blocks	4	0.35	0.09	1.04	3.26	NS
Treatments	3	0.7	0.23	2.72	3.49	NS
Error	12	1.03	0.09			
Total	19	2.08				

*represents the value is significant at 5 percent significance level

The highest stem girth obtained for the T3 treatment, approximately 2 cm girth obtained one month after transplanting.

4.1.1.5.2 Stem girth two month after transplanting

Stem girths measured two months after transplanting are given in Table 14 and Fig.4.

Table 14. Stem girth two month after transplanting

Treatments	Stem girth (cm)
T1	2.70
T2	*2.58*
T3	3.56
T4	2.38

Table 15. ANOVA for stem girth

Source	DF	SS	MS	F-Ratio	Table value	Remarks
Blocks	4	0.22	0.05	0.62	3.26	NS
Treatments	3	4.06	1.35	15.46	3.49	*
Error	12	1.05	0.09			
Total	19	5.33				

*represents the value is significant at 5 percent significance level **CD=0.41**

The stem girth is highest for fertigation tank treatment than other three treatments. The stem girth obtained is 3.56 cm

4.1.1.5.3 Stem girth three month after transplanting

Stem girths measured three months after transplanting are given in Table 16 and Fig.4.

Table 16. Stem girth three month after transplanting

Treatments	Stem girth (cm)
T1	4.98
T2	4.72
T3	6.72
T4	4.16

Table 17. ANOVA for stem girth

Source	DF	SS	MS	F-Ratio	Table value	Remarks
Blocks	4	1.22	0.3	2.61	3.26	NS
Treatments	3	18.29	6.1	52.3	3.49	*
Error	12	1.4	0.12			
Total	19	20.91				

*represents the value is significant at 5 percent significance level **CD=0.47**

From Table 16, it can be seen that highest stem girth is obtained for T3 and lowest for the control.

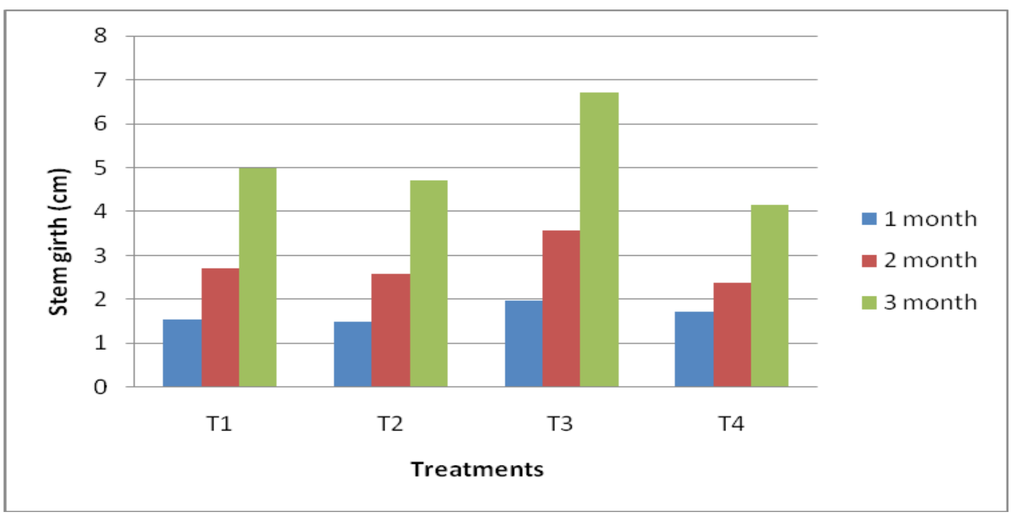

Fig. 4 Stem girth measurement one month, two month and three month after transplanting from various treatments.

4.1.1.6 Number of branches

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

4.1.1.6.1 Number of branches one month after transplanting

The number of branches recorded one month after transplanting are given in Table 18 and Fig.5.

Table 18. Number of branches one month of after transplanting

Treatments	Number of branches
T1	2
T2	3
T3	2
T4	3

Table 19. ANOVA for number of branches

Source	DF	SS	MS	F-Ratio	Table value	Remarks
Blocks	4	0.7	0.17	0.64	3.26	NS
Treatments	3	2.95	0.98	3.58	3.49	*
Error	12	3.3	0.28			
Total	19	6.95				

*represents the value is significant at 5 percent significance level **CD=0.72**

From given tables and figure, it is understood that there is no significant difference between the numbers of branches between the treatments.

4.1.1.6.2 Number of branches two month after transplanting

The number of branches recorded two months after transplanting are given in Table 20 and Fig.5.

Table 20. Number of branches two month after transplanting

Treatments	Number of branches
T1	4

T2	4
T3	5
T4	3

Table 21. ANOVA for number of branches

Source	DF	SS	MS	F-Ratio	Table value	Remarks
Blocks	4	3.8	0.95	1.73	3.26	NS
Treatments	3	10.15	3.38	6.15	3.49	*
Error	12	6.6	0.55			
Total	19	20.55				

*represents the value is significant at 5 percent significance level **CD=1.02**

From tables and figure it can be seen that the highest number of branches are obtained for T3 and the lowest for control.

4.1.1.6.3 Number of branches three month after transplanting

The number of branches recorded three months after transplanting are given in Table 22 and Fig.5.

Table 22. Number of branches three month after transplanting

Treatments	Number of branches
T1	9
T2	9
T3	11
T4	6

Table 23. ANOVA for number of branches

Source	DF	SS	MS	F-Ratio	Table value	Remarks

Blocks	4	25.30	6.33	1.14	3.26	NS
Treatments	3	50.80	16.93	3.05	3.49	NS
Error	12	66.70	5.56			
Total	19	142.80				

The highest number of branches are obtained for T3 and the lowest for control.

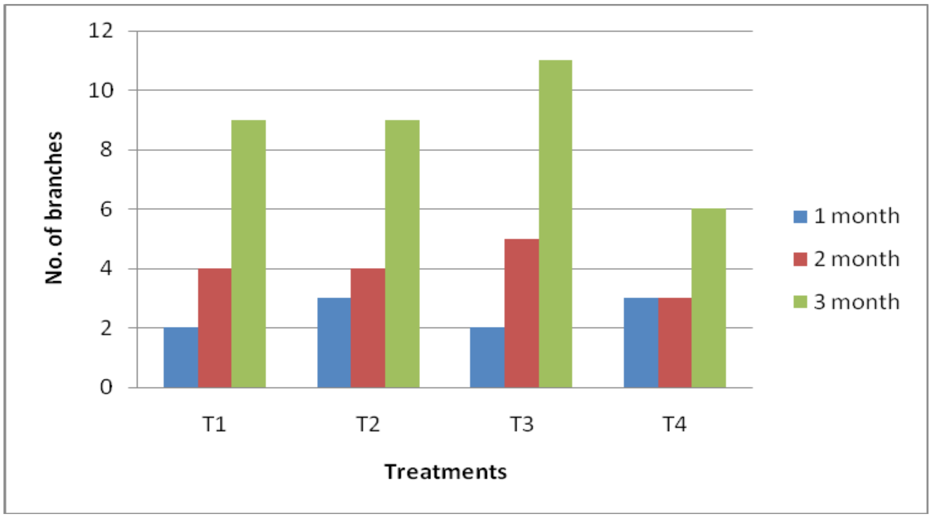

Fig. 5 Number of branches one month, two month and three month after transplanting from various treatments.

4.1.2 Uniformity coefficient

Uniformity coefficients of emitters were determined for cost effective fertigation tank, drip system alone with manual fertilizer application and venturi fertigation system. The variation in uniformity coefficients with elapsed time is shown in Tables- 24, 25 and 26 and Fig.6.

Table 24.Variation in uniformity for drip irrigation

Uniformity Coefficient (EU)	Elapsed time (min)
0.96	10
0.958	20
0.956	30
0.953	40
0.950	50

Uniformity coefficient for drip system varies in between 0.96 and 0.95.

Table 25.Variation in uniformity coefficient for fertigation tank

Uniformity Coefficient(EU)	Elapsed time (min)
0.952	10
0.95	20
0.9493	30
0.949	40
0.9475	50

For fertigation tank, the uniformity coefficient obtained is in between 0.952 and 0.947, which is same as that for drip system with manual fertilizer application.

Table 26.Variation in uniformity for venturi fertigation system

Uniformity Coefficient(EU)	Elapsed time (min)
0.920	10
0.917	20
0.915	30
0.913	40
0.909	50

The EU for venturi varied between 0.84 and 0.89.

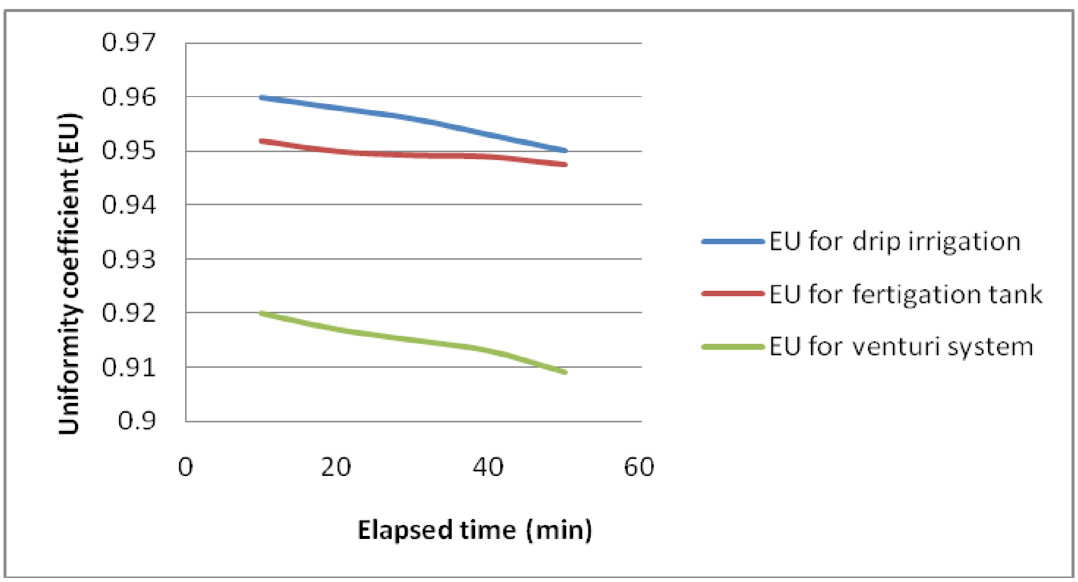

Fig.6 Varation of uniformity coefficient in between normal drip system, fertigation tank and venturi injector unit.

From the tables and figures, it is clear that the uniformity coefficient obtained for drip and fertigation tank are approximately equal, which is greater than that of for a venturi system.

4.1.3 Cost analysis

Cost of drip system includes installation cost which amounts to Rs.9000/- for 5 cents. Laterals and drippers constituted about 65 per cent of total cost of the system. Cost of Jain fertigation tank is Rs 3500 and that of venturi injector is Rs 1250. Cost of fertigation tank evaluated in the present study is only Rs 500. Thus the fertigation tank evaluated is much cheaper than the other two systems.

Table 27. Comparison of cost economics of fertigation tank, venturi injector and drip with manual fertilizer application

Sl. No.	Item	No. of workers x day	Unit price (Rs)	Fertigation tank (Rs)	Venturi injector (Rs)	Drip with manual fertilizer application (Rs)
1	Tomato seeds (Rs 5/packet)	-	-	250	250	250
2	Nursery land preparation	2	300	600	600	600
3	Land preparation – tractor hiring charge(1 day)	2	500	1000	1000	1000
4	Ridge and furrow preparation (man days)	50	400	45,000	45,000	45,000
5	Transplanting (women days)	10	300	3000	3000	3000
6	Pumping cost(rent of pump)	40	300	10000	10000	10000
7	Drip laying (man days)	25	500	12,500	12,500	12,500
8	Plant protection (women days)	15	300	4500	4500	4500
9	Weeding (women days)	25	300	7500	7500	7500
10	Support providing (women days)	500	300	150000	150000	150000
11	Manual fertilizer application (women days)	48	300	-	-	14400
12	Fertilizers(N:P:K)	-	-	3000	3000	3000
13	Chemicals	-	-	2500	2500	2500
14	Mains,sub mains,laterals,drippers	-	-	1,75,000	1,75,000	1,75,000
15	Pressure gauge	-	350	350	350	350
16	Screen fliter	-	3500	3500	3500	3500
17	Fertigation tank	-	500	500	-	-
18	Venturi injector	-	1500	-	1500	-

19	Harvesting (women days)	25	300	7500	7500	7500
20	**Total cost of cultivation**	-	-	**4,26,700**	**4,27,700**	**4,40,600**
21	Yield (t/ha)	-	-	97.39	90.21	87.50
22	**Yield (Rs..) @ Rs 20/kg**	-	-	**19,47,800**	**18,04,200**	**17,50,000**
	Benefit cost ratio	-	-	**4.60**	**4.22**	**3.97**

Table 28. Cost economics of control system

Sl. No.	**Items**	**Number of workers x day**	**Unit price (Rs)**	**Control system with manual fertilizer application (Rs)**
1	Tomato seeds (Rs 5/packet)	-	-	250
2	Nursery land preparation	2	300	600
3	Land preparation –tractor hiring charge(1 day)	2	500	1000
4	Ridge and furrow preparation (women days)	50	400	45,000
5	Transplanting (women days)	10	300	3000
6	Pumping cost(rent of pump)	40	300	10000
7	Plant protection (women days)	15	300	4500
8	Weeding (women days)	250	300	75,000
9	Support providing (women days)	500	300	1,50,000
	Manual fertilizer application (women days)	48	300	14400
	Fertilizers(N:P:K)	-	-	3000
	Chemicals	-	-	2500
	Irrigation cost	240	500	1,20,000
	Harvesting (women days)	25	300	7500
	Total cost of cultivation	-	-	**4,36,750**
	Yield (t/ha)	-	-	73.436
	Yield (Rs..) @ Rs 20/kg	-	-	**14,68,720**
	Benefit cost ratio	-	-	**3.36**

From the results it can be seen that moderately higher yield with all the positive effects of fertigation was obtained under fertigation tank system which further resulted in higher returns (Rs 19, 47,800/ha) than the venturi system (Rs 18, 04,200/ha). BC ratio for the fertigation tank was obtained as 4.60, which implies that better benefit can be obtained from the first crop season onwards using the fertilizer tank. For the venture system, BC ratio obtained was 4.22. The BC ratio for traditional irrigation with manual application of fertilizer is only 3.36. Hence we can conclude that the cost effective fertigation tank can be easily adapted by small scale farmers.

4.1.4 Weed infestation

The major problem associated with irrigated farming under fertilizer application is weed growth. Through visual observation it was noticed that weed growth was greater in case of control when compared with the treatments. Drip fertigation resulted substantial reduction of the weed growth.

CHAPTER V

SUMMARY AND CONCLUSION

The present study, “Performance evaluation of cost effective drip fertigation system,” was aimed to analyze the performance of the cost effective fertigation tank with venturi system and drip irrigation with conventional manual fertilizer application. The statistical analysis of the biometric observations, uniformity coefficient and the cost effectiveness of the system were evaluated.

The field experiment was conducted in the plot near to the Vasudevapuram temple beside the RKVY project inside the KCAET campus, Tavanur. The total area chosen for the study was 5 cents. The experiment was laid out in RCBD and the entire area was divided into 20 plots having 4 treatments with 5 replications.

The study revealed marked differences in the yield and growth parameters of tomato crops under the various ferigation treatments. The yield, stem height, stem girth, number of branches and number of fruits were recorded for different treatments to evaluate the fertigation systems as well as to determine the effective treatment for tomato. The results obtained from the experiments conducted under the present study can be summarized as follows.

- Maximum average yield was obtained from the treatment with fertigation tank compared to the other treatments. There seem to be less variation of yields between replications within each treatment. The average yield was found to be 19.48 t/ha for the treatment fertigation tank (T3) and for the control, yield was 14.69 t/ha.

- Average number of fruits harvested for the control (T4) was found to be maximum. Average number of fruits harvested was 469792 and for venturi injector system (T1) was 368125, which is the lowest.

- Maximum height of the plant was obtained the treatment fertigation tank (T3). But the average plant height measured one month after transplanting was found to be more for venturi injector system (T1), which was 44.4 cm. Plant height measured two months and three months after transplanting were greater the treatment fertigation tank (T3), which were 73.1 and 148.14 cm respectively.

- Stem girth recorded one month, two months and three months after transplanting were maximum for the treatment fertigation tank (T3), and were 1.96 cm, 3.56 cm and 6.72 cm respectively.

- The number of branches recorded one month after transplanting was highest (3) for the treatments T2 (drip irrigation with manual fertilizer application) and T4 (control). The number of branches recorded two months and three months after transplanting were maximum for T3 (fertigation tank) and were 5 and 11 respectively.

- Uniformity coefficient varied from 0.96 to 0.95 for drip irrigation, 0.952 to 0.947 for fertigation tank and 0.92 to 0.909 for venturi system, which indicates that the uniformity coefficient of fertigation tank is greater than that of venturi system.

- Moderately higher yields with all the positive effects were obtained with the fertigation tank, resulting in higher returns (Rs 19, 47,800/ha) than the venturi (Rs 18,04,200/ha). BC ratio for the fertigation tank was 4.60 and for venturi it was 4.22, which indicates that greater benefit can be obtained using fertilizer tank.

- Through visual observation it was noticed that weed growth was more under the control. Drip fertigated plots showed substantial reduction in the weed growth.

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APPENDICES

Appendix I. Biometric observations one month after transplanting

Treatments	Replication	Stem girth (cm)	Plant height (cm)	No. of branches	No. of fruits (/m^2)	Fruit weight (kg/ m^2)
Venturi fertigation	1	1.9	43	1	16	0.78
	2	1.5	46	2	17	0.84
	3	1.4	45	2	13	0.61
	4	1.6	39	2	17	0.84
	5	1.3	49	2	16	0.80
Drip irrigation with manual fertilization	1	1.5	45	3	21	0.92
	2	1.2	39	2	23	1.01
	3	1.3	44	3	20	0.88
	4	1.6	43	2	19	0.80
	5	1.8	42	2	29	1.23
Fertigation tank	1	2	42	2	22	1.15
	2	2.3	47	3	18	0.94
	3	1.3	40	2	17	0.89
	4	2	45	2	21	1.07
	5	2.2	46	2	35	1.83
Control treatments	1	2.1	40	2	13	0.40
	2	1.4	39	2	16	0.49
	3	1.9	39	1	24	0.72
	4	1.7	43	1	31	0.94
	5	1.5	38.5	1	30	0.91

Appendix II. Biometric observations two months after transplanting

Treatments	Replication	Stem girth (cm)	Plant height (cm)	No. of branches	No. of fruits (/m^2)	Fruit weight (kg/m^2)
Venturi fertigation	1	2.4	67	3	41	2.01
	2	3	70	4	45	2.20
	3	2.8	72	4	31	1.49
	4	2.8	65	4	33	1.63
	5	2.5	70	4	28	1.39
Drip irrigation with manual fertilization	1	2.3	68	4	46	1.99
	2	2.5	65	4	33	1.42
	3	2.6	71	4	38	1.65
	4	2.6	72	3	44	1.87
	5	2.9	75	5	52	2.22
Fertigation tank	1	3.8	70	4	36	1.85
	2	4	74	5	43	2.22
	3	3	65	3	38	1.98
	4	3.5	76	6	44	2.30
	5	3.5	80.5	6	27	1.40
Control treatments	1	2.8	58	3	55	1.66
	2	2.3	63	3	62	1.86
	3	2.1	65	2	70	2.10
	4	2.4	62	3	69	2.06
	5	2.3	56	3	49	1.47

Appendix III. Biometric observations three months after transplanting

Treatments	Replication	Stem girth (cm)	Plant height (cm)	No. of branches	No. of fruits (/m²)	Fruit weight (kg/m²)
Venturi fertigation	1	4.9	127	9	47	2.31
	2	4.5	131	10	48	2.31
	3	5.1	140	9	74	3.61
	4	5.3	139.5	8	64	3.13
	5	5.1	141	9	63	3.08
Drip irrigation with manual fertilization	1	4.2	130	10	53	3.08
	2	5	126.5	9	66	2.81
	3	4.9	135	8	67	2.88
	4	5.1	132.1	10	56	2.38
	5	4.4	146	9	44	1.88
Fertigation tank	1	6	141.5	9	58	3.04
	2	7.5	146	11	49	2.57
	3	6.8	148.5	8	50	2.60
	4	7	149.1	12	41	2.15
	5	6.3	155.6	13	62	3.22
Control treatments	1	4.1	127.6	7	77	2.32
	2	4	135	8	66	1.99
	3	4.3	133.3	6	43	1.28
	4	4.5	138	7	49	1.46
	5	3.9	127	5	79	2.38

Appendix IV. Average yield obtained from all replications (kg/m²)

Treatments / Replications	T1	T2	T3	T4
R1	1.69	1.73	2.01	1.45
R2	1.79	1.75	1.90	1.44
R3	1.91	1.80	1.82	1.36
R4	1.86	1.68	1.84	1.48
R5	1.76	1.78	2.16	1.58

Appendix V. Average fruits obtained from all replications (/m²)

Treatments / Replications	T1	T2	T3	T4
R1	35	40	39	49
R2	37	41	37	48
R3	39	42	35	46
R4	38	39	35	50
R5	36	41	41	53

ABSTRACT

Fertigation refers to the combined application of irrigation water and soluble fertilizer through an irrigation system directly to the crop root zone. Fertigation is a frontier technology, which saves the fertilizers and increases the use efficiency of applied nutrients and the yield of crop. Nutrients can be injected into the system at various frequencies viz., once a day or once every two days or even once a week, depends on system design constraints, on soil type and on grower preference. Surface application of dry fertilizer may not ensure optimum placement, requires lot of manpower and is a time consuming processes compared to fertigation through drip system. Now a days micro irrigation technique such as the drip and micro sprinkler systems are gaining momentum and popularity among the farmers.

The generally used fertigation system is comparatively costly and prone to clogging. It is therefore necessary to introduce a low cost effective fertigation system with a performance meeting the design expectations. The present study was undertaken to analyze the performance of a low cost effective fertgation tank fabricated locally. The fabricated fertilizer tank was compared with venturi injector assembly, drip irrigation system with manual fertilizer application and conventional surface irrigation method for its performance, uniformity coefficient and cost effectiveness.

In the field study, fertigation systems were compared on the basis of biometric observations such as yield, stem girth, stem height, number of fruits and number of branches. From the observations, it was seen that fabricated fertigation tank was more efficient compared to the other systems. The fabricated fertigation tank was tested for its hydraulic performance in terms of uniformity coefficient in the field. The uniformity coefficient values of the system were found to range between 89 to 94 %. The system was also analyzed for the cost effectiveness. It was noted that the returns obtained using the fabricated fertigation system was greater compared to the venturi injector system.