EFFECT OF DRIP IRRIGATION MANAGEMENT AND DIFFERENT SOILLESS CULTURE ON GROWTH AND YIELD OF TOMATO GROWN IN NATURALLY VENTILATED GREENHOUSE

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PROJECT REPORT
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TAVANUR-679 573, MALAPPURAM
2011

DECLARATION

We hereby declare that this project report entitled "**Effect of Drip Irrigation Management and Different Soilless Culture on Growth and Yield of Tomato Grown in Naturally Ventilated Greenhouse**" is a bonafide record of project work done by us during the course of project and the report has not previously formed the basis for the award to us of any degree, diploma, associateship, fellowships or other similar title of any other university or society.

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Place: Tavanur
Date:

CERTIFICATE

Certified that this project report entitled "**Effect of Drip Irrigation Management and Different Soilless Culture on Growth and Yield of Tomato Grown in Naturally Ventilated Greenhouse**" is a record of project work done by Aswathi, P. R., Naima, P. M., Neethu Varghese, K. and Ranjit Singh under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship/fellowship to them.

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Dedicated
to
Profession of Agricultural Engineering
and
Farming community

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SYMBOLS AND ABBREVATIONS

ºC : Degree centigrade
cc : Cubic centimetre
CD : Critical difference
cm : Centimeter
cm^2 : Square centimeter
C:N ratio : Carbon Nitrogen ratio
CPE : Cumulative pan evaporation
cv : Crop variety
ºC : Degree celcious
Dept. : Department
DF : Degrees of freedom
Dr. : Doctor
dS : Deciseimen
EC : Electrical conductivity
EC_i : Electrical conductivity of irrigation water
EC_t : Threshold electrical conductivity
Er. : Engineer
ETc : Crop evapotranspiration
et al : And others
Fig : Figure
FPME : Farm Power Machinery and Energy
FYM : Farm yard manure
gm : Gram
ha : Hectare

hr : Hour

IDE : Irrigation and Drainage Engineering

IWUE : Irrigation water use efficeincy

KCAET : Kelappaji College of Agricultural Engineering and Technology

K_{cp} : Pan evaporation coefficient

Kg : Kilogram

kPa : Kilo pascal

KVK : Krishi Vigyan Kendra

l : Litre

LDPE : Low Density Poly Ethylene

lph : Litre per hour

m : Metre

meq : Million equivalent

mg : Milligram

mm : Millimetre

MPa : Mega pascal

mS : Milliseimen

MS : Mean sum of Squares

No : Number

NS : Non significant

% : Percentage

RBD : Randomized Block Design

SS : Sum of Squares

t : Tonne

TA : Titratable acidity

TSS : Total soluble solids

UV : Ultra violet

viz : Vice versa

WUE : Water use efficiency

CHAPTER I

INTRODUCTION

Irrigation is the application of water to soil which assist in the production of crops. Irrigation water is applied to supplement the water available from rainfall, soil moisture and the capillary rise of ground water. The objective of efficient irrigation is to increase agricultural production. Drip or trickle irrigation is an efficient irrigation method, which is becoming increasingly popular in areas of water scarcity and poor quality irrigation water. Water is applied frequently to the soil through drippers attached to water delivery lateral line placed near the plant row .The principle of drip irrigation is to irrigate the root zone of the plant at a slower rate to get minimal wetted soil surface. Very high water application efficiency (90-95%) can be obtained through drip irrigation method. This system can be used for all wide-spaced crops, as in orchards, plantation, row crops and others.

Proper irrigation management is essential for improving the productivity and quality of crops grown in the greenhouse in which rainfall is obstructed by the cover. Exact time and amount of irrigation are two deterministic factors for efficient irrigation management. Irrigation scheduling is the process of determining the time to irrigate and how much water is to be applied (irrigation depth) in each irrigation. Scheduling water application is very critical to make the most efficient use of drip irrigation system, as excessive irrigation can reduce yield, while inadequate irrigation causes water stress and reduces production. The optimal use of irrigation can be characterized as the supply of sufficient water according to plant needs in the rooting area, and at the same time, avoiding the leaching of nutrients into deeper soil levels and other media.

Green house is a structure with transparent covering that is used for growing plants under controllable condition. With reasonable structure, easy to construct and maintain, it is becoming more and more popular because it can produce huge amount of vegetables and fruits and bring plenty of benefit for the farmers. In greenhouse cultivation, it is possible to control the weather parameters such as temperature and humidity suitable for optimal crop growth. The main advantage of greenhouse farming is that the production can be obtained round the year even in adverse climatic conditions.

Soilless culture as a crop production system has been used around the world for centuries and is currently relied on heavily in greenhouse vegetable production. Many of these soilless systems are referred to as hydroponic culture. Soilless culture is used in greenhouse cultural systems because crop culture is practiced frequently in the same site without fumigation. Soilless culture offers a valuable alternative compared to crop production in soil and has been widely adopted by specialist producers of greenhouse crops in the world, particularly for vegetable crops such as tomatoes and cucumber. The problems with production factors such as soil born pests and diseases, soil salinity, lack of arable soil etc. have led to the development of substrates for soilless cultivation.

Moreover, soilless culture could lead to solve the global issues such as the shortage of water, environmental pollution and instability of ecological system in various ways. Constituting high values for agricultural crops by using low water inputs and high fertilizer efficiencies is one of the methods used in addressing the environmental and resources problems. Soilless culture could be arranged with optimum environmental medium for crop growth in order to gain maximum yield and high quality products. In this way, less land area is required for agriculture production system resulting in increased land productivity.

Use of organic substances as soilless growing mediums in the hydroponics industry is becoming very popular these days. There are several reasons for this popularity. They are easy to use, there is no interaction between the medium and nutrients, they offer improved availability of nutrients to plants, and in general they provide better physical and chemical properties suitable for best plant growth. There are a number of different organic medium available for growing vegetables and ornamental plants. Each medium used these days has certain advantages and disadvantages. As a matter of fact some have more disadvantages than advantages. Selection of a proper medium is very critical in successful plant production and obtaining high yield. In general an ideal medium should be free of any disease, weeds and toxic salts, and light enough to facilitate shipping and handling easily. An ideal medium should also be well-drained, have better air to water porosity, and have the ability to hold moisture and nutrients for long term supply to plants. The most widely used organic soilless mediums are: sawdust, coir pith, compost and peat moss.

For the last so many years sawdust has been the most widely used medium in commercial greenhouses growing vegetables at places where the availability of sawdust is not a problem. The major advantage of this medium is that the material itself is free of cost and easily available all year round. There are many variables that determine how well sawdust will work, most predominantly are the kind of wood that the dust is made from. Some kinds of wood can give off chemicals that are unfavorable to the health of the plants. Another problem with sawdust is that it will decompose, which can cause problems. It also retains a lot of moisture, so care must be taken not to over irrigate. It has an EC value of 0.17dS/m. It has ideal pH in the range of 6.0 - 6.6. It has high C:N ratio(400:1).

Coir pith is a relatively new growing medium available these days for the hydroponics soilless culture. It is being produced as a bi-product of the coconut tree. Coconut husk is processed to produce fibrous material. Its use as a growing medium performs better than any other medium used for growing vegetables, ornamentals and tree plants. Its soft structure promotes easy root penetration and healthy growth. Coir pith has the best physical and chemical properties to promote better plant growth. It has high water-holding capacity. It can hold water up to eight times of its weight and release it over a period of time. It has ideal pH in the range of 5.4-6.8. It has excellent drainage and air porosity for better plant growth. It has very good cation exchange capacity and very low EC (>200 µS/cm^2). It has some anti-fungal properties that help plants to get rid of soil borne diseases. It inhibits pathogens like Pithium. It is a biodegradable source that degrades very slowly and has a life of three to four years. It contains significant amounts of phosphorous (10-50ppm) and potassium (150-450 ppm). It has low C:N ratio(80:1).

Hence, combination of greenhouse farming and drip irrigation can save water compared to the open drip irrigated farming system. More water can be conserved if we are go for soilless media such as coir pith and sawdust since they are having high water holding capacity than soil. So many studies have been reported all over the world to find the combined effect of drip irrigation management and different soilless culture. Most of them deal with the combinations of different soilless media. Hence, the present project is an attempt to study the effect of drip irrigation management under soil and different soilless media such as coir pith and sawdust for the crop tomato growing inside a naturally ventilated greenhouse.

The objectives of the study are:

- To compare the effect of different drip irrigation water management strategies on growth and yield of tomato.
- To compare the effect of different soilless culture on growth and yield of tomato.
- To determine the optimum irrigation requirement for tomato grown on soilless culture.

CHAPTER II

REVIEW OF LITERETURE

Soilless culture could lead to solve the global issues such as the shortage of water, environmental pollution and instability of ecological system in various ways. Constituting high values for agricultural crops by using low water inputs and high fertilizer efficiencies is one of the methods used in addressing the environmental and resources problems. This research was conducted to determine the optimal irrigation strategy for drip irrigated fresh tomato grown in different soilless culture in a greenhouse .Hence in this chapter the research and development efforts carried out at different parts of the world have been critically viewed regarding objectives of study under the following headings.

2.1 Naturally ventilated greenhouse
2.2 Different soilless culture
2.3 Drip irrigation management in soilless culture

2.1 Naturally ventilated greenhouse

The growth and development of most vegetable crops are adversely affected at temperatures less than 5^{o}C. Growth normally increases with increasing temperatures up to 40^{o}C, and thereafter it decreases drastically. Growth of tomato in a plastic house immediately after planting was the best with high air temperature but later on air temperature of 25^{o}C during the day gave better results (Fuji and Ito 1968).

Maeglasson and Adata (1977) stated that the day temperature of 43^{o}C during April in greenhouse caused premature flowering, and fruit drops.

Moss (1982) reported low yields in lower temperature regime for glasshouse tomato.

Tanaka and Komochi (1982) studied the relationship between plant density and topping on the growth and yield of tomato in greenhouse. With increasing plant density, leaf size, stem diameter, weight of leaves and stem per plant decreased and flowering as well as ripening was delayed up to 7 days and yield per unit area increased.

The primary advantages with greenhouses are that any crop can be grown in any season of the year depending on the market demand, excellent quality of the produce, disease free produce etc. The yield of okra in greenhouse was 2.5 to 3 times higher as per Nimje (1991) and nearly 1.5 times higher according to More (1996) compared to the yield obtained in open field cultivation.

Nimje and Shyam (1993) reported poor yield in tomato under greenhouse as compared to open field crop because of higher temperature during growth, flowering and fruiting period in the green house. They also reported that the relative humidity is higher inside the greenhouse than in the open field condition.

Saglam *et al*. (1995) reported that a spacing of 0.75 X 0.35 m gave more fruits/plant and heavier fruits than closer spacing but yield/unit area were increased with closer spacing.

Khan *et. al*. (1996) has suggested that the cultivation under naturally ventilated low cost poly/greenhouses should be adopted for making its cultivation a profitable venture.

Papadopoulos and Pararajasingham (1997) reported that greater fruit yields are possible in narrow plant spacing than with wide plant spacing in greenhouse tomatoes. The main factors responsible for the increase in fruit yield at narrow spacing were greater crop biomass and increased availability of total assimilates for distribution to the fruits.

A study on biometric characteristics of tomato (cv. Vaishali) grown in uncontrolled poly-greenhouse was conducted by Ganesan and Subashini (2001). The results revealed that performance of the crop grown inside the poly-greenhouse (2985.84 g/plant) was comparatively better than that grown in open condition (819.94 g/plant) and the increase was nearly 3½ times higher in fruit yield.

Ganesan (2002) compared four different poly-greenhouse models with open field condition. Different sized poly-greenhouse ventilation gaps with 25% shade net and UV stabilized plastic film sheet materials were used. The effects of temperature on plant growth and yield of tomato in poly-greenhouses and open field condition were investigated. The air temperature in the open field condition was lower than in the poly-greenhouse treatments throughout the growth period. Poly-greenhouse with ventilation gaps in the triangular roof and four sidewalls was found more suitable for better plant growth and yield of tomato than those with the other ventilation gaps in poly-greenhouses and open field condition.

The effect of changes in microclimate produced by poly greenhouse conditions on plant growth characteristics and fruit yield of tomato was studied by Ganesan (2002). UV stabilized plastic film covered greenhouse recorded higher day temperature than the open environment but relative humidity at 8 am was lower inside the greenhouse except from May to August. The light intensity inside the greenhouse was lower than in the open. Height of the plant, number of nodes, internodal length total dry matter production and average fruit weight increased under greenhouse conditions as compared to open field condition. The yield performance inside the greenhouse was highest 2145 g/plant and 2156 g/plant in the first and second season, respectively) than the open field crop. The fruit yield inside the greenhouse was nearly two times more than in the open field condition.

2.2 Different Soilless culture

Abbott *et al*. (1986) mentioned that the amount and severity of fruit cracking was least from the soilless, bag-cultured plants. Total mean fruit weight was greatest from soil grown plants. Although no differences in cracking occurred in the fruit from soilless, bag-cultured plants, those whose irrigation was based on soilless medium tensiometer readings produced lower total mean fruit weight than those whose irrigation was based on soil tensiometer readings.

Smith (1995) found that some plant species grow better in coir than in peat media, possibly due to its high air capacity.

Vavrina (1996) found that there were no adverse effects of coir pith to tomato and pepper transplants.

Celikel (1999) conducted experiments in a plastic and a glass greenhouse to test different substrates in tomato growing. Peat + volcanic tuff + spent mushroom compost (1:1:1), volcanic tuff + spent mushroom compost (1:1), peat + volcanic tuff (1:1), and volcanic tuff were used in both trials. In addition to those, spent mushroom compost and peat in the plastic house, and rock wool in the glasshouse were also tested. In both trials, plants grown in soil were evaluated as control. Peat + volcanic tuff + spent mushroom compost (1:1:1) gave the highest early and total yields in both greenhouses. Early and total yields were higher in all substrates compared to the yield obtained from soil grown plants. Fruit weight also increased in plants grown in substrates compared to soil and the heaviest fruits were harvested from the plants grown in peat + volcanic tuff + spent mushroom compost (1:1:1). In terms of fruit quality (TSS, TA, pH and vitamin C) there were no significant differences between the substrates and soil.

Abad *et al.* (2001) prepared an inventory of materials suitable for use as growing media for ornamental potted plant production in Spain. Special attention had been paid to solid organic wastes generated by production, industrial and consumer activities. Information obtained from the study has been organised into two data bases. Data base 1 contains the ``General Characteristics" file of more than 105 materials. In the file, data are available regarding generation points, material availability, uses, cost, disposal expenses, etc. Data base 2 is comprised of the ``Specific Properties" file of 63 materials selected from data base 1. The main physical, chemical and biological properties of these materials as container media have been characterized, and the results obtained have been compiled. Finally, a computerized data bank has been created.

Tuzel *et al.* (2001) conducted a study on soilless culture using tomato cv. *Fantastic F1* as test material to determine the effects of three irrigation scheduling and substrates (perlite, volcanic tuff, pumice, perlite (80%) + peat (20%), volcanic tuff (80%) + peat (20%), pumice (80%) + peat (20%). Among the substrates, perlite (19.20 kg m^{-2}) and perlite + peat mixture (19.66 kg m^{-2}) resulted in the highest yield.

Abad *et al.* (2002) evaluated the selected physico- chemical and chemical characteristics of 13 coconut coir dust samples as peat alternatives. All properties studied significantly between and within sources, and from the control peat. pH of coir dust was slightly acidic, whereas salinity varied dramatically between 39 and 597 mSm^{-1} in the saturated media extract. The cation exchange capacity and carbon / nitrogen ratio ranged from 31.7 to 95.4 meq and from 75 to 186, respectively. Most carbon was found as lignin and cellulose. The concentrations of available nitrogen, calcium, and magnesium and micro- element were low, while those of phosphorus and potassium were remarkably high. Saline ion concentrations, especially chloride and sodium were also high.

Arenas *et al*. (2002) found that the media with more than 50% coir had reduced growth compared to peat-grown control plants.

Rovdan et al. (2002) investigated the changes in the water characteristics of peat soils under anthropogenic evolution. It was stated that the transformation of organic formations as a result of drainage and agricultural utilization leads to changes in their physical properties, i.e., it causes the increase of bulk density and ash content and the decrease of total porosity as well as the quantity of macro and micro pores. Water retention of drained peat soils which have reached a more advanced stage of decomposition is lower and the loss of water with the increase of the water potential is smaller. Anthropogenic evolution does not cause significant changes of effective useful retention in the investigated organic soils. Saturated hydraulic conductivity is higher for deeper peat layers which have a small degree of decomposition than for upper layers where the decomposition reaches a higher level. Anthropogenic evolution of peat soils leads to the considerable increase of unsaturated hydraulic conductivity at low soil water potentials or in the whole range of soil water potentials, only in the 25% of cases of the investigated organic soils is this relationship reversed.

Lin *et al*. (2004) conducted experiments to evaluate the effects of potassium levels on fruit quality on ‘Tiantian No. 1’ muskmelon (*Cucumis melo*, cv. *reticulatus Naud*.) in soilless medium culture under a greenhouse. Three potassium levels, K120 (insufficient), K240 (suitable), and K360 (excessive) in nutrient solution, which represent 120, 240, and 360 mgl^{-1} of potassium (K), respectively, were applied. At potassium level of 240 mgl^{-1}, the concentrations of total sugar, total soluble solids, glutamic acid, aspartic acid, alanine, and volatile acetate components (*n*-amyl acetate, 2-butoxyethyl acetate) significantly increased in fruit flesh, which should improve the taste and aroma of muskmelon. However, no significant difference in fruit appearance or size was recorded among the treatments. Favorable qualities of muskmelon in soilless medium culture were achieved when potassium level was adjusted to near 240 mgl^{-1} in nutrient solution.

Ma and Nichols (2004) reported that the problems with coir pith extended beyond its high salinity indicate that high concentration of phenolic components in fresh coir is partly responsible for the growth reductions.

Rippy *et al*. (2004) conducted an experiment to develop a certifiable organic regimen for growing greenhouse tomatoes that would be comparable with those grown conventionally with regard to production methods, as well as nutritional status in leaf tissue, plant development, and harvest yields. The variations in the nutritional status of the plants that did occur were largely attributed to either the actual amounts of nutrients added, in the case of Ca and Mg, or the pH level of the media. Thus the media pH plays a greater role in nutrient availability, and consequently plant growth and harvest yields, in conventional systems than it do in organic systems. Organic media found to be more stable if they were allowed to stand for approximately 4 weeks after mixing in order to achieve equilibrium.

Benito *et al*. (2005) analysed the use of pruning wastes compost (PWC) as a growing media component for ornamental plants. The main physical, chemical and biological characteristics of PWC were analysed in order to evaluate its suitability for use in soilless cultivation. Six growth substrates were prepared by mixing PWC with peat (P), ground leaves (GL), sand (S) and spent mushroom compost (SMC) in different proportions. Two different pot experiments were carried out to test its characteristics of production using perennial ryegrass (*Lolium perenne L.*) and cypress (*Cupressus sempervirens L.*) as indicators and the different media as treatments. The growth experiments showed that PWC required mixing with a nutrient-richer material to produce higher results. Therefore, substrates containing SMC (PWC + P + SMC and PWC + SMC) seems to be the most adequate growing media.

Kannan *et al.* (2005) conducted a field experiment with tomato to study the influence of different organic N sources *viz*, FYM, vermicompost and coir pith compost with biofertilizers on the soil physical properties, nutrient availability and biological properties. Based on N content of the organic N sources on dry weight basis, the quantity required for the substitution of recommended doses at 50, 75 and 100 per cent level worked out and applied along with 2 kg azospirillum. Application different organics with azospirillum favorably influence the soil physical, chemical and biological environment such as bulk density, water holding capacity, organic carbon and available nitrogen, beneficial bacterial and fungal population over the inorganic alone applied plot. Among the different organic N sources the application 75 per cent vermicompost with azospirillum was found to be superior in improving soil health over the other treatments. The above finding revealed that organic farming would able to sustain the soil fertility for a longer period by meeting the demands of present and future generation.

Samartzidis *et al*. (2005) studied cultivation of roses in various soilless media with the aim to identify the optimum soil condition for rose production. Madelon roses grafted on rootstock of *Rosa indica* var. major were transplanted to polyethylene bags containing zeolite and perlite (at ratios of 25z:75p, 50z:50p, 75z:25p and 100z:0p, v/v) in a climate-controlled greenhouse. Cumulative production of rose plants did not differ among substrate mixtures. Productivity significantly differed among flower stem classes. Stem class I (>70 cm) and class V (≤30 cm) exhibited the least production, contributing to only 7.6 and 3.7% of the total production, respectively. The highest productivity was observed in classes III (51–60 cm) and IV (31–50 cm), contributing to the bulk of productivity (68.4%). Class II contributed a 20.3% of the production. Results showed that zeolite and perlite acted as inert materials. Zeolite did not exert any positive effect on productivity. Use of perlite resulted in a little improvement in photosynthesis; however this improvement was not reflected by a significant increase in production.

Urrestarazu *et al*. (2005) evaluated three commercially produced random samples of woody endocarp of two different textures and two volumes (19 and 25 L). Three experiments were conducted to evaluate the effects of volume and texture and to compare this substrate with rock wool in terms of yield and quality characteristics of fruits in melon and tomato culture. The physical, physio-chemical and chemical properties studied did not differ significantly between both textures. Tomato plants grown in almond shell residue used 21% less water compared to rock wool over the course of production. We found non-limiting in comparison to rock wool for melon and tomato crops in relation to fertigation parameters, water uptake and yield. Significant differences of yield were found when we used the big size, especially in melon crop where commercial yield and soluble solids of plants growing on 25 L bags was higher than that on small one. The results suggested that almond shells seem to be an acceptable growing media as rock wool substitute for soilless vegetable production.

Benito *et al*. (2006) evaluated chemical and physical properties of 12 different selected pruning waste compost (PWC) samples to assess their suitability as substrates for ornamental plants. Samples were taken periodically from the same composting facility over 18 months in order to determine if there was any seasonal variability. In addition to the PWC samples, a Canadian Sphagnum peat and a commercial growing medium (CGM) were used as standard materials. With respect to PWC properties, pH values were above 8, significantly higher than the pH of peat and the commercial substrate. All samples showed adequate levels of organic matter and correspondingly high cation exchange capacity (CEC) values. The C/N ratio varied between 22 and 48, significantly higher than the optimal values of 15–20. Although composts were sampled from piles established in different seasons, no significant differences were found in their chemical properties. However, water retention characteristics were affected by seasonal changes in components entering the facility. Comparing the properties of PWC to those of peat and commercial growing medium, this material appears to be an acceptable component of a substrate for container-grown ornamental plants.

Bernstein *et al*. (2006) investigated the effect of irrigation with treated sewage water on roses cultivated in two soilless medium, perlite, an inert mineral medium and coir (coconut fibers), an organic medium of high ion absorption capacity. During 12 months of exposure to the treated water, the visible appearance of the plants, their growth, the quantity and size of the flowering stems and their postharvest performance were not affected by the irrigation treatments. Contents of macroelements in the leaf tissues were unaffected by the irrigation with the secondary treated sewage water. At the same time, Cl contents increased 47% in perlite and 73% in coir grown plants reaching levels characteristic of exposure to moderate salinity. Mn, Cu and B contents increased as well under cultivation in both perlite and coir under irrigation with treated sewage water. On the other hand, contents of Fe, Zn, Mo and Al, were similar in all treatments. In all treatments contents of all the examined micro and macroelements were within the range accepted for proper plant function.

Juneau *et al.* (2006) studied (1) the effect of different substrates on greenhouse tomato yield and root rot caused by Pythium, and (2) the threshold values of some substrate physico-chemical properties for tomato yield and Pythium root rot. Two experiments (fall, spring) were conducted using five substrates. In the fall experiment, yield was related to water availability, as long as aeration was sufficient. In the spring experiment, yield depended on air storage and gas concentrations (O_2, CO_2) in the substrate because of their low aeration levels. The effect of substrate types and their physico-chemical properties on Pythium root rot varied according to the cultural conditions. Under fall cropping conditions, substrates showing wet and anaerobic conditions favoured Pythium root rot. In these experiments, adequate aeration properties for tomato plant productivity were obtained with a maximum of 30% low quality peat added to a mixture of sawdust and compost.

Liu *et al.* (2006) studied the effect of indoor air relative humidity on leaf area and water transport of flower stems in a greenhouse rose crop grown on a soilless substrate on 2-year-old plants, in a freely draining irrigated system ensuring a high leaching fraction. In one compartment of the greenhouse, the roof opened when the air temperature reached 28^0C. In the other, an evaporative wet pad and fans were operated at 28^0C. The wet pad treatment decreased vapor pressure deficit (VPD). A maximum VPD difference of 1.45 kPa between the two compartments occurred during the noon-hours on a warm day with high atmospheric evaporative demand. On days with moderate evaporative demand, the wet pad was either not operated or when operated, produced VPD differences smaller than 1.45 kPa. Wet pad treatment decreased the transpiration rate per unit leaf area of the flower stem. On a typical summer day, with high evaporative demand, mean maximum water loss per unit leaf area was 2.63 ± 0.13 and 1.79 ± 0.09 kg m^{-2} day^{-1} for the high and low VPD compartments, respectively. The wet pad treatment mitigated leaf water potential drop at noon-time. The results suggest that rose flower stems adapt to high VPD by decreasing leaf area for maintaining high sap flow rate per unit area.

Rodrigues *et al.* (2006) were conducted experiments in the spring of 2001 and 2002, using different combinations of media (coarse perlite, medium perlite and pine bark) and containers (polythene bags and plastic pots) which used for hydroponic production of Galia muskmelons (*Cucumis melo L.*) to determine their effect on fruit yield and quality, and their influence on cost of production. Marketable yields obtained for Galia-152 in the spring 2001 and 2002 were 25.5 kgm^{-2} and 39.0 kgm^{-2} respectively. Use of pine bark media and plastic pots instead of perlite and bags were found to be economical.

Shah *et al.* (2006) conducted a study to optimize the propagation technology to see the effect of rooting media on the root initiation and development in two different types of cuttings (hardwood and softwood). Five different rooting media were used including silt, sawdust, rice husk, leaf mold and control (soil + silt + FYM at 1:1:1 ratio). It was surprising that the hardwood cuttings did not produce roots in any media. The data recorded on the softwood cuttings revealed that the quickest sprouting occurred in cuttings that were planted in sawdust. The cuttings grown in leaf mold produced maximum leaves which were the longest with maximum leaf area and maximum roots. However, the leaf mold produced minimum root length and weight and took comparatively longer time to sprout. Plants grown in silt produced longest roots and maximum root weight but they also resulted in minimum leaf number and shortest leaves.

Lee *et al*. (2007) produced fruiting bodies of Oudemansiella mucida, porcelain fungus, on the oak sawdust medium, using screened additives which are suitable for the mycelial growth and fruiting body formation. The mycelial growth of the three strains of O. mucida used in the study have been good on oak sawdust mixed rice bran of 20-30%. The mycelia incubated in potato dextrose broth for 7 days were inoculated on oak sawdust medium supplemented with various ratios of rice bran and incubated for 30 days at 25^{o}C in the dark condition until the mycelia of O. mucida fully colonized the media from top to bottom. Then, top surface of the media in the bottles were horizontally scratched with a spatula and filled with tap water for 3 hours. To induce the primordial formation of O. mucida, the bottles were transferred to the mushroom cultivating room under 12 hrs of light (350 lux) and dark condition with relative humidity of 95% at 17^{o}C. The primordia of O. mucida were formed on the surface of oak sawdust media after 7 days of incubation. The mature fruiting bodies were observed 5 days after primordial formation. The fruiting bodies O. mucida were formed on oak sawdust medium mixed with 5 to 30% rice bran. However, abundant fruiting-bodies of O. mucida were produced in oak sawdust medium supplemented with 20% rice bran.

Melgarejo *et al*. (2007) conducted a fig soilless culture in a greenhouse to get rid of all the inconveniences of traditional farming such as low profitability. The research showed a different way of growing fig trees (*Ficus carica L.*) so that farmers could benefit from it by improving yields. This type of soil-free culture may allow irrigated farms to boost their fig productions from 4500 kg/ha-year up to 81,000 kg/ha-year; that is an 18-fold yield increase compared to traditional farming. Likewise, water efficiency would also be maximised. A 90% water reduction was achieved by applying this growing technique. Furthermore, fertilisers and pesticide applications, as well as farming costs (hand labour) may be reduced by growing the appropriate fig cultivars. Moreover, the highest fig market demand could be met by scheduling harvesting to provide quality fruit all year round.

Azarmi *et al.* (2008) studied the effects of vermicompost on soil chemical and physical properties in tomato. The experiment was arranged in a randomized complete block design with four replications. Different amounts of vermicompost (0, 5, 10, 15 t ha^{-1}) were incorporated into the top 15 cm of soil. The soil sampling and measurements carried out 3 months after the application of vermicompost in soil and the soil samples were collected from depth of 15 cm. The results showed that addition of vermicompost at rate of 15 t ha^{-1} significantly increased contents of soil total organic carbon, total N, P, K, Ca, Zn and Mn substantially compared with control plots. The soils treated with vermicompost had significantly more EC in comparison to unamended plots. The addition of vermicompost in soil resulted in decrease of soil pH. The physical properties such as bulk density and total porosity in soil amended with vermicompost were improved. The results of this experiment revealed that addition of vermicompost had significant ($P < 0.05$) positive effects on the soil chemical, physical properties.

Chavez *et al.* (2008) investigated the use of alternative soilless media based on river waste and *Sphagnun sp*. and *Carex sp.* from Argentinean peat lands on *Petunia hybrida* and *Impatiens wallerana* production at two fertilization levels (200 and 400 mg l^{-1} N). River waste or ‘temperate peat’ is the name given to a material, resulting from the accumulation of aquatic plant residues under an anaerobic subtropical environment, which is dredged from river banks. Our results showed that alternative substrates based on river waste can be used to grow high quality plants. This result was not fully explained on the basis of established methods to evaluate substrate quality. Highly concentrated fertigation solution decreased the substrate quality parameters and plant growth. Nitrate leaching from the alternative substrates containing river waste was lower than the standard peat-based materials, which makes river waste desirable from a sustainable pot production system perspective. River waste and Carex peat are suitable alternatives to Sphagnum peat from the Northern Hemisphere.

Dasgan *et al.* (2008) conducted an experiment in Mycorrhizal fungi species *Glomus fasciculatum* to determine its effects on tomato growth, yield, fruit properties, nutrient uptake and substrate ion accumulation of plants grown hydroponically under open and re-cycling (closed) perlite substrate. AM inoculation in both open and closed soilless systems did not increasingly influence the vegetative plant growing and nutrient uptake of tomato cultivar M19. However, fruit yield absolutely increased with inoculation. AM inoculated tomato plants could effectively use photo assimilates for fruit production instead of vegetative growing. In the closed system with AM, ion accumulation and EC increases (salinity effects) were well controlled. Results indicated that mycorrhizal inoculation improved yield and fruit size, which can help alleviate deleterious effects of re-cycling soilless systems for tomato crop.

Fandi *et al*. (2008) mentioned that open soilless system using tuff as a substrate may be suitable for tomato production without dramatic changes in yield or fruit quality and it is concluded that open soilless culture system using tuff substrate may save about 65-70% of water applied by conventional farmers for tomato under plastic house.

Magan *et al*. (2008) evaluated the effect of salinity on fruit yield, yield components and fruit quality of tomato grown in soilless culture in plastic greenhouses in Mediterranean climate conditions. Two spring growing periods (experiments 1 and 2) and one long season, autumn to spring growing period (experiment 3) studies were conducted. Two cultivars, ‘Daniela’ (experiment 1) and ‘Boludo’ (experiments 2 and 3), were used. Total and marketable yield decreased linearly with increasing salinity above a threshold EC value (EC_t). There were only small effects of climate and cultivar on the EC_t value for yield. Average threshold EC values for total and marketable fruit yield were, respectively, 3.2 and 3.3 dS m^{-1}. The decrease of fresh fruit yield with salinity was mostly due to a linear decrease of the fruit weight of 6.1% per dS m^{-1} from an EC_t of 3.0 dS m^{-1} for marketable fruits. Blossom end rot (BER) increased with increasing salinity. There was a higher incidence of BER with spring grown crops, and ‘Boludo’ was more sensitive than ‘Daniela’. Increasing salinity improved various aspects of fruit quality, such as: (i) proportion of ‘Extra’ fruits (high visual quality), (ii) soluble solids content, and (iii) titratable acidity content. An economic analysis indicated that the EC threshold value above which the value of fruit production decreased linearly with increasing salinity was 3.3 dS m^{-1}, which was the same as that for marketable yield.

Menaie *et al.* (2008) evaluated growth and flowering patterns of *Gardenia jasminoides* as influenced by growing media in both indoor and outdoor varieties for producing good quality plants with better foliage and flowering habits. The experiment was carried out in the Urban Demonstration Garden Site of Kuwait Institute for Scientific Research, with various combinations of sand, potting soil, peat moss and perlite as the growing media. Results indicated that growing media played a significant role in the growth and flowering of *Gardenia jasminoides*. Comparison of the effect of growing media showed that a mixture of potting soil: perlite in 1:1 ratio for indoor plants and potting soil: peat moss in 1:1 ratio for outdoor plants had a positive effect on healthy canopy development and thereby maximized flower production. Similarly the canopy of the treated plants had a positive influence both in the indoor and outdoor varieties. Moisture, aeration and organic matter of the growing medium were the three factors that influenced growth and flowering of gardenia plants.

Pathmashini *et al.* (2008) conducted a study to examine the effect of different types of spawns on oyster mushroom production using sawdust. Locally available grains of kurakkan, maize (broken), sorghum and paddy were used for spawn production. Sawdust spawned with different types, spawns were examined for spawn running (mycelia development), pinhead formation and fruit body formation, mean yield, and biological efficiency. The experiment was setup as a complete randomized design with three replicates. The kurakkan spawn produced an acceleration of spawn running, pinhead formation, fruit body formation and increased yield, compared with other types of spawn *viz.*; maize, sorghum, and paddy. The fastest spawn running of 21 ± 1 day, pinhead formation of 35 ± 1 days, highest mean yield of 55.37 ± 0.67 g and maximum fresh mushroom yield percentage of 30.76 ± 0.01 were realized for kurakkan spawn.

Islam *et al.* (2009) conducted a study to find suitable sawdust as substrate for growing Mushroom. Seven different type of substrates *viz*. Mango, Jackfruit, Coconut, Jam, Kadom, Mahogony, Shiris sawdust with wheat bran and $CaCO_3$ were evaluated to find their growth and yield of Mushroom. The maximum biological yield per packet was obtained with Mango sawdust (150 gm) followed by Mahogony (148 gm), Shiris (146 gm), Kadom (136 gm), Jam (114 gm), Jackfruit (97 gm) and Coconut sawdust (83 gm). The lowest yield was observed in Coconut sawdust (83 gm). However, highest return was obtained with Mango sawdust while the lowest with Jackfruit sawdust. Cost benefit analysis revealed that the Mango sawdust and Shiris sawdust were promising substrates for the growing of Oyster Mushroom.

Parra *et al*. (2009) studied recirculation strategies in three different substrates as an alternative to tomato soilless culture in open system in the canary island. The results indicate that the closed system saved up to 45% of water applied, and up to 69% of the water discharged, depending on the substrate. Furthermore, recycling could decrease nutrients both applied as well as discarded, reducing input by 53% and, more importantly, eventual nitrate pollution by up to 76% in relation to open system culture.

Ekpo and Sita (2010) carried out an experiment to evaluate the growth of pine seedlings in different growing media and to assess the influence of the growing media on ecological characteristics of pine seedlings. The treatments consisted of 6 organic growing media: T1, pine-bark compost; T2, Super medium; T3, pine sawdust; T4, topsoil; T5,cattle manure; and T6, bagasse. Effects on stem diameter, weed infestation and soil chemical properties were assessed at 4-16 weeks after planting (WAP). Results showed that seedlings established in pine-bark compost (stem diameter, 2.6 mm), Super medium (stem diameter, 2.6 mm) and topsoil (stem diameter, 2.3 mm) had significantly ($p < 0.05$) greater stem diameter than seedlings raised in pine sawdust (stem diameter, 2.0 mm), cattle manure (stem diameter, 1.4 mm) and bagasse (stem diameter, 1.8 mm) at 16 WAP. Topsoil had the largest number of weed species (8 weed species) and bagasse had zero weed species at 8 WAP. The most abundant weed species was *Ageratum conyzoides* (58.3% in pine bark and 25.0% in Super medium). It is concluded that growing pine seedlings in pine-bark compost and Super medium gave the best results; it is recommended that pine seedlings be grown in nurseries using Super medium.

Vivek *et al.* (2010) studied the characters of hydro-physical properties of plant growth media that are commonly used in nurseries. Hydro-physical characteristics such as water infiltration, texture and structure, particle size distribution affect the quality of the media used in containerized agricultural systems and the water availability to plants. Water retention characteristics depend on particle size distribution as well as the composition of the media used. Materials with coarser particles allow faster percolation of water and also retain relatively higher amounts moisture per unit weight due to higher porosity, while draining faster due to smaller surface area per unit weight. Faster drainage can result into airflow through coarser materials causing the media to dry. Experimental analyses were performed to characterize the plant growth mixtures in terms of particle size distribution and hydraulic conductivity using three different methods (i.e., constant head permeability, falling head permeability test, and tension infiltrometer test). The saturated hydraulic conductivity of the mixtures was measured by tension infiltrometer. Understanding water retention and permeation characteristics of the plant growing media could assist development of best management practices for containerized agricultural systems for efficient management of irrigation water and agrochemical use.

2.3 Drip Irrigation Management in Soilless Culture

Tuzel *et al*. (1994a, 1994b) compared different irrigation interval and pan coefficients on spring season glasshouse tomato production. In the study, irrigation was scheduled at 1 or 3 day intervals and irrigation rates were calculated from pan evaporation within the glasshouse. Four different coefficients were used namely 0.60, 0.80, 1.00 and 1.20. Increasing the irrigation rate up to 120% of pan evaporation increased crop yield but decreased total soluble solids. Class A pan coefficient of 1.20 resulted in highest yield and quality. The irrigation intervals did not significantly affect the crop yield, but affected other parameters, that is total soluble solid, dry matter content, pH and skin resistance were slightly changed during harvesting period.

Pasternak *et al.* (1995) conducted a series of trials over a period of three growing seasons to determine optimal conditions for irrigation of processing tomatoes planted on a sandy soil. Cultural conditions were the same for all trials. Tomatoes were drip irrigated with brackish (EC_i = 6.2 dS m^{-1}) and fresh (EC_i = 1.2 dS m^{-1}) water. In the first trial, the effect of irrigation frequency (twice a day, once a day, every second and every third day) was determined. Yields in the fresh and the brackish water treatments were similarly affected by one or by two irrigations per day. Irrigation every 2 and every 3 days significantly reduced yields in the two water quality treatments. On average, yields of brackish water irrigated plants were about 44% of yields from fresh water plants. The effect of three planting dates on yields of fresh and brackish water irrigated tomatoes was investigated in the second season. Fresh water yields were similar for the first two planting dates but significantly reduced at the third planting date. Brackish water yields were reduced with each subsequent planting date. The detrimental effect of brackish water on tomato yield was completely overcome through the use of pulse-irrigation. Brackish water irrigation resulted in lower leaf water potential, higher crop stress index but had little effect on leaf carbohydrate content. Salinity had no effect on chloride concentration in leaves but more than doubled the concentration of sodium. It had little effect on leaf calcium content but reduced the levels of potassium and phosphorus.

Hartz (1997) conducted a study on impact of preharvest drip irrigation management on muskmelon. All plots were irrigated uniformly until 10 days or 20 days before harvest; differential treatments were then imposed, ranging from a complete cutoff of irrigation to full irrigation (applied daily) through the harvest period. Fruit quality (firmness, seed cavity and mesocarp condition and soluble solids content) was evaluated at harvest, and after 7 or 14 days of refrigerated storage at 4°C or 2°C. Drip irrigation management did not affect marketable yield, fruit size or % cull fruit. All irrigation treatments produced high quality fruit of equal soluble solids content. There were significant cultivar effects on both yield and quality, but no cultivar - irrigation interactions were noted.

Ayars *et al.* (2001) studied the management of subsurface drip irrigation in the presence of shallow ground water. A 3-year project compared the operation of subsurface drip irrigation and a furrow irrigation system in the presence of shallow saline ground water. We evaluated five types of drip irrigation tubing installed at a depth of 0.4 m with lateral spacing of 1.6 and 2 m on 2.4 ha plots of both cotton and tomato. Approximately 40% of the cotton water requirement and 10% of the tomato water requirement were obtained from shallow (<2 m) saline ground water. Yields of the drip irrigated cotton improved during the 3-year study, while that of the furrow-irrigated cotton remained constant. Tomato yields were greater under drip than under furrow in both the years in which tomatoes were grown. Salt accumulation in the soil profile was managed through rainfall and pre-plant irrigation. Both drip tape and hard hose drip tubing are suitable for use in our subsurface drip system. Maximum shallow ground water use for cotton was obtained when the crop was irrigated only after leaf water potential of −1.4 MPa was reached.

Mofoke *et al.* (2006) conducted a study on yield of tomato grown under continuous-flow drip irrigation. The drip system was evaluated. Irrigation seasons under four continuous-flow rates of 0.03, 0.05, 0.06, and 0.07 l/h against a bi-daily application was the control. The recorded yields were 42.9, 42.6, 44.4, and 44.4 t/ha, respectively for the four treatments and 22.3 t/ha from the control. The associated Water Use Efficiencies were more than that of the control. The continuous-flow drip schedule offered water savings over short level impoundment furrow irrigation. However, at the higher discharges the system rather applied additional water over furrow irrigation. Results of this study summarily demonstrate promising prospects of the affordable continuous-flow drip irrigation system in delivering high crop yields especially if the crops are grown under appropriate agronomic practices that enable protraction of the growth season. The recommended range of continuous dripping for tomato is 0.03–0.05 l/h.

Sezen *et al*. (2006) conducted studies to determine the most suitable irrigation scheduling of fresh market tomato grown in volcanic ash, peat and their mixture (1:1) under plastic house conditions. Four different irrigation levels (WL1=75%; WL2=100%; WL3=125% and WL4=150% of Class A Pan evaporation) and two watering frequencies (once and twice daily applications) were evaluated. Highest yield and fruit number were obtained from the ash + peat mixture (1:1) with irrigation once a day at WL4 and ash + peat (1:1) with twice a day watering at WL3 and WL4 irrigation levels. The highest WUE was obtained from WL1 with peat + ash (1:1). WUE decreased in all treatments as the amount of irrigation water increased.

Wang *et al*. (2007) examined the effect of five soil metrics potential (SMP) treatments under drip irrigation conditions. The temporal and spatial SMP changes observed in the soil profile along with changes in potato root growth suggest that tensiometers placed immediately beneath the emitter (at 20 cm) can be effectively used in scheduling the drip irrigation regimen. Although rain affected soil water distribution during the growing season, the affects of SMP on potato growth were very clear. Other potato growth properties such as crop height, leaf and stem water content, tuber bulk rate and grade, as well as WUE and *I*WUE were measured. Suggest that an SMP of −25 kPa was the most favorable setting for potato production, while −15 kPa was too high and −45 kPa lead to severe water stress.

Payero *et al.* (2008) evaluated the effect of irrigation applied with subsurface drip irrigation on field corn evapotranspiration, yield, water use efficiencies and dry matter production in the semiarid climate. Eight treatments were imposed with irrigation amounts ranging from 53 to 356 mm and from 22 to 226 mm. A soil water balance approach was used to estimate daily soil water and ET_c. Yields among treatments differed by as much as 22% and 52%. In both seasons, irrigation significantly affected yields, which increased with irrigation up to a point where irrigation became excessive. Distinct relationships were obtained each season. Yields increased linearly with seasonal ET_c. The yield response factor which indicates the relative reduction in yield to relative reduction in ET_c. WUE increased non-linearly with seasonal ET_c and with yield. Both seasons, IWUE decreased sharply with irrigation. Irrigation significantly affected dry matter production and partitioning into the different plant components. The dry mass of the plant and that of each plant component tended to increase with seasonal ET_c. The good relationships obtained in the study between crop performance indicators and seasonal ET_c demonstrate that accurate estimates of ET_c on a daily and seasonal basis can be valuable for making tactical in-season irrigation management decisions and for strategic irrigation planning and management.

Shrivastava *et al.* (2008) conducted experiments on fine-textured heavy soils. These sought to study the effect of drip, mulches and irrigation levels on tomato yield. The treatments comprised various combinations of two irrigation methods namely, drip and surface flood, with and without two mulches of either black plastic of sugarcane trash. For drip, three irrigation levels were tried. In surface flood, the recommended irrigation schedule, i.e. 8 cm depth of irrigation at 100 mm cumulative pan evaporation, was followed. This study revealed that drip plus sugarcane trash mulch scheduled at 0.4 pan evaporation level was the best combination, which gave the highest fruit yield.

Mubarak *et al*. (2009) studied the effect of changes in the hydraulic properties of loamy topsoil on water transfer under daily drip irrigation over a cropping cycle. The soil hydraulic properties determined after irrigation started were found to be much more representative of the majority of the irrigation season, as confirmed by the accuracy of the simulation results with high values of the index of agreement and with values of RMSE similar in magnitude to the error associated with field measurements (0.020 cm^3 cm^{-3}). The highest RMSE values (about 0.04 cm^3 cm^{-3}) were found when the model used input soil parameters measured before irrigation started. It is probable that irrigating in the daytime when crop evapotranspiration is highest could prevent the effects of a temporal change and other problems connected with the soil. Moreover, water will be always available for the crop.

Sezen *et al*. (2010) conducted experiments to determine the optimal irrigation strategy for drip irrigated fresh market tomato grown in different soilless culture in a glasshouse. Volcanic ash, peat and their mixture were used as growth media. Four different irrigation levels (WL1=75%; WL2=100%; WL3=125% and WL4=150% of Class A Pan evaporation) and two watering frequencies (once and twice daily applications) were evaluated. Highest yield and fruit number were obtained from the ash + peat mixture (1:1) with twice a day watering at WL4 irrigation level. Soluble solids of tomato fruit decreased with increasing available water. The highest irrigation water use efficiency (IWUE) was obtained from once a day irrigation WL1 irrigation level with peat + ash (1:1). IWUE decreased in all treatments as the amount of irrigation water increased.

Antony *et al.* (2004) conducted a study to understand the effect of different irrigation methods and schedules on morphological, biophysical, yield and water use efficiency (WUE) of capsicum. The plants grown under drip irrigation had more number of branches and plant heights compared to that of surface irrigated plants. The total yield was less at lower levels of irrigation. Above ground matter that included stem and leaf dry weight had positive correlation with yield under drip and surface irrigation. The carbon dioxide exchange rates varied considerably under different methods of irrigation due to difference in irrigation timings and quantity of water applied. A shift in photosynthetic mechanism was observed in plants under IW/CPE 1.0 treatment. The relationship of WUE and net photosynthesis was also studied. The yield was found to have significant positive correlation with total dry matter (TDM) and net photosynthesis. Any factor that could bring in a change in net photosynthesis and TDM may cause variation in yield in capsicum. Root mass was more in surface irrigated crop where as total root length was more in drip irrigated crop. As the quantity of water applied increased the root finesses decreased. Thus drip irrigation at 100% CPE is beneficial for capsicum plant in terms of yield, better plant morphological characters, *viz.* plant height number of branches, root finesses and root length.

Westarp *et al.* (2004) studied the comparison of the effects on soil volumetric water content and cauliflower yield of three irrigation methods (low cost drip irrigation (LCDI), conventional drip irrigation and hand watering) operated under three different irrigation regimes. Irrigation regime R1 supplied only half of the estimated crop water requirement, characterized by small volumes applied on alternate days. The other two irrigation regimes (regimes R2 and R3), supplied the full estimated crop water requirement, however differed in application timing. Small volumes were applied frequently under regime R2, whereas in regime R3, greater water volumes were applied less frequently. Although differences in the soil volumetric water content (SVWC) were present between the irrigation methods, differences were not consistent between the three irrigation regimes. Regardless of irrigation regime, cumulative cauliflower yields were lowest under conventional drip irrigation. In contrast, there were significant differences in cauliflower yield between LCDI and hand watering between irrigation regimes. Irrigation regime R1 resulted in lower SVWC and lower cumulative yields than regimes R2 and R3, however, water-use efficiency was greater under regime R1 than under regimes R2 and R3. These results suggest that LCDI and hand watering are both viable options to increase food production in water scarce, small-scale farming. However, long-term economic and labour benefits are greater under LCDI.

Sezen *et al.* (2005) examined the effects of different irrigation regimes on yield and water use of green beans irrigated with a trickle system under field conditions. Irrigation regimes consisted of four irrigation intervals and three plant-pan coefficients *(*K_{cp}) were evaluated. Both K_{cp} and irrigation intervals influenced significantly green bean yields. As the K_{cp} value decreased the total yields in each irrigation interval also decreased. However, with the lower irrigation frequency, lower yields were obtained with all K_{cp} coefficients. Significant linear relations were found for green bean yield and total water use for each irrigation interval. Both K_{cp} coefficients and irrigation frequencies had significantly different effects on quality parameters such as fresh bean length, width, number of seed per pod and 100 fresh bean weights.

CHAPTER III

MATERIALS AND METHODS

The materials used and methodology adopted for conducting experiment is presented in this chapter. A field experiment was conducted to standardize the irrigation requirement of tomato in soil and soilless media such as coir pith and sawdust using drip irrigation. The experiment was conducted from May 2011 to August 2011.

3.1 Location and Climate

The experiment was conducted inside a naturally ventilated greenhouse located at E block of the Instructional Farm, Kelappaji College of Agricultural Engineering and Technology, Tavanur. The place is situated at 10^0 52’ 33” N latitude and 76^0 E longitude. It is oriented in north-south direction having $18 \times 5 m^2$ in sizes and the cover material is 200 micron UV stabilized polythene sheet.

This area has a typical humid tropical climate. Agro-climatically, the area falls within the border line of northern zone and central zone of Kerala. Most part of the rainfall received in this region is from South- West monsoon. The average annual rainfall varies from 2500 mm to 2900 mm. The climatological data of the experimental area is shown below.

- Mean maximum monthly temperature: 32.5°C
- Mean minimum monthly temperature: 22°C
- Average monthly relative humidity: 83%
- Average annual rainfall: 2500 mm
- Mean evaporation: 6 mm/day
- Mean solar radiation: 85 $W/m^2/day$

3.2 Crop Description

The tomato variety LE – 66 is used in this study. This variety is introduced to KAU from a foreign germplasm and is bacterial wilt resistant. It shows semi-determinate plant growth. Its fruit is globular. The crop spacing is 75×75 cm. The total duration of the crop is 4 months.

3.3 Determination of In-situ Media Properties

The determination of bulk density, dry density, particle size distribution and moisture retention pattern of all the media were carried out using the standard methods.

3.3.1 Bulk Density

Bulk density of a medium is defined as the total mass per unit volume. Bulk density is determined using core cutter method.

3.3.2 Dry Density

Dry density of a medium is defined as the mass of solids per unit volume of the medium. The equation used;

$$\rho d = \frac{\rho}{1 + w}$$

Where,

ρd = dry density (g/cc)

ρ = bulk density (g/cc)

w = water content

3.3.3 Particle Size Distribution

The knowledge about the average particle size and their distribution facilitate the selection of desired densification process. Sieve analysis is the most common method used for analyzing the particle size in the range of 0.075 to 3.00 mm approximately. Since the particle size of coir pith lies within this range, differential sieve analysis method was used. In the differential sieve analysis, the assumption is made that all the particles in a single fraction are equal in size and that the size is the arithmetical mean of the mesh dimensions of the two screens that define the fraction.

3.3.4 Moisture Depletion Pattern

For finding the moisture depletion pattern for the soilless media, the media were filled in a plastic pot with drainage holes. It is then fully saturated and kept inside the greenhouse. The moisture content for the samples were daily measured at 10 cm depth using gravimetric method. The measurements were done at 2.00 pm. The measurements were taken for 6 days.

3.4 Air temperature inside greenhouse compared to open field during the crop period

The air temperature measurements were taken at frequent interval using a thermometer during the entire crop period. The inside and outside air temperatures were taken at 12.00 pm.

3.5 Experimental details

3.5.1 Determination of Crop Water Requirement

The daily water requirement of the crop is calculated using the formula

$$V = \frac{E_p \times K_p \times K_c \times S_p}{\eta_{drip}}$$

where,

V = crop water requirement (litres/day/plant)

E_p = evaporation (mm/day)

K_p = canopy factor

K_c = crop factor

S_P = Plant spacing (m^2)

η_{drip} = efficiency of drip

Here we have assumed,

E_p = 6 mm/day

η_{drip} = 90 %

S_P = 0.75m×0.75m

Table 1 : Water requirement of tomato crop

Stages	K_c	K_p	Water requirement (l/day/plant)
Initial	0.4 – 0.5	0.4	0.67
Development	0.7 – 0.8	0.6	1.69
Middle	1.05 – 1.25	0.9	3.88
Late	0.8 – 0.95	0.95	3.12
Harvest	0.6 – 0.7	0.8	1.95
Average water requirement (l/day/plant)			2.26

Hence the water requirement of tomato is approximately taken as 2 litres/day/plant.

3.5.2 Nursery preparation

Nursery for the tomato seedlings was prepared in the pro tray. Each pro tray were contains 97 seedlings. Seedlings are placed in 3 pro trays. They were filled with an equal mixture of perlite, vermiculite and coir pith. They were kept inside the greenhouse for 21 days and water is sprinkled every day.

Plate 1. Preparation of nursery for LE-66 Variety of Tomato

3.5.3 Field Preparation

The experiment is conducted in three different growing media namely coir pith, sawdust and soil with three different levels of irrigation. The experimental design is RBD with three replications, each replication containing 9 treatments. There will be a total of 27 plots with dimensions 1.20m×1.20m. For growing tomato in soilless media, a pit of 0.35m depth is made in the plot. Black polythene plastic sheet of 250 micron thickness is used for lining the pits to prevent the contact of cultural material with natural soil. The growing media is filled in the pits up to a height of 0.3m with compaction. Drainage facilities are not provided for the pits filled with soilless media.

Plate 2, 3, 4. Setting up of the field for the experiment

3.5.4 Details of the experimental field

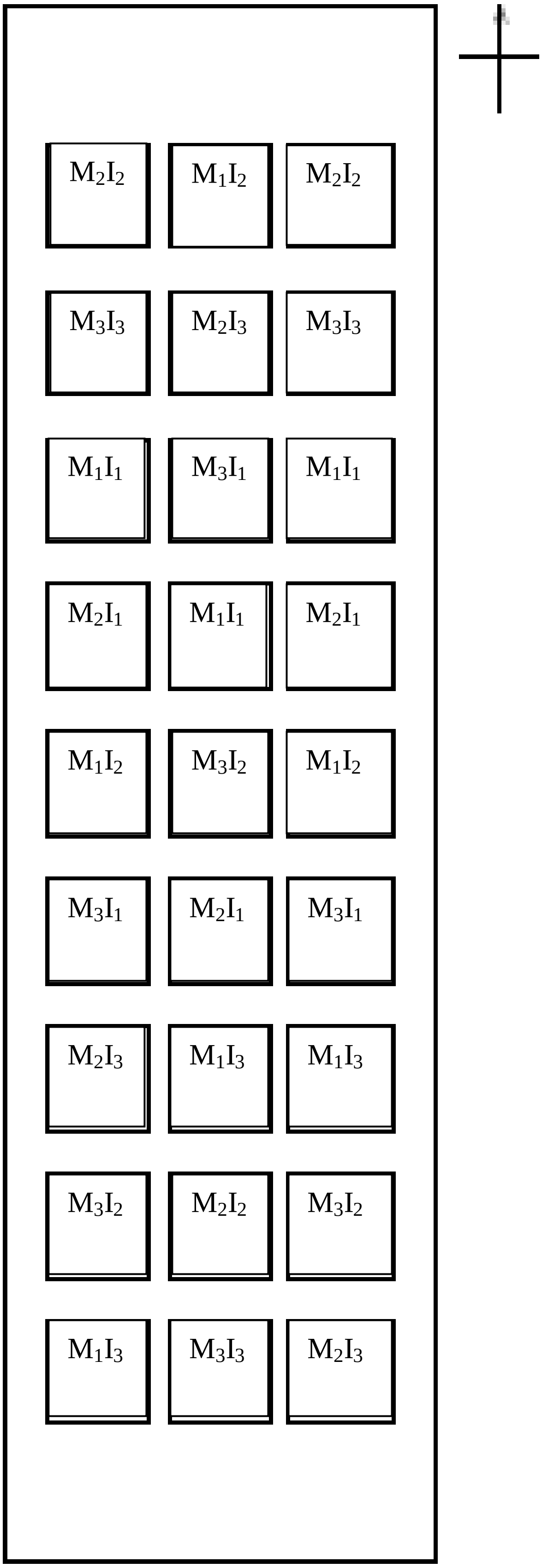
3.5.4.1 Treatments

Three irrigation levels; I_1 = 100 %, I_2 = 75 %, I_3 = 50 % of the crop water requirement was tried for the experiment. The treatments are,

M_1I_1 – Coir pith with 50 % irrigation
M_1I_2 – Coir pith with 75 % irrigation
M_1I_3 – Coir pith with 100 % irrigation
M_2I_1 – Sawdust with 50 % irrigation
M_2I_2 – Sawdust with 75 % irrigation
M_2I_3 – Sawdust with 100 % irrigation
M_3I_1 – Soil with 50 % irrigation
M_3I_2 – Soil with 75 % irrigation
M_3I_3 – Soil with 100 % irrigation

3.5.4.2 Layout of the experiment

The layout is shown in fig.1. The various treatments with replications are marked in the figure.



M_2I_2	M_1I_2	M_2I_2
M_3I_3	M_2I_3	M_3I_3
M_1I_1	M_3I_1	M_1I_1
M_2I_1	M_1I_1	M_2I_1
M_1I_2	M_3I_2	M_1I_2
M_3I_1	M_2I_1	M_3I_1
M_2I_3	M_1I_3	M_1I_3
M_3I_2	M_2I_2	M_3I_2
M_1I_3	M_3I_3	M_2I_3

Fig 1. Layout of the experimental plot in the field

3.5.5 Installation of Drip Irrigation System

Field was prepared and drip irrigation system was installed in the field. The discharge rate of dripper selected for the study was 4 litre per hour at a pressure of 1 kg/cm^2. 16 mm laterals were used in the study. There were nine laterals in the drip system. Each lateral was laid along width wise for applying required level of irrigation. One dripper serves one plant. Each lateral contains 12 such drippers to supply water.

Plate 5, 6, 7. Plots after installation of drip irrigation system

3.5.6 Transplanting and Fertilizer Application

21 days old seedlings of tomato (LE-66) were transplanted into the plots in the greenhouse along with basal fertilizer application and irrigation. . Four tomato seedlings were planted in each plot with a spacing of 0.75m×0.75m. Micro-nutrient mix and water soluble fertilizers were used as per the standard requirement. Fertilizers were supplied as per the package of practices recommended by KAU. The amount of fertilizers was distributed equally among the plots manually.

Plate 8. Plots after transplanting of tomato seedlings

3.5.7 Irrigation Scheduling

Irrigation was scheduled based on the daily crop water requirement of the crop in the region. The irrigation was applied to the crop at the rate of 50%, 75% and 100% of the crop water requirement. Water was applied using a drip system with emitters of 4lph discharge. Since the moisture depletion rates in the coir pith and sawdust were observed very low, the irrigation interval was taken as two days (ie, for the treatments with 50%, 75% and 100% irrigation levels the water supplied was 1.0 l/plant, 1.5 l/plant and 2.0 l/plant respectively in two days). The water application is carried out at 4.00 pm. Irrigations were continued until one week before the final harvest.

3.5.8 Plant Protection

Plant protection measures are carried out as per the requirement. To protect the plant from the attack of *Alternaria blight*, the fungicides such as *Carbendazin* and *Mancozeb* were sprayed on the plant. *Flubendiamide* was used for protecting the plants from the attack of *Spodoptera litura.*

Plate 9. Fungicide application

3.5.9 Harvesting

Harvesting of tomatoes were started 65 days after transplanting. Manual harvesting was done with three days interval. Harvest continued until no economic yield is obtained.

3.5.10 Growth and Yield Characteristics

Biometric characteristics such as height of plant and length of root were noted for knowing the growth characteristics. Total yield per plant, number of fruits per plant and average fruit weight were noted for knowing the yield characteristics.

3.5.11 Water Use Efficiency

Water use efficiency (WUE) values were calculated for each treatment. It is the ratio of yield of crop in kg/ha and total water applied in mm.

$$E_w = Y / W_u$$

Where,

E_w = Water use efficiency (kg/ha mm)
Y = Yield of the crop in kg/ha
W_u = Total water applied in mm

3.5.12 Statistical analysis of experimental data

The results obtained during the experiment were statistically analyzed by analysis of variance using computer software. Analysis of variance was done to find out the significant difference in the treatments. The level of significance used was p=0.05. Critical differences in treatments were also calculated for all the treatment means. The results are presented in the next chapter.

CHAPTER IV

RESULTS AND DISCUSSION

A field study was conducted to determine the effect of drip irrigation management and soilless culture on growth and yield of tomato grown in naturally ventilated greenhouse. The experiment was laid out during May (2011) to August (2011). The result obtained from the study were analysed and presented in this chapter under the following subheads.

4.1 In-situ media properties

The in-situ properties such as bulk density, dry density and particle size distribution of all the three growing media were determined.

4.1.1 Bulk density and dry density

The determined values of bulk density and dry density are shown in the Table 2. The measurements from core cutter and gravimetric method were given in APPENDICES I & II respectively.

Table 2. Bulk density and dry density of growing media

	Coir pith	**Sawdust**	**Soil**
Bulk density	1.03	0.92	1.99
Dry density	0.22	0.33	1.69

4.1.2 Particle size distribution

The results of textural analysis of different growing media are shown in APPENDIX III. The results of the mechanical analysis (sieve analysis) were plotted to get particle size distribution curve. In this curve, percentage finer “N’ was taken as ordinate and particle diameter (mm) as the abscissa on logarithmic scale. The resulting curve is shown in Fig. 2. A logarithmic scale for grain size has advantage that soil or other media of approximately equal uniformity exhibit the same shape, irrespective of grain size distribution. From the particle size distribution curve it is clear that the soil used for the study is well graded. The soilless media such as coir pith and sawdust exhibit the similar textural properties as that of the soil.

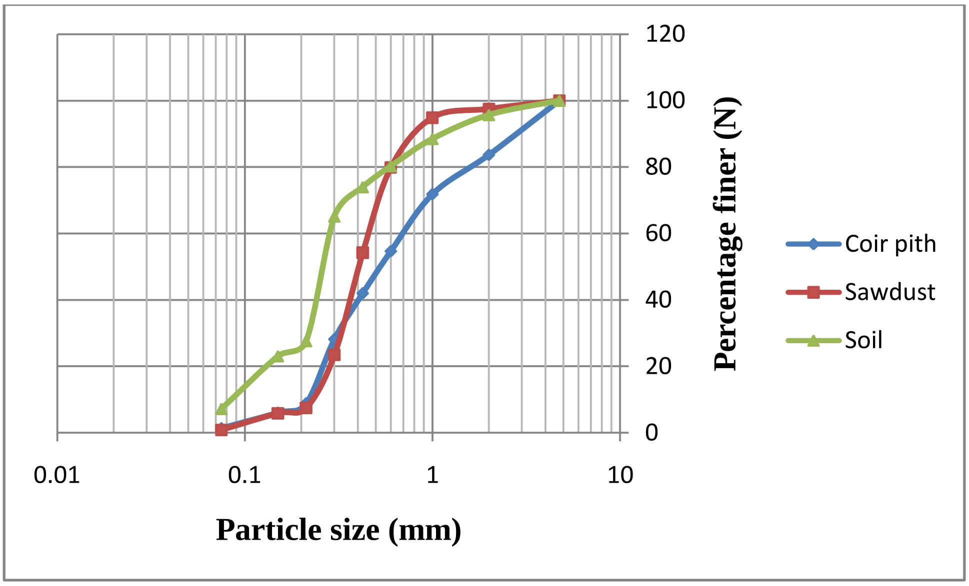


Fig. 2. Particle size distribution of growing media

4.1.3 Moisture depletion pattern for soilless media

The rate of depletion of moisture from the soilless media is very slow in the field condition. The results of moisture depletion pattern for the soilless media such as coir pith and sawdust were shown in APPENDIX IV and the results are graphically represented in Fig. 3.

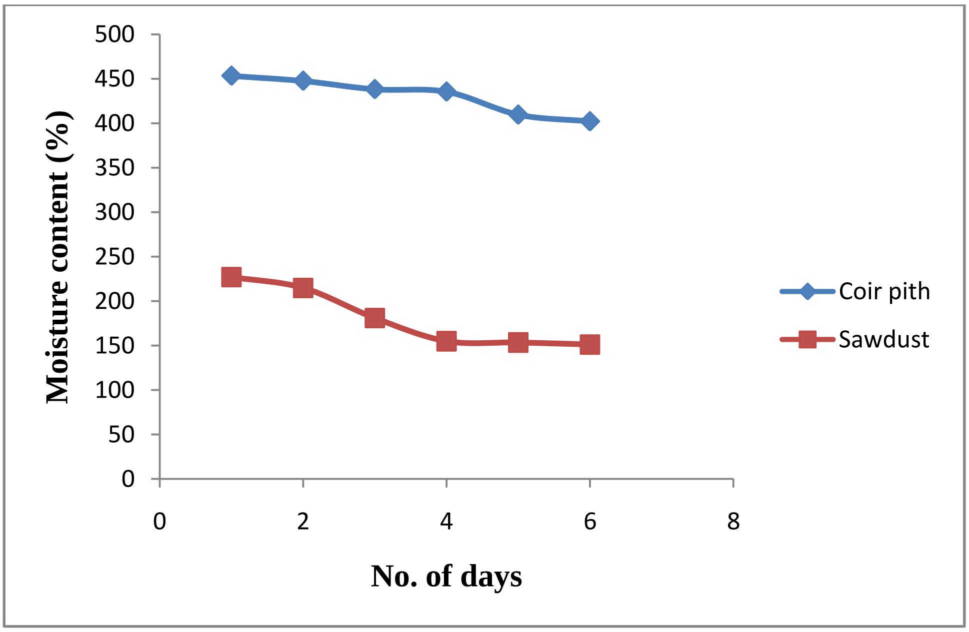


Fig. 3. Moisture depletion pattern for soilless media

4.2 Air temperature inside greenhouse compared to open field during the crop period

Air temperature in the open field condition was lower than in the greenhouse throughout the crop period. A difference of 1.5^o C to 3^{o}C between greenhouse and open field condition was observed during the entire period. The temperature measurements are given in APPENDIX IV. The graphical representation of the temperature variation is shown in Fig. 4.

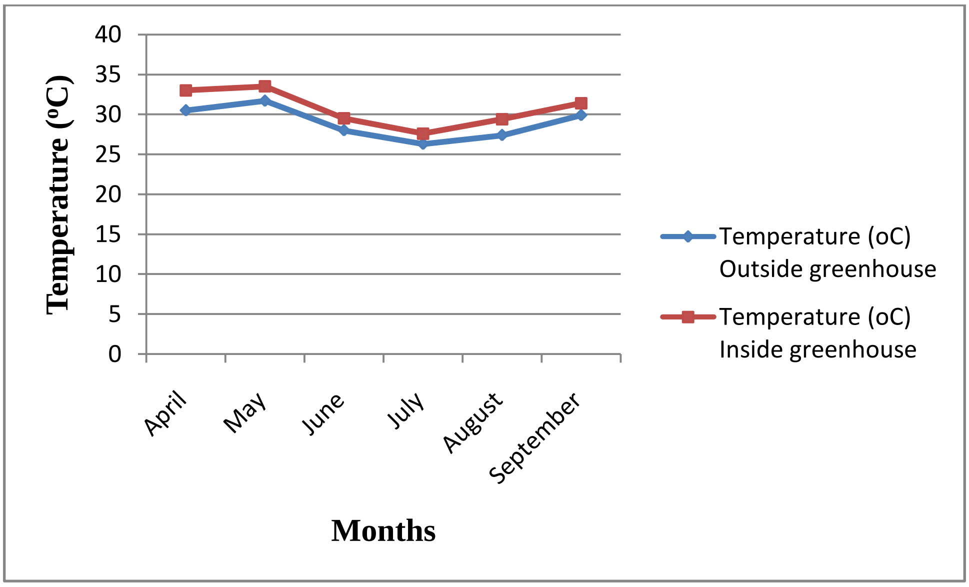


Fig. 4. Air temperature inside greenhouse compared to open field during the crop period

4.3 Effect of irrigation management and growing media on growth of tomato

The various growth characteristics such as height of plant and length of root were noted and the results are analysed statistically.

4.3.1 Height of plant

The height of the plant was measured at 15 days, 45 days and 75 days after transplanting.

4.3.1.1 Height of plant 15 days after transplanting

The height of plant 15 days after transplanting from various treatments was shown in Table 3. and the same is represented in Fig. 5.

Table 3. Height of plant 15 days after transplanting for various treatments

	R_1	R_2	R_3	Average plant height
	cm	cm	cm	cm
M_1I_1	22.30	20.05	24.93	22.43
M_1I_2	24.98	21.58	20.00	22.19
M_1I_3	24.63	22.70	26.30	24.54
M_2I_1	16.48	16.13	17.23	16.61
M_2I_2	17.15	17.35	18.53	17.68
M_2I_3	16.90	15.58	16.10	16.19
M_3I_1	22.60	20.55	26.25	23.13
M_3I_2	17.10	18.23	18.65	17.99
M_3I_3	18.43	20.85	19.13	19.47

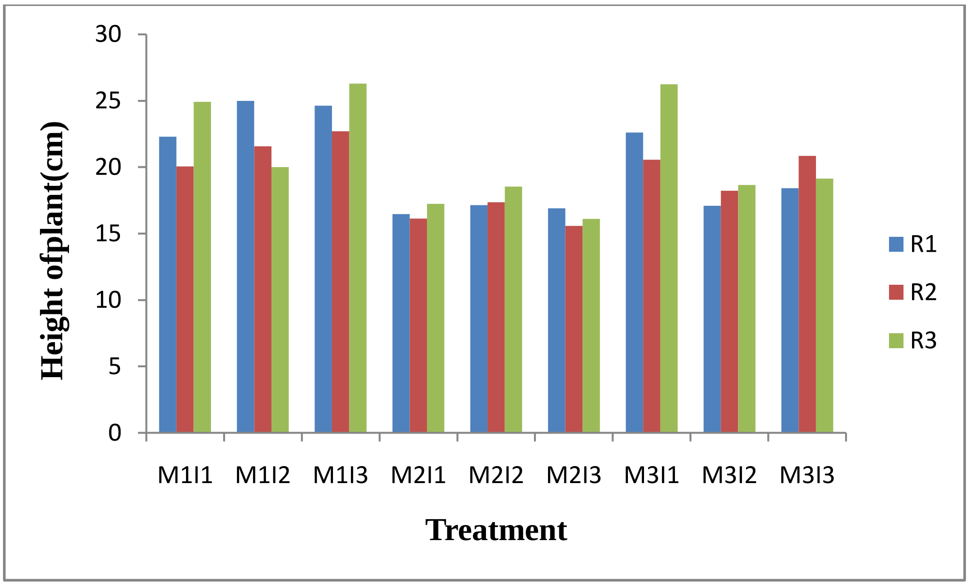


Fig. 5. Height of plant 15 days after transplanting for various treatments

Table 4. RBD analysis of height of plant 15 days after transplanting

Source	DF	SS	MS	f-ratio	Tab-Val	Remarks
Blocks	2	11	6	2.02	3.63	NS
Treatment	8	230	29	10.42	2.59	*
Error	16	44	3			
Total	26	285				
*Significant at 5 percent significance level CD=2.88						

From the Table 3. the treatment M_1I_3 (soil with 100% irrigation) reported highest plant height (24.54 cm) and the treatment M_2I_3 (sawdust with 100% irrigation) reported the lowest plant height (16.19 cm) on 15 days after transplanting. The treatment M_1I_3 is statistically superior to the treatments such as M_2I_1, M_2I_2, M_2I_3, M_3I_2 and M_3I_3. In case of treatments under soil and sawdust, highest plant height was obtained in the treatments M_3I_1 (50% irrigation level) and M_2I_2 (75% irrigation level) respectively.

4.3.1.2 Height of plant 45 days after transplanting

The height of plant 45 days after transplanting from various treatments was shown in Table 5. and the same is represented in Fig. 6.

Table 5. Height of plant 45 days after transplanting for various treatments

	R_1	**R_2**	**R_3**	**Average plant height**
	cm	**cm**	**cm**	**cm**
M_1I_1	88.00	86.67	76.75	83.81
M_1I_2	68.00	83.00	74.25	75.08
M_1I_3	64.00	84.00	91.75	79.92
M_2I_1	73.50	70.75	76.25	73.50
M_2I_2	64.25	66.00	76.75	69.00
M_2I_3	70.25	70.00	74.50	71.58
M_3I_1	102.00	107.5	116.75	108.75
M_3I_2	94.25	101.75	111.25	102.42
M_3I_3	95.00	100.25	88.75	94.67

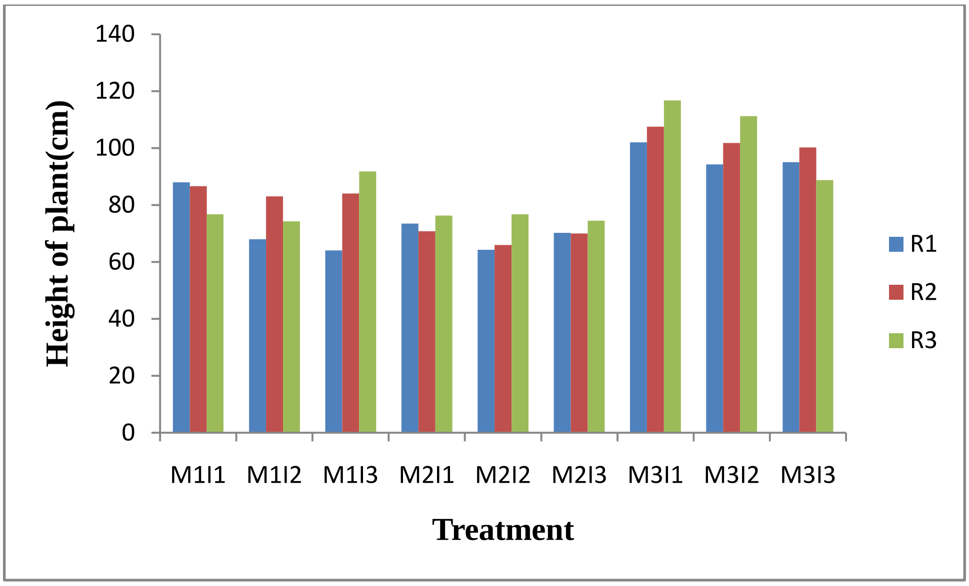


Fig. 6. Height of plant 45 days after transplanting for various treatments

Table 6. RBD analysis of height of plant 45 days after transplanting

Source	DF	SS	MS	f-ratio	Tab-Val	Remarks
Blocks	2	276	138	2.88	3.63	NS
Treatment	8	4951	619	12.94	2.59	*
Error	16	765	48			
Total	26	5992				
*Significant at 5 percent significance level CD=11.97						

From the Table 5. The treatment M_3I_1 (soil with 50% irrigation) reported highest plant height (108.75 cm) and the treatment M_2I_2 (sawdust with 50% irrigation) reported the lowest plant height (69.00 cm) on 45 days after transplanting. The treatment M_3I_1 is statistically superior to all the other treatments except M_3I_2. In case of treatments under coir pith and sawdust, highest plant height was obtained in the treatments M_1I_1 (50% irrigation level) and M_2I_1 (50% irrigation level) respectively.

4.3.1.3 Height of plant 75 days after transplanting

The height of plant 75 days after transplanting from various treatments was shown in Table 7. and the same is represented in Fig. 7.

Table 7. Height of plant 75 days after transplanting for various treatments

	R_1	R_2	R_3	Average plant height
	cm	cm	cm	cm
M_1I_1	125.33	123.00	113.75	120.69
M_1I_2	123.00	129.00	115.5	122.50
M_1I_3	117.75	101.33	122.25	113.78
M_2I_1	114.50	116.50	122.00	117.67
M_2I_2	115.00	100.50	116.50	110.67
M_2I_3	116.00	113.00	115.25	114.75
M_3I_1	172.67	176.00	151.50	166.72
M_3I_2	164.00	151.50	150.00	155.17
M_3I_3	137.50	150.50	147.00	145.00

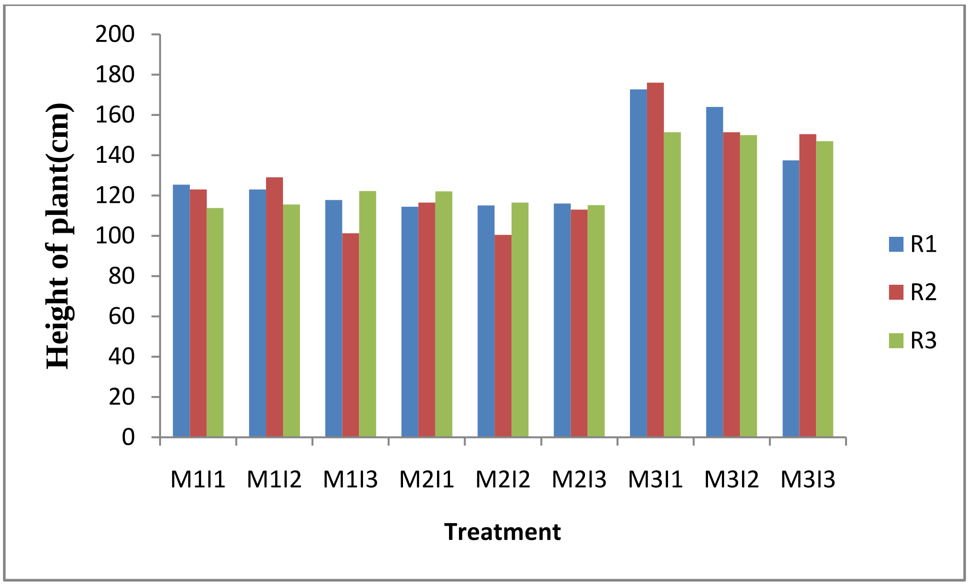


Fig. 7. Height of plant 75 days after transplanting for various treatments

Table 8. RBD analysis of height of plant 75 days after transplanting

Source	DF	SS	MS	f-ratio	Tab-Val	Remarks
Blocks	2	62	31	0.45	3.63	NS
Treatment	8	10111	1264	18.39	2.59	*
Error	16	1100	69			
Total	26	11273				
*Significant at 5 percent significance level CD=14.35						

From the Table 7. the treatment M_3I_1 reported highest plant height (166.72 cm) and the treatment M_2I_2 reported the lowest plant height (110.67 cm) on 75 days after transplanting. The treatment M_3I_1 is statistically superior to all the other treatments except M_3I_2. In case of treatments under coir pith and sawdust, highest plant height was obtained in the treatments M_1I_2 (75% irrigation level) and M_2I_1 (50% irrigation level) respectively.

From the observations taken after 15 days of transplanting, plants grown in coir pith gave highest plant height. But, after 45 days and 75 days of transplanting, plant height was found maximum for plants grown in soil. The presence of high lignin content (growth retardant) in soilless media may also contribute to low plant height.

4.3.2 Length of root

The length of the root was measured after the final harvest. The length of root for various treatments is shown in Table 9. and the same is represented in Fig. 8.

Table 9. Length of root for various treatments

	R_1	R_2	R_3	Average root length
	cm	cm	cm	cm
M_1I_1	100.00	96.00	104.00	100.00
M_1I_2	82.00	118.00	97.00	99.00
M_1I_3	92.00	105.50	108.00	101.83
M_2I_1	77.00	72.00	52.00	67.00
M_2I_2	56.00	54.00	76.00	62.00
M_2I_3	74.00	81.00	108.00	87.67
M_3I_1	135.00	130.00	135.00	133.33
M_3I_2	128.00	109.00	128.00	121.67
M_3I_3	102.00	146.00	142.00	130.00

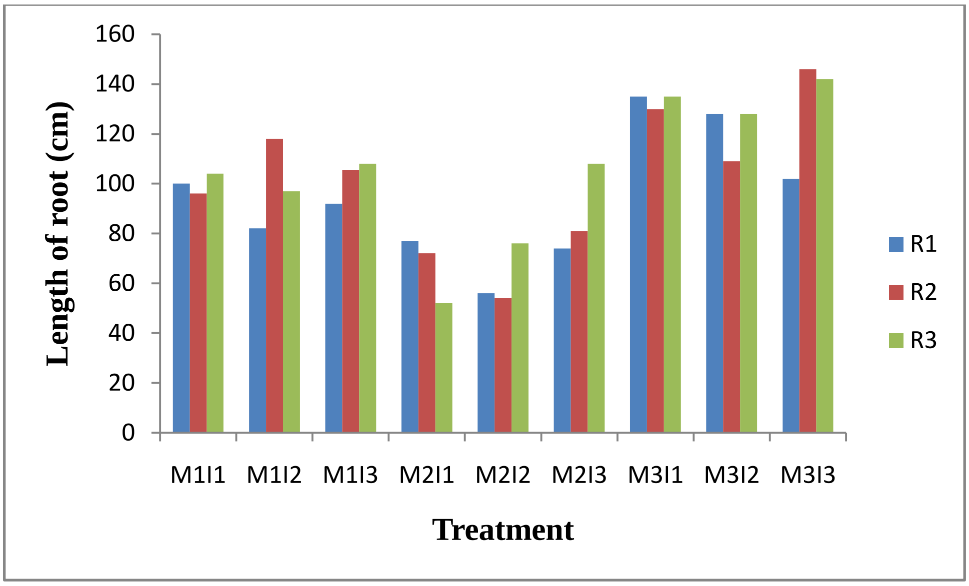


Fig. 8. Length of root for various treatments

Table 10. RBD analysis of length of root

Source	DF	SS	MS	f-ratio	Tab-Val	Remarks
Blocks	2	614	307	1.67	3.36	NS
Treatment	8	15508	1939	10.51	2.59	*
Error	16	2952	184			
Total	26	19074				
*Significant at 5 percent significance level CD=23.51						

From the Table 9. the treatment M_3I_1 reported highest length of root (133.33 cm) and the treatment M_2I_2 reported the lowest length of root (62.00cm). The treatment M_3I_1 is statistically superior to all the treatments under coir pith and sawdust. In the case of coir pith and sawdust, the maximum root length was obtained in the treatments M_1I_3 (100% irrigation level) and M_2I_3 (100% irrigation level) respectively. Most of the applied water was distributed laterally in coir pith and sawdust than soil. In the case of plants grown under coir pith and sawdust, lateral root growth was more compared to soil.

4.4 Effect of irrigation management and growing media on yield of tomato

The various yield characteristics such as total yield per treatment, number of fruits per treatment and average weight were noted and the results are analyzed statistically.

Plate 10. Plants at flowering stage

Plate 11, 12. Plants at fruiting stage

Plate 13. A view of fruits after a single harvest

4.4.1 Total yield

The yield response was highly remarkable under different growing media. The average yields obtained from various treatments were shown in Table 11. and the same is represented graphically in Fig.9.

Table 11. Total yield obtained from various treatments

	R_1	R_2	R_3	Average yield
	g/plot	g/plot	g/plot	g/plot
M_1I_1	468	748	751	655.67
M_1I_2	185	1421	861	822.33
M_1I_3	1075	927	1423	1141.67
M_2I_1	447	94	541	360.67
M_2I_2	198	402	135	245.00
M_2I_3	244	265	275	261.33
M_3I_1	1425	2850	2095	2123.33
M_3I_2	1122	2115	2590	1942.33
M_3I_3	1620	2179	950	1583.00

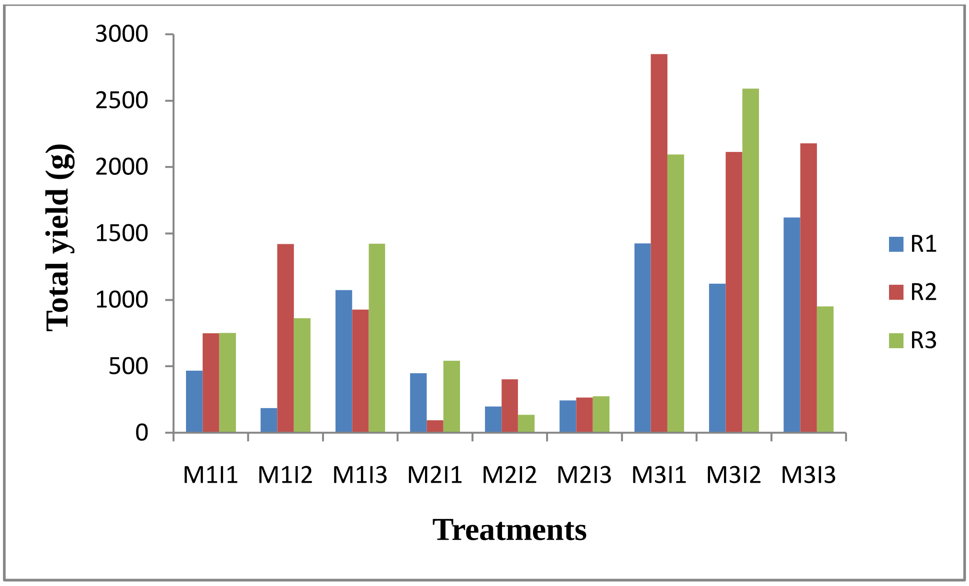


Fig. 9. Total yield obtained from various treatments

Table 12. RBD analysis of yield

Source	**DF**	**SS**	**MS**	**f-ratio**	**Tab-Val**	**Remarks**
Blocks	2	1027262	513631	2.77	3.63	NS
Treatments	8	12546980	1568372	8.46	2.59	*
Error	16	2967894	185493			
Total	26	16542130				
*Significant at 5 percent significance level CD=745.51						

From the Table 11, it can be seen that the treatments under soil (M_3I_1, M_3I_2 and M_3I_3) are statistically superior to all other treatments except M_1I_3. Highest yield obtained in M_3I_1 (2123.33 g/plot) and lowest yield obtained in M_2I_2 (245 g/plot). In case of treatments under coir pith and sawdust, highest yield was obtained in the treatments M_1I_3 (100% irrigation level) and M_2I_1 (50% irrigation level) respectively. There is no significant difference between the treatments M_1I_3 and M_3I_3. It means that at 100% irrigation level the yield obtained from the plants growing in coir pith and soil are similar. Very low yield was obtained in the case of all the treatments under sawdust (M_2I_1, M_2I_2, M_2I_3). This low yield in sawdust may be due to the high lignin content which act as the novel sites for plant growth retardants.

The attack of *Alternaria blight* and *Spodoptera litura* were found highest in the plants grown in coir pith. The yield from the treatments under coir pith is increased with the increase in irrigation water. Eventhough the water holding capacity of coir pith is higher than the other two media, the moisture absorbing rate of the plant from the medium is less. Thus the plant can utilize the water efficiently only if excess water is present in the crop root zone. So water saving cannot be achieved in coir pith.

4.4.2 Number of fruit

The number of fruits harvested from each treatment was found to be highly remarkable under different growing media. The average number of fruits harvested from various treatments was shown in Table 13. and the same is represented graphically in Fig.10.

Table 13. Number of fruits obtained from various treatments

	R_1	R_2	R_3	Average no. of fruits
M_1I_1	21	35	33	29.67
M_1I_2	7	67	33	35.67
M_1I_3	50	36	54	46.67
M_2I_1	10	11	14	11.67
M_2I_2	9	13	7	9.67
M_2I_3	9	7	6	7.33
M_3I_1	28	68	40	45.33
M_3I_2	21	61	74	52.00
M_3I_3	48	68	19	45.00

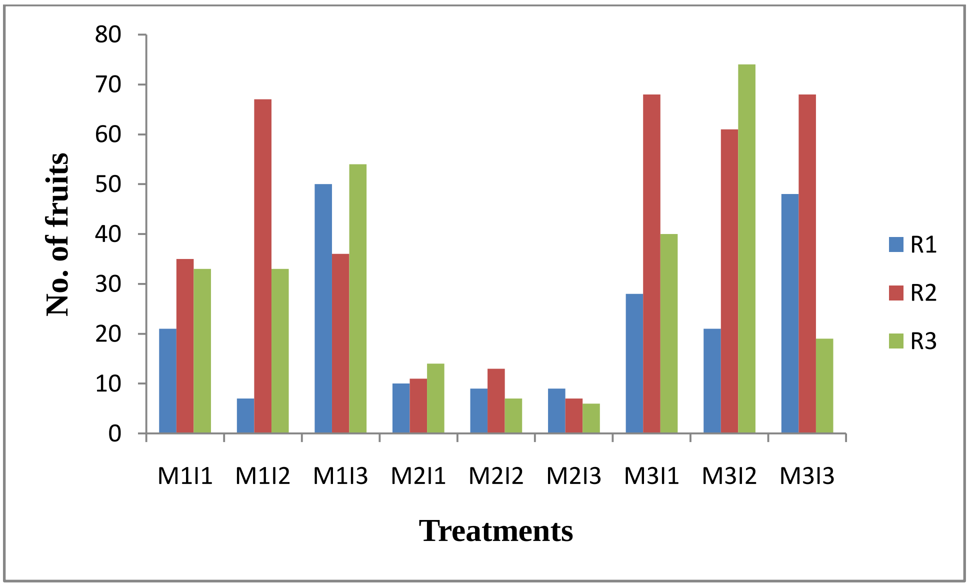


Fig. 10. Number of fruits obtained from various treatments

Table 14. RBD analysis of number of fruits

Source	DF	SS	MS	f-ratio	Tab-Val	Remarks
Blocks	2	1478	739	2.79	3.63	NS
Treatment	8	7496	937	3.53	2.59	*
Error	16	4241	265			
Total	26	13215				
*Significant at 5 percent significance level CD=28.18						

From the Table 13. it is seen that the treatment M_3I_2 is statistically superior to all the treatments under sawdust (M_2I_1, M_2I_2 and M_2I_3). More number of fruits were obtained in the treatment M_3I_2 (soil with 75% irrigation) and less number of fruits were obtained from the treatment M_2I_3 (sawdust with 100% irrigation). In case of treatments under coir pith and sawdust, large number of fruit was obtained in the treatments M_1I_3 (100% irrigation level) and M_2I_1 (50% irrigation level) respectively. There is no significant difference between the treatments under coir pith and soil. Since the yield from the plants grown in sawdust (M_2I_1, M_2I_2 and M_2I_3) is very low, the number of fruits obtained from the treatments are also very less.

4.4.3 Average fruit weight

Similar to the total yield and number of fruits, the average fruit weight also varies in different treatments. The average fruit weight obtained from various treatments was shown in Table 15. and the same is represented graphically in Fig.11.

Table 15. Average fruit weight obtained from various treatments

	R_1	R_2	R_3	Average fruit weight
	g	g	g	g
M_1I_1	22.29	21.37	22.75	22.14
M_1I_2	26.43	21.21	26.09	24.58
M_1I_3	21.50	25.75	26.35	24.53
M_2I_1	44.70	8.55	38.64	30.63
M_2I_2	22.00	30.92	19.29	24.07
M_2I_3	27.11	37.86	45.83	36.93
M_3I_1	50.89	41.91	52.38	48.39
M_3I_2	53.43	34.67	35.00	41.03
M_3I_3	33.75	32.04	50.00	38.60

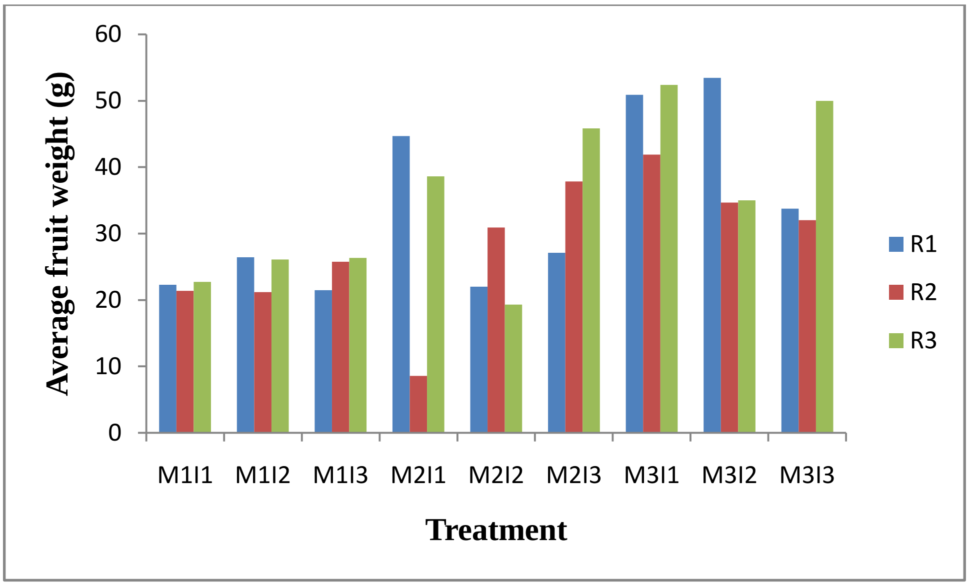


Fig. 11. Average fruit weight obtained from various treatments

Table 16. RBD analysis of average fruit weight

Source	DF	SS	MS	f-ratio	Tab-Val	Remarks
Blocks	2	236	118	1.46	3.63	NS
Treatment	8	2072	259	3.22	2.59	*
Error	16	1289	81			
Total	26	3596				
*Significant at 5 percent significance level					CD=15.53	

From the Table 15. it is seen that in case of average fruit weight the treatments under soil such as M_3I_1 (with 50% irrigation), M_3I_2 (with 75 % irrigation) were statistically superior to the treatments such as M_1I_1, M_1I_2, M_1I_3, and M_2I_2. Maximum fruit weight (48.39g/fruit) were obtained in the treatment M_3I_1, and minimum fruit weight (22.14g/fruit) were obtained from the treatment M_1I_1. In case of treatments under coir pith and sawdust, highest fruit weight was obtained in the treatments M_1I_2 (75% irrigation level) and M_2I_3 (100% irrigation level) respectively. Though the number of fruits from the plants under sawdust (M_2I_1, M_2I_2 and M_2I_3) is very less, the average fruit weight is higher compared to coir pith. This may be due to the low leaching rate of nutrients in the sawdust than the coir pith.

4.5 Determination of Water Use Efficiency

The water use efficiency for different treatment was calculated. The calculation method is shown in APPENDIX V. The water use efficiency values were given in Table 17. and the same is plotted in Fig. 12. The water use efficiency values were highly remarkable under different growing media.

Table 17. Water use efficiency for various treatments

	R_1	R_2	R_3	Average water use efficiency
	(kg/ha mm)	(kg/ha mm)	(kg/ha mm)	(kg/ha mm)
M_1I_1	26	41.55	41.72	36.42
M_1I_2	6.85	52.63	31.89	30.46
M_1I_3	29.86	25.75	39.53	31.71
M_2I_1	24.83	5.22	30.05	20.03
M_2I_2	7.33	14.89	5.00	9.07
M_2I_3	6.78	7.36	7.64	7.26
M_3I_1	79.17	158.33	116.39	117.96
M_3I_2	41.56	78.33	95.93	71.94
M_3I_3	45	60.53	26.39	43.97

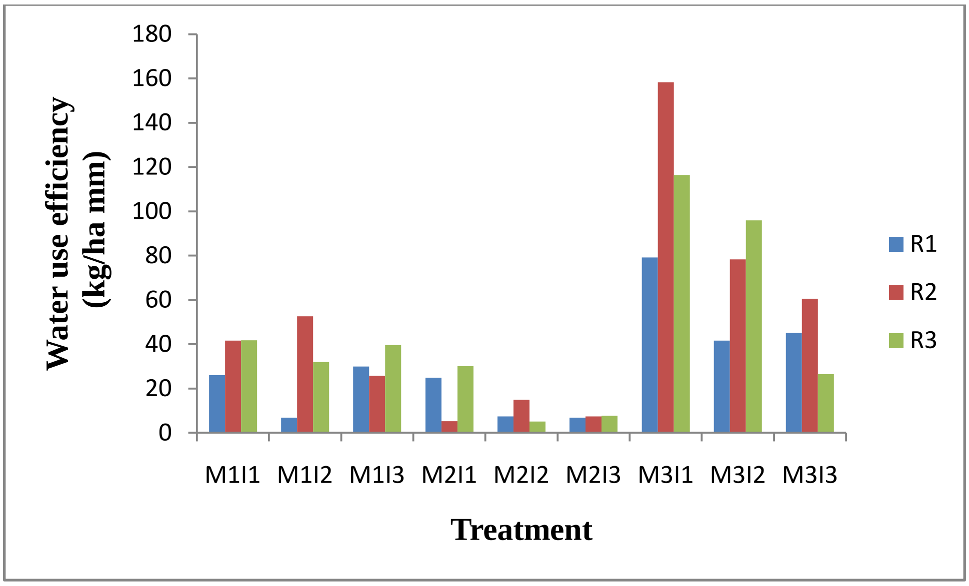


Fig. 12. Water use efficiency for various treatments

The highest water use efficiency (117.96 kg/ha mm) was noted for the treatment M_3I_1 (soil with 50 % irrigation level) and lowest water use efficiency (7.26 kg/ha mm) was noted for the treatment M_2I_3 (sawdust with 100 % irrigation level). For the treatments under coir pith and sawdust also 50 % irrigation level gave maximum water use efficiency. Thus water use efficiency decreased in all the media as the amount of irrigation water increased.

CHAPTER V

SUMMARY AND CONCLUSION

The study entitled “Effect of Drip Irrigation Management and Different Soilless Culture on Growth and Yield of Tomato Grown in Naturally Ventilated Greenhouse” was aimed to determine the effect of different drip irrigation water management strategies on growth and yield of tomato in soil and different soilless culture. This study also helps in determining the optimum water requirement for tomato grown on different soilless culture and soil. The experiment was done at E block of the Instructional Farm KCAET, Tavanur.

The experiment was laid out in randomized block design and the entire area was divided into 27 plots having nine treatments with three replications for each treatment inside the naturally ventilated greenhouse. Here different levels of irrigation were practiced by drip irrigation for 27 plots.

From the water requirement calculation, the average water requirement for the crop for the entire crop period is taken as 2 litre/day/plant. It was found that drip irrigation has a positive effect on growth and yield of crop of different media having different level of irrigation. Crops drip irrigated at the rate of 50%, 75% and 100% of the total crop water requirement to all the three media.

From our study the major observations obtained can be concluded as below

- The textural properties of all the three growing media are similar, but there is a drastic difference in the water holding capacity. This may be due to the high porosity and low bulk density of soilless media compared to soil.

- Crop inside the green house under soil with 50 % irrigation level gave highest yield (2123.33 g/plot) rather than 75% and 100% irrigation levels. In the case of crops grown in coir pith and sawdust, maximum yield is obtained for 100% and 50% irrigation levels respectively. The low yield in sawdust may be due to the high lignin content which act as the novel sites for plant growth retardants.

- Maximum number of fruits is obtained in M_3I_2 (soil with 75% irrigation level) but the maximum value of average fruit weight (48.39 g/fruit) is obtained for M_3I_1 (soil with 50% irrigation level) which gave an average of 46 fruits. It means healthier fruit obtain in 50% irrigation level. Comparing all the treatments, minimum number of fruits was obtained for the treatments under sawdust but the average weight of the fruits from these treatments was more compared to coir pith. This may be due to the high leaching rate of sawdust compared to coir pith.

- Treatments with 50 % irrigation level performed well with highest water use efficiency of 117.96 kg/ha mm for soil (M_3I_1), 36.42 kg/ha mm for coir pith (M_1I_1) and 20.03 kg/ha mm for sawdust (M_2I_1) which indicate that maximum yield at 50% irrigation level. Thus water use efficiency decreased in all the media as the amount of irrigation water increased.

- From the observations taken after 15 days of transplanting, plants grown in coir pith gave highest plant height. But, after 45 days and 75 days of transplanting, plant height was found maximum for plants grown in soil. The presence of high lignin content in soilless media may also contribute to low plant height.

- Length of root found maximum in the treatment under soil with 50% irrigation level (133.33 cm). In the case of plants grown under coir pith and sawdust, the maximum root length was obtained in the treatments with 100% irrigation level. For plants grown under coir pith and sawdust, lateral root growth was more compared to soil.

- The yield from the plants grown in coir pith is increased with the increase in irrigation water. Eventhough the water holding capacity of coir pith is higher than the other two media, the moisture absorbing rate of the plant from the medium is less. Thus the plant can utilize the water efficiently only if excess water is present in the crop root zone. So water saving cannot be achieved in coir pith.

- So 50% irrigation level is best suited for tomato cultivation of LE-66 Variety through drip irrigation in soil and sawdust. Sawdust may perform best in case of yield, growth and water use efficiency, if the irrigation level is reduced to less than 50% since they have more water holding capacity. The overall performance of sawdust is very less compared to soil. This may be due to the fact that we are over irrigating the crop. This will clarify when we take separate study of different irrigation level (less than 50%) for sawdust which will increase tomato production in quality and quantity.

- Thus for achieving maximum production under soilless culture further studies are required using different combinations of the soilless growing media.

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APPENDIX I

Determination of bulk density by core cutter method

Sl.No	Particulars	Coir pith	Sawdust	Soil
1	Mass of core cutter + wet sample (M_1), g	1882.00	1890.50	3089.50
2	Mass of core cutter (M_2), g	924.00	981.00	1074.00
3	Mass of wet sample (M_3), g	958.00	909.50	2015.50
4	Volume of core cutter (V_1), cc	926.02	989.10	1012.65
5	Bulk density (M_3/V_1), g/cc	1.03	0.92	1.99

APPENDIX II

Determination of dry density from bulk density and moisture content

Sl.No	Particulars	Coir pith	Sawdust	Soil
1	Mass of container + wet sample (M_1), g	43.00	35.50	74.00
2	Mass of container (M_2), g	26.50	21.50	34.50
3	Mass of wet sample (M_3), g	16.50	14.00	39.50
4	Moisture content, %	371.43	180.00	17.91
5	Bulk density, g/cc	1.03	0.92	1.99
6	Dry density, g/cc	0.22	0.33	1.69

APPENDIX III

Grain Size Distribution of the media (Sieve analysis)

Coir pith

Sl No.	IS Sieve	Particle size	Mass retained	% Retained	Cumulative % retained	Cumulative % finer
		mm	g			
1	4.75 mm	4.750	-	-	-	100.00
2	2.00 mm	2.000	49.00	16.33	16.33	83.67
3	1.00 mm	1.000	35.50	11.83	28.16	71.84
4	600 µm	0.600	51.50	17.17	45.33	54.67
5	425 µm	0.425	38.00	12.67	58	42.00
6	300 µm	0.300	41.50	13.83	71.83	28.17
7	212 µm	0.212	58.00	19.33	91.16	8.84
8	150 µm	0.150	8.50	2.83	93.99	6.01
9	75 µm	0.075	14.00	4.67	98.66	1.34
10	Pan	-	3.00	1.00	99.66	0.34

Saw dust

Sl No.	IS Sieve	Particle size	Mass retained	% Retained	Cumulative % retained	Cumulative % finer
		mm	g			
1	4.75 mm	4.750	-	-	-	100.000
2	2.00 mm	2.000	10.00	2.500	2.500	97.500
3	1.00 mm	1.000	10.50	2.625	5.125	94.875
4	600 µm	0.600	60.00	15.000	20.125	79.875
5	425 µm	0.425	102.50	25.625	45.750	54.250
6	300 µm	0.300	123.00	30.750	76.500	23.500
7	212 µm	0.212	64.00	16.000	92.500	7.500
8	150 µm	0.150	6.50	1.625	94.125	5.875
9	75 µm	0.075	20.00	5.000	99.125	0.875
10	Pan	-	2.50	0.625	99.750	0.25

Soil

Sl No.	IS Sieve	Particle size	Mass retained	% Retained	Cumulative % retained	Cumulative % finer
		mm	g			
1	4.75 mm	4.750	-	-	-	100.00
2	2.00 mm	2.000	43.00	4.30	4.30	95.70
3	1.00 mm	1.000	72.00	7.20	11.50	88.50
4	600 µm	0.600	82.00	8.20	19.70	80.30
5	425 µm	0.425	63.00	6.30	26.00	74.00
6	300 µm	0.300	88.4	8.84	34.84	65.16
7	212 µm	0.212	375.00	37.50	72.34	27.66
8	150 µm	0.150	45.50	4.55	76.89	23.11
9	75 µm	0.075	158.50	15.85	92.74	7.26
10	Pan	-	67.50	6.57	99.31	0.69

APPENDIX IV

Moisture depletion pattern for soilless media

Days	Moisture content (%)	
	Coir pith	Sawdust
1	453.22	226.79
2	447.52	214.68
3	438.11	180.89
4	435.35	154.96
5	409.47	153.49
6	401.98	151.23

APPENDIX V

Air temperature inside greenhouse compared to open field during the crop period

	Temperature (^oC)	
	Outside greenhouse	Inside greenhouse
April	30.5	33.0
May	31.7	33.5
June	28.0	29.5
July	26.3	27.6
August	27.4	29.4
September	29.9	31.4

APPENDIX VI

Determination of water use efficiency for each replica

Replication I

Treatment	Area (m^2)	Yield	Water used	Water used	Water used	Water use efficiency
		(kg/ha)	(litres)	(litres/ha)	mm	(kg/ha mm)
M_1I_1	1.44	3250.00	180	1250000	125.00	26
M_1I_2	1.44	1284.72	270	1875000	187.5	6.85
M_1I_3	1.44	7465.28	360	2500000	250.00	29.86
M_2I_1	1.44	3104.17	180	1250000	125.00	24.83
M_2I_2	1.44	1375.00	270	1875000	187.50	7.33
M_2I_3	1.44	1694.44	360	2500000	250.00	6.78
M_3I_1	1.44	9895.83	180	1250000	125.00	79.17
M_3I_2	1.44	7791.67	270	1875000	187.50	41.56
M_3I_3	1.44	11250.00	360	2500000	250.00	45

Replication II

Treatment	Area (m^2)	Yield	Water used	Water used	Water used	Water use efficiency
		(kg/ha)	(litres)	(litres/ha)	mm	(kg/ha mm)
M_1I_1	1.44	5194.44	180	1250000	125.00	41.55
M_1I_2	1.44	9868.05	270	1875000	187.5	52.63
M_1I_3	1.44	6437.50	360	2500000	250.00	25.75
M_2I_1	1.44	652.78	180	1250000	125.00	5.22
M_2I_2	1.44	2791.67	270	1875000	187.50	14.89
M_2I_3	1.44	1840.28	360	2500000	250.00	7.36
M_3I_1	1.44	19791.67	180	1250000	125.00	158.33
M_3I_2	1.44	14687.5	270	1875000	187.50	78.33
M_3I_3	1.44	15131.94	360	2500000	250.00	60.53

Replication III

Treatment	Area (m^2)	Yield	Water used	Water used	Water used	Water use efficiency
		(kg/ha)	(litres)	(litres/ha)	mm	(kg/ha mm)
M_1I_1	1.44	5215.28	180	1250000	125.00	41.72
M_1I_2	1.44	5979.17	270	1875000	187.5	31.89
M_1I_3	1.44	9881.94	360	2500000	250.00	39.53
M_2I_1	1.44	3756.94	180	1250000	125.00	30.05
M_2I_2	1.44	937.50	270	1875000	187.50	5.00
M_2I_3	1.44	1909.72	360	2500000	250.00	7.64
M_3I_1	1.44	14548.61	180	1250000	125.00	116.39
M_3I_2	1.44	17986.11	270	1875000	187.50	95.93
M_3I_3	1.44	6597.22	360	2500000	250.00	26.39

ABSTRACT

The present project was to study the effect of drip irrigation management under soil and different soilless media such as coir pith and saw dust for the crop tomato growing inside a naturally ventilated greenhouse. The experiment was laid out in randomized block design and the entire area was divided into 27 plots having nine treatments with three replications for each treatment. The average water requirement for the crop for the entire crop period is taken as 2 litre/day/plant. Crops were supplied with drip irrigation at the rate of 50%, 75% and 100% of the total crop water requirement to all the three media.

The crop inside the naturally ventilated greenhouse in the soil with drip irrigation of 1.0 l/day/plant (50 % irrigation level) performed well during the experiment with a water use efficiency of 117.96 kg/ha mm and average yield of 14.81 t/ha. The crops in the soil media give higher yield than the soilless media. In case of coir pith, the treatment with 2.0 l/day/plant (100 % irrigation level) recorded the highest yield (7.93 t/ha) where as in sawdust the highest yield (2.50 t/ha) is obtained for the treatment having 1.0 l/day/ plant irrigation.

The highest water use efficiency values were obtained for treatments with drip irrigation of 1.0 l/day/ plant for all the growing media. So 50% irrigation level in soil is found to be best suited for tomato cultivation of LE-66 Variety through drip irrigation.