Standardization of Soilless Media and Irrigation Schedule for Improving Yield and Quality of Tomato in UV Stabilized Polybags Under Polyhouse

A

Thesis

Submitted to

For the award of

DOCTOR OF PHILOSOPHY

in

VEGETABLE SCIENCE

Supervised By
Dr. Shailesh Kumar Singh

Submitted By
Ranjit Singh Spehia
(41400716)

LOVELY FACULTY OF TECHNOLOGY ANDSCIENCES
LOVELY PROFESSIONAL UNIVERSITY
PUNJAB

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To Madhu

for her advice, her patience and her faith

because she always understood

CANDIDATE'S DECLARATION

I hereby declare that this thesis
or part thereof has not been submitted
by me or other person
to any other university or institute
for a degree or diploma.

Place: LPU, Phagwara
Date: **(Ranjit Singh Spehia)**

Dr Shailesh Kumar Singh
Associate Professor
Department of Horticulture
Lovely Professional University, Punjab

CERTIFICATE

This is to certify that the thesis entitled"**STANDARDIZATION OF SOILLESS MEDIA AND IRRIGATION SCHEDULE FOR IMPROVING YIELD AND QUALITY OF TOMATO IN UV STABILIZED POLYBAGS UNDER POLYHOUSE"**submitted to the faculty of Technology and Sciences, Lovely Professional University, Phagwara, Punjab in partial fulfilment of the requirement for the degree of DOCTOR OF PHILOSOPHY IN VEGETABLE SCIENCE embodies the results of a piece of bonafide research carried out by SH. RANJIT SINGH SPEHIA under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma or published in any other form. All the assistance and help received during the course of investigation and the sources of literature have been duly acknowledged by him.

Place: **Dr. Shailesh Kumar Singh**
Date: **(Supervisor)**

SCHOOL OF AGRICULTURE
LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA

Title	**:**	Standardization of Soilless Media and Irrigation Schedule For Improving Yield and Quality of Tomato inUVStabilizedPolybags Under Polyhouse
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Year of Admission	**:**	2014
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ABSTRACT

The present investigation was conducted at Precision farming development Centre, Department of Soil Science and Water Management, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during March- Octoberin 2016 and 2017.The experiment was laid out in Completely Randomized Design (Factorial) and the treatments, 24 in all, were replicated thrice. Different soilless media (Cocopeat, vermicompost and vermiculite) and their combinations along with different levels of irrigations (50, 75, 90 and 100 % crop evapotranspiration (ET_c) and irrigation intervals (daily and on alternate days) were used as the treatments of the study with the objectives of determining best soilless growing media along with standardizing frequency and amount of irrigation and to work out cost economics of same under protected conditions. The study resulted in increase in plant height (33.68 %), number of fruits per plant (29.81 %), fruit weight (34.82 %) and yield (77.80 %) along with higher nutrient uptake of N (104.07 kg ha^{-1}), P (128.87 kg ha^{-1}) and K (105.51 kg ha^{-1}) under the treatment containing cocopeat + vermicompost (70:30, w/w) with irrigation at 50 per cent ET_c on daily basis over control treatment of cocopeat, alone, with irrigation at 100% ET_c on daily basis. Water use efficiency was recorded highest (119.68t ha^{-1} cm^{-1}) under cocopeat + vermicompost (70:30 w/w) with irrigation at 50 per cent ET_c on daily basiswhereas, it

was lowest (33.93t ha^{-1} cm^{-1}) under cocopeat, alone, with irrigation at 100% ET_c on daily basis. Highest Benefit cost ratio (2.76:1)was observed in the media combination of cocopeat + vermicompost (70:30, w/w) while lowest (0.93:1) in the media combination of vermiculite + vermicompost (70:30, w/w).

Based on the results, soilless culture with cocopeat + vermicompost (70:30, w/w) irrigating at 50 % ET_c on daily basis can be recommended to the farmers for improving quality and yield characteristics besides increasing water use efficiency and benefit cost ratiofor tomato cultivation under protected environment.

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I also thank Management, LPU, for giving me this opportunity to complete my cherished dream of accomplishing highest degree in my subject.

Dated: **(Ranjit Singh Spehia)**

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LIST OFABBREVIATIONS

Abbreviation		Meaning
%	:	Per cent
@	:	at the rate
°C	:	Degree celcius
C.D.	:	Critical difference
cm	:	Centimeter
cm^2	:	Square centimeter
et al.	:	*Et allii* (Co-workers)
EC	:	Electrical conductivity
ETc	:	Evapotranspiration of crop
CRD	:	Complete Randomized Design
Fig.	:	Figure
g	:	Gram
Ha	:	Hectare
Ha^{-1}	:	Per hectare
i.e.	:	That is
kg	:	Kilogram
K	:	Potassium
Km	:	Kilometer
L.	:	Linneous
m	:	Meter
mg	:	Milligram
ml	:	Milliliter
N	:	Nitrogen
No.	:	Number
NS	:	Non-significant
P	:	Phosphorus
ppm	:	Parts per million
TSS	:	Total Soluble Solids
T	:	Ton
t/ha	:	tons per hectare
WUE	:	Water Use Efficiency

Chapter-1

INTRODUCTION

Tomato (*Solanum lycopersicum* L.), a member of Solanaceous family having chromosome number 2n=24, is important vegetable crop grown world over (Rick, 1969). Ithas its center of origin in Peru (Vavilov, 1951). Tomato is consumed widely in many ways and is second most important Solanaceous crop after potato. It has large number of varieties for open as well as greenhouse conditions. It is basically a perennial crop but grown mostly as an annual. Globally, 182.30 million MTtomato is produced in an area of 4.84 million ha while Indiaproduces 20.71 million MT tomato under 0.70 million ha area with productivity level of 29.58 t/ha. China ranks first with 31 per cent of world production while India and United States rank second and third, respectively(Anonymous, 2017). The fruits are eaten in varied ways, as raw in fast foods or cooked as a vegetable (Joshi and Kohli, 2006). Water (95 per cent), carbohydrates (4 per cent) with less than one per cent protein and fats constitute a tomato fruit.Its importance as protective food cannot be underestimated due to supply of vitamin A and C and antioxidants like lycopene which helps in preventing cancer (Bhutani and Kallo,1983).

Generally, tomato production is done under severe weather conditions limiting its genetical capabilities. Though, soil of uniform texture and high nutrient status is least expensive medium for plant growth, but soil does not always occur in perfect package under field conditions. Therefore, farmers prefer tomato production under protected conditions to get higher and better yield. Moreover, higher returns per unit of land, extended crop growth period leading to a greater number of harvests in addition to early harvests also make protected cultivation a better prospective.Protected cultivation in Himachal Pradesh is being undertaken in 223.18 hectares with 150 hectares area under vegetable production (Spehia, 2015).

To overcome limitations of soil production system (soil born pests and other chemical and biological heterogeneity), growing media without soil, can be an important component for better crop production under protected conditions. Soilless media is becoming popular for successful cultivation under protected condition due to numerous benefits. The characteristics of ideal growing media for successful cultivation of tomato includes better aeration, water holding along with drainage besides biological and chemical stability. Soilless culture provides precise control over water application andother production factors keeping pH, root temperature, etc. in control along with increased productivity and better cost benefit ratio(Tuzel*et al*., 2008). The standardization of best media may help in recommending the same to the farmers which will further improve economic viability of producing vegetable crops under protected cultivation.

Cocopeat has the property of increasing the water availability of the potting mix as it increases the porosity and is free from soil borne pathogens with slightly acidic pH (5.7-6.5), that is ideal for plant growth. Cocopeat delays flowering and keeps humidity high in the medium (Rahbarian and Sardoei, 2014). The root growth of plants in cocopeat mix is better, enabling higher uptake of water and nutrients. Vermicompost, when addedproportionately to potting mixture produces significantly positive effects on quality and yield contributing traits.

Vermicompost is a byproduct of degradation of organic matter when it passes through earthworms (Edwards and Burrows, 1988). It is rich in major and minor nutrients resulting in positive effect on biochemical processes in plant. Humic acid percentage is also high in vermicompost, promoting synthesis of phenolic compounds which help in making the plant resistant to biological stresses (Theunissen*et al*., 2010).

Vermiculiteis a hydrated magnesium aluminum silicate mineral and used as a moisture retentive media for growing plants as the physiological processes ofvegetables are enhanced, when produced in inert growing media compared to soil. The same have been recommended by several researchers for yield enhancement of vegetables compared to organic growing media (Olle *et al.,* 2012).

Drip irrigation system helps in assured production with minimum water usage and is preferred over conventional irrigation methods due to its superiority in achieving almost 90% water use efficiency(Santosh *et al.,* 2017). To manage plant water stress, it is necessary to schedule irrigation carefully. Crop water requirements (CWR) are a function of crop characteristics, management, and environmental demands. CWR refers to the irrigation water required to overcome losses from evapotranspiration (ET) during a specified period. The CWR can be used for estimating and scheduling irrigation water requirement. Water is applied through drip irrigation under protected conditions for better crop management, for which specific amount of water is required. Drip irrigation helps in timely and precise application of water to meet the crop evapotranspiration (ETc). As crops under protected conditions are required to be healthy and it is imperative that exact amount of water and fertilizers are applied to the plant. Tomato is being grown in soilless media under protected conditions but the optimization of irrigation requirement under different growing media is still not defined. Under open field conditions per hectare water requirement ranges from 22.3 cm to 34.97 cm (Raina *et al.*,1999 and Santosh *et al.*, 2017). However, in polyhouse, 22.65 cm of irrigation is required in soil as growing media (Santosh *et al.*, 2017). Since, ET inside polyhouse is considerablylower than outside, the water requirement per plant also decreases significantly. However, the level of irrigation may vary according to the growing media as water holding capacity of different growing media varies according to the building material. Therefore, the irrigation levels need to be optimized for effective plant growth and saving precious natural resources under protected conditions as effect of wind and rain is negligible, the frequency of irrigation also needs to be optimized based upon water retention capacity of the growing media. The frequency of irrigation depends upon uptake of plants and percolation of water beyond root zone. Moreover, optimization of frequency may help in avoiding over irrigating the crop. However, no significant literature is available for irrigation levels and frequency of irrigation underdifferent growing media except for soil (Ismail *et al.*, 2007; Xiukang, and Yingying, 2016). Therefore, there is an urgent need of standardizing irrigation levels and frequency for tomato under different growing media. So that tomato production can be maximized with minimal amount of available water. As such to establish best media and irrigation practices for tomato production in UV stabilized grow bags the present studies were undertaken.

Chapter-2

REVIEW OF LITRATURE

The present investigation entitled **"Standardization of soilless media and irrigation schedule for improving yield and quality of tomato in UV stabilized polybags under polyhouse"**was carried out at the experimental field of Department of Soil Science and Water Management, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during the year 2016 and 2017. The study was proposed to determine the influence of soilless media and irrigation scheduling on tomato production. The pertinent literature has been reviewed as follows:

1. Soilless growing media

Effect of peat as a growing medium was investigated by Luoto (1984) to determine texture and colour of tomatoes by sensory evaluation and by chemical analysis and observed that dry matter content, pH and acidity along with quality of tomato was significantly affected bythe growing medium. Luoto recorded redder, softer and tastier tomatoes under peat with best taste at the beginning of the harvesting season.

Gul and Sevgican (1992) recorded early and higher yield in tomato grown under different combinations of growing media when compared toproduction under soil.

Abak and Celikel (1994) compared some organic and inorganic media for tomato cultivation under greenhouse. Media used for comparison were spent mushroom compost, volcanic tuff, peat in comparison to rockwool and soil. Highest yield (25 kg/m^2) was obtained under peat followed by rockwool (23.3 kg/m^2). The observed properties of substrate and leaves revealed that spent mushroom compost and peat can be used successfully forgrowing greenhouse tomatoes.

Alan *et al.* (1994) studied influence of different growing media and their combinations on tomato production. They observed 30% more produce with a mixture of pumice: perlite : peat (80:10:10) mediumin comparison to the soil. However, qualitative contents varied amongst treatments with highest ascorbic acid under perlite; higher total soluble solids concentration were observed under peat whilehigher acidity was observed under sand while qualitative traits were observed maximum in growing media containing 50% pumice + 50% sand.

Assche and Vangheel (1994) studied the changed techniques in West European agriculture and horticulture over decades and opined that deterioration in soil health due to monocultures is leading to new issues and problems with an explosive growth of hydroponics and substrate culture.

Gul and Sevgican (1994) evaluated various substrates for growing tomato under greenhouse. Different substrates used were perlite, sand, peat, lava rock (kula), sawdust, decomposed or grounded *Pinus brutia* bark. The fruits mature earlier in soilless media compared to soil. TSS, acidity and fruit size were significantly greater in the growing media compared to soil medium. Maximum yield was observed from the plants grown in peat -sand (1:1), lava rock, perlite and perlite – sand, respectively. Total increase in yield compared to soil was higher in perlite -sand (165.2 %) in first harvesting and in peat-sand in 2nd, 3rd and 4th harvesting to the tune of 76.5%, 25.4% and 13.8 %, respectively.

Permuzic *et al.* (1998) observed better qualitative (highest TSS in coco-peat) and quantitative traits (maximum fruit number in perlite and rough rice media)in tomato fruit under organic medium compared to inorganic medium.

Atiyeh *et al.* (1999) compared 100% vermicompost as a growing media to commercial medium(100%)and recorded significant growth in plant height and root and shoot biomass with 50% substitution of vermicompost for the same amount of commercial medium. Moreover, improved plant growth and yield per plantover unamended mediumwas also observed withsubstitution of 20 % vermicompost in cocopeat.

Lee *et al. (*1999) observed 6.0° Brixincrease in sugar contents in the fruits under rice hull when formulated rice hull;perlite (fine and coarse granule);carbonized rice hull and peatmosswere tested for suitability of growing media in tomato.
Madrid *et al*. (1999) investigated the influence of inorganic substrates on the development of colour along with minimum maturity in two varietiesof red pepper (*Capsicum annuum* L.) fruits and observed higher values with sand than perlite.

Ymeri *et al.* (1999) evaluated substrate (Perlite: zeolite (2:1)) along with slow release fertilizers (SRF) @ 30, 60 and 90 g/plantfor growth and quality parameters of tomato and recorded highest yield but low TSS and titratable acidity under substrate with 30 or 60 g of slow release fertilizers and least under plants grown on 90 g SRF.

Atiyeh *et al.* (2000) studied the influence of substituting commercial greenhouse medium (Metro-mix 360)with different levels (100%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20% and 10%, v/v) of earthworm-processed pig manure (vermicompost) on germination and performance of tomato (*Lycopersicon esculentum* Mill.) under glasshouse withMetro-Mix 360 alone as control. They recorded maximum yield and fruit weightwhen Metro-Mix 360 was substituted with 20% vermicompost.

Ribeiro *et al.* (2000) applied 600 g/pot vermicompost @ 12 t/ha; 1000 g/pot cattle manure @ 20t/ha with and without NPK or alone to sweet pepper (*Capsicum annuum*) cv. Nacional AG 506 under greenhouse conditions and recorded greater yield with organic fertilizer than mineral fertilizer and observed no significant effect with addition of NPK.

Uzun *et al*. (2000) recorded improved performance of some vegetable cropsunder sand:FYM:rice husk substrate in unheated glasshouse during late autumn season.

Yau and Murphy (2000) recorded increase in plant height (2.90 m), number of fruits/plant (70.5) and fruit yield (2.95 kg/plant) of tomato under biodegraded cocopeat as growing medium.

Atiyeh *et al.* (2001) studied vermicompost prepared from pig manure and growth medium Metro-Mix 360 as a growing media fortomato production. Only vermicompost reduced plant growth, possibly due to poor aeration, porosity and high soluble salt concentrations.However, when Metro-Mix 360 was substituted with 25% and 50% vermicompost along with fertigation, tomato seedlings exhibited better growth than in control (no fertilizer applied). Substrate mixtures exhibited increased plant growth due to the combined effects of improved porosity, aeration and water retention combined with high nitrate content.

Nurzynski *et al.* (2001) studied the influence of rockwool, brown peat and sand growing media on tomato cultivar Cunerowith same amount of fertigation in all media and recorded lower fruit yield along with 89.4, 51.2, 30.8 and 43.9% lower content of nitrogen, potassium, calcium and magnesium, respectively, under sand after 9month cultivation period.

Growing media of perlite:peat and perlite produced higher total yield of tomato than volcanic ash,pumice,pumice:peat and volcanic ash:peat (Tuzel*et al.,* 2001). The substrate containing perlitemixtures had significant effect on performanceof tomato while harvest was delayed under coco peat alone (Traka-Mavrona*et al.,* 2001).

Apahidean *et al.* (2002) undertook a study to evaluate substrates of different compositions in polythene bags for tomato production in polyhouse. New mixture consisted of brown peat (80%): long duration fallow soil:well decomposed manure (20%) added with primary and secondary nutrients. They observed maximum plant and fruit parameters when the new mixture was used alone or with 50 per cent partite along with irrigation with 8 liters water/plant.

Gunadi *et al*. (2002) observed increased marketable pepper fruits (30%) under inorganic fertilizer added with vermicompostin field trials compared to application of inorganic fertilizer, alone.

In tomato fruits, the dry matter content was higher under cocvita than rockwool but content of sugars and ascorbic acid was no affected by growing medium in tomatoes grown on cocovita containing lesser nutrients (Kobryn, 2002).

Arancon *et al.* (2003) treated the inorganically fertilized experimental plots with vermicompost to studyyield and quality of strawberries,tomatoes and peppers and observed greater marketable fruits of tomato in all plots treated with vermicompost than from only inorganic plots.Increase in shoot weight, leaf area and total fruit yield were observed in pepper and strawberry in the same treatment. They concluded thatvermicompost applications increased the soil microbial biomass which could be the probablecause as it might have led to production of chemicals in the vermicompost, that might have acted as growth promoting regulators independent of nutrient supply.

Cantliffe *et al*. (2003) recorded performance of different soilless media (peat, coarse perlite, pine bark) and their combinationsfor greenhouse grown peppers and observed that the media containing peat mix (peat: perlite (2:1)) produced higher percentage of marketable pepper fruitregardless of growing system or plug type.

Grazia *et al*. (2004) evaluated growth and quality of sweet pepper seedlings under irrigation regimes of 12, 24 and 48-hour intervals in two peat-based substrates mix viz. 60 % peat + 40 % perlite and 45 % peat + 30 % perlite + 25 % compost and each of them was amended with polymers. Earliness, uniformity and seedling size improved by polymer addition, especially for the substrate without compost. Seedlings grown on this type of substrate had also smaller shoot: root ratio while seed quality improved by addition of polymers.

Hashemimajd *et al.* (2004) mixed different proportions (0, 15, 30 and 45%) of vermicompost prepared from dairy manure (RDM)of pot volume in compostproduced from tobacco residue ; yard leaf; sewage sludge:rice hull; sewage sludge:yard leafand RDMto study its effect on tomato growth and found all potting mixtures to be better than the control (soil + sand) and raw dairy manure in respect of biomass production.

Inden and Torres (2004) evaluated performance of tomato plant undergrowing mediaviz.rockwool (R);perlites:carbonized rice hulls (PCRH); Cyprus bark (CB) and coconut coir (CD)under polyhouse. They concluded thatnumber of fruits/cluster and productivity was highest underCD followed by PCRH treatment.

Janet *et al.* (2004) found no effect of growing media on precocity of flowering but observed significance in yield and fruit weight of tomato under organic growth media viz. $0M_1$-85% Fafards special organic mix (peat/ pine bark); OM_2-63% coconut coir:composted pine bark; OM_3-85% Fafards special organic mix (P/PB): 22% composted pine bark; OM_4-63% coconut coir:15% vermicompost; OM_5-85% special organic mix:15% vermicompost; OM_6-100% special organic mix:natural wet soil.

Zhang and He (2005) undertook an experimentwithten different treatment combinations of soilless culture to determine its effecton the successful production of tomato cultivar Zhongza No.9. Substrate containing manure: sawdust (25%:75%) recorded maximum ascorbic acid (16.9 mg/100 g), reducing sugar (4.55%), soluble solids (6.4%) and highest number of fruits/plant (26.3), yield/plant (3.81 kg) while manure: maize stalk (25%:50%:25%) vermiculite recordedmaximum fruit weight (146g) and least blossom end rot incidence (2.0%), whereas most lycopene content (48.5 mg/100 g) was observed undermanure:maizestalk:mushroom residue (25%:50%;25%).

Hashemimajd *et al.* (2006) recommended replacing other substrates including peat withvermicompost as a potting media. Bulk density and particle density decreased but increased the water holding capacity when vermicompost was mixed with other potting media. The performance of tomato seedlings was also affected by the source of vermicompost.

Haddad (2007) observed taller plantsand increase in fresh weight of tomato fruits when grown in sand substrate compared to perlite or stone pumice while Lee *et al.* (2007) observed better growth of red pepper plug seedlings in peatmoss based substrates .

Roberts *et al.* (2007) concluded that the proportion of vermicompost amendment to potting mixtureshould depend upon variety as type of crop or cultivar used also behaves differently to the vermicompost percentage.

Zaller (2007a) tried amendment of peat potting substrate with 0, 20, 40, 60, 80 and 100% (v/v) of vermicompost (VC) to assess its impact on tomato seedlings under controlled conditions andeffecton yield and fruit quality when transplanted into equally fertilized field soil. Vermicompost additions significantly influencedroot: shoot ratio along though yield parameters were not affected by VC additions.

Zaller (2007b) concludedthat peat can be replaced by vermicompost in potting media as an environment friendly substitute after assessing the impact of vermicompost on the performance of tomato varieties. Vermicompost amendments significantly influencedemergence but no effect was observed on yield.

Peat based growing media, aloneand with coco's derivatives were compared to mineral wool for rooting and yield of tomato plants. Results revealed that tomato plants rooted more easily when grown in the pure peat than under other medias. However, yield showed no effect of media (Grunert *et al.*, 2008).

Al-Ajmi *et al.* (2009) reported highest performance related to yield and fruit quality of cherry tomato with zeolite alonewhen different inorganic substrates (sand (S); perlite (P); zeolite (Z) and mixtures (v/v) of P:S (2:1), Z:P (1:1), Z:S (1:1) and Z:P:S (1:1:1))were tried, which may probably be related to its high water holding capacity and cation exchange capacity.

Flores *et al*. (2009) studied the nutritional quality and antioxidant activity of pepper under organic, low-input and soilless cultures and observed higher phenolic and sugarsunder soilless culture.

Gruda (2009) observed higher yields and quality of tomatoes when grown in soilless substrates in all growing conditions including in areas where crop production is not feasible.Hanna (2009) reported higher total marketable yield for tomato plants in perlite than plants grown in pine bark or rockwool.

Sharma *et al.* (2009) reported soil: vermicompost: sand (2:1:1) as best media for increased yield (8.33 kg/plant)along with fertigation @ 300 kg NPK/hafor growing cucumber in naturally ventilated polyhouse in mid hills of Himachal Pradesh during August-December and February-June.

Kurubetta and Patil (2009) evaluated capsicum hybrids *viz.*, Orobelle, Bomby and Indra under different types of protected structures viz. naturally ventilated polyhouse (NVP), naturally ventilated shadow hall, shade house with misting and shade house without misting. NVP recorded precocity in flowering (33.00 days) and harvesting (86.00 days) along with the quality charactershigher than naturally ventilated shadowhall.

Mohammed *et al*. (2009) conducted an varietal evaluation of bell pepper to gauge the impact of substrates viz. peat moss:perlite(1:1)as control; peat moss:perlite: vermicompost (2:2:1) and peat moss:perlite:vermicompost:cocopeat(1:4:3:2) and observed that growing media containing peat moss and perlite performed best for growing bell pepper.

Borji *et al.* (2010) evaluated four types of substrate i.e. cocopeat, perlite and two types of date-Palm (with and without fermentation); perlite;cocopeat:date-palm peat 2 (50%v/v); cocopeat:date palm peat 1(50%v/v); perlite:date-palm peat 2(50%v/v); perlite:date-palm peat 1(50%v/v) and cocopeat:perlite for tomato cultivation under protected conditions. Maximum fruit yield (4.19 kg/plant) was recorded under perlite media and minimum (3.25 kg/plant) under Palmpeat+perlite media.

Jing-xia*et al*. (2010) undertook an experiment using peat, sand and perlite in different proportions as the culture medium to overcome the problems of soil salinization, continuous cropping obstacles, low yield and relative poor-quality issues in pepper cultivation and found that soilless culture showed greater growth potential and early flowering, higher yield and better quality.

Sixteen media combinations were prepared from peat, coir, vermiculite or perlite to standardize growing media for tomato transplants by Arenas *et al.* (2002).

They observed that transplants grown with more than 50 per cent coir exhibited lesser plant growth compared to peat-grown transplants, a response they linked with high nitrogenfixation by microorganisms and increased C:N ratio.

Tomato varieties in growing media viz.coconut coir:vermicompostand aged pine bark:coconutcoir:vermicompostproduced higher fruit yield compared with the plants grown in rockwool (Surrage*et al.,* 2010).

Ghehsareh *et al.* (2011a) assessed the influence of different substrates viz. date-palm peat; cocopeat and perlite on growth indices and nutrient uptake of tomato in controlled conditions and reported that TSS was maximum in media combination of cocopeat and perlite while, on other parameters such as, nutrient uptake, yield, vitamin C substrate had no significant effect.

Ghehsareh *et al.* (2011b) compared date-palm waste (incubated and sans incubation) and perlite as growing media for tomato cultivation. The TSS (6.37 ºB), yield (4.17 kg/plant) and plant height (298.5 cm) were found to be maximum, respectively, with perlite as a growing medium whereas, stem diameter (18.45 mm) and biomass (1.76 kg) were maximum under date palm (without incubation) growing medium.

Mazur *et al.* (2012) recommended coconut fiber as a environmental friendly medium for cultivation of cherry tomatoes as the plants grown in this mediarecorded higher yield compared to plants grown in mineral wool.

Nair *et al.*, (2011) amended growing media (peat:vermiculite:compost (2:1:1,v/v))with alfalfa-based organic amendment (0, 0.6, 1.2, 1.8, or 2.4 %, w/w) and incubated it for 0 to 4 weeks. Tomato plants growing in the amended medium had increased plant growth characteristics relative to medium with no amendments, provided it was incubated for at least one week.

Chemical fertilizer when applied, alone and in combination with vermicompost as growing media were studied by Narkhede*et al*. (2011) in capsium and recorded increase in cropcharacteristics and yield of pepper plants when treated with vermicompost.

Radhouani *et al.* (2011) tried different substrates (perlite, sand and compost) in soilless culture to study their effect on muskmelon (*Cucumis melo*) production. Provisional substrates like sand and compost promoted root growth that permitted an effective nutrientjptake leading to larger leaves, higher fresh and dry matter content and taller stems. Sand and compost reverberated precocity and yield while compost increased fruit characteristics.

Roy *et al*. (2011) recordedsoil, sand, FYM, vermicompost (1:1:5:5) as the best growing media for qualitative and quantitative parameters of capsicum cv. California wonder.

Gholamnejad *et al*. (2012) tried different proportions of cocopeat and vermicompost for better seed emergence and some qualitative and quantitative characteristics of sweet pepper transplant (cv. California wonder). The treatments included: vermicompost + cocopeat (3:1), vermicompost + cocopeat (1:3), vermicompost + cocopeat (1:1) (v/v) and normal soil and recorded maximum plant weight (fresh and dry), stem diameter, internode quantity, leaf area and height of transplant under treatment vermicompost + cocopeat (3:1).

Kumar and Raheman (2012) investigated vermicompost proportions in soilmix along with pot sizefor producing seedlings suitable for mechanical transplanting. Potting mix of 25 % vermicompost and 75 % soil and sand in equal proportion by volume in cubical shaped paper pots of 50 cm^3performed best for the large-scale production of paper pot seedlings of tomato, eggplant and peppers.

Luitel *et al.* (2012) evaluated different growing media (cocopeat, rockwool and masato) along with varying bed size (20 cm, 40 cm, 60 cm, and 80 cm width) onyield and fruit quality of tomato. Number of fruits per plant were recorded highest (16) under cocopeat followed by rockwool (15.2). Maximum Fruit weight (54.7 g) and yield (571.5 g/plant) was found to be in cocopeat based substrate and minimum fruit weight (50.4 g) and yield per plant (540.7 g) was in masato substrate. Total soluble solids ranged from 5.3 ºBrix (rockwool substrate) to 5.6 ºBrix (masato).

Nasirabad *et al*. (2012) studied seedling emergence undervarious proportions of cocopeat and vermicompost and found the treatments consisting of vermicompost: cocopeat in the ratio of 1:3significantly affecting fresh weight, seedling diameter, internode quantity and seedling length of tomato.

Olle *et al.* (2012) recorded higher fruit chemical contents and acidity in tomato under soilless culture compared to soil culture while investigating the influence of growing media on productivity of vegetables. They also observed higher yield of various vegetables under substrates than in the soil.

Ramadani *et al.* (2012) observed major effect on growth parameter of pepper seedlings in substrate with on-farm organic media whileassessing the effect of 10 growing media formulations developed from commercially available peat, inorganic media.

The efficacy of vermicompost on production of tomato was studied byAbduli *et al.* (2013) and reported that the plant parameters and yield of tomato plants were obtained in growing media containing 1:1 ratioof soil:vermicompost after 90 days of testing. Vermicompost also increased vitamin C and total sugar content in tomatoes.
Aktas *et al.* (2013) compared influence of different growing media viz. cocopeat, split mushroom compost, perlite, volcanic tuff and sawdust on growth, yield and quality of brinjal. Maximum plant height (82.2 and 78.7 cm) and number of leaves (51.1 and 51.4) was obtained with cocopeat and spent mushroom compost, respectively. Yield was found to be highest with cocopeat media followed by spent mushroom compost. Researchers concluded that spent mushroom compost growing media can be alternative media to commercial cocopeat and perlite in eggplant growing under greenhouse conditions as it produces result which were similar to cocopeat.

Bhat *et al.* (2013) studied the influence of vermicompost; cocopeat; sphagnum peatmoss; perlite; farmyard manure and avicumus with ready-to-use organic substrate on tomato, cucumber and capsicum under greenhouse conditions. Growing media combination of vermicompost:cocopeat:perlite:sphagnum peat moss (2:1:1:1 or 1:1:1:1 v/v) produced significantly better results regarding economic parameters in tomato, cucumber and capsicum than other mixtureswhile in some parameters, provisionally prepared substrates were better compared tocommercial mixes and soil cultivation.

Lopez *et al*. (2013) undertook varietal evaluation of pepper cultivars (Almden and Quito) under organic and inorganic cultivation and they observed higher NO_3content under inorganic culture than in soil.

Lorenzo *et al.* (2013) analyzed, the main differences between soilless culture and traditional cultivation techniques and their advantages and disadvantages.

Marquez *et al*. (2013) evaluated vermicompost tea (VCT) as organic fertilizer in combination with mixtures of sand, compost (C) and vermicompost (VC) forpiquin pepper production grown under greenhouse condition using 5 combinations viz. sand:inorganic nutrient solution (control, F_1), sand:VCT (F_2), sand:C (1:1 ratio, v/v):VCT (F_3), sand:VC (1:1 ratio, v/v): VCT (F_4) and sand:C:VC (2:1:1 ratio, v/v): VCT (F_5). Investigators reported thatsand:C (1:1 ratio, v/v):VCT (F_3) when used a growing media performed best with respect to organic treatments. However, plants grown under control (F_1) recorded maximum yield, exceeding F_2, F_3, F_4 and F_5 treatments with 26.10, 9.00, 29.47 and 29.05%, respectively.

Mokhtari *et al*. (2013) assessed the impact of empty fruit bunch (EFB) and vermicompost (VC) as organic addition (10% to 40%, v/v) on the quantitative and qualitative parameters of tomato in coconut coir dust. They tried six treatments with 100 % coconut coir dust (CD) media with nutrient solution (electrical conductivity = 2.5 $mScm^{-1}$) as control. They reported higher vegetative growth and yield under CD with 20% VC.

Rahimi *et al.* (2013) evaluated different culture media (peat moss, coco-peat, jahrom palm peat washed-sand and soil) for tomato transplant production under greenhouse conditions reporting better seedling growth under peat moss media. They concluded that coco-peat and peat moss, alone, or in combination with sand performed better.

Abafita *et al.* (2014) evaluated different quantities of vermicompost as growing media and found that application of vermicompost @ 20% in potting mixture had telling effect on tomatoes as they had higher growth and yield whereas, lower (10%) as well as higher (40%) doses of vermicompost recorded lower yields of the tomato plants.

Albaho*et al.* (2014) tried different growing media in combinations ofM_1- peat moss:, perlite:vermicompost (35:40:25%); M_2- peat moss:perlite:vermicompost:coco peat (25:25:25:25%); M_3- coco peat (100%) and M_4-peat moss: perlite (50:50%)) as the control for tomato production in growbags. They found M_1 and M_2 as the best substrate and recommended vermicompost and coco peat as alternative to peat moss.

Biwalkar and Jain (2014) evaluated the sweet pepper production under naturally ventilated greenhouse condition using three levels of fertigation as well as irrigation. The net returns from greenhouse cultivation without subsidy for green, yellow and red coloured sweet pepper was calculated as Rs. 83,677.85, 1,20,577.85 and 53,797.85, whereas with 50% subsidy these were calculated as Rs. 1,28,794.72, 1,65,694.72 and 98.914.72, respectively. Cost-benefit ratio (B: C ratio) of green, yellow and red coloured sweet pepper without subsidy was calculated as 1.71, 2.02 and 1.45, respectively, whereas with 50% subsidy it was calculated as 2.76, 3.26 and 2.35, respectively. The maximum B: C ratio (3.53) was found for yellow coloured sweet pepper.

Hussain *et al.* (2014) suggested soilless culture as better alternative for soil-based agriculture for improving quality and yield of crops and providing solutions for problems like decreasing per capita land availability.

Lari *et al.* (2014) conducted study on nutrient content in 3 varieties of capsicum (var. Alonso, Roxy, Baiela) using substrates viz. vermicompost: perlite

(1:1), cocopeat: vermicompost (1:1), cocopeat: perlite: vermicompost (2:1:1), Cocopeat: perlite: vermicompost (1:2:1), cocopeat: perlite: vermicompost (1:1:2), cocopeat: perlite (1:1). The result showed highest in soluble solids and phosphorous under vermicompost: cocopeat (1:1) whereas, highest average potassium and iron was under cocopeat: perlite: vermicompost (1:2:1).

Moreno *et al.* (2014) studied optimal concentration of the mixture Vermicompost: Sand (VC: S, by volume) for meeting the nutritional requirements of cultivation of Chile pepper type Hungaro (*Capsicum annuum*) under protected conditions. The mixture evaluated consisted of four combinations of VC: S with ratios 1: 1, 2: 1, 3: 1 and 4: 1 and a control 0: 1 (sand with nutrient solution). The ratio of 1: 1 by volume of VC: S was most appropriate mixture for development of Chile pepper type Hungaro in protected conditions.

Ahirwar and Hussain (2015) evaluated vegetable transplants in vermicompost for transplant quality and field performance and reported positive effect on growth of transplants, assuming alteration in the nutritional balance of the medium being responsible.

Aslani *et al*. (2015) evaluated the results of two planting substrates viz. cocopeat (80%) + perlite (20%) and moss peat (80%) + perlite (20%) on vegetative growth, flowering rate, fruit quality and yield of bell pepper cultivars with the treatment consisting of moss peat giving better effects for all vegetative and reproductive factors in comparison to cocopeat.

Gungor and Yildirim (2015) conducted varietal evaluation of some pepper cultivars for effect of peat, alone, and in mixture as peat, perlite, sand growing media (1:1:1, v:v:v) on fruit characteristics, fruit number , yield, ascorbic acid content and TSS under controlled conditions. Growing media comprising of peat + perlite + sand (1:1:1) gave best results for pepper cultivars in polythene bags.

Hafshjani *et al.* (2015) observed the maximum dry weight (shoot and root), earliest flowering and fruiting in bell pepper grown in sawdust. The results showed the highest chlorophyll content in the peat bed and number of fruits per plantwere also influenced by substrates. However, sawdust bed after peat had the maximum number of fruits/plant but the plants planted in most cases in a sawdust bed after peat possessed better vegetative and reproductive growth.

Nagaraj *et al.* (2015) investigated different combinations of growing media viz., cocopeat;rice husk;sawdust:vermicompost (1:1); rice husk:vermicompost (1:1);sawdust:vermicompost (1:1) and sandy loam on quality, growth and yield of capsicum and observed highest yield in sandy loam soil (88.62 tha^{-1}) and lowest in sawdust (62.00 tha^{-1}).

Sayel-El *et al.* (2015) investigated, the effect of some soilless culture techniques (perlite, rice straw and modified plant plane hydroponin) on qualitative and quantitative characteristics and recommended straw culture for higher sweet pepper production and with reduced water consumption under greenhouse conditions.

Xiang *et al*. (2015) studied effect of organic substrate for cultivation of *Capsicum annuum* L. by using six mixed substrates consisting of cow dung, wheat straw, chicken manure, river sand, turf and vermiculite under solar greenhouse. The result showed that substrate containing (cow dung: wheat straw: chicken manure: river sand: vermiculite (3.5:2.5:0.5:2:1.5) was most suitable for pepper cultivation.

Mathowa *et al.* (2016) investigated different growing media (germination mix, cocopeat and hygromix) for consequence on development of tomato seedling under shaded conditions and reported that plant height was maximum in hygromix but was at par with the media germination mix while minimum was observed under cocopeat media.

Rekani *et al.* (2016) undertook a study on germination and growth of sweet pepper plants in relation to different potting mixture under greenhouse conditions. The seed germination was enhanced under media peatmoss and sheep manure compared to soil. Growing media peatmoss and sheep manure recorded significantly higher growth parameters compared to soil and Municipal Solid Waste compost.

Truong *et al.* (2017) investigated impact of different growing media viz.1/3 Peat moss: 1/3 rice husk ash:1/3 coconut fiber (T1); 1/3 Vermicompost:1/3 rice husk ash:1/3 coconut fiber (T2); 1/3 Cattle manure compost:1/3 rice husk ash: 1/3 coconut fiber (T3); 1/3 Chicken manure compost:1/3 rice husk ash:1/3 coconut fiber (T4); 1/3 Hog manure compost:1/3 rice husk ash:1/3 coconut fiber (T5)on varietal performance of tomato under greenhouse conditions. They observed statistical significance in physico-chemical properties of the media along with significant concentrations of total primary and secondary nutrients in the plants. Media composition also affected the root and shoot weight in seedling stage.

Xiong *et al.* (2017) evaluated effect of coconut coir, rockwool, and peat vermiculite media in tomatoon physico-chemical properties of drainage solution and crop performance. The results revealed that K and S uptake, fruit weight and yield were significantly affected by coconut coir compared to rockwooland phosphorus and potassium uptake along with fruit yield in comparison to peat vermiculite. Moreover, the organic acid in first truss was also significantly increased under coconut coir compared to both rockwool and peat vermiculite. Coconut coir also recorded lower uncredited nutrient than under rockwool and peat vermiculite (the lower, the better). They recommended coconut coir as a potential substrate for use in tomato production.

2. Water requirement and frequency of drip irrigation

Hanson *et al.* (2003) evaluatedresponse of vegetables on silt loam to drip-irrigation frequencies of two irrigations a day (2/d); one irrigation a day (1/d);biweekly (2/week) and weekly (1/week) irrigations with all treatments receivingsame amount of water. Results revealed that weekly frequency had negative effect on the shallow rooted crops in sandy soil and concluded that one irrigation a day (1/d) or biweekly (2/week) irrigationcan be recommended for medium to fine textured soils. However, no yield benefit could be accrued out of multiple irrigations per day.

Singandhupe *et al.* (2003) investigated yield and nutrient uptake of tomato under drip irrigation and fertigationlevels. Investigators reported 8-11 per cent higher nitrogen uptake under drip irrigation compared toflood irrigation. Accordingly, drip irrigation recorded 37 per cent saving of water along with 3.7-12.5 per cent higher fruit yield with 77 per cent higher WUE over flood irrigation.

Ismail *et al.* (2007) studied the effect of irrigation timings (early morning, afternoon and night) upon the average yield of tomato and observed 15 per cent and 14 per cent increase in yield under early morning irrigationthan irrigation at afternoon and night, respectively.

Sezen *et al.* (2010) studied different levels of irrigation levels (WL_1-75%; WL_2-100%; WL_3-125% and WL_4-150%)along with two frequencies (once and twice daily) on qualitative and quantitative characteristics of tomatoes grown in different soilless media (volcanic ash, peat and their mixture) in a glasshouse. Maximum fruit number and yield was recorded under treatment having growth media of ash:peat mixture (1:1) with twice a day irrigation at 150% irrigation level. However, TSS decreased with increasing water levels. Once a day irrigation (WL1) with peat:ash (1:1) recorded highest irrigation water use efficiency (121.4 kg m^{-3}).

. Gore and Sreenivasa (2011) observed increase in the quality characteristics of tomato with the mixture of liquid organic manures with and without fertilizers as compared to recommended dose of fertilizers (RDF) alone. The nitrogen, phosphorus and potassium concentration alongwithyield were maximum with the application of liquid organic manures + RDF followed by Beejamruth + Jeevamruth + Panchagavya.

Pires *et al.* (2011) evaluated crop performance of tomato with levels of irrigation frequencies and volume of coconut fibre substrate under greenhouse conditions and observed maximum leaf area index under largest substrate volume (10 L). Moreover,fruit yield was favoured by a greater number of irrigations and not on the substrate volume.

Luvai *et al.* (2014) investigated influence of different irrigation levels on growth parameters of tomato and found that treatment with irrigation @ 120% of crop evapotranspiration on daily basisproduced impressive growth along with improved fruit quality and highest yield (4.44 kg/ m^2). However, irrigation @ 60% of crop evapotranspiration on daily basisproduced best irrigation water use efficiency (13.26 kg/ m^3).

Shin and Son (2016) concluded that the modified irrigation method improved the production of paprika in soilless culture and has a direct influence on the productivity and the production cost. They observed 3.7 per cent higher water-use efficiency with the drip irrigation compared to the control treatment of furrow irrigation.

Xiukang and Yingying (2016) studied the effect of irrigation (W_1:100% ETc; W_2:75% ETc and W_3: 50% ETc) and fertigation on yieldand water-use efficiency of tomatoin controlled conditions and observed maximum plant height of 115 cm under W_3but was statistically at par with W_2. Authors reported increased fruit yield but lower WUE with increase in irrigation level which, however, had positive correlation with fertigation levels. Further, water use efficiency was observed to be directly related to irrigation to fertilization.

3. Cost economics

Jadhav *et al.* (1990) reported higher benefit : cost ratio of 5.15 and 2.96 under trickle irrigation and furrow irrigation, respectively, with respective yield of 48t/ha and 32 t/ha for tomato.

Patil (2013) studied the performance of tomato undertrickle and flood irrigation and reported the yield 53.6 t/ha under trickle irrigation system and 40.0 t per ha under flood irrigation. The benefit : cost ratios were 3.37 and 3.07, respectively.

Dunage *et al.* (1990) observed highest benefit: cost ratio of 4.54 and WUE of 11.90 t ha cm^{-1}using trickle irrigation at 60% evapotranspiration compared to benefit cost ratio of 4.44 with WUE of 7.45 t ha.cm^{-1}at120% evapotranspiration in tomato under net conditions.

Chapter-3

HYPOTHESIS FOR RESEARCH

The importance of tomato is only second to potato as far as its usage and economy is concerned. High nutritive value and varied climatic adaptability make the tomato cultivation even more popular.At large, tomato production under open field condition is affected by natural influences like precipitation (sometimes untimely) combined with rising and falling temperature regimes affecting profit margins of the growers. These challenges have forced growers to opt for protected cultivation under which they get additional benefit of extended crop growth period resulting in higher productivity levels besides quality produce.In Himachal Pradesh, the crop is being cultivated over 11080 hectares with annual production of 4, 89,960 MT, while Punjab gives 2,00,150 MTtomato from 8060 hectares (NHB, 2017). The present study has been taken based on following hypothesis:

- **Farmers have been growing vegetable in the soil for past many years and due to continuous monoculture under polyhouse soil health have deteriorated considerably, mainly due to soil borne diseases, which costs major portion of expenditure on crop production, therefore, soilless media that can support plant growth without affecting yield is required**. The best remedy for the problem of poor soil health is growing the high value cash crops in soil less media which is pre-sterilized and is devoid of any diseases and pests. The media when supplied with sufficient quantity of water and fertilizer may yield better than soil with high quality produce. So, there is need to select suitable potting mixture/ medium with better characteristics among the different medias available in the market for production of tomato under poly-houses which is highly remunerative crop for the farmer in Himachal Pradesh, as well across India. The standardization of best media may help in recommending the same to the farmers which will further improve economic viability of producing vegetable crops under protected cultivation (Liang *et al.*, 2013 and Fu *et al.*, 2017).

- **Irrigation water programming (level and frequency) will ensure maximum water-use efficiency and so quantitative behaviour of tomato plant is expected to be different** to drip irrigation in different growing media. Very little literature is available for irrigation scheduling in tomato in polybags under protected cultivation.
- **Production of tomato in polybags is expected to cost more than producing tomato in soil.** However, it is assumed that due to sterile environment in the growing media, quality and yield of tomato shall be better compared to soil. This shall compensate for higher inputs and be authenticated by working out economics of producing tomato in growing media using polybagsAbak and Celikel (1994) and Alan *et al.* (1994)

Chapter-4

OBJECTIVES OF THE STUDY

The present research work entitled **"Standardization of soilless media and irrigation schedule for improving yield and quality of tomato in UV stabilized polybags under polyhouse"** has been designed in view of the challenges faced by growers of tomato. This study has been carried out for comparing various growing media which can replace soil without affecting growth and yield. Further, irrigation scheduling has been studied to strengthen the concept of efficient water utilization which can provide better economic yield to farmers. The objectives of the study are:

1. To standardize soilless growing media for better growth and yield.
2. To determine optimum water requirement and frequency of drip irrigation.
3. To work out economics of tomato.

Chapter-5

MATERIALS AND METHODS

The investigation entitled **“Standardization of soilless media and irrigation schedule for improving yield and quality of tomato in UV stabilized polybags under polyhouse”** was undertaken during 2016 and 2017. The information related to experimental location and methodology followed areas follows:

5.1 Location and climate of the study area
5.2 Experimental materials
5.3 Experimental details
5.4 Media and plant analysis
5.5 Observation details
5.6 Benefit cost analysis
5.7 Statistical method

5.1 LOCATION AND CLIMATE OF THE STUDY AREA

5.1.1 Experimental location

The experiment was undertaken at the Departmental Research Farm of Soil Science and Water Management, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The elevation of study area is 1175 m above mean sea level having an average slope of 7-8 per cent at 30º 51′ N latitude and 76º 11′ E longitude.

5.1.2 Climate

Nauni campus falls under agro-climate zone-2 of Himachal Pradesh having mild climate with an average annual rainfall of 1100 mm, mostly skewed duringmid June-mid September. The area receives meagre winter rains during the month of January and February.

5.1.3 Media characteristics

Before undertaking the study, samples of growing media (Cocopeat, Vermicompost, Vermiculite, Cocopeat+ Vemicompost and Cocopeat + Vermiculite) were collected from the grow bags and were subjected to standard analysis for their properties. The results of analysis on their characteristics and available nutrient status of different media is enumerated in Table 5.1.

Table 5.1: Nutrient content of different media and their combinations before the start of experiment

Properties	Cocopeat	Vermiculite	Vermicompost	Vermiculite + vermicompost (70:30)	Cocopeat + vermicompost (70:30)
pH	6.23	6.65	7.03	6.80	6.65
Nitrogen (%)	0.05	0.0014	1.54	0.09	0.91
Phosphorus (%)	0.03	0.0004	1.01	0.05	0.58
Potassium (%)	0.08	0.0061	1.20	0.09	0.99

5.2 EXPERIMENTAL MATERIAL

5.2.1 Planting Material

Solan Lalima hybrid of tomato developed by Dr. Y.S. Parmar University of Horticulture and Forestry Nauni, Solan (H P) was used in the study.

5.2.2 Organic Manures

5.2.2.1 Vermicompost (VC)

Vermicompost, an organic manure having nutrients and microbial population, was procured from the Department of Soil Science and Water Management, UHF, Nauni, Solan.

5.2.2.2 Cocopeat

Cocopeat retain moisture up to eight times of its volume and have a slow degradation rate, making it useful for using multiple times and was procured from the market.

5.2.2.3 Vermiculite

Vermiculite improves drainage and is light weight. It is chemically inert, so it will not change pH and was procured from the market.

5.3 EXPERIMENTAL DETAILS

5.3.1 Factors

Three factors at different levels were studied under Factorial design and have been elaborated below:

A. Substrate/Growing Media: 3

S_1- Vermiculite+ vermicompost (70:30, w/w),

S_2- Cocopeat + vermicompost (70:30, w/w),

S_3- Cocopeat,

B. Irrigation frequency: 02

I_1 – Daily through Drip, I_2 – Alternate day through drip

C. Irrigation Levels: 04

D_1- 50 %ETc (Crop Evapotranspiration), D_2- 75 %ETc,

D_3- 90%ETcD_4-100%ETc

The daily irrigation water requirement for the tomato was estimated by using the following relationship:

$WR = ET_o \times Kc \times A$

Where, WR = Crop water requirement (L/plant)

ET_o= Reference evapotranspiration (mm d^{-1})

K_c = Crop coefficient

A = Plant area, m^2 (here, total area of growbags was taken)

Reference evapotranspiration (ET_o) was calculated using modified Penman Monteith method (Doorenbos and Pruitt, 1977) by keeping Class A pan inside the polyhouse. The crop factor (Kc) and pan factor (Kp) values were considered, as described in the FAO Irrigation and Drainage paper No. 56 (Appendix-III) $K_{c\ ini}$: Doorenbos and Kassam (1979)$K_{c\ mid}$ and $K_{c\ end}$: Doorenbos and Pruitt (1977); Pruitt (1986); Wright (1981); Snyder *et al.*(1989).

Total area shaded by the crop varied from 50 per cent during initial stage to 85 per cent at full maturity. The dripper discharge was one litre per hour and overall efficiency of drip irrigation system was recorded to be 92 per cent for all the treatments. The irrigation was accomplished by placing two laterals along the treatments, one each for daily and alternate day irrigation.

Table 5.2: Detail of treatments used for study

Number	Combination	Detail of Treatments
T_1	$S_1 I_1 D_1$	Vermiculite+ vermicompost (70:30, w/w), Daily through drip irrigation @ 50 %ETc
T_2	$S_1 I_1 D_2$	Vermiculite+ vermicompost (70:30, w/w), Daily through drip irrigation @ 70 %ETc
T_3	$S_1 I_1 D_3$	Vermiculite+ vermicompost (70:30, w/w), Daily through drip irrigation @ 90%ETc
T_4	$S_1 I_1 D_4$	Vermiculite+ vermicompost (70:30, w/w), Daily through drip irrigation @ 100%ETc
T_5	$S_1 I_2 D_1$	Vermiculite+ vermicompost (70:30, w/w), Alternate day through drip irrigation @ 50 %ETc
T_6	$S_1 I_2 D_2$	Vermiculite+ vermicompost (70:30, w/w), Alternate day through drip irrigation @ 75 %ETc
T_7	$S_1 I_2 D_3$	Vermiculite+ vermicompost (70:30, w/w), Alternate day through drip irrigation @ 90%ETc
T_8	$S_1 I_2 D_4$	Vermiculite+ vermicompost (70:30, w/w), Alternate day through drip irrigation @ 100%ETc
T_9	$S_2 I_1 D_1$	cocopeat + vermicompost (70:30, w/w), Daily through drip irrigation @ 50 %ETc
T_{10}	$S_2 I_1 D_2$	cocopeat + vermicompost (70:30, w/w), Daily through drip irrigation @ 75 %ETc
T_{11}	$S_2 I_1 D_3$	cocopeat + vermicompost (70:30, w/w), Daily through drip irrigation @ 90%ETc
T_{12}	$S_2 I_1 D_4$	cocopeat + vermicompost (70:30, w/w), Daily through drip irrigation @ 100%ETc
T_{13}	$S_2 I_2 D_1$	cocopeat + vermicompost (70:30, w/w), Alternate day through drip irrigation @ 50 %ETc
T_{14}	$S_2 I_2 D_2$	cocopeat + vermicompost (70:30, w/w), Alternate day through drip irrigation @ 75%ETc
T_{15}	$S_2 I_2 D_3$	cocopeat + vermicompost (70:30, w/w), Alternate day through drip irrigation @ 90%ETc
T_{16}	$S_2 I_2 D_4$	cocopeat + vermicompost (70:30, w/w), Alternate day through drip irrigation @ 100%ETc
T_{17}	$S_3 I_1 D_1$	cocopeat, Daily through drip irrigation @ 50%ETc
T_{18}	$S_3 I_1 D_2$	cocopeat, Daily through drip irrigation @ 75 %ETc
T_{19}	$S_3 I_1 D_3$	cocopeat, Daily through drip irrigation @ 90%ETc
T_{20}	$S_3 I_1 D_4$	cocopeat, Daily through drip irrigation @ 100%ETc
T_{21}	$S_3 I_2 D_1$	cocopeat, Alternate day through drip irrigation @ 50 %ETc
T_{22}	$S_3 I_2 D_2$	cocopeat, Alternate day through drip irrigation @ 75 %ETc
T_{23}	$S_3 I_2 D_3$	cocopeat, Alternate day through drip irrigation @ 90%ETc
T_{24}	$S_3 I_2 D_4$	cocopeat, Alternate day through drip irrigation @ 100%ETc

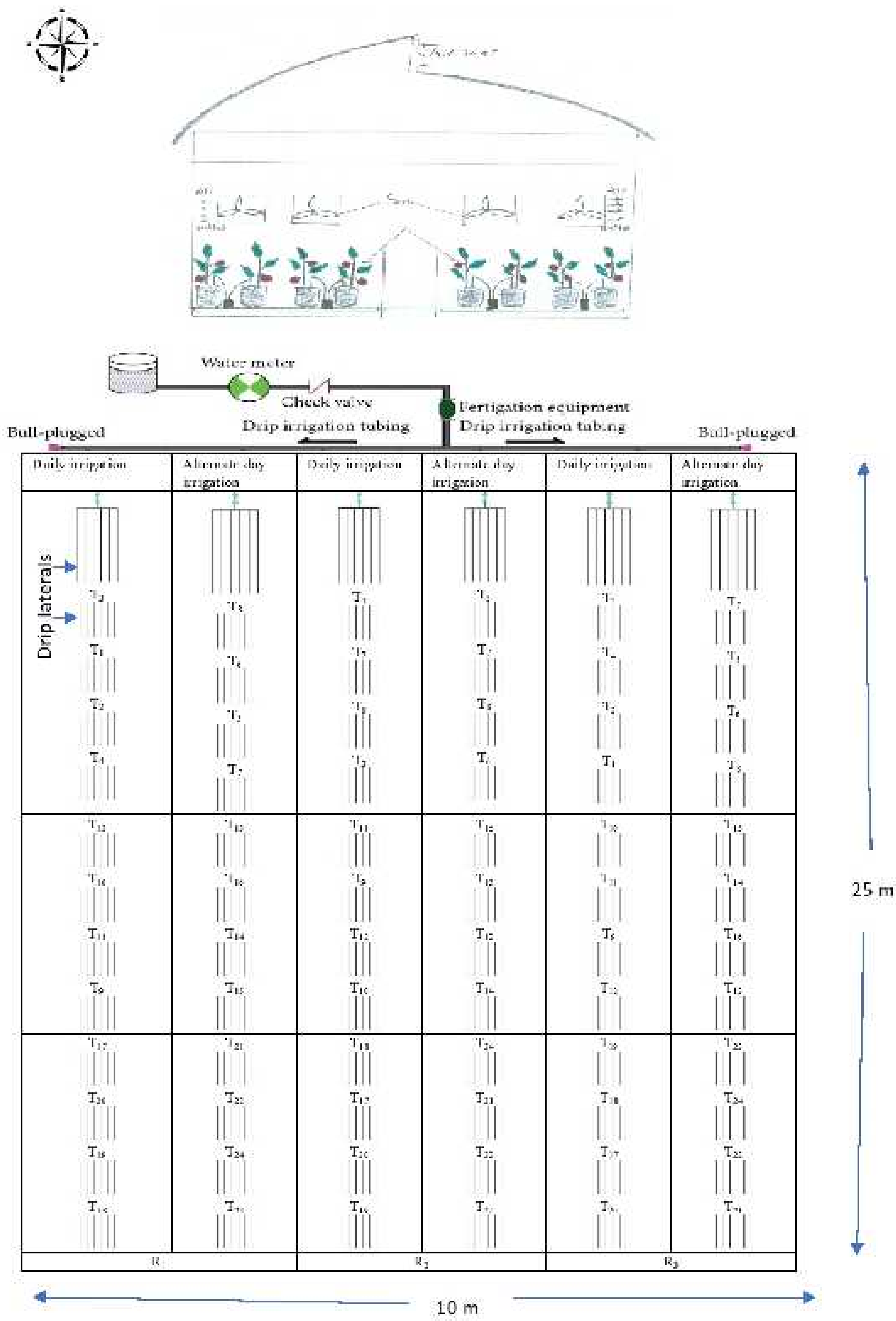

Plate 1: Schematic description of experimental polyhouse with the layout of the treatments

The nutrient requirement was met through fertigation of recommended dose (Anonymous, 2013). A total of 14.21 Kg of 19:19:19, 2.5 Kg of Urea Phosphate and 4.07 Kg of Urea, was applied biweekly which was split in 64 applications.

5.3.2 Layout details of the Experiment

A total of 24 treatment combinations have been studied (Table 5.2). The layout details are:

Number of treatments	:	24
Number of plants per treatment	:	8
Number of replications	:	3
Area under trial	:	250 m^2
Design	:	Complete Randomized Design (Factorial)

Parameters studied:

- pH of growing media
- Nutrient content of media
- Plant height (cm)
- Internodal length (cm)
- Number of branches
- Number of fruits/plants
- Fruit length and breadth (cm)
- Average Fruit weight (g)
- Fruit colour
- Total Soluble Solids (°Brix)
- Acidity (%)
- Sugar content (%)
- Lycopene content (mg $100g^{-1}$)
- Vitamin C (mg $100g^{-1}$)
- Phenols (mg $100g^{-1}$)
- Leaf nutrient content (%)
- Nutrient uptake (kg ha^{-1})
- Fruit yield/plant (kg)

5.3.2.1 Nursery raising

The protrays were used for nursery raising with cocopeat as a growing media and oneseed per cell of protrays were sown of Solan Lalima hybrid under protected conditions.

5.3.2.2 Transplanting of seedlings

The healthy and uniform seedlings were transplanted after 34 and 36 days during 2016 and 2017, respectively,with each grow bag accommodating one plant per bag. Complete care was taken to protect the root system of the seedlings during uprooting and, therefore, the protrays were watered one hour before. Transplanting in the grow bags containing moist media was done during evening hours. Standard plant care procedures were followed as per Package of Practices of Vegetable Crops, DrYSPUHF, Nauni, Solan (Anonymous, 2013).

5.4 MEDIA AND LEAF ANALYSIS

5.4.1 Analysis of growing media and plant samples

Leaf samples from fully matured plants along with growing media were collected after completion of experiment (November) during 2016 and 2017. Standard procedure for analyzing leaf samples and growing media was undertaken by washing with tap water followed by 0.1N HCl and last with double distilled water to clear samples of any outside influence. The samples after air drying by spreading on filter paper were put in paper bags and oven dried in hot air oven at 60 ± 5°C for 48 hours. Stainless steel mortar was used to crushand ground the samples and same were stored in butter paper bags for the estimation of nitrogen, phosphorus and potassium contents.

5.4.2 Digestion of growing media and plant samples

Diacid mixture prepared by mixing concentrated HNO_3 and $HClO_4$ in the ratio of 4:1 was used for digesting well ground samples of known weight of different media and leaf byobserving all relevant precautions as laid down by Piper (1966) for estimation of phosphorus and potassium. Nitrogen was estimated using concentrated

Plate 2: A view of the experimental polyhouse

Plate 3: Healthy nursery of tomato plants

Plate 4: Healthy tomato plants transplanted in the polybags containing soilless growing media

Plate 5: A view of Arrow drippers used for irrigation

H_2SO_4 and digestion mixture (potassium sulphate 400 parts, copper sulphate 20 parts, mercuric oxide 3 parts and selenium powder 1 part) as suggested by Jackson (1973). The methods adopted for nutrient estimation is presented in Table 5.3.

Table 5.3: Methods followed for the analysis of growing media and plant parameters

Sr. No.	Parameter	Reference (Method)
1.	pH	1:2 soil: water suspension, measured with digital pH meter (Jackson, 2005)
2.	N	Microkjeldhal method (Jackson, 1973)
3.	P	Vando-molybdate phosphoric yellow color method (Jackson, 1973)
4.	K	Flame photometer method (Jackson, 1973)

5.5 OBSERVATION DETAILS:

5.5.1 Plant height (cm)

Average height was calculated from base level to top of the main shoot of 5 randomly selected plants of each treatment by measuring scale.

5.5.2 Internodal length (cm)

The distance between two nodes in five randomly selected plants was taken and averaged to record average internodal length.

5.5.3 Number of branches

Average number of branches per plant were worked out by counting total branches shooting out from the main stem of 5 randomly selected plants.

5.5.4 Number of fruits per plant

Mean number of fruits per plant were recorded by first counting the total harvested fruits from 5 randomly selected plants and then taking the mean of the same.

5.5.5 Fruit length (cm)

Twenty fruits, randomly selected fruits from 5 randomly selected plants were subjected to length measurement with the help of vernier caliper and average fruit length was recorded.

5.5.6 Fruit breadth (cm)

Twenty fruits, randomly selected fruits from 5 randomly selected plants were subjected to breadth measurement with the help of vernier caliper and average fruit breadth was recorded.

5.5.7 Average fruit weight (g)

Twenty fruits were selected randomly from 5 randomly selected plants and weighed to obtain average fruit weight.

5.5.8 Fruit Colour

The colour of the 10 fruits taken randomly from selected plants was observed by comparing it with the colour charts of the Royal Horticultural Society, London.

5.5.9 Total Soluble Solids (º Brix)

The Total Soluble Solids were estimated by Erma hand refractometer (0-32^0 brix) as per method described by Ranganna (1995). Fruits were crushed and juice was passed through cheese cloth and was placed on platform of reflectometer and reading viewed on its screen was recorded. An average of 20 fruits were taken from randomly selected plants.

5.5.10 Acidity

Fruit pulp of twenty randomly selected fruits from 5 randomly selected plants was made to twenty five grams and thoroughly homogenized in an electric blender. The total volume was made to 250 ml and mixture was filtered through Whatman No. 1 filter paper. Then 50 ml of sample was titrated using Phenolphthalein as an indicator against N/10 NaOH solution, till it gave pink coloured at end point. Titratable acidity was calculated in terms of citric acid on the basis of 1 ml of N/10 NaOH equivalent to 0.0067 grams of anhydrous citric or per cent citric acid in juice (Ranganna, 1995). The remaining filtered solution was used for sugar estimation.

$$\text{Titratable acidity (\%)} = \frac{\text{Titre} \times \text{Normality of alkali} \times \text{volume made up} \times \text{equivalent weight of acid}}{\text{Volume of sample taken} \times \text{volume of aliquot taken} \times 1000} \times 100$$

5.5.11 Sugar content

Sugar content of fruits was calculated from200 ml filtered stock solution (left from titratable acidity) following the standard procedure (brought to the end point indicated by the appearance of brick red colour) as suggested by Ranganna (1995). Total sugar content was expressed as percentage of fresh berry weight basis.

$$\text{Total sugars (\%)} = \frac{\text{Factor} \times \text{Dilution}}{\text{Titre} \times \text{weight of sample taken}} \times 100$$

5.5.12 Lycopene content (mg 100 g^{-1})

Lycopene content of twenty ripe tomato fruits selected from 5 randomly selected plants was determined according to the absorption measurement procedure of petroleum ether extract f total carotenoids at 503 nm as method described by Ranganna (1995).

5.5.13 Vitamin c (mg 100 g^{-1})

Vitamin C content of the fruit was recorded by following the method suggested by Ranganna (1995) using 2,6- dichlorophenol Indophenol dye and titrating the sample extracted in metaphosphoric acid solution with dye to a pink end point. It is calculated as:

$$\text{mg of Ascorbic acid/100 g} = \frac{\text{Titre} \times \text{Dye factor} \times \text{volume made up} \times 100}{\text{Aliquot of extract taken for estimation} \times \text{Weight of sample taken for estimation}}$$

5.5.14 Total phenols (mg/100g)

Total phenol content was determined by Folin-Ciocalteu procedure given by Singleton and Rossi (1965) in which absorbance was measured at 650 nm in spectrophotometer. Phenols with phosphomolybdic acid in Folin-Ciocalteu reagent and in alkaline medium produce a highly dark blue coloured complex (molybdenum blue). The intensity of this colour is measured at 650 nm. A standard calibration curve of gallic acid using different concentrations of total phenols was prepared. From standard curve concentrations of total phenols was estimated and expressed as mg/100 g of sample.

5.5.15 Nutrient Uptake (kg ha^{-1})

Dry matter yield of 5 randomly selected plants were taken to determine the nutrient uptake by subjecting data to the following formula(Hochmuth, 2001; Van Ranst*et al.,* 1999).

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%) x dry matter yield (kg ha}^{-1}\text{)}}{100}$$

5.5.16 Fruit yield per plant (kg)

Average yield per plant (kg) was calculated by weighing total number of fruits from 5 randomly selected plants from all the pickings and working out the mean.

5.5.17 Water use efficiency

Water use efficiency (WUE) was computed using yield per hectare and total water applied as t ha^{-1} cm^{-1} as given by Wu*et al.,* 2014.

WUE = Y/TWA

Where;

Y = Fruit yield (tonnes ha^{-1})

TWA = Total amount of water applied (cm)

5.6. BENEFIT-COST ANALYSIS

Benefit cost analysis was worked out to evaluate profitability and the economics was calculated at prevailing market rates as follows:

Net return = Gross return – Cost of cultivation

$$\text{Benefit: cost ratio} = \frac{\text{Net return (Rs)}}{\text{Cost of cultivation (Rs)}}$$

5.7 STATISTICAL ANALYSIS

In the present investigation, pooled data of two years (2016 & 2017) was taken for drawing conclusion after subjecting the same to statistical analysis using the statistical package SPSS (20.0) at 5% Critical difference (CD) for testing the significant difference among the treatment means.

Chapter-6

RESULTS AND DISCUSSION

The investigation entitled **"Standardization of soilless media and irrigation schedule for improving yield and quality of tomato in UV stabilized polybags under polyhouse"** was carried out at the experimental field of Department of Soil Science and Water Management, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during the year 2016 and 2017. The investigation was aimed at standardizing growing media and determining the effect of soilless media and irrigation scheduling on economic traits of tomato. The results thus obtained have been presented and discussed in this chapter with possible explanations establishing a cause and effect relationship, wherever, necessary or feasible in the light of available literature under the following heads and subheads:

6.1 Chemical properties of growing media as affected by treatments
- **6.1.1 pH of growing media**
- **6.1.2 Nitrogen content of growing media**
- **6.1.3 Phosphorus content of growing media**
- **6.1.4 Potassium content of growing media**

6.2 Effect of growing media and irrigation scheduling on plant growth and quality

6.3 Effect of growing media and irrigation scheduling on nutrient content

6.4 Effect of growing media and irrigation scheduling on nutrient uptake

6.5 Effect of growing media and irrigation scheduling on yield

6.6 Effect of growing media and irrigation scheduling on irrigation water requirement and water use efficiency

6.7 Benefit: Cost analysis of tomato production under protected conditions

6.1 Chemical properties of growing media as affected by treatments

Chemical properties of media after harvesting in UV stabilized polybags under polyhouse was investigated for two consecutive years i.e. 2016 to 2017.

6.1.1 pH of growing media

The data pertaining to the effect of growing media, irrigation frequency and irrigation level on pH have been presented in Table 6.1. Highest pH (6.61) was recorded with the media S_2 comprising of cocopeat + vermicompost (70:30, w/w) which was significantly higher than other treatments, whereas, lowest pH (6.27) was observed under S_3 comprising of cocopeat only. The data on irrigation level (D) and irrigation frequency (I) was found to be non-significant. Likewise, different interactions between media (S), irrigation frequency (I) and irrigation level (D) viz., S×I, S×D, D×I and S x D x I were also found to be non-significant.

Unavailability of nutrients at high pH can result in nutrients being unavailable to the plant. In present studies, pH remained near neutral levels. Similar results were reported by Voogt (1995), Gislerod *et al.* (1996) and Chen *et al.* (1999) in various cut flower crops where high pH led to a decrease in the various growth and yield parameters. It can be seen that substrates amended with compost as one of the constituents had near neutral pH. Such conditions are usually favourable for uptake and utilization of nutrients. Dutt and Sonawane (2006) also reported similar results for different media.

6.1.2 Nitrogen content of growing media (%)

A perusal of data in Table 6.2 clearly indicates that nitrogen after harvesting was significant during both the years of study. However, highest N content (1.15%) was observed under the treatment (S_2) cocopeat + vermicompost (70:30, w/w) which was significantly higher than other treatments while lowest N content (0.16%) was recorded under the treatment having only cocopeat (S_3) as the growing media. Irrigation levels also had significant effect on N content and highest nitrogen (0.54%) was observed under treatment having irrigation at 50 %ETc (Crop Evapotranspiration) [D_1] which was statistically at par (0.53%) with treatment having irrigation at 75 %ETc (D_2) while lowest (0.48%) was recorded under treatment having irrigation at 100 %ETc (D_4). Under irrigation frequency, statistically significant higher N content (0.54%) was reported under daily irrigation through drip (I_1) as compared to (0.50%) alternate day irrigation through drip (I_2).

Table 6.1: Effect of growing media and irrigation scheduling on pHof different growing media

pH of growing media(1:2)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	6.43	6.77	6.36	6.52	6.34	6.37	6.35	6.35	6.38	6.57	6.35	6.43
D_2	6.33	6.73	6.23	6.43	6.31	6.62	6.22	6.38	6.32	6.67	6.23	6.41
D_3	6.32	6.72	6.22	6.42	6.38	6.47	6.34	6.40	6.35	6.60	6.28	6.41
D_4	6.35	6.72	6.22	6.43	6.27	6.50	6.22	6.33	6.31	6.61	6.22	6.38
Mean	6.36	6.73	6.26	6.45	6.32	6.49	6.28	6.37	6.34	6.61	6.27	
$CD_{(0.05)}$					Interaction							
S	**0.14**				**S x I**	**NS**						
I	**NS**				**S x D**	**NS**						
D	**NS**				**D x I**	**NS**						
					S x D x I	**NS**						

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.2: Effect of growing media and irrigation scheduling on nitrogen content of different media

Nitrogen content of growing media(%)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	0.34	1.28	0.25	0.63	0.17	1.11	0.11	0.46	0.26	1.20	0.18	0.54
D_2	0.27	1.16	0.18	0.54	0.24	1.16	0.16	0.52	0.26	1.16	0.17	0.53
D_3	0.24	1.13	0.15	0.51	0.27	1.17	0.19	0.54	0.26	1.15	0.17	0.52
D_4	0.19	1.07	0.14	0.47	0.20	1.13	0.13	0.49	0.20	1.10	0.14	0.48
Mean	0.26	1.16	0.18	0.54	0.22	1.14	0.15	0.50	0.24	1.15	0.16	
$CD_{(0.05)}$					Interaction							
S	**0.01**				**S x I**	**0.01**						
I	**0.01**				**S x D**	**0.02**						
D	**0.01**				**D x I**	**0.02**						
					S x D x I	**0.03**						

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

The interaction between growing media and irrigation frequency (S x I) was found to be statistically significant and maximum N content (1.16%) was recorded in the treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) which was statistically significant than other treatments while minimum (0.15%) was recorded under cocopeat with irrigation on alternate days (S_3I_2). The interaction between irrigation level and irrigation frequency (D x I) was also found to be significant and highest N content (0.63%) was recorded under treatment having irrigation at 50 % ETc (D_1I_1) which was statistically significant than other treatments while minimum (0.46%) was recorded under irrigation at 50 % ETc on alternate days (D_1I_2). Further, the interaction between media and irrigation level (S x D) was also significant with maximum N (1.20%) recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum N (0.14%). The interaction between media, irrigation level and frequency (S x D x I) was also found to be statistically significant with treatment having cocopeat+ vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)recording maximum N content (1.28%) which was statistically significant than all other treatments whereas treatment having only cocopeat along with irrigation at 75% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum N content (0.11%).

6.1.3 Phosphorus content of growing media (%)

A perusal of the data presented in Table 6.3 revealed that phosphorus content in growing media after harvesting was significant during both the years of study.

However, higher P content (0.79%) was observed under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded lowest (0.14%).Irrigation level also recorded significant P content (0.40%) under irrigation at 50 % ETc (Crop Evapotranspiration) [D_1] but was statistically at par (0.39%) with irrigation at 75 % ETc (D_2) while treatment having irrigation at 100 % ETc (D_4) recorded minimum content (0.35%). Under the treatments of irrigation frequency, maximum P content (0.41%) was observed under daily irrigation through drip (I_1) which was statistically significant than irrigation on alternate days through drip (I_2) that recorded 0.36% P content.

The interaction between growing media and irrigation frequency (S x I**)** was found to be statistically significant and maximum P content (0.84%) was recorded in treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum P content (0.14%). The interaction between irrigation level and irrigation frequency (D x I**)** was also found to be statistically significant and higher P content (0.48%) was recorded under treatment having irrigation at 50 % ETc (D_1I_1) which showed statistical significance over other treatments while lowest P content (0.32%) was recorded under irrigation at 50 % ETc on alternate days (D_1I_2). Further, the interaction between media and irrigation level (S x D**)** was also found to be significant under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) recording maximum P content (0.82%) and was statistically significant than all other treatments while minimum P content (0.12%) was observed under treatment having only cocopeat with irrigation at 100% ETc (S_3D_4). Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be statistically significant and maximum phosphorus content (0.95%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$) which was statistically significant than all other treatments whereas minimum P content (0.10%) was observed under treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$).

6.1.4 Potassium content of growing media (%)

It is evident from Table 6.4 that potassium content in different media was influenced by treatment combinations during both the years of study.

Higher potassium content (0.95%) was recorded in (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media

Table 6.3: Effect of growing media and irrigation scheduling onphosphorus content of different media

Phosphorus content of growing media (%)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	0.26	0.95	0.21	0.48	0.15	0.72	0.10	0.32	0.20	0.84	0.16	0.40
D_2	0.23	0.87	0.17	0.42	0.20	0.75	0.13	0.36	0.21	0.81	0.15	0.39
D_3	0.20	0.76	0.16	0.37	0.22	0.80	0.17	0.40	0.21	0.78	0.17	0.38
D_4	0.17	0.76	0.13	0.35	0.17	0.75	0.12	0.35	0.17	0.75	0.13	0.35
Mean	0.21	0.84	0.17	0.41	0.18	0.75	0.13	0.36	0.20	0.79	0.15	
$CD_{(0.05)}$						Interaction						
S	0.01					S x I	0.02					
I	0.01					S x D	0.03					
D	0.01					D x I	0.02					
						S x D x I	0.04					

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.4: Effect of growing media and irrigation scheduling on potassium content of different media

Potassium content of growing media (%)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	0.37	1.17	0.29	0.61	0.21	0.88	0.15	0.41	0.29	1.03	0.22	0.51
D_2	0.30	1.06	0.26	0.54	0.25	0.93	0.17	0.45	0.28	1.00	0.22	0.50
D_3	0.29	0.94	0.22	0.48	0.29	1.00	0.19	0.49	0.29	0.97	0.21	0.49
D_4	0.26	0.90	0.21	0.46	0.23	0.89	0.16	0.42	0.25	0.89	0.18	0.44
Mean	0.31	1.02	0.25	0.52	0.24	0.92	0.17	0.44	0.27	0.97	0.21	
$CD_{(0.05)}$						Interaction						
S	0.01					S x I	0.02					
I	0.01					S x D	0.02					
D	0.01					D x I	0.02					
						S x D x I	0.03					

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

recorded minimum K content (0.20%). Similarly, irrigation levels and irrigation frequency also had significant effect on K content in the growing media. Maximum K content (0.51%) was observed under irrigation at 50 % ETc (Crop Evapotranspiration) [D_1] but was statistically at par (0.50%) with irrigation at 75 % ETc (D_2) while treatment having irrigation at 100 % ETc (D_4) recorded minimum K content (0.44%) in the media.

Irrigation frequency under daily irrigation through drip (I_1) recorded maximum K content (0.52%) and was statistically significant than irrigation on alternate days through drip (I_2) which recorded minimum K content (0.44%).

The interaction between growing media and irrigation frequency (S x I**)** was found to be statistically significant and maximum K content (1.02%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum K content (0.17%). The interaction between irrigation level and irrigation frequency (D x I**)** was also found to be significant with higher K content (0.61%) recorded under treatment having irrigation at 50 % ETc (D_1I_1) which showed statistical significance over other treatments while lowest K content (0.41%) was recorded under irrigation at 50 % ETc on alternate days (D_1I_2). Further, the interaction between media and irrigation level (S x D**)** was found to be significant and maximum K content (1.03%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatments while minimum K content (0.18%) was recorded under treatment having only cocopeat with irrigation at 100% ETc (S_3D_4). Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be statistically significant and maximum K content (1.17%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$) which was statistically significant than all other treatments whereas minimum K content (0.15%) was observed under treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$).

Similar results were observed by Dutt and Sonawane (2006) for different media. They reported in chrysanthemum that plants growing on cocopeat + compost followed by soilrite + compost produced the highest leaf nitrogen content, while coco peat + compost followed by coco peat + soilrite recorded the maximum phosphorus content. In case of potassium, highest levels were recorded in plants growing in soilrite + compost + rice husk which was followed by soilrite + compost. The results validate with that results of Hicklenton (1983) and Carlino*et al.*(1998). High nutrient content and favorable growth conditions in the substrate can promote increased uptake and utilization leading to improved shoot growth and leaf nutrient. Similarly, high uptake of phosphorus and potassium can lead to greater root mass production and improvement in vase life.

6.2 Effect of growing media and irrigation scheduling on plant growth and quality

Growth and yield performance of tomato crop in UV stabilized polybags under polyhouse was investigated for two consecutive years i.e. 2016 and 2017.

6.2.1 Plant height (cm)

Plant height is an important biometric parameter related to growth and development of the crop. Data presented in Table 6.5 demonstrated that growing media and irrigation scheduling had significant effect on plant height of tomato crop during both the years. Under growing media, plant height was reported maximum (144.53cm) under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum plant height (135.97cm). Under different irrigation levels, higher plant height (145.31cm) was observed under irrigation at 50 % ETc (Crop Evapotranspiration) [D_1] which was statistically significant than all other treatments while treatment having irrigation at 100 % ETc (D_4) recorded minimumand lower plant height (133.68cm). Irrigation frequency of daily irrigation through drip (I_1) recorded maximum plant height (142.90cm) and was statistically significant than irrigation on alternate days through drip (I_2) that recorded minimum plant height (137.17cm). The interaction between growing media and irrigation

Plate 6a: Established tomato plants under vermiculite + vermicompost (S_1)

Plate 6b: Established tomato plants under cocopeat + vermicompost (S_2)

Plate 6c: Established tomato plants under cocopeat (S_3)

frequency (S x I) was found to be significant and higher plant height (149.12cm) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum plant height(134.70cm). The interaction between irrigation level and irrigation frequency (D x I) was also found to be significant and maximum plant height (161.66cm) was recorded under treatment having irrigation at 50 % ETc (D_1I_1) which showed statistical significance over other treatments while minimum plant height (128.97cm) was recorded under irrigation at 50 % ETc on alternate days (D_1I_2). Further, the interaction between media and irrigation level (S x D) was also found to be significant and higher plant height (151.99cm) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation at 100% ET (S_3D_4) recorded lower (130.84cm) plant height. Confirming the effect of different treatments on plant height, the interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be statistically significant with treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$) recording maximum plant height (171.44 cm) which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded lowest plant height (125.18cm).

Maximum plant height under growing media of vermicompost + Cocopeat may be due to better physico-chemical properties of the media as also reported by Ten and Kirienko (2002) and Arancon *et al.* (2003) where Improved plant height was observed under all the vermicompost growing media. Irrigation levels also affected plant height significantly. When water was applied daily through drip, maximum plant height was obtained under irrigation level of 50% ETc whereas 90% ETc performed best but was statistically at par with irrigation level of 75% ETc when water was applied on alternate days. This might be due to the adequate moisture content provided by irrigation level at 50% ETc on regular basis and 90% ETc and 75% ETc in alternate days and the results are in agreement with published work of

Luvai *et al.* (2014). Xiukang and Yingying (2016) reported that plant height was maximum under irrigation level of 75 % ETc and was significantly higher than the other irrigation levels. The results were the same as those of Zhu *et al*. (2010) who reported that higher levels of irrigation can inhibit plant height increase.Our findings support Truong and wang (2015) and Truong *et al.* (2018) who reported that the plant height of tomato was maximum in the medium containing mixture of vermicompost, cocopeat and rice husk as the physico-chemical properties of media were optimal for the root growth development. According to Atiyeh *et al*. (1999) amendment of media with 20 per cent vermicompost improves plant growth and yield significantly over unamended medium.

6.2.2 Internodal length

The data pertaining to effect of growing media, irrigation frequency and irrigation level resulted in significant variation with respect to internodal length during both the years (Table 6.6).

Lower internodal length (7.08 cm) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded higher internodal length (7.58 cm). Irrigation levels also had significant effect on internodal length and minimum internodal length (7.23 cm) was observed under irrigation at 50 % ETc (Crop Evapotranspiration) [D_1] which was statistically at par (7.32 cm) with irrigation at 75 % ETc (D_2) and (7.36 cm) irrigation at 90 %ETc (D_3) while treatment having irrigation at 100 % ETc (D_4) recorded maximum internodal length (7.58 cm). Irrigation frequency also reported significant impact on internodal length with minimum internodal length (7.12 cm) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded maximum fruit breadth (7.62 cm).

The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and minimum internodal length (6.99 cm) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation

(S_2I_1) but was statistically at par (7.12 cm) with vermiculite + vermicompost (70:30, w/w) with daily irrigation (S_1I_1) while treatment having only cocopeat with irrigation on alternate days (S_3I_2) recorded maximum internodal length (7.73 cm). The interaction between irrigation level and irrigation frequency (D x I) was found to be significant and lowest internodal length (6.61 cm) was recorded under treatment having irrigation at 50 % ETc (D_1I_1) but was statistically at par (6.93 cm) with irrigation at 75 % ETc (D_2I_1) and highest internodal length (7.85 cm) was recorded under irrigation at 50 % ETc on alternate days (D_1I_2).Further, the interaction between media and irrigation level (S x D) was also found to be significant and minimum internodal length (7.10 cm) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded maximum (7.75 cm) internodal length. Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and minimum internodal length (6.42 cm) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)while treatment having only cocopeat along with irrigation at 100% ETc on alternate day basis ($S_3D_4I_2$) recorded maximum internodal length (8.00 cm).

Sibomana *et al.* (2013) have reported similar results and observed that different irrigation levels had significant effect on internodal length. Minimum internodal length was recorded when irrigation @ 40 per cent of pot capacity was given compared to 100 per cent pot capacity of irrigation. Internodal length increased with increasing irrigation levels compared to the low level of irrigation, as plant growth decreases with reducing water. Inhibitive growth was reported in tomato when they were subjected to different levels of water stress under field conditions (Nyabundi and Hsia, 2009).The above results support the work of Olympios (1992) and Lee *et al.* (1999), Kaciu *et al.* (2009) who also reported similar results.

6.2.3 Number of branches

Data presented in Table 6.7 confirms significant effect of growing media and irrigation scheduling on number of branches of tomato crop during both the years.

Maximum number of branches (6.73) were recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum number of branches (5.42). Irrigation levels also had significant effect on number of branches and maximum number of branches (6.62) were observed under irrigation at 50 %ETc (Crop Evapotranspiration) [D_1] which was statistically significant than all other treatments while treatment having irrigation at 100 %ETc (D_4) recorded minimum number of branches (5.23). Irrigation frequency also reported significant impact on number of branches with maximum number of branches (6.23) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum number of branches (5.89).

The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum number of branches (6.98) were recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2) recorded minimum number of branches (5.40). The interaction between irrigation level and irrigation frequency (D x I**)** was found to be significant and the greatest number of branches (7.82) were recorded under treatment having irrigation at 50 % ETc (D_1I_1) which showed statistical significance over other treatments and least number of branches (5.07) were recorded under irrigation at 100 % ETc on daily basis (D_4I_1).

Further, the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum number of branches (7.40) were recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) but was statistically at par (7.22) with cocopeat + vermicompost (70:30, w/w) with irrigation at 75% ETc (S_2D_2) while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum (4.74) number of branches. Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum number of branches (8.59) were recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)but was statistically at par with vermiculite + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_1D_1I_1$)with 8.28 number of branches while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum number of fruits per plant (4.83).

These results are in confirmation with the findings of Rahimi *et al.* (2013). Antony and Singandhupe (2004) reported that number of branches per plant increases with increase in irrigation level when applied on two days interval in irrigation. Similar, results were presented by Saleh *et al.* (2018) in french bean.

6.2.4 Number of fruits per plant

Data presented in the Table 6.8 demonstrated that growing media and irrigation scheduling had registered significant effect on number of fruits per plant of tomato crop during both the years.

Maximum number of fruits per plant (82.97) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than allother treatments while thetreatment having only cocopeat (S_3) as the growing media recorded minimum number of fruits per plant (78.48). Irrigation levels also had significant effect on number of fruits per plant and maximum number of fruits per plant (83.44) were observed under irrigation at 50 % ETc (Crop Evapotranspiration) [D_1] which was statistically significant than all other treatments while treatment having irrigation at 100 % ETc (D_4) recorded minimum number of fruits per plant (77.12).

Irrigation frequency also reported significant impact on number of fruits per plant with maximum number of fruits per plant (83.50) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum number of fruits per plant (78.42). The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum number of fruits per plant (86.01) were recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily

Table 6.5: Effect of growing media and irrigation scheduling on plant height of tomato under polyhouse

Plant height (cm)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	163.99	171.24	149.75	161.66	128.98	132.74	125.18	128.97	146.48	151.99	137.47	145.31
D_2	140.66	148.82	138.58	142.69	140.64	141.81	139.49	140.65	140.65	145.31	139.04	141.67
D_3	134.66	139.94	132.40	135.67	141.83	147.25	140.71	143.26	138.25	143.60	136.56	139.47
D_4	130.02	136.47	128.25	131.58	135.96	137.99	133.42	135.79	132.99	137.23	130.84	133.68
Mean	142.33	149.12	137.25	142.90	136.85	139.95	134.70	137.17	139.59	144.53	135.97	
$CD_{(0.05)}$						Interaction						
S	1.82					S x I	2.57					
I	1.49					S x D	3.64					
D	2.10					D x I	2.97					
						S x D x I	5.14					

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.6: Effect of growing media and irrigation scheduling oninternodal length of tomato under polyhouse

Internodal length (cm)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	6.68	6.42	6.73	6.61	7.85	7.78	7.92	7.85	7.26	7.10	7.32	7.23
D_2	6.91	6.76	7.13	6.93	7.70	7.65	7.75	7.70	7.30	7.21	7.44	7.32
D_3	7.60	7.58	7.69	7.62	7.10	6.95	7.25	7.10	7.35	7.27	7.47	7.36
D_4	7.30	7.21	7.50	7.34	7.85	7.63	8.00	7.83	7.58	7.42	7.75	7.58
Mean	7.12	6.99	7.26	7.12	7.62	7.50	7.73	7.62	7.33	7.08	7.58	
$CD_{(0.05)}$						Interaction						
S	0.16					S x I	0.23					
I	0.14					S x D	0.33					
D	0.19					D x I	0.27					
						S x D x I	0.47					

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.7: Effect of growing media and irrigation scheduling onnumber of branches of tomato under polyhouse

Number of branches												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	8.28	8.59	6.57	7.82	5.24	6.20	4.83	5.42	6.76	7.40	5.70	6.62
D_2	6.25	7.58	5.44	6.42	6.19	6.86	5.86	6.30	6.22	7.22	5.65	6.36
D_3	5.62	6.10	5.12	5.61	6.40	6.92	6.05	6.46	6.01	6.51	5.59	6.04
D_4	4.94	5.64	4.64	5.07	5.40	5.94	4.84	5.39	5.17	5.79	4.74	5.23
Mean	6.27	6.98	5.44	6.23	5.80	6.48	5.40	5.89	6.04	6.73	5.42	
$CD_{(0.05)}$												
S		0.16				S x I		0.22				
I		0.13				S x D		0.31				
D		0.18				D x I		0.26				
						S x D x I		0.44				

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.8: Effect of growing media and irrigation scheduling onfruit counts per plant of tomato under polyhouse

Number of fruits per plant												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	94.81	95.94	84.41	91.72	75.35	77.06	73.07	75.16	85.08	86.50	78.74	83.44
D_2	86.07	87.27	83.51	85.62	79.09	80.01	78.01	79.04	82.58	83.64	80.76	82.33
D_3	80.50	81.72	78.99	80.40	81.27	82.82	80.47	81.52	80.88	82.27	79.73	80.96
D_4	75.81	79.11	73.91	76.28	78.51	79.86	75.50	77.96	77.16	79.49	74.70	77.12
Mean	84.30	86.01	80.20	83.50	78.56	79.93	76.76	78.42	81.43	82.97	78.48	
$CD_{(0.05)}$						Interaction						
S		0.75				S x I			1.05			
I		0.61				S x D			1.49			
D		0.86				D x I			1.22			
						S x D x I			2.11			

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2) recorded minimum number of fruits per plant (76.76).

The interaction between irrigation level and irrigation frequency (D x I**)** was found to be significant and most number of fruits per plant (91.72) were recorded under treatment having irrigation at 50 % ETc (D_1I_1) which showed statistical significance over other treatments and least number of fruits per plant (75.16) were recorded under irrigation at 50 % ETc on alternate days (D_1I_2). Further the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum number of fruits per plant (86.50) were recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum (74.70) number of fruits per plant. Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum number of fruits per plant (95.94) were recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum number of fruits per plant (73.07).

Higher number of fruits under treatment cocopeat + vermicompost (70:30, w/w) [S_2] might be due to the combined effect of Vermicompost (due to its rich nutrient content) and good water holding capacity and aeration provided by cocopeat. Similar results were obtained by Alaoui *et al.* (2014), Abak and Celikel (1994), Alan *et al.* (1994) and Raviv *et al.* (2004). Water application levels and frequencies also significantly affected number of fruits per plant in tomato. The results indicated that daily irrigated treatments with 50% ETc resulted in higher number of fruits as compared to 100% ETc. When water was applied on alternate days 90 % ETc resulted in higher number of fruits per plant while low moisture content given by 50% ETc on alternate days restricted plant development and ultimately resulted in lesser number of fruits per plant. These results are in line with Peet and Willits (1995), Luvai *et al.* (2014) and Ismail *et.al* (2007).

6.2.5 Fruit length (cm)

It was observed from the data presented in Table 6.9 that the effects of different growing media, irrigation frequency and irrigation level were found statistically significant with respect to fruit length during both the years.

Maximum fruit length (5.81cm) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum fruit length (5.70cm). Irrigation level under irrigation at 50 % ETc (Crop Evapotranspiration) [D_1] recorded highest fruit length (5.79 cm) which was statistically at par with 75% ETc (D_2) [5.78 cm] and 90% ETc (D_3) [5.76 cm] while treatment having irrigation at 100 %ETc (D_4) recorded lowest fruit length (5.66 cm). Irrigation frequency also had statistically significant effect on fruit length and highest fruit length (5.81 cm) was recorded under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that reported lowest fruit length (5.68 cm).

The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum fruit length (5.91 cm) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum fruit length (5.66 cm). The interaction between irrigation level and irrigation frequency (D x I**)** was also found to be significant and highest fruit length (6.01 cm) was recorded under treatment having irrigation at 50 % ETc (D_1I_1) which showed statistical significance over other treatments and least (5.56 cm) was recorded under irrigation at 50 % ETc on alternate days (D_1I_2). Further, the interaction between media and irrigation level (S x D**)** was also observed to be significant and maximum fruit length (5.88 cm) was recorded under treatment having vermiculite + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_1D_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum fruit length(5.76 cm). Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found significant and maximum fruit length (6.23 cm) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 100% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum fruit weight (5.53 cm).

Ismail *et.al* (2007) also reported similar results in tomato crop. Nagaraj *et al.* (2015) reported that fruit length was more in the growing media cocopeat + vermicompost as compared to the cocopeat alone in bell pepper.

6.2.6 Fruit breadth (cm)

The data pertaining to effect of growing media, irrigation frequency and irrigation level resulted in significant variation with respect to fruit breadth during both the years (Table 6.10).

Higher fruit breadth (5.62 cm) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded lower fruit breadth (5.44 cm). Irrigation levels also had significant effect on fruit breadth and maximum fruit breadth (5.57 cm) was observed under irrigation at 50 % ETc (Crop Evapotranspiration) [D_1] which was statistically at par (5.56 cm) with irrigation at 75 % ETc (D_2) and (5.55 cm) irrigation at 90 % ETc (D_3) while treatment having irrigation at 100 % ETc (D_4) recorded minimum fruit breadth (5.43 cm). Irrigation frequency also reported significant impact on fruit breadth with maximum fruit breadth (5.56 cm) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum fruit breadth (5.49 cm).

The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum fruit breadth (5.68 cm) were recorded

Plate 7: Measurement of physical fruit characters

under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum fruit breadth (5.42 cm). The interaction between irrigation level and irrigation frequency (D x I**)** was found to be significant and highest fruit breadth (5.78 cm) were recorded under treatment having irrigation at 50 % ETc (D_1I_1) which showed statistical significance over other treatments and least fruit breadth (5.37 cm) were recorded under irrigation at 50 % ETc on alternate days (D_1I_2). Further, the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum fruit breadth (5.73 cm) were recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum fruit breadth (5.34 cm). Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum fruit breadth (6.01 cm) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum fruit breadth (5.27 cm).

Ismail *et.al* (2007) also reported similar results in tomato crop. Nagaraj *et al.* (2015) reported that fruit breadth was more in the growing media cocopeat + vermicompost as compared to the cocopeat alone in bell pepper.

6.2.7 Average fruit weight (g)

A perusal of data in Table 6.11 depicted that the growing media, irrigation frequency and irrigation level resulted in significant variation with respect to average fruit weight during both the years.

Maximum average fruit weight (72.31g) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum average fruit weight (67.44g). Irrigation level under irrigation at 50 %ETc (Crop Evapotranspiration) [D_1] recorded highest average fruit weight (73.06g) which was statistically significant than all other treatments while treatment having irrigation at 100 % ETc (D_4) recorded lowest average fruit weight (65.21g). Irrigation frequency also had statistically significant effect on fruit weight and highest average fruit weight (71.08g) was recorded under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that reported lowest fruit weight (68.47g).

The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum average fruit weight (74.10g) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum fruit weight(66.64g). The interaction between irrigation level and irrigation frequency (D x I**)** was also found to be significant and highest average fruit weight (84.28g) was recorded under treatment having irrigation at 50 % ETc (D_1I_1) which showed statistical significance over other treatments and least average fruit weight (61.84g) was recorded under irrigation at 50 % ETc on alternate days (D_1I_2). Further, the interaction between media and irrigation level (S x D**)** was also significant and maximum average fruit weight per plant (76.75g) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum fruit weight(62.72g). Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found significant and maximum average fruit weight (89.44g) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum fruit weight (59.40g). The present results get the support from the findings of Lopez *et al.* (2014) and Arancon*et al.* (2003) where they also reported direct beneficial effect of vermicompost on average fruit weight which may be due to increased nutrient status and better moisture conservation through cocopeat. An adequate water management helps in higher fruit weight and yield with high water use efficiency which was obtained by plants grown with 50 % ETc at daily irrigation frequency and 90 % ETc at alternate day frequency. Similar results have been reported by Helyes *et al.* (2012) in tomato.

Addition of vermicompost to the media increased average fruit weight compared to control (media without vermicompost) also reported by Truong and wang (2015).

6.2.8 Fruit Colour

Visual determination of colour is the most important criteria in quality determination of tomato which is associated with redness of colour in tomato. Fruit colour was observed Red Group 44 A under all the treatments and different treatments did not exhibit any influence on fruit colour of tomato.

6.2.9 TSS in fruits (ºB)

The data presented in Table 6.12 revealed that the effects of different growing media, irrigation frequency and irrigation level on TSS were found statistically significant during both the years. Maximum TSS in fruits (4.84 ºB) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum TSS (4.75 ºB). Irrigation levels also had significant effect on TSS and maximum TSS (4.87 ºB) was observed under irrigation at 50 %ETc (Crop Evapotranspiration) [D_1] which was statistically significant than all other treatment while treatment having irrigation at 100 %ETc (D_4) recorded minimum TSS (4.68 ºB). Irrigation frequency also reported significant impact on TSS with maximum TSS (4.81 ºB) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded TSS (4.76 ºB).

Table 6.9: Effect of growing media and irrigation scheduling on fruit length of tomato under polyhouse

Fruit length (cm)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	6.23	5.91	5.91	6.01	5.55	5.61	5.53	5.56	5.88	5.76	5.73	5.79
D_2	5.75	6.19	5.76	5.90	5.72	5.69	5.61	5.67	5.68	5.94	5.74	5.78
D_3	5.69	5.86	5.64	5.73	5.81	5.79	5.77	5.79	5.73	5.82	5.72	5.76
D_4	5.62	5.68	5.55	5.61	5.65	5.73	5.73	5.70	5.67	5.70	5.60	5.66
Mean	5.82	5.91	5.71	5.81	5.68	5.70	5.66	5.68	5.74	5.81	5.70	
$CD_{(0.05)}$						Interaction						
S	0.05					S x I	0.07					
I	0.04					S x D	0.10					
D	0.06					D x I	0.08					
						S x D x I	0.14					

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.10: Effect of growing media and irrigation scheduling on fruit breadth of tomato under polyhouse

Fruit breadth (cm)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	5.77	6.01	5.56	5.78	5.39	5.45	5.27	5.37	5.58	5.73	5.41	5.57
D_2	5.59	5.71	5.45	5.58	5.53	5.56	5.50	5.53	5.56	5.63	5.48	5.56
D_3	5.47	5.54	5.44	5.49	5.61	5.68	5.58	5.62	5.54	5.61	5.51	5.55
D_4	5.41	5.46	5.35	5.41	5.50	5.54	5.33	5.46	5.46	5.50	5.34	5.43
Mean	5.56	5.68	5.45	5.56	5.51	5.56	5.42	5.49	5.54	5.62	5.44	
$CD_{(0.05)}$						Interaction						
S	0.04					S x I	0.05					
I	0.03					S x D	0.07					
D	0.04					D x I	0.06					
						S x D x I	0.10					

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.11: Effect of growing media and irrigation scheduling onaverage fruit weight of tomato under polyhouse

Average fruit weight (g)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	83.03	89.44	80.37	84.28	62.07	64.06	59.40	61.84	72.55	76.75	69.88	73.06
D_2	72.83	75.33	70.20	72.79	69.90	71.75	68.54	70.06	71.36	73.54	69.37	71.42
D_3	64.72	66.87	63.02	64.87	73.99	75.24	72.63	73.95	69.35	71.06	67.83	69.41
D_4	62.04	64.77	60.34	62.38	68.04	70.99	65.11	68.05	65.04	67.88	62.72	65.21
Mean	70.65	74.10	68.48	71.08	68.50	70.51	66.42	68.47	69.58	72.31	67.45	
$CD_{(0.05)}$					Interaction							
S	0.52				S x I	0.74						
I	0.43				S x D	1.05						
D	0.60				D x I	0.85						
					S x D x I	1.48						

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.12: Effect of growing media and irrigation scheduling onTSS of tomato under polyhouse

TSS in fruits (ºB)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	4.99	5.21	4.96	5.05	4.68	4.73	4.66	4.69	4.84	4.97	4.81	4.87
D_2	4.86	4.89	4.82	4.86	4.78	4.82	4.77	4.79	4.82	4.86	4.79	4.82
D_3	4.71	4.77	4.68	4.72	4.83	4.86	4.82	4.84	4.77	4.82	4.75	4.78
D_4	4.62	4.65	4.57	4.61	4.74	4.77	4.71	4.74	4.68	4.71	4.64	4.68
Mean	4.79	4.88	4.76	4.81	4.76	4.80	4.74	4.76	4.78	4.84	4.75	
$CD_{(0.05)}$					Interaction							
S	0.02				S x I	0.03						
I	0.02				S x D	0.05						
D	0.03				D x I	0.04						
					S x D x I	0.06						

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

The interaction between growing media and irrigation frequency (S x I) was also found to be significant and maximum TSS (4.88 ºB) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum TSS (4.74 ºB). The interaction between irrigation level and irrigation frequency (D x I) was found to be significant and highest TSS (5.05 ºB) was recorded under treatment having irrigation at 50 % ETc on daily basis (D_1I_1) which showed statistical significance over other treatments and least (4.61 ºB) was recorded under irrigation at 100 % ETc on daily basis (D_4I_1). Further, the interaction between media and irrigation level (S x D) was also found to be significant and maximum TSS (4.97 ºB) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatment while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum (4.64 ºB) TSS. Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum TSS (5.21ºB) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 100% ETc on daily basis ($S_3D_4I_1$) recorded minimum TSS (4.57 ºB).

Sunafawi*et al.* (2005), Truong and wang (2015) and Truong *et al.* (2018) has also reported high TSS content due to higher potassium levels in the nutrient media with the addition of vermicompost in Cocopeat. The increase in TSS confirm that potassium can play an important role in the constitution of tomato fruit quality and TSS. This is in confirmation to the findings of Adams and Ho (1993) and Dorais, Ehret, and Papadopoulos (2008) that potassium plays a key role in the improvement of several quality traits in tomato fruits and in almost all vegetables.

Mazur *et al.* (2012) have reported that different growing media with same nutrient composition do not had significant effect on the total soluble solids of the tomato.Ghehsareh*et al.* (2011a) reported that media with combination of cocopeat had higher TSS compared to cocopeat alone. El Sunafawi*et.al* (2005) has also reported high TSS content due to the addition of Vermicompost. Similarly, the water applied had significant effect on the TSS and maximum irrigation supply affected the total soluble solids negatively.

Similar results were also reported by Ahmed *et al*. (2014), Leskovar (1998) and Banjaw et al. (2017).

6.2.10 Acidity in fruits

A glance at data in Table 6.13 showed that growing media and irrigation scheduling had registered significant effect on acidity in tomato fruits during both the years.

Maximum acidity in fruits (0.75 %) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum acidity (0.68%). Irrigation levels also had significant effect on number of branches and maximum acidity (0.75%) was observed under irrigation at 50 %ETc (Crop Evapotranspiration) [D_1] which was statistically significant than all other treatments while treatment having irrigation at 100 % ETc (D_4) recorded minimum acidity (0.68%). Irrigation frequency also reported significant impact on acidity with maximum acidity (0.72%) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum acidity (0.71%).

The interaction between irrigation level and irrigation frequency (D x I**)** was found to be significant and highest acidity (0.84%) was recorded under treatment having irrigation at 50 % ETc (D_1I_1) which showed statistical significance over other treatments and least acidity (0.65%) was recorded under irrigation at 50 % ETc on alternate days (D_1I_2). Further, the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum acidity (0.79%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ET (S_2D_1) but was statistically at par with vermculite + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_1D_1) while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum (0.67) acidity. Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum acidity (0.91%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum acidity (0.63%).

Kowalczyk *et al*. (2011) and Mazur *et al*. (2012) reported that for ‘cherry’ tomato fruits, obtained from coconut fibre and mineral wool titratable acidity was equal to 0.44 -0.45 % and 0.51-0.52 %, respectively. Toor *et al.* (2006) found that titratable acidity for ‘Flavouriono’ “cherry” tomato fruit was on the level of 0.45 - 0.55% and for ‘Tradiro’ fruits 0.60-0.71%. Odriozola-Serrano *et al.* (2008) reported that titratable acidity for ‘Bola’ tomato fruits was equal to 0.61%.

6.2.11 Sugar content in fruits (%)

The data presented in Table 6.14 revealed that the effects of different growing media, irrigation frequency and irrigation level on sugar content were found statistically significant during both the years. Maximum sugar content in fruits (1.11%) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum sugar content (1.03%). Irrigation levels also had significant effect on sugar content and maximum sugar content (1.10%) was observed under irrigation at 50 %ETc (Crop Evapotranspiration) [D_1] but was statistically at par (1.08%)with irrigation at 75 %ETc (D_2) while treatment having irrigation at 100 %ETc (D_4) recorded minimum sugar content (1.03%). Irrigation frequency also reported significant impact on sugar content with maximum sugar content (1.09%) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded sugar content (1.05%).

The interaction between growing media and irrigation frequency (S x I) was also found to be significant and maximum sugar content (1.14%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2) recorded minimum sugar content (1.03%).The interaction between irrigation level and irrigation frequency (D x I) was found to be significant and highest sugar content (1.18%) was recorded under treatment having irrigation at 50 % ETc on daily basis (D_1I_1) which showed statistical significance over other treatments and least sugar content (1.01%) was recorded under irrigation at 100 % ETc on daily basis (D_4I_1) and irrigation at 50 % ETc on alternate days basis (D_1I_2). Further, the interaction between media and irrigation level (S x D) was also found to be significant and maximum sugar content (1.15%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatment while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum (0.98%) sugar content. Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum sugar content (1.29%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum sugar content (0.94%).
Radhouani*et al.* (2011) and Rahimi *et al.* (2013) also reported higher sugar content in Vermicompost related treatments. Mazur *et al.* (2012) have reported that different growing media with same nutrient composition do not had significant effect on the sugar content of the different cultivars of cherry tomato.

6.2.12 Lycopene content in fruits (mg/100g)

Data presented in the Table 6.15 demonstrated that growing media and irrigation scheduling had registered significant effect on lycopene content on tomato crop during both the years.

Maximum lycopene content in fruits (3.99 mg/100g) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum lycopene content (3.72 mg/100g). Irrigation levels also had significant effect on lycopene content and maximum lycopene content (4.23 mg/100g) was observed under irrigation at 50 %ETc (Crop Evapotranspiration) [D_1] which was statistically at par (4.20 mg/100g)with irrigation at 75 %ETc (D_2) while treatment having irrigation at 100 %ET (D_4) recorded minimum lycopene content (3.18 mg/100g). Irrigation frequency also reported significant impact on lycopene content with maximum lycopene content (3.89 mg/100g) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum lycopene content (3.78 mg/100g).

The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum lycopene content (4.06 mg/100g) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum lycopene content (3.69 mg/100g). The interaction between irrigation level and irrigation frequency (D x I**)** was found to be significant and highest lycopene content (5.11 mg/100g) was recorded under treatment having irrigation at 50 % ETc (D_1I_1) which showed statistical significance over other treatments and leastlycopene content(2.82 mg/100g) was recorded under irrigation at 100 % ET on daily basis (D_4I_1). Further, the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum lycopene content (4.39 mg/100g) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatment while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum lycopene content (3.08 mg/100g).

Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum lycopene content (5.33 mg/100gm) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along

Table 6.13: Effect of growing media and irrigation scheduling onacidity of tomato under polyhouse

Acidity in fruits (%)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	0.84	0.91	0.77	0.84	0.65	0.68	0.63	0.65	0.75	0.79	0.70	0.75
D_2	0.71	0.76	0.66	0.71	0.73	0.74	0.71	0.73	0.72	0.75	0.69	0.72
D_3	0.69	0.71	0.64	0.68	0.73	0.77	0.72	0.74	0.71	0.74	0.68	0.71
D_4	0.66	0.69	0.63	0.66	0.70	0.72	0.71	0.71	0.68	0.70	0.67	0.68
Mean	0.72	0.77	0.67	0.72	0.70	0.73	0.69	0.71	0.71	0.75	0.68	
$CD_{(0.05)}$						Interaction						
S	0.01					S x I	0.02					
I	0.01					S x D	0.02					
D	0.01					D x I	0.02					
						S x D x I	0.03					

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.14: Effect of growing media and irrigation scheduling on sugar content of tomato under polyhouse

Sugar content in fruits (%)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	1.18	1.29	1.09	1.18	1.02	1.01	1.00	1.01	1.10	1.15	1.04	1.10
D_2	1.11	1.14	1.06	1.10	1.07	1.10	1.03	1.06	1.09	1.12	1.05	1.08
D_3	1.06	1.10	1.04	1.07	1.08	1.10	1.07	1.08	1.07	1.10	1.05	1.07
D_4	1.04	1.06	0.94	1.01	1.03	1.07	1.02	1.04	1.04	1.06	0.98	1.03
Mean	1.10	1.14	1.03	1.09	1.05	1.07	1.03	1.05	1.07	1.11	1.03	
$CD_{(0.05)}$						Interaction						
S	0.01					S x I	0.02					
I	0.01					S x D	0.03					
D	0.02					D x I	0.02					
						S x D x I	0.04					

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum lycopene content (3.29 mg/100g).

This could be attributed to increased nutrient availability, higher CEC, moisture retention and a greater number of pore spaces as reported by Helyes *et al.* (2012) and Olle*et al.* (2012). Mazur *et al.* (2012) have reported that different growing media with same nutrient composition do not had significant effect on the lycopene content of the cherry tomato.

6.2.13 Vitamin C content in fruits

The data presented in Table 6.16 revealed that the effects of different growing media, irrigation frequency and irrigation level on vitamin C content were found to be statistically significant during both the years.

Maximum vitamin C content in fruits (19.66 mg/100g) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum vitamin C content (17.36 mg/100g). Irrigation levels also had significant effect on vitamin C content and maximum vitamin C content (20.10 mg/100g) was observed under irrigation at 50 %ETc (Crop Evapotranspiration) [D_1] which was statistically significant than all other treatment while treatment having irrigation at 100 %ETc (D_4) recorded minimum vitamin C content (15.57 mg/100g). Irrigation frequency also reported significant impact on vitamin C content with maximum vitamin C (19.80 mg/100g) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum vitamin C content (17.16 mg/100g).

The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum vitamin C content (21.51 mg/100g) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum vitamin C content (16.27 mg/100g). The interaction between irrigation level and irrigation frequency (D x I**)** was found to be significant and highest vitamin C content (23.84 mg/100g) was recorded under treatment having irrigation at 50 % ETc on daily basis (D_1I_1) which showed statistical significance over other treatments while least vitamin C content (15.92 mg/100g) was recorded under irrigation at 100 % ETc on daily basis (D_4I_1). Further, the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum vitamin C content (21.53 mg/100g) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatment while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum (14.43 mg/100g) vitamin C content. Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum vitamin C content (26.32 mg/100g) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 100% ETc on daily basis ($S_3D_4I_1$) recorded minimum vitamin C content (13.93 mg/100g).

The results are in agreement with the findings of Ahmed *et al.* (2014) and Vijitha and Mahendran (2010) who reported significant decrease in vitamin C content due to excess and deficit irrigation. Truong and wang (2015) and Truong *et al.* (2018) reported that Vitamin C content of fruit juice increased with increasing vermicompost added to the media. Ghehsareh*et al.* (2011a) reported that media containing cocopeat had lower amount vitamin C than other growing media in tomato.

6.2.14 Phenol content in fruits (mg/100g)

The data presented in Table 6.17 revealed that the effects of different growing media, irrigation frequency and irrigation level were found statistically significant during both the years.

Maximum phenol content in fruits (3.76 mg/100g) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum phenol content (3.59 mg/100g).

Irrigation levels also had significant effect on phenol content and maximum phenol content (3.74 mg/100g) was observed under irrigation at 50 %ETc (Crop Evapotranspiration) [D_1] but was statistically at par (3.73 mg/100g)with irrigation at 75 %ETc (D_2) while treatment having irrigation at 100 %ETc (D_4) recorded minimum phenol content (3.56 mg/100g). Irrigation frequency also reported significant impact on phenol content with maximum phenol content (3.71 mg/100g) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum phenol content (3.66 mg/100g).

The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum phenol content (3.82 mg/100g) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum phenol content (3.61 mg/100g). The interaction between irrigation level and irrigation frequency (D x I**)** was found to be significant and highest phenol content (3.96 mg/100g) was recorded under treatment having irrigation at 50 % ET on daily basis (D_1I_1) which showed statistical significance over other treatments and least (3.52 mg/100g) was recorded under irrigation at 100 % ET on daily basis (D_4I_1) but was statistically at par (3.53 mg/100g) with 50 % ETc on alternate days $D_1I_{2.}$ Further, the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum phenol content (3.84 mg/100g) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatment while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum (3.45 mg/100g) phenol content. Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum phenol content (4.10 mg/100gm) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum phenol content (3.47 mg/100g).

The results are in line with Helyes *et al.* (2012). Castilla (1996) and Kobryn (2002) reported that temperature have a positive effect on phenolic compounds which is a stress reaction of fruits and so optimum supply of water enhances phenol content in tomato. Mazur *et al.* (2012) have reported that different growing media with same nutrient composition do not had significant effect on the phenolic content of the cherry tomato.

6.3 Effect of growing media and irrigation scheduling on nutrient content of tomato leaves

Effect of growing media and irrigation scheduling on nutrient content of tomato leaves under UV stabilized polybags under polyhouse was investigated for two consecutive years i.e. 2016 and 2017.

6.3.1 Leaf Nitrogen content

The data on leaf nitrogen content as influenced by different growing media, irrigation frequency and irrigation level enumerated in Table 6.18 revealed significant effect during both the years.

Maximum leaf N content (2.83%) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum leaf N content (2.68%). Irrigation levels also had significant effect on leaf N content and maximum leaf N content (2.84%) was observed under irrigation at 50 %ETc (Evapotranspiration) [D_1] which was statistically significant than all other treatment while treatment having irrigation at 100 %ETc (D_4) recorded minimum leaf N content (2.62%). Irrigation frequency also reported significant impact on leaf N with maximum leaf N content (2.79%) observed under daily irrigation through drip

Table 6.15: Effect of growing media and irrigation scheduling onlycopene content of tomato under polyhouse

Lycopene content in fruits (mg/100g)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	5.05	5.33	4.95	5.11	3.35	3.44	3.29	3.36	4.20	4.39	4.12	4.23
D_2	4.40	4.78	4.33	4.50	3.85	4.02	3.84	3.90	4.12	4.40	4.08	4.20
D_3	3.11	3.28	2.96	3.12	4.26	4.42	4.24	4.31	3.69	3.85	3.60	3.71
D_4	2.81	2.87	2.78	2.82	3.46	3.80	3.38	3.55	3.14	3.34	3.08	3.18
Mean	3.84	4.06	3.75	3.89	3.73	3.92	3.69	3.78	3.79	3.99	3.72	
$CD_{(0.05)}$						Interaction						
S		0.12				S x I			0.17			
I		0.10				S x D			0.24			
D		0.14				D x I			0.20			
						S x D x I			0.34			

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.16: Effect of growing media and irrigation scheduling onvitamin C content of tomato under polyhouse

Vitamin C content in fruits (mg/100g)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	23.02	26.32	22.17	23.84	16.34	16.74	16.01	16.36	19.68	21.53	19.09	20.10
D_2	21.14	23.34	20.10	21.53	17.55	18.43	17.00	17.66	19.34	20.89	18.55	19.59
D_3	17.55	19.32	16.58	17.82	18.91	19.07	18.13	18.70	18.23	19.19	17.36	18.26
D_4	16.09	17.06	14.92	16.02	16.79	17.03	13.93	15.92	16.44	17.05	14.43	15.97
Mean	19.45	21.51	18.44	19.80	17.40	17.82	16.27	17.16	18.42	19.66	17.36	
$CD_{(0.05)}$						Interaction						
S		0.29				S x I			0.41			
I		0.24				S x D			0.58			
D		0.33				D x I			0.47			
						S x D x I			0.82			

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.17: Effect of growing media and irrigation scheduling onphenol content of tomato under polyhouse

Phenol content in fruits (mg/100g)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	3.96	4.10	3.82	3.96	3.53	3.59	3.47	3.53	3.74	3.84	3.64	3.74
D_2	3.76	3.80	3.62	3.73	3.73	3.77	3.71	3.74	3.75	3.79	3.67	3.73
D_3	3.70	3.73	3.53	3.65	3.77	3.82	3.67	3.75	3.73	3.77	3.60	3.70
D_4	3.59	3.64	3.33	3.52	3.59	3.66	3.57	3.61	3.59	3.65	3.45	3.56
Mean	3.75	3.82	3.57	3.71	3.65	3.71	3.61	3.66	3.70	3.76	3.59	
$CD_{(0.05)}$					Interaction							
S	0.02				S x I	0.03						
I	0.02				S x D	0.04						
D	0.03				D x I	0.04						
					S x D x I	0.06						

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.18: Effect of growing media and irrigation scheduling onleaf nitrogen content of tomato under polyhouse

Leaf Nitrogen content (%)												
	I_1				I_2							
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
D_1	2.99	3.36	2.93	3.09	2.58	2.60	2.56	2.58	2.79	2.98	2.74	2.84
D_2	2.74	2.91	2.70	2.78	2.74	2.83	2.72	2.76	2.74	2.87	2.71	2.77
D_3	2.68	2.72	2.63	2.67	2.78	2.90	2.74	2.81	2.73	2.81	2.69	2.74
D_4	2.59	2.63	2.57	2.60	2.62	2.69	2.60	2.63	2.61	2.66	2.58	2.62
Mean	2.75	2.91	2.70	2.79	2.68	2.76	2.65	2.70	2.71	2.83	2.68	
$CD_{(0.05)}$					Interaction							
S	0.03				S x I	0.04						
I	0.02				S x D	0.06						
D	0.03				D x I	0.05						
					S x D x I	0.08						

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

(I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum leaf N content (2.70%).

The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum leaf N (2.91%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum leaf N (2.65%).

The interaction between irrigation level and irrigation frequency (D x I**)** was found to be significant and highest leaf N (3.09%) was recorded under treatment having irrigation at 50 % ETc on daily basis (D_1I_1) which showed statistical significance over other treatments while least leaf N content (2.58%) was recorded under irrigation at 50 % ETc on alternate day basis (D_1I_2) which was statistically at par (2.60%) with 100 % ETc on daily basis (D_4I_1). Further, the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum leaf N content (2.98%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatment while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum (2.58%) leaf N content. Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum leaf N content (3.36%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$) which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum leaf N content (2.56%).

6.3.2 Leaf Phosphorus content

The data presented in Table 6.19 reveals that leaf P content was significantly influenced by different growing media, irrigation frequency and irrigation level during both the years.

Maximum leaf P content (1.97%) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatmenthaving only cocopeat (S_3) as the growing media recorded minimum leaf P content (1.85%).

Irrigation levels also had significant effect on leaf P content and maximum leaf P content (1.99%) was observed under irrigation at 50 %ETc (Evapotranspiration) [D_1] which was statistically significant than all other treatments while treatment having irrigation at 100 %ETc (D_4) recorded minimum leaf P content (1.82%). Irrigation frequency also reported significant impact on leaf P content with maximum leaf P content (1.95%) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum leaf P content (1.85%).

The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum leaf P content (2.04%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum leaf P content (1.82%). The interaction between irrigation level and irrigation frequency (D x I**)** was found to be significant and highest leaf P content (2.21%) was recorded under treatment having irrigation at 50 % ETc on daily basis (D_1I_1) which showed statistical significance over other treatments and least leaf P content (1.78%) was recorded under irrigation at 50 % ETc on alternate day basis (D_1I_2). Further, the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum leaf P content (2.13%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatment while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum (1.79%) leaf P content.

Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum leaf P content (2.44%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum leaf P content (1.76%).

6.3.3 Leaf Potassium content

A glance of data in Table 6.20 showed that leaf K content was significantly influenced by different growing media, irrigation frequency and irrigation level during both the years.

Maximum leaf K content (1.97%) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum leaf K content (1.80%). Irrigation levels also had significant effect on leaf K content and maximum leaf K content (1.97%) was observed under irrigation at 50 %ETc (Evapotranspiration) [D_1] and irrigation at 75 %ETc (D_2) while treatment having irrigation at 100 %ETc (D_4) recorded minimum leaf K content (1.71%). Irrigation frequency also reported significant impact on leaf K content with maximum leaf K content (1.92%) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum leaf K content (1.85%).

The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum leaf K content (2.05%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum leaf K content (1.80%). The interaction between irrigation level and irrigation frequency (D x I**)** was found to be significant and highest leaf K content (2.23%) was recorded under treatment having irrigation at 50 % ETc on daily basis (D_1I_1) which showed statistical significance over other treatments and least leaf K content (1.65%) was recorded under irrigation at 100 % ETc on daily basis (D_4I_1).

Table 6.19: Effect of growing media and irrigation scheduling onleaf phosphorus content of tomato under polyhouse

Leaf Phosphorus content (%)												
	I_1				I_2							
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
D_1	2.15	2.44	2.03	2.21	1.77	1.82	1.76	1.78	1.96	2.13	1.89	1.99
D_2	1.93	1.97	1.89	1.93	1.88	1.93	1.84	1.88	1.91	1.95	1.86	1.91
D_3	1.84	1.90	1.82	1.85	1.92	1.95	1.90	1.92	1.88	1.92	1.86	1.89
D_4	1.81	1.86	1.78	1.82	1.83	1.86	1.80	1.83	1.82	1.86	1.79	1.82
Mean	1.93	2.04	1.88	1.95	1.85	1.89	1.82	1.85	1.89	1.97	1.85	
$CD_{(0.05)}$						Interaction						
S	0.02					S x I	0.03					
I	0.02					S x D	0.04					
D	0.02					D x I	0.03					
						S x D x I	0.06					

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.20: Effect of growing media and irrigation scheduling on leaf potassium content of tomato under polyhouse

Leaf Potassium content (%)												
	I_1				I_2							
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
D_1	2.21	2.49	1.98	2.23	1.73	1.76	1.67	1.72	1.97	2.12	1.83	1.97
D_2	2.05	2.08	1.97	2.03	1.89	1.98	1.84	1.90	1.97	2.03	1.90	1.97
D_3	1.77	1.91	1.67	1.78	2.01	2.04	1.97	2.01	1.89	1.98	1.82	1.89
D_4	1.66	1.71	1.58	1.65	1.76	1.83	1.74	1.78	1.71	1.77	1.66	1.71
Mean	1.92	2.05	1.80	1.92	1.85	1.90	1.81	1.85	1.88	1.97	1.80	
$CD_{(0.05)}$						Interaction						
S	0.03					S x I	0.05					
I	0.03					S x D	0.07					
D	0.04					D x I	0.06					
						S x D x I	0.10					

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Further, the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum leaf K content (2.12%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatment while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum (1.66%) leaf K content. Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum leaf K content (2.49%) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum leaf K content (1.67%).

Leaf is very important part of the plant which accomplishes photosynthesis and translocates nutrients to various sinks to support activities. The growth and fruitfulness of a plant can therefore, be considered as an index of nutrient status of the leaf. So, amendment of media to ensure optimum nutrient status will go a long way in ensuringhigh levels of productivity. The increased availability of macro nutrients in tomato leaves with the addition of vermicompost to cocopeat might be due to acceleration of improved physical condition of media, more moisture retention and thus increased uptake of water and nutrient. These results are in line with the Sezen*et al.* (2010), Soltani and Naderi (2016). Stepowska and Kosson (2003) who also reported optimum supply of water has a positive impact on NPK uptake in plants. Our findings are in line with the findings of Truong and Wang (2015) who reported increase in the contents of nitrogen and phosphorus in both stem and leaf with increasing proportion of vermicompost in growing media. The high total nitrogen and phosphorus concentrations in stem and leaf might be due to higher mineral nitrogen and phosphorus contents in the medium. The level of potassium decreases with increasing vermicompost in the media. This could be due to high proportion of vermicompost which may reduce root growth and K uptake.

6.4 Effect of growing media and irrigation scheduling on nutrient uptake

Effect of growing media and irrigation scheduling on nutrient uptake of tomato under UV stabilized polybags under polyhouse was investigated for two consecutive years i.e. 2016 and 2017.

6.4.1 Nitrogen uptake

Table 6.21 embodying the data of N uptake revealed that it was significantly influenced by different growing media, irrigation frequency and irrigation interval during both the years of study.

Maximum N uptake (57.74 kg ha^{-1}) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum N uptake (37.41 kg ha^{-1}).Irrigation levels also had significant effect on N uptake and maximum N uptake (50.0 kg ha^{-1}) was observed under irrigation at 50 %ETc (Crop Evapotranspiration) [D_1] statistically significant than all other treatment while treatment having irrigation at 100 %ETc (D_4) recorded minimum N uptake (43.21 kg ha^{-1}).

Irrigation frequency also reported significant impact on N uptake with maximum N uptake (50.04 kg ha^{-1}) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum N uptake (45.30 kg ha^{-1}).

The interaction between growing media and irrigation frequency (S x I) was also found to be significant and maximum N uptake (60.32 kg ha^{-1}) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum N uptake (34.09 kg ha^{-1}). The interaction between irrigation level and irrigation frequency (D x I) was found to be significant and highest N uptake (58.01 kg ha^{-1}) was recorded under treatment having irrigation at 50 % ETc on daily basis (D_1I_1) which showed

Table 6.21: Effect of growing media and irrigation scheduling onnitrogen uptake of tomato under polyhouse

N uptake (kg ha^{-1})												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	55.62	69.14	49.28	58.01	42.46	50.76	32.70	41.98	49.04	59.95	40.99	50.00
D_2	50.74	61.48	41.78	51.34	49.05	57.44	34.03	46.84	49.90	59.46	37.90	49.09
D_3	46.54	56.15	38.00	46.90	51.84	60.58	37.18	49.87	49.19	58.37	37.59	48.38
D_4	43.29	54.51	33.88	43.90	43.29	51.85	32.44	42.53	43.29	53.18	33.16	43.21
Mean	49.05	60.32	40.74	50.04	46.66	55.16	34.09	45.30	47.85	57.74	37.41	
$CD_{(0.05)}$					Interaction							
S	0.76				S x I	1.07						
I	0.62				S x D	1.51						
D	0.87				D x I	1.24						
					S x D x I	2.14						

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.22: Effect of growing media and irrigation scheduling onphosphorus uptake of tomato under polyhouse

P uptake (kg ha^{-1})												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	13.67	18.15	11.80	14.54	8.33	9.49	7.36	8.39	11.00	13.82	9.58	11.47
D_2	11.44	14.99	10.03	12.15	10.32	10.70	9.00	10.00	10.88	12.84	9.52	11.08
D_3	10.18	11.88	8.96	10.34	10.51	13.92	9.84	11.42	10.35	12.90	9.40	10.88
D_4	8.59	9.66	7.93	8.72	8.59	9.62	7.89	8.70	8.59	9.64	7.91	8.71
Mean	10.97	13.67	9.68	11.44	9.44	10.93	8.52	9.63	10.20	12.30	9.10	
$CD_{(0.05)}$					Interaction							
S	0.44				S x I	0.62						
I	0.36				S x D	0.88						
D	0.51				D x I	0.72						
					S x D x I	1.25						

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

statistical significance over other treatments and least N uptake (41.98 kg ha^{-1}) was recorded under irrigation at 50 % ETc on alternate day basis (D_1I_2). Further, the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum N uptake(59.95 kg ha^{-1}) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum (33.16 kg ha^{-1}) N uptake. Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum N uptake (69.14 kg ha^{-1}) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum N uptake (32.70 kg ha^{-1}).

6.4.2 Phosphorus uptake

A glance of data in Table 6.22 showed that different growing media, irrigation frequency and irrigation interval had significant effect on P uptake during both the years of study.

Maximum P uptake (12.30 kg ha^{-1}) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum P uptake (9.10 kg ha^{-1}). Irrigation levels also had significant effect on P uptake and maximum P uptake (11.47 kg ha^{-1}) was observed under irrigation at 50 %ETc (Crop Evapotranspiration) [D_1] which was statistically at par (11.08 kg ha^{-1}) with irrigation at 75 %ETc (D_2) while treatment having irrigation at 100 %ETc (D_4) recorded minimum P uptake (8.71 kg ha^{-1}). Irrigation frequency also reported significant impact on P uptake with maximum P uptake (11.44 kg ha^{-1}) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum P uptake (9.63 kg ha^{-1}). The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum P uptake (13.67 kg ha^{-1}) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum P uptake (8.52 kg ha^{-1}). The interaction between irrigation level and irrigation frequency (D x I**)** was found to be significant and highest P uptake (14.54 kg ha^{-1}) was recorded under treatment having irrigation at 50 % ETc on daily basis (D_1I_1) which showed statistical significance over other treatments and least P uptake (8.39 kg ha^{-1}) was recorded under irrigation at 50 % ETc on alternate day basis (D_1I_2).

Further, the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum P uptake(13.82 kg ha^{-1}) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum(7.91 kg ha^{-1}) P uptake. Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum P uptake (18.15 kg ha^{-1}) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all othertreatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum P uptake (7.36 kg ha^{-1}).

6.4.3 Potassium uptake

An examination of data presented in Table 6.23 revealed that K uptake was significantly influenced by different growing media, irrigation frequency and irrigation level during both the years.

Maximum K uptake (48.45 kg ha^{-1}) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum K uptake (32.23 kg ha^{-1}). Irrigation levels also had significant effect on K uptake and maximum K uptake (41.30 kg ha^{-1}was observed under irrigation at 50 %ETc (Crop Evapotranspiration) [D_1] which was significantly higher than other treatments while treatment having irrigation at 100 %ETc (D_4) recorded minimum K uptake (35.86 kg ha^{-1}). Irrigation frequency also reported significant impact on K uptake with maximum K uptake (40.35 kg ha^{-1}) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum K uptake (38.33 kg ha^{-1}).

The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum K uptake (50.72 kg ha^{-1}) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum K uptake (28.33 kg ha^{-1}). The interaction between irrigation level and irrigation frequency (D x I**)** was found to be significant and highest K uptake (46.46 kg ha^{-1}) was recorded under treatment having irrigation at 50 % ETc on daily basis (D_1I_1) which showed statistical significance over other treatments and least K uptake (35.16 kg ha^{-1}) was recorded under irrigation at 100 % ETc on daily basis (D_4I_1). Further, the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum K uptake(50.67 kg ha^{-1}) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum(29.50 kg ha^{-1}) K uptake.

Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum K uptake (58.22 kg ha^{-1}) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETc on daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 50% ETc on alternate day basis ($S_3D_1I_2$) recorded minimum K uptake (28.33 kg ha^{-1}).The media cocopeat + Vermicompost recorded highest nutrient uptake of N, P and K by tomato crop.

Table 6.23: Effect of growing media and irrigation scheduling onpotassium uptake of tomato under polyhouse

K uptake (kg ha^{-1})												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	42.88	58.22	38.27	46.46	34.96	43.11	30.33	36.13	38.92	50.67	34.30	41.30
D_2	40.26	51.89	33.30	41.82	37.00	47.67	31.33	38.67	38.63	49.78	32.32	40.24
D_3	35.25	47.96	30.66	37.95	40.33	50.59	34.99	41.97	37.79	49.27	32.83	39.96
D_4	32.33	44.81	28.33	35.16	35.67	43.33	30.67	36.56	34.00	44.07	29.50	35.86
Mean	37.68	50.72	32.64	40.35	36.99	46.18	31.83	38.33	37.34	48.45	32.23	
$CD_{(0.05)}$						Interaction						
S	0.60					S x I	0.85					
I	0.49					S x D	1.21					
D	0.70					D x I	0.98					
						S x D x I	1.71					

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Table 6.24: Effect of growing media and irrigation scheduling on fruit yield of tomato under polyhouse

Fruit Yield (kg/plant)												
	I_1				I_2				S_1	S_2	S_3	Mean
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean				
D_1	7.29	8.25	7.12	7.56	5.26	5.42	5.16	5.28	6.27	6.84	6.14	6.42
D_2	6.36	6.55	6.23	6.38	6.12	6.19	6.05	6.12	6.24	6.37	6.14	6.25
D_3	5.77	6.23	4.83	5.61	6.18	6.40	6.08	6.22	5.97	6.32	5.46	5.91
D_4	5.10	5.36	4.64	5.03	5.71	5.80	5.41	5.64	5.41	5.58	5.03	5.34
Mean	6.13	6.60	5.70	6.14	5.82	5.95	5.68	5.81	5.97	6.27	5.69	
$CD_{(0.05)}$						Interaction						
S	0.11					S x I	0.15					
I	0.90					S x D	0.22					
D	0.12					D x I	0.18					
						S x D x I	0.31					

S_1- Vermiculite+ vermicompost (70:30), S_2- cocopeat + vermicompost (70:30), S_3- cocopeat, I_1 – Daily through drip, I_2 – Alternate day through drip, D_1- 50 % ETc (evapotranspiration), D_2- 75 % ETc, D_3- 90% ETc and D_4-100% ETc

Generally, lowest uncredited nutrient content is considered better (meaning more uptake by plants) but two treatments having Vermicompost showed better nutrient credit due to availability of some percentage of nutrient in Vermicompost. The findings are in line with report of Xiong Jing *et al.* (2017), Truong and Wang (2015) and Truong *et al.* (2018). Mawalagedera (2012) also reported higher nutrient uptake in the cocopeat medium under standard irrigation system.

Alifar *et al.* (2010) observed no significant difference on concentration of nitrogen, phosphors and potassium uptake in substrates including peat, coco peat and perlite cucumber fruit.

6.5 Effect of growing media and irrigation scheduling on yield

6.5.1 Yield

The data pertaining to effect of different growing media, irrigation frequency and irrigation level on fruit yield per plant are presented in Table 6.24 which showed significant effect during both the years.

Maximum yield per plant (6.27kg/plant) was recorded under (S_2) cocopeat + vermicompost (70:30, w/w) which was statistically significant than all other treatments while the treatment having only cocopeat (S_3) as the growing media recorded minimum yield per plant (5.69 kg/plant). Irrigation levels also had significant effect on yield per plant and maximum yield per plant (6.42 kg/plant) was observed under irrigation at 50 %ETc (Crop Evapotranspiration) [D_1] which was statistically significant than all other treatment while treatment having irrigation at 100 %ETc (D_4) recorded minimum yield (5.34 kg/plant). Irrigation frequency also reported significant impact on yield per plant with maximum yield per plant (6.14 kg/plant) observed under daily irrigation through drip (I_1) and was statistically significant than treatment of irrigation on alternate days through drip (I_2) that recorded minimum yield per plant (5.81 kg/plant).

The interaction between growing media and irrigation frequency (S x I**)** was also found to be significant and maximum yield per plant (6.60 kg/plant) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with daily irrigation (S_2I_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation on alternate days (S_3I_2)recorded minimum yield per plant (5.68 kg/plant). The interaction between irrigation level and irrigation frequency (D x I**)** was found to be significant and highest yield per plant (7.56 kg/plant) was recorded under treatment having irrigation at 50 % ETc on daily basis (D_1I_1) which showed statistical significance over other treatments while least fruit yield per plant (5.03 kg/plant) was recorded under irrigation at 100 % ETc on daily basis (D_4I_1). Further, the interaction between media and irrigation level (S x D**)** was also found to be significant and maximum yield per plant (6.84 kg/plant) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) with irrigation at 50% ETc (S_2D_1) and was statistically significant than all other treatments while treatment having only cocopeat with irrigation at 100% ETc (S_3D_4) recorded minimum (5.03 kg/plant) yield per plant. Interaction between media, irrigation level and irrigation frequency (S x D x I) was also found to be significant and maximum yield per plant (8.25 kg/plant) was recorded under treatment having cocopeat + vermicompost (70:30, w/w) along with irrigation at 50% ETcon daily basis ($S_2D_1I_1$)which was statistically significant than all other treatments while treatment having only cocopeat along with irrigation at 100% ETc on daily basis ($S_3D_4I_1$) recorded minimum yield per plant (4.64 kg/plant).

Regulated liberalization and balanced supply of nutrients in media supplemented with vermicompost recorded higher yielding attributes and yield of tomato making beneficial microbial dynamics favourable for crop growth. Similar results were reported by El-Sanafawi*et al.* (2005); Ten and Kirinko (2002); Joseph and Muthuchamy (2014). Ghehsareh*et al.* (2011a) reported that media with cocopeat had lower yield compared to other growing media as coco peat has low aeration within the medium due to high-water holding capacity and poor air-water relationship (Abad *et al.*, 2002).Stronger and healthier plants can produce increased flowering, fruit set, and ripened fruits. Effect of irrigation on yield is complex and one of the main effects was the increased number of marketable fruits per hectare. When water was applied daily through drip, best performance was obtained under irrigation level

Plate 8: General view of the experiment

Plate 9: Healthy fruits under different treatments

of 50% ET whereas, irrigation on alternate days yielded maximum along with other characteristic sunder 90% ET which was statistically at par with irrigation dose of 75% ET.This might be due to the adequate moisture content provided by irrigation level of 50% ET on regular basis and 90% ET and 75%ET on alternate days. The excessive moisture provided by 100% ET could have led to leaching of nutrients when water applied daily through drip. Simultaneously, low moisture content under 50% ET on alternate days might have restricted plant development and ultimately resulted in reduced yield. Similar results were reported by Sawan*et al.* (1999), Joseph and Muthuchamy (2014), Sezen*et al*. (2010) and Helyes *et al. (*2012*)* in tomato, Natarajan and Kothandaraman (2018) and Parameshwarareddy et al. (2018). Our results are also in confirmation with the findings of Fandi *et al.* (2008) who reported decreased height, number and area of leaves/plant and number of flowers with low moisture content.

6.6 Irrigation water requirement and water use efficiency (WUE)

The seasonal water requirement of tomato plants in soilless growing media comes out to be 6.13cm, 9.12cm, 10.94cm and 12.15cm under irrigation @ 50%, 75%, 90% and 100% ET_c, respectively, which were effectively met by operating the drip system at daily or alternate days, as per the treatments, w.e.f. mid-March to October (Table 6.25). The lesser irrigation water requirement can be explained in light of higher humidity and lower or negligible other atmospheric factors such as wind speed and solar radiation inside the polyhouse as evapotranspiration inside polyhouse isgreatly affected by the cladding material which significantly moderates the radiation balance as to the external environment due to change in wave length of solar radiation as such evapotranspiration under polyhouse was lower while air temperature was higher under polyhouse as compared to open field conditions (Annexure I). The results are supported by the findings of Sentelhas (2001) and Abdrabbo (2001).

Water use efficiency (WUE) was found to be influenced by different treatments. WUE under different treatments ranged from 33.93t ha^{-1} cm^{-1} ($S_3I_1D_4$) to 119.68 t ha^{-1} cm^{-1}(S_2 I_1D_1). The WUE under media cocopeat+ vermicompost (70:30 w/w) @ 50 per cent ETc on daily basis was maximum due to moisture retention in the media and resulted in higher yield whereas, in case of cocopeat media @100 per cent ETc on daily basis may be due to leaching of water and nutrient from the media thereby resulting in lower yield and ultimately lowers the WUE. Higher WUE under irrigation level @ 50 per cent ETc compared to 100 per cent ETc have earlier been reported by Badr*et al.* (2012). Similar results were reported by Joseph and Muthuchamy (2014) and Helyes *et al*. (2012) in tomato and Nikolaou et al. (2018) in cucumber.

Table 6.25: Effect of different treatments on water use efficiency (WUE) of tomato

Number	Combination	Water applied (cm)	Yield/plant (t/ha)	Water use efficiency (t ha^{-1} cm^{-1})
T_1	S_1 I_1D_1	6.13	648.29	105.76
T_2	S_1 I_1D_2	9.12	565.48	62.00
T_3	S_1 I_1D_3	10.94	512.59	46.85
T_4	S_1 I_1D_4	12.15	453.33	37.31
T_5	S_1 I_2D_1	6.13	467.11	76.20
T_6	S_1 I_2D_2	9.12	544.29	59.68
T_7	S_1 I_2D_3	10.94	549.03	50.19
T_8	S_1 I_2D_4	12.15	507.70	41.79
T_9	S_2 I_1D_1	6.13	733.62	119.68
T_{10}	S_2 I_1D_2	9.12	581.92	63.81
T_{11}	S_2 I_1D_3	10.94	554.07	50.65
T_{12}	S_2 I_1D_4	12.15	476.00	39.18
T_{13}	S_2 I_2D_1	6.13	481.92	78.62
T_{14}	S_2 I_2D_2	9.12	549.77	60.28
T_{15}	S_2 I_2D_3	10.94	569.03	52.01
T_{16}	S_2 I_2D_4	12.15	515.40	42.42
T_{17}	S_3 I_1D_1	6.13	632.88	103.24
T_{18}	S_3 I_1D_2	9.12	553.62	60.70
T_{19}	S_3 I_1D_3	10.94	429.33	39.24
T_{20}	S_3 I_1D_4	12.15	412.29	33.93
T_{21}	S_3 I_2D_1	6.13	458.66	74.82
T_{22}	S_3 I_2D_2	9.12	537.62	58.95
T_{23}	S_3 I_2D_3	10.94	540.44	49.40
T_{24}	S_3 I_2D_4	12.15	481.18	39.60
$CD_{0.05}$			27.55	

The water holding capacity of soil-less media was more and due to this the number of irrigations had been reduced hence higher water use efficiency could be achieved in closed system. (Metin*et al.,* 2010; Barikara*et al.,* 2013).

Table 6.26: Benefit-cost analysis of tomato under different growing media combinations

Treatments	Total cost of cultivation (variable +fixed cost)	Gross income	Net Returns	B:C Ratio
Cocopeat + Vermicompost (70:30 w/w)	83313.52	313500	230186.48	2.76:1
Vermiculite + Vermicompost (70:30 w/w)	154271.85	298500	144288.15	0.93:1
Cocopeat	82938.52	284500	201561.48	2.43:1

6.7 Benefit: Cost analysis of tomato production under protected conditions

To study the feasibility of cultivation of tomato under poly house with soilless media, cost of structure, cost of cultivation and net return were estimated. Benefit cost ratio for polyhouse grown tomatoes worked out for different treatments has been presented in Table 6.26 and Appendix-VI. The average selling price of tomato was 20 Rs/kg. A perusal of data reveals that maximum gross income (Rs 313500) was recorded in media combination of cocopeat + vermicompost (70:30 w/w) followed by (Rs 298500) under media combination of vermiculite + vermicompost (70:30 w/w) while minimum (Rs 284500), was recorded under cocopeat media, alone. Similarly, net returns were maximum (Rs 230186.48) under media combination of cocopeat + vermicompost (70:30 w/w) and minimum (Rs 144288.15) under Vermiculite + Vermicompost (70:30 w/w). The highest benefit cost ratio (2.76:1) was worked out in media combination of cocopeat + vermicompost (70:30 w/w) which was rated as the most profitable and cost effective whereas, lowest benefit cost ratio (0.93:1) was recorded under media vermiculite + vermicompost (70:30 w/w).

These results are in agreement with the findings of Metin*et al.* (2006) and Barikara*et al.*(2013). The results have indicated that the poly house cultivation of tomato using soil-less media.

Chapter-7

SUMMARY AND CONCLUSION

Tomato production in polyhouses is facing critical challenges due to soil problems and to counter this, farmers are using different media for growing tomatoes. When a growing media is changed, amount of irrigation water and frequency of irrigation also changes, which needs to be standardized. Though lot of work is being done on growing media, very little or negligible literature is available on the drip irrigation scheduling of tomato grown in polybags/growbags along with suitable growing media. Therefore, to establish best media and irrigation practices for tomato production in UV stabilized growbags, an experiment under protected condition was conducted during 2016 and 2017. Different soilless media (Cocopeat, vermicompost and vermiculite) and their combinations along with different levels of irrigations (50, 75, 90 and 100 % Evapotranspiration (ET_c)) and irrigation intervals (daily and on alternate days) were used as the treatments of the study with the objectives of determining best soilless growing media along with frequency and amount of irrigation and to work out cost economics of same.

The results obtained from present investigation entitled **"Standardization of soilless media and irrigation schedule for improving yield and quality of tomato in UV stabilized polybags under polyhouse"**have been summarized below:

7.1 Effect of different growing media, irrigation levels and irrigation frequencies on chemical properties of media:

In the present investigation, different soilless media viz. cocopeat, vermicompost, vermiculite and their different combinations were used. The chemical properties at the start of experiment were pH 6.23, 6.80 and 6.65 in the media cocopeat, vermiculite + vermicompost (70:30 w/w) and cocopeat +vermicompost (70:30 w/w), respectively. Nitrogen was 0.05, 0.09 and 0.91 per cent in the media cocopeat, vermiculite + vermicompost (70:30 w/w) and cocopeat +vermicompost (70:30 w/w), respectively. Phosphorus was 0.03, 0.05 and 0.58 per cent in the media cocopeat, vermiculite + vermicompost (70:30 w/w) and cocopeat +vermicompost

(70:30 w/w), respectively. Potassium was 0.08, 0.09 and 0.99 per cent in the media cocopeat, vermiculite + vermicompost (70:30 w/w) and cocopeat +vermicompost (70:30 w/w), respectively.

pH (6.77), Nitrogen (1.28 %), Phosphorus (0.95 %) and potassium (1.17 %) in the media was observed to be maximum in the treatment containing cocopeat + vermicompost (70:30) along with 50 per cent ET irrigation on daily basis. Whereas, minimum pH (6.22), Nitrogen (0.11 %), Phosphorus (0.10 %) and potassium (0.15 %) was recorded in the treatment comprising of cocopeat along with irrigation @ 50 per cent Evapotranspiration (ETc) on alternate day basis.

7.2 Effect of different growing media, irrigation levels and irrigation frequencies on plant growth parameters:

Among different treatments maximum plant height (171.44 cm), number of fruits per plant (95.94), average fruit weight (89.44 g), fruit length (6.23 cm), fruit breadth (6.01 cm), number of branches (8.59), yield (8.25 kg/plant) and minimum internodal length (6.42 cm) were found to be under cocopeat + vermicompost (70:30 w/w) with 50 per cent irrigation on daily basis ($S_2D_1I_1$),whereas, minimum plant height (125.18 cm), number of fruits per plant (73.07), average fruit weight (59.40 g), fruit length (5.55 cm), fruit breadth (5.27 cm), number of branches (4.83) and yield (4.64 kg/plant) while internodal length (8.00 cm) was maximum under the treatment containing cocopeat media along with irrigation @ 100 per cent ETc on daily basis ($S_3D_4I_1$).

Under biochemical characters, highest TSS (5.21 ºBrix), acidity (0.91 %), sugars (1.29 %), lycopene content (5.33 mg/100g), phenols (3.47 mg/100gm) and vitamin-C (26.32 mg/100g) were observed under cocopeat + vermicompost (70:30 w/w) with irrigation @ 50 per cent ETc on daily basis($S_2D_1I_1$) while lowest values of TSS (4.57 ºBrix), acidity (0.63 %), sugars (0.94 %), lycopene content (3.29 mg/100g), phenols (4.10 mg/100gm) and vitamin-C (13.93 mg/100g) were observed under cocopeat media along with irrigation @ 100 per cent ETc on daily basis ($S_3D_4I_1$) treatment.

7.3 Effect of different growing media, irrigation levels and irrigation frequencies on nutrient content and uptake:

Treatment combination of cocopeat + vermicompost (70:30 w/w) with irrigation @ 50 per cent ET on daily basis ($S_2D_1I_1$) recorded maximum leaf nitrogen (3.36 %), phosphorus (2.44%) and potassium (2.49%) along with higher nutrient uptake of Nitrogen (69.14 %), phosphorus (18.15 %) and potassium (58.22 %). Minimum leaf nitrogen (2.57 %), phosphorus (1.76 %) and potassium (1.67 %) along with minimum nutrient uptake of Nitrogen (32.70 %) and phosphorus (7.36 %) was recorded under cocopeat media along with irrigation @ 50 per cent ETc on alternate day basis ($S_3D_1I_2$). Potassium uptake (28.33 %) was minimum under cocopeat media with irrigation @ 100 per cent ETc on daily basis.

7.4 Effect of different growing media, irrigation levels and irrigation frequencies on irrigation water requirement and water use efficiency:

Under different media and their combinations tried, the total water requirement at @ 50%, 75%, 90% and 100% ET_c, was calculated as 6.13cm, 9.12cm, 10.94cm and 12.15cm, respectively. Daily irrigation at 50% ET_c gave best results in relation to yield and yield contributing traits while minimum yield and related traits were recorded under daily irrigation at 100% Etc. This significantly underlines the fact that irrigation lower than daily crop evapotranspiration at regular intervals gives better results than irrigation at full crop evapotranspiration. As such, water use efficiency (WUE) was also found to be influenced by different treatments. WUE was observed to be highest (119.68t ha^{-1} cm^{-1}) in the treatment combination of cocopeat + vermicompost (70:30 w/w) with irrigation @ 50 per cent ETc on daily basis (S_2 I_1D_1) whereas lowest water use efficiency (33.93 t ha^{-1} cm^{-1}) was observed under treatment of cocopeat along with irrigation @ 100 per cent ETc on daily basis ($S_3I_1D_4$).

7.5 Effect of different growing media, irrigation levels and irrigation frequencies on Benefit: Cost ratio:

Net returns were maximum (Rs 230186.48) under media combination of cocopeat + vermicompost (70:30 w/w) and minimum (Rs 144288.15) under Vermiculite + Vermicompost (70:30w/w). The highest (2.76:1) benefit cost ratio was worked out in media combination of cocopeat + vermicompost (70:30 w/w) which was rated as the most profitable and cost effective whereas, lowest (0.93:1) benefit cost ratio was recorded under media vermiculite + vermicompost (70:30w/w).

CONCLUSION:

From the present investigations, it is concluded that treatment combination of cocopeat + vermicompost (70:30 w/w) along with irrigation at 50 per cent crop evapotranspiration (Etc) on daily basis resulted in better growth, quality, yield and yield contributing traits. The nutrient uptake was recorded highest under this treatment indicating best utilization of available nutrients at 50% ET_c. Total seasonal water requirement under this treatment was recorded to be 6.13cm which indicates considerable irrigation water saving compared to 12.15cm under full replenishment of crop evapotranspiration. This treatment also recorded highest water use efficiency (119.68t $ha^{-1}cm^{-1}$), further cementing the fact that better yield can be obtained by deficit irrigation. The above results were further corroborated by maximum net returns and positive benefit cost ratio under the same treatment suggesting beneficial combination. During the study, no influence of disease was recorded, thereby, indicating safe and healthy growing environment for crop production under soilless growing media. Therefore, it can be concluded, that growing tomatoes under protected condition with soilless media of cocopeat + vermicompost (70:30 w/w) helps in better yield and quality with minimum water requirement of 6.13 cm for 8 months of growing season based on 50 per cent crop evapotranspiration (ETc) on daily basis. The treatment also provides highest cost benefit ratio of 2.76 depicting that farmers can earn significant revenue by growing tomato in this growing medium. The findings from the study can be helpful to the growers involved in tomato production under protected conditions for utilizing available water efficiently by saving 50 per cent irrigation water and maximizing yield and net income.

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APPENDIX-I

Agro metrological data March 2016 to November 2016

Months	Polyhouse				outside				
	Minimum Temperature (^0C)	Maximum Temperature (^0C)	Pan evaporation (mm)	Relative Humidity (%)	Minimum Temperature (^0C)	Maximum Temperature (^0C)	Relative Humidity (%)	Evaporation (mm)	Rainfall (mm)
March	18.6	34.9	2.3	63.2	9.1	24.2	55.5	2.9	87.5
April	22.4	38.1	3.5	57.4	13.5	29.4	44.5	4.3	25.6
May	23.0	37.0	4.1	55.0	16.6	30.6	46	4.9	115.0
June	26.09	43.74	3.8	69.5	19.2	29.6	65	4.7	118.9
July	25.73	33.33	2.8	82.1	20.6	27.4	82	3.4	151.9
August	26.11	33.99	1.04	79.4	19.9	26.9	83	2.5	164.1
September	23.35	34.94	2.2	75.1	17.4	28.6	73.5	3.7	11.2
October	17.04	30.96	1.9	57.9	11.6	27.4	55	3.7	Nil

Agro metrological data March 2017 to November 2017

Months	Polyhouse				outside				
	Minimum Temperature (^0C)	Maximum Temperature (^0C)	Pan evaporation (mm)	Rh (%)	Minimum Temperature (^0C)	Maximum Temperature (^0C)	Relative Humidity (%)	Evaporation (mm)	Rainfall (mm)
March	13.72	32.52	2.2	38	7.8	22.9	45	3.1	33.2
April	20.55	39.80	3.5	44	13.2	29.3	44	4.2	57.8
May	18.91	30.13	4.1	46	15.8	30.5	53	4.9	100.8
June	24.30	35.40	3.9	56	17.9	28.7	68	4.7	197.8
July	25.40	33.30	2.7	68	20.4	27.6	81	3.4	162.3
August	24.30	35.70	1.02	68	20.1	26.7	82	2.5	233.8
September	23.10	36.00	2.2	70	16.8	27.2	77	3.8	133.8
October	16.80	28.75	1.9	58	11.4	26.8	56	3.7	Nil

APPENDIX-II

ANOVA of the tables:

pH of growing media					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.105003	0.052501	1.0163	3.199582
S	2	1.973453	0.986726	19.10063	3.199582
D	3	0.012994	0.004331	0.083847	2.806845
I	1	0.044006	0.044006	0.851841	4.051749
S×D	6	0.229414	0.038236	0.740149	2.303509
S×I	2	0.163803	0.081901	1.585412	3.199582
D×I	3	0.084594	0.028198	0.545848	2.806845
S×D×I	6	0.171397	0.028566	0.552972	2.303509
Error	46	2.376331	0.051659		
Total	71	5.160994			

Nitrogen content in growing media (%)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.000619	0.00031	0.873319	3.199582
S	2	14.46547	7.232735	20394.02	3.199582
D	3	0.043522	0.014507	40.90629	2.806845
I	1	0.018689	0.018689	52.69675	4.051749
S×D	6	0.005386	0.000898	2.531188	2.303509
S×I	2	0.001786	0.000893	2.518134	3.199582
D×I	3	0.113589	0.037863	106.7616	2.806845
S×D×I	6	0.004136	0.000689	1.943754	2.303509
Error	46	0.016314	0.000355		
Total	71	14.66951			

Phosphorus content in growing media (%)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.003203	0.001601	2.179584	3.199582
S	2	6.181136	3.090568	4206.444	3.199582
D	3	0.027182	0.009061	12.33207	2.806845
I	1	0.044501	0.044501	60.569	4.051749
S×D	6	0.010664	0.001777	2.41903	2.303509
S×I	2	0.009236	0.004618	6.285444	3.199582
D×I	3	0.080182	0.026727	36.37744	2.806845
S×D×I	6	0.015764	0.002627	3.575929	2.303509
Error	46	0.033797	0.000735		
Total	71	6.405665			

Potassium content in growing media (%)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.002553	0.001276	2.671174	3.199582
S	2	8.592169	4.296085	8990.669	3.199582
D	3	0.051137	0.017046	35.67282	2.806845
I	1	0.111235	0.111235	232.7874	4.051749
S×D	6	0.021475	0.003579	7.490332	2.303509
S×I	2	0.003186	0.001593	3.333881	3.199582
D×I	3	0.110682	0.036894	77.2102	2.806845
S×D×I	6	0.029814	0.004969	10.39888	2.303509
Error	46	0.021981	0.000478		
Total	71	8.944232			

Plant height (cm)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.036311	0.018156	0.003841	3.199582
S	2	212.612	106.306	22.49128	3.199582
D	3	622.5923	207.5308	43.90753	2.806845
I	1	87.78125	87.78125	18.57199	4.051749
S×D	6	32.62758	5.43793	1.150509	2.303509
S×I	2	1.228825	0.614412	0.129992	3.199582
D×I	3	3005.613	1001.871	211.9671	2.806845
S×D×I	6	6.781042	1.130174	0.239112	2.303509
Error	46	217.4209	4.726541		
Total	71	4186.693			

Number of fruits per plant					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.707244	0.353622	0.073421	3.199582
S	2	66.98795	33.49398	6.954185	3.199582
D	3	310.1975	103.3992	21.46825	2.806845
I	1	579.3608	579.3608	120.2897	4.051749
S×D	6	12.37007	2.061678	0.428056	2.303509
S×I	2	0.126658	0.063329	0.013149	3.199582
D×I	3	753.4105	251.1368	52.14227	2.806845
S×D×I	6	3.114431	0.519072	0.107772	2.303509
Error	46	221.5534	4.816377		
Total	71	1947.829			

Average fruit weight (g)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.312108	0.156054	0.098596	3.199582
S	2	134.6715	67.33576	42.54298	3.199582
D	3	404.5066	134.8355	85.18959	2.806845
I	1	158.42	158.42	100.0903	4.051749
S×D	6	1.395464	0.232577	0.146943	2.303509
S×I	2	0.404008	0.202004	0.127627	3.199582
D×I	3	3052.468	1017.489	642.8536	2.806845
S×D×I	6	17.01298	2.835497	1.791477	2.303509
Error	46	72.80742	1.58277		
Total	71	3841.998			

Fruit Length (cm)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.003033	0.001517	0.800995	3.199582
S	2	0.044433	0.022217	11.73326	3.199582
D	3	0.30405	0.10135	53.52583	2.806845
I	1	0.009339	0.009339	4.932134	4.051749
S×D	6	0.001967	0.000328	0.173109	2.303509
S×I	2	0.003478	0.001739	0.918357	3.199582
D×I	3	0.765983	0.255328	134.8459	2.806845
S×D×I	6	0.001167	0.000194	0.102692	2.303509
Error	46	0.0871	0.001893		
Total	71	1.22055			

Fruit breadth (cm)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.005658	0.002829	0.888895	3.199582
S	2	0.147808	0.073904	23.21993	3.199582
D	3	0.087937	0.029312	9.209688	2.806845
I	1	0.130901	0.130901	41.12788	4.051749
S×D	6	0.016058	0.002676	0.840894	2.303509
S×I	2	0.002203	0.001101	0.346045	3.199582
D×I	3	0.543226	0.181075	56.89206	2.806845
S×D×I	6	0.041286	0.006881	2.161946	2.303509
Error	46	0.146408	0.003183		
Total	71	1.121487			

Internodal length (cm)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.459558	0.229779	1.107751	3.199582
S	2	2.410508	1.205254	5.810458	3.199582
D	3	9.115278	3.038426	14.64807	2.806845
I	1	1.632022	1.632022	7.867881	4.051749
S×D	6	2.050281	0.341713	1.64738	2.303509
S×I	2	0.570286	0.285143	1.374657	3.199582
D×I	3	18.83028	6.276759	30.25988	2.806845
S×D×I	6	1.834281	0.305713	1.473826	2.303509
Error	46	9.541708	0.207428		
Total	71	46.4442			

Number of branches					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	1.657703	0.828851	2.077613	3.199582
S	2	3.775586	1.887793	4.731973	3.199582
D	3	7.252026	2.417342	6.05935	2.806845
I	1	0.000735	0.000735	0.001842	4.051749
S×D	6	0.469503	0.07825	0.196144	2.303509
S×I	2	0.023519	0.01176	0.029477	3.199582
D×I	3	12.27328	4.091094	10.2548	2.806845
S×D×I	6	0.729814	0.121636	0.304894	2.303509
Error	46	18.35143	0.398944		
Total	71	44.5336			

Acidity (%)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	2.5E-05	1.25E-05	0.021211	3.199582
S	2	0.029033	0.014517	24.63326	3.199582
D	3	0.03295	0.010983	18.63757	2.806845
I	1	0.002939	0.002939	4.986986	4.051749
S×D	6	0.0013	0.000217	0.367661	2.303509
S×I	2	0.002978	0.001489	2.526488	3.199582
D×I	3	0.184639	0.061546	104.4376	2.806845
S×D×I	6	0.003978	0.000663	1.124979	2.303509
Error	46	0.027108	0.000589		
Total	71	0.28495			

Lycopene Content (mg/ 100g)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.018136	0.009068	0.916239	3.199582
S	2	0.430869	0.215435	21.76759	3.199582
D	3	12.29645	4.098817	414.1457	2.806845
I	1	0.03645	0.03645	3.682919	4.051749
S×D	6	0.066242	0.01104	1.115513	2.303509
S×I	2	0.000225	0.000112	0.011367	3.199582
D×I	3	19.84778	6.615928	668.4753	2.806845
S×D×I	6	0.124575	0.020763	2.097849	2.303509
Error	46	0.455264	0.009897		
Total	71	33.27599			

Phenol Content (mg/ 100g)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	8.61E-05	4.31E-05	0.038348	3.199582
S	2	0.067511	0.033756	30.06465	3.199582
D	3	0.229811	0.076604	68.22768	2.806845
I	1	0.081339	0.081339	72.44511	4.051749
S×D	6	0.003056	0.000509	0.453576	2.303509
S×I	2	0.002744	0.001372	1.22218	3.199582
D×I	3	0.763961	0.254654	226.8093	2.806845
S×D×I	6	0.009022	0.001504	1.339285	2.303509
Error	46	0.051647	0.001123		
Total	71	1.209178			

Sugar content (%)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	3.33E-05	1.67E-05	0.237113	3.199582
S	2	0.009508	0.004754	67.6366	3.199582
D	3	0.03205	0.010683	151.9897	2.806845
I	1	0.03125	0.03125	444.5876	4.051749
S×D	6	0.000625	0.000104	1.481959	2.303509
S×I	2	0.000158	7.92E-05	1.126289	3.199582
D×I	3	0.080606	0.026869	382.2532	2.806845
S×D×I	6	0.000686	0.000114	1.626861	2.303509
Error	46	0.003233	7.03E-05		
Total	71	0.15815			

TSS (°B)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.001478	0.000739	0.444557	3.199582
S	2	0.019244	0.009622	5.789275	3.199582
D	3	0.274515	0.091505	55.05466	2.806845
I	1	0.007813	0.007813	4.700443	4.051749
S×D	6	0.001389	0.000231	0.139272	2.303509
S×I	2	0.000933	0.000467	0.280773	3.199582
D×I	3	0.470193	0.156731	94.29827	2.806845
S×D×I	6	0.000744	0.000124	0.07465	2.303509
Error	46	0.076456	0.001662		
Total	71	0.852765			

Vitamin C (mg/ 100g)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.075269	0.037635	0.185618	3.199582
S	2	20.99235	10.49618	51.76815	3.199582
D	3	248.3598	82.78662	408.3115	2.806845
I	1	1.878568	1.878568	9.265278	4.051749
S×D	6	3.235614	0.539269	2.659726	2.303509
S×I	2	1.956736	0.978368	4.825405	3.199582
D×I	3	292.1926	97.39753	480.374	2.806845
S×D×I	6	2.359008	0.393168	1.939143	2.303509
Error	46	9.326664	0.202754		
Total	71	580.3767			

Yield (Kg/plant)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.031225	0.015612	0.240248	3.199582
S	2	1.902025	0.951012	14.63435	3.199582
D	3	9.148228	3.049409	46.92484	2.806845
I	1	0.91125	0.91125	14.02247	4.051749
S×D	6	0.839197	0.139866	2.152286	2.303509
S×I	2	0.679508	0.339754	5.228197	3.199582
D×I	3	20.76798	6.922661	106.5271	2.806845
S×D×I	6	0.788025	0.131337	2.021044	2.303509
Error	46	2.989308	0.064985		
Total	71	38.05675			

Yield (t/ha)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	657.0129	328.5065	1.168968	3.199582
S	2	32410.37	16205.18	57.66504	3.199582
D	3	97038.59	32346.2	115.1017	2.806845
I	1	15422.57	15422.57	54.88017	4.051749
S×D	6	7207.56	1201.26	4.274601	2.303509
S×I	2	9031.018	4515.509	16.06813	3.199582
D×I	3	197705	65901.68	234.5066	2.806845
S×D×I	6	4977.415	829.5691	2.951965	2.303509
Error	46	12927.04	281.0227		
Total	71	377376.6			

Nitrogen content in leaf (%)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.002217	0.001109	0.420557	3.199582
S	2	0.304942	0.152471	57.83712	3.199582
D	3	0.46159	0.153863	58.3652	2.806845
I	1	0.148059	0.148059	56.16332	4.051749
S×D	6	0.051288	0.008548	3.242538	2.303509
S×I	2	0.03253	0.016265	6.1698	3.199582
D×I	3	1.135993	0.378664	143.6393	2.806845
S×D×I	6	0.12049	0.020082	7.617582	2.303509
Error	46	0.121266	0.002636		
Total	71	2.378375			

Phosphorus content in leaf (%)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.000938	0.000469	0.41171	3.199582
S	2	0.161563	0.080782	70.89917	3.199582
D	3	0.266193	0.088731	77.8761	2.806845
I	1	0.175035	0.175035	153.6218	4.051749
S×D	6	0.064309	0.010718	9.406962	2.303509
S×I	2	0.030676	0.015338	13.46149	3.199582
D×I	3	0.673015	0.224338	196.894	2.806845
S×D×I	6	0.068708	0.011451	10.05038	2.303509
Error	46	0.052412	0.001139		
Total	71	1.492849			

Potassium content in leaf (%)					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	0.018786	0.009393	2.620567	3.199582
S	2	0.351447	0.175723	**49.02501**	3.199582
D	3	0.792587	0.264196	**73.70792**	2.806845
I	1	0.090667	0.090667	**25.29518**	4.051749
S×D	6	0.066878	0.011146	**3.109736**	2.303509
S×I	2	0.071063	0.035532	**9.912955**	3.199582
D×I	3	1.460848	0.486949	**135.8539**	2.806845
S×D×I	6	0.096684	0.016114	4.495644	2.303509
Error	46	0.164881	0.003584		
Total	71	3.113841			

Nitrogen uptake (Kg ha^{-1})					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	10.0524	5.0262	2.955235	3.199582
S	2	4959.324	2479.662	**1457.957**	3.199582
D	3	500.5448	166.8483	**98.10112**	2.806845
I	1	403.2327	403.2327	**237.0871**	4.051749
S×D	6	29.84968	4.974946	**2.9251**	2.303509
S×I	2	56.04517	28.02258	**16.47633**	3.199582
D×I	3	893.5934	297.8645	**175.1342**	2.806845
S×D×I	6	31.15711	5.192851	**3.053221**	2.303509
Error	46	78.2358	1.700778		
Total	71	6962.035			

Phosphorus uptake (Kg ha^{-1})					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	3.688203	1.844101	3.172565	3.199582
S	2	126.8954	63.44768	109.1544	3.199582
D	3	82.89089	27.6303	47.53476	2.806845
I	1	58.93361	58.93361	101.3885	4.051749
S×D	6	11.09015	1.848358	3.179888	2.303509
S×I	2	8.195719	4.09786	7.049897	3.199582
D×I	3	137.313	45.77101	78.74377	2.806845
S×D×I	6	19.23505	3.205841	5.515282	2.303509
Error	46	26.7382	0.581265		
Total	71	474.9802			

Potassium uptake (Kg ha^{-1})					
SV	**df**	**SS**	**MSS**	**F cal**	**F tab**
Replication	2	5.995869	2.997935	2.755202	3.199582
S	2	3299.249	1649.624	1516.06	3.199582
D	3	308.7596	102.9199	94.58678	2.806845
I	1	73.02361	73.02361	67.11113	4.051749
S×D	6	16.09981	2.683301	2.466043	2.303509
S×I	2	57.68986	28.84493	26.50945	3.199582
D×I	3	532.4111	177.4704	163.1012	2.806845
S×D×I	6	21.84446	3.640744	3.345965	2.303509
Error	46	50.0526	1.0881		
Total	71	4365.126			

APPENDIX-III

Amount of water applied under different treatments (Pooled)

Month	Number of days	Crop Coefficient (Kc)	Evaporation (mm)	Area of growbag (m^2)	Pan Factor (Kp)	Amount of irrigation applied (cm)			
						50%	75%	90%	100%
March	25	0.6	0.75	0.05	0.7	0.40	0.60	0.71	0.79
April	30	0.6	1.1	0.05	0.7	0.70	1.04	1.24	1.38
May	31	1.15	0.8	0.05	0.7	1.01	1.51	1.81	2.01
June	30	1.18	1.4	0.05	0.7	1.74	2.61	3.12	3.47
July	31	1.18	0.6	0.05	0.7	0.78	1.16	1.38	1.54
August	31	1.18	0.8	0.05	0.7	1.03	1.52	1.85	2.05
September	30	0.84	0.35	0.05	0.7	0.31	0.46	0.55	0.61
October	13	0.84	0.4	0.05	0.7	0.16	0.22	0.28	0.30
Total						**6.13**	**9.12**	**10.94**	**12.15**

APPENDIX-IV

Benefit: Cost analysis of vermiculite + vermicompost (S_1 -70:30 w/w)

S. No.	Particulars	Quantity	Rate/unit (Rs.)	Total (Rs.)
Variable Cost				
1	Seed (g)	20.0	650.0	1300.0
2	Bags	2500.0	10.0	25000.0
	Used for 10 seasons			2500.0
3	Fertilizer			
	19:19:19 (Kg)	19.08	110	2098.8
	Urea Phosphate (17:44:00) Kg	10.18	35	356.3
	Urea (Kg)	14.14	5.9	83.42
4	Fungicide		500	500
5	Labour (man-days)	100	275	27500
6	Vermiculite (Kg)	4.9/bag	25	306250
	Used for 3 seasons			**102083**
7	Vermicompost (Kg)	1.8/bag	9	40500
	Used for 3 seasons			**13500**
Fixed Cost				
8	Polyhouse along with drip system	250m^2	1940/m^2	*4850
Benefit: Cost ratio				
9	Gross income	5.97(kg/per plant) x 2500 (plants) = 14925 Kg	Rs. 20/kg	298500
10	Cost of cultivation			154271.85
11	Net Return			144288.15
12	B:C ratio			0.93

* Total cost of polyhouse to be borne by the farmer with subsidy of 85% divided by life expectancy of 15 years (Total cost of polyhouse= Rs.485000 or 72750 (15 % farmers share of 485000); Average life span of polyhouse= 15 years, therefore, per year cost of polyhouse= Rs. 4850)

Benefit: Cost analysis of Cocopeat: Vermicompost (S_2-70:30 w/w)

S. No.	Particulars	Quantity	Rate/unit (Rs.)	Total (Rs.)
Variable Cost				
1	Seed (g)	20.0	650.0	1300.0
2	Bags	2500.0	10.0	25000.0
	Used for 10 seasons			2500.0
3	Fertilizer			
a	19:19:19 (Kg)	19.08	110	2098.8
b	Urea Phosphate (17:44:00) Kg	10.18	35	356.3
c	Urea (Kg)	14.14	5.9	83.42
4	Fungicide		500	500
5	Labour (man-days)	100	275	27500
6	Cocopeat (Kg)	2.45/bag	15	91875
	Used for 3 seasons			**30625**
7	Vermicompost (Kg)	1.8/bag	9	40500
	Used for 3 seasons			**13500**
Fixed Cost				
8	Polyhouse along with drip system	$250m^2$	$1940/m^2$	*4850
Benefit: Cost ratio				
9	Gross income	6.27 (kg/plant) x 2500 plants = 15675 Kg	Rs. 20/kg	313500
10	Cost of cultivation			83313.52
11	Net Return			230186.48
12	B:C ratio			2.76

*Total cost of polyhouse to be borne by the farmer with subsidy of 85% divided by life expectancy of 15 years (Total cost of polyhouse= Rs.485000 or 72750 (15 % farmers share of 485000); Average life span of polyhouse= 15 years, therefore, per year cost of polyhouse= Rs. 4850)

Benefit: Cost analysis of Cocopeat (S_3)

S. No.	Particulars	Quantity	Rate/unit (Rs.)	Total (Rs.)
Variable cost				
1	Seed (g)	20.0	650.0	1300.0
2	Bags	2500.0	10.0	25000.0
	Used for 10 seasons			2500.0
3	Fertilizer			
a	19:19:19 (Kg)	19.08	110	2098.8
b	Urea Phosphate (17:44:00) Kg	10.18	35	356.3
c	Urea (Kg)	14.14	5.9	83.42
4	Fungicide		500	500
5	Labour (man-days)	100	275	27500
6	Cocopeat (Kg)	3.5/bag	15	131250
	Used for 3 seasons			43750
Fixed Cost				
7	Polyhouse along with drip system	$250m^2$	$1940/m^2$	*4850
Benefit: Cost ratio				
8	Gross Income	5.69kg/plant x 2500 plants = 14225 kg	Rs.20/kg	284500
9	Cost of cultivation			82938.52
10	Net Return			201561.48
11	B:C ratio			2.43

* Total cost of polyhouse to be borne by the farmer with subsidy of 85% divided by life expectancy of 15 years (Total cost of polyhouse= Rs.485000 or 72750 (15 % farmers share of 485000); Average life span of polyhouse= 15 years, therefore, per year cost of polyhouse= Rs. 4850)