EVALUATION OF DIFFERENT SOILLESS GROWING MEDIA UNDER SHADE HOUSE FOR BELL PEPPER (*Capsicum annuum* var. *grossum*)

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CERTIFICATE

This is to certify that the thesis entitled **EVALUATION OF DIFFERENT SOILLESS GROWING MEDIA UNDER SHADE HOUSE FOR BELL PEPPER (*Capsicum annuum* var. *grossum*)** submitted by **Mr. Nagaraj Malappanavar** for the **degree of Master of Technology (Agricultural Engineering)** in Soil and Water Engineering of the University of Agricultural Sciences, Raichur, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis of award of any degree, diploma, associate ship, fellowship or other similar titles.

Place: Raichur
Date: June, 2014

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(Chairman)

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(M. G. Patil)

Affectionately Dedicated

To

My Beloved Parents,
Teachers and Friends

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With Regardful Memories…

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Date: June, 2014 **(NAGARAJ MALAPPANAVAR)**

CONTENTS

SYMBOLS AND ABBREVIATIONS

%	:	Per cent
±	:	Plus or minus
AOAC	:	Association of Official Analytical Chemists
cc	:	Cubic centimeter
cm	:	Centimeter
DAT	:	Days After Transplanting
et al.	:	and others
Fig	:	Figure
H_2O_2	:	Hydrogen peroxide
ha	:	Hectare
hp	:	Horse power
kg	:	Kilogram
l	:	Litre
LLDPE	:	Linear Low Density Polyehtylene
m	:	Meter
m^2	:	Meter square
meq/lt	:	Mili equivalents per litre
mm	:	Milimeter
ppm	:	Parts per million
PVC	:	Polyvinyl chloride
rpm	:	Revolution per minute
SEd	:	Standard Error difference
t	:	Tonne
WUE	:	Water use efficiency
μ m	:	Micro meter
MJ m^{-2}	:	Mega joule per square metre
dS m^{-1}	:	Decisiemens per meter
mg l^{-1}	:	Milligram per litre
^{0}C	:	Degree Celsius
CD (P=0.05%)	:	Critical difference at 5 per cent level

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I. INTRODUCTION

Land and water resources are the two basic pre-requisites for life in this universe. The demand for these two natural resources is increasing more and more due to the escalation of population, large scale industrialization and production of food needed for the growing population.

Soil is the natural resource for cultivation of many crops. It provides anchorage, nutrients, air, water, etc. for successful plant growth. However, it has problems like soil borne diseases, undesirable microbial activities, nematodes, changing acidity levels, salinity, poor drainage, poor nutrient levels and undesirable soil characteristics. Further, continuous cultivation of crops has resulted in poor soil fertility, which in turn has reduced the opportunities for natural soil fertility build up by microbes. This situation has lead to poor crop yield and quality. In addition, conventional crop growing in soil (Open Field Agriculture) is difficult as it involves large space, lot of labour and large volume of water. In some places like metropolitan areas, good quality soil is not available for crop cultivation. Another serious problem experienced in present condition is the difficulty to hire labour for conventional open field agriculture. To overcome these problems, new methods are being introduced such as soilless culture and cultivation of crops under protected environments.

Soilless culture is an artificial means of providing plants with support and a reservoir for nutrients and water. The simplest and oldest method for soilless culture is a vessel of water in which inorganic chemicals are dissolved to supply all of the nutrients that plants require. It is often called “solution culture or water culture” and the method was originally termed as “hydroponics” (that is, “water working”). Over the years, hydroponics has been used sporadically throughout the world as a commercial means of growing both food and ornamental plants.

In recent years, a wide range of soilless culture techniques have been developed and commercially introduced for intensive production of horticultural crops, particularly in greenhouses. Reasons for replacing soils by soilless growing media is to overcome plant protection problems, soil borne pathogens and environmental regulations against groundwater pollution with nitrate and pesticides (Ahmad, M.G., 2013).

In protected cultivation, the adoption of soilless culture together with technical practices such as integrated plant protection, fertigation, drip irrigation and climate control would increases the yield potential and water use efficiency, while decreasing harmful effects of agro-chemicals on environment. The advantage of soilless culture is it uses limited inputs like water, nutrients and labour for crop production. In soilless culture, the crop can be taken up with limited water sources.

Advantages of protected cultivation are

1. Higher productivity resulting in increased yield
2. Provides better growing environment to plants
3. Protects from rain, wind, high temperatures and minimizes the damage of insect, pests and diseases there by improving the quality and yield
4. Facilitates year round production coupled with yield enhancement by 2-3 times compared to open cultivation

The agricultural and horticultural activities which are dependent on irrigation have become most precarious as rainfall distribution during the rainy season in these regions is uncertain and erratic. Hence, better management of the available water resources through more efficient methods of water application like drip irrigation under conditions of protected cultivation is great importance to enhance the yield and water use efficiency.

The soilless techniques offer a way of improving water use efficiency and obtaining better water management in crop production. A good grower may achieve the same yield in soil as in soilless cultivation, but is likely to use 50-100 per cent more water as a result of water losses from over watering the soil and evaporation from the soil surface. If yield per unit of water applied is considered, soilless systems may increase yield substantially over soil based systems.

In soilless culture, the irrigation frequency must be several times per day, dividing the daily water requirements, according to the evaporative demand and the water storage characteristics of the substrate. Drip irrigation introduces possibilities for precise application of fertilizer and other chemicals. The restricted root growth necessitates "fertigation", to prevent nutrient deficiencies.

In soilless culture, drip irrigation is used to deliver water to crop. The amount of irrigation is applied and its timing throughout the crop cycle influence both yield and crop quality. However, the yield and quality of marketable fruits are dependent upon local agronomic and environmental conditions. Irrigation scheduling based on class A pan evaporation may improve water use efficiencies. This would be particularly useful where water availability is limited (Metin Sezen, *et al*. 2006).

Capsicum (*Capsicum annuum* L. var. grossum Sendt) is also called as bell pepper or sweet pepper and is one of the most popular and highly remunerative annual herbaceous vegetable crop. Sweet pepper (*Capsicum annuum* L. var. grossum Sendt) belongs to the family solanaceae. Capsicum is cultivated in most parts of the world, especially in temperate regions of Central and South America and European countries, tropical and subtropical regions of Asian continent mainly in India and China. India contributes one fourth of world production of capsicum with an average annual production of 0.9 million tonne from an area of 0.885 million hectare with a productivity of 1266 kg per hectare. In India, capsicum is extensively cultivated in Andhra Pradesh, Karnataka, Maharashtra, Tamil Nadu, Himachal Pradesh and hilly areas of Uttar Pradesh. Andhra Pradesh stands first in area of 236.5 thousand ha with a production of 748.5 thousand tonne. While, Karnataka stands second in area of about 76 thousand ha with a production of about 131 thousand tonne (Sreedhara, *et al*. 2013).

Capsicum is a cool season crop, but it can be grown round the year using protected structures where temperature and relative humidity (RH) can be manipulated. This crop requires day temperature of 25-30° C and night temperature of 18-20° C with relative humidity of 50- 60 per cent. If temperature exceeds 35° C or falls below 12° C, fruit setting is affected. Coloured capsicums are in great demand in urban markets. The demand is mostly driven by hotel and catering industry. The traditionally grown green capsicum, depending upon variety and season, usually yields 20-40 tonne per hectare in about 4-5 months. In greenhouse, the crop duration of green and coloured capsicum is about 7-10 months and yields about 80-100 tonne per hectare (Anonymous, 2011).

In semi-arid tropics areas like Raichur, limited information is available in cultivation of capsicum in soilless cultivation under protected environment. Therefore, the present study has been taken up with following objectives.

1. To identify a suitable soilless growing media for bell pepper in shade house
2. To evaluate of water use efficiency in selected soilless media
3. To work out the economics of soilless culture under shade house

II. REVIEW OF LITERATURE

Protected cultivation is a unique and specialized form of agriculture. The greenhouse technology has the potential of regulating environmental parameters such as temperature, relative humidity, light intensity, crop response and irrigation system. This technology will continue to contribute to a better understanding of growth factor requirements and inputs for improving the crop productivity in open fields. Adaptation of proper management practices under protected condition would help to achieve maximum yield per unit area. The literature on shade house cultivation, temperature, growing media, irrigation, fertigation and physical properties of different media pertaining to capsicum and other crops are reviewed under here.

- ❖ The studies reviewed in soilless culture under protected cultivation are presented under following sub-divisions.
- ❖ Shade house cultivation
- ❖ Soilless culture with different growing media
- ❖ Standardization of growing media
- ❖ Drip irrigation and fertigation in soilless culture
- ❖ Physical and chemical properties of different soilless media
- ❖ Cost economics

2.1 Shade house cultivation

Plasticulture Development Center (2001) at a Bangalore reported that tomato cultivated under greenhouse yields about 2.5 times more than the open field. Among the four treatments, the maximum yield was obtained in the treatment with 150 per cent fertilizer dose (969.1 kg/100 m^2). The response of tomato was very good in the low cost greenhouse particularly during summer and they found the quality of fruits obtained under greenhouse also significantly superior in all aspects.

Plasticulture Development Center (2001) at Gujarat suggested that the tomato production under low cost greenhouses is about 149 per cent more compared to the open field cultivation and it will give more production as well as more net return (467 per cent) compared to open field.

Plasticulture Development Center (2001) at Bhuwaneswar was found that initial harvesting in open field condition was four days earlier in comparison to greenhouse conditions. But the period of harvesting inside the greenhouse was 20 days more as that of open field. The tomato yield per plant (1.47 kg) was higher inside greenhouse than the open field (0.58 kg).

Plasticulture Development Center (2001) at Raipur was experimented that the yield obtained in capsicum under polyhouse was higher (15 g/plant) than open field (11 g/plant) and quality of fruits was better under polyhouse. Yield obtained in cucumber under polyhouse raised cucumber give higher yield (7.31 kg m^{-2}) than open field (5.12 kg m^{-2}).

Yellavva Kurubetta and Patil (2008) conducted an experiment in the Department of horticulture, Agricultural College, Dharwad. Capsicum hybrids *viz.,* Orobelle, Bomby and Indra were grown under naturally ventilated polyhouse (NVP), naturally ventilated shadow hall, shadehouse with misting and shadehouse without misting during summer 2007 at Hi-Tech Unit. Planting was done in two rows on 1m wide beds leaving 50 cm path between two beds following the spacing of 45 x 60 cm. The results revealed that the earliest flower initiation (33.00 days), least time taken for first harvesting (86.00 days) and highest fruit set (49.81 per cent) were recorded under NVP. The hybrid Indra recorded significantly earliest flower initiation (35.42 days), lower time taken for first harvesting (86.00 day) and higher fruit set (45.45 per cent) as compared to other two hybrids. The quality parameters like fruit weight (160.00 g), fruit volume (320.00 cc), rind thickness (0.91 cm) and shelf life (8.62 days) were also significantly maximum under naturally ventilated polyhouse than under naturally ventilated shadow hall. Among the hybrids, Bomby recorded significantly higher fruit weight (158.50 g), fruit volume (310.00 cc) and Indra recorded higher rind thickness (0.87 cm) and shelf life (8.60 days).

Rajasekar *et al.* (2013) conducted at the Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, India to screen ten vegetables for cultivation under shade net house (33 per cent shade) and open field for year round production of vegetables. The influence of environmental variables temperature, relative humidity and light intensity were studied. Relative humidity was always higher under shade net house than in open field during both seasons. Light intensity in the shade net house was lower than in the open field. Mean weekly temperature during summer and winter were higher under open field conditions than in the shade net house. Lower temperature caused plant height, number of branches, internodal length, average fruit weight and yield per plant to be higher in the shade net house than in the open field. Hence shade house conditions will be more profitable than open field.

2.1.1. Weather parameters

The greenhouse environment has a profound effect on crop productivity and profitability. In this study, environment is taken in its narrow meaning and includes only temperature.

2.1.1.1. Temperature

In general, temperature plays an important role in the vegetative and photosynthetic activity of the plants. The maximum activity is obtained in a defined range of temperatures. Below and above this range the activity slows down. Soil and media temperature influences the availability, adsorption and utilization of mineral elements and water and seed germination and root system of the plant. Leaf temperatures affect the transpiration rates of the plants. Temperature also affects the quality of the products and maturity rates of the plants and has an important role virtually in all plant responses including photosynthesis, transpiration and respiration.

Kavitha *et al.* (2003) conducted a study in poly house equipped with solar module aided spinning disc sprayer and solar energy aided exhaust fan. The crop response could be altered by achieving specific climatic conditions in the poly-house. In the case of tomato, 96 per cent increase in shoot length and 27 per cent increase in yield were observed inside the poly-house as compared to control. For brinjal, the shoot length increased by 55 per cent and the yield increased by 85 per cent.

Miguel *et al.* (2009) conducted a study to observe how different environmental factors [temperature, solar radiation and vapour–pressure deficit (VPD)] influenced the pectin solubilization and the calcium concentration in cherry tomato fruits grown in two experimental greenhouses: improved parral type (low technology) and multi span type (high-technology). For three years (2004, 2005 and 2006), three fruit samples were taken over the entire production period: at the beginning of harvest [16 weeks after transplanting

(WAT)], at mid-harvest (26 WAT), and at the end of harvest (35 WAT)]. Values for temperature, solar radiation, and VPD picked in the third sampling in both greenhouses during the three years, being higher in the parral greenhouse during the production cycle. No-market production and peroxidation indicators [measured as H_2O_2 and malondialdehyde (MDA) concentrations] significantly increased at the end of the productive period in both greenhouses, indicating the presence of oxidative stress caused by the rise in temperature, solar radiation, and VPD, which was more pronounced in the parral greenhouse. Water-soluble pectins, pectate and protopectin contents were measured, revealing an increase in the former two and a reduction in the latter under environmental stress. This indicates a clear pectin solubilization in cherry tomato fruit. The enzymes pectolytic polyglacturonase (PG), pectin methyl esterase (PME), and pectate lyase (PEL), altered their activities during the third sampling, while the calcium concentration fell drastically. Therefore, both the increase in pectin solubilization as well as the reduction in the Ca concentration during harshest environmental stress in the third sampling, especially in the greenhouse, could degenerate the textural properties of the cherry tomato, reducing its quality and consumer acceptance.

2.2 Soilless culture with different growing media

Soilless culture systems (SCSs), the most intensive production method in today's horticulture industry, are based on environmentally friendly technology, which can result in higher yields, even in areas with adverse growing conditions. However, using SCSs does not automatically result in the production of high-quality vegetables. Numerous studies confirm that a SCSs enables growers to produce vegetables without quality losses compared to soil cultivation.

Ustun sahin *et al*. (2002) carried out study in 2001 using some organic (peat moss, peat, sawdust) and inorganic (perlite, pumice, creek sand) substrates. pH, electrical conductivity, cation exchange capacity, carbonates, organic matter, particle size distribution, bulk density, water retention characteristics and pore size distribution of substrates were determined. The amount of water retained at the low tensions (<pF 2.52) in pumice, sawdust, peat moss, perlite, peat and creek sand was 62.6, 59.2, 53.7, 53.0 52.4 and 28.9 based on volume basis, respectively. However, among the organic-organic, inorganic-inorganic and organic-inorganic mixes, those values were highest in peat:

sawdust (60.0 per cent), perlite: creek sand (40.1 per cent) and sawdust: perlite (57.2 per cent). Among the organic, inorganic, organic-organic, inorganic-inorganic mixes, the highest amount of macropores (>100 μ m) supply aeration were 56.9 per cent (sawdust), 60.2 per cent (pumice), 56.0 per cent (peat: sawdust), 34.4 per cent (perlite:creek sand), 52.6 per cent (sawdust: perlite). The lowest bulk density of substrates were 0.086 g cm^{-3} (peat moss), 0.118 g cm^{-3} (perlite), 0.121 g cm^{-3} (peat moss: sawdust), 0.325 g cm^{-3} (perlite: pumice) and 0.099 g cm^{-3} (peat moss: perlite), respectively. pH values of substrates varied from 5.1 (peat moss and peat) to 7.6 (pumice). The highest electrical conductivity, cation exchange capacity, carbonates and organic matter values of substrates were 1.065 dS m^{-2} (peat), 206.4 cmol kg^{-1} (peat moss), 0.75 per cent (pumice) and 95.0 per cent (peat moss), respectively.

George Hochmuth and Robert Hochmuth (2003) reported that the tomato and cucumber are grown successfully in perlite media.

Samartzidis *et al*. (2005) conducted roses in various soilless media with the aim to identify the optimum soil condition for rose production. Madelon roses grafted on root stock of Rosa indica var. major were transplanted to polyethylene bags containing zeolite and perlite (at ratios of 25z:75p, 50z:50p, 75z:25p and 100z:0p, v/v) in a climate-controlled greenhouse. Results showed that zeolite and perlite acted as inert materials. Zeolite did not exert any positive effect on productivity, in contrast to what has been reported in literature recently. Use of perlite resulted in a little improvement in photosynthesis; however this improvement was not reflected by a significant increase in production.

Janapriya *et al.* (2010) indicated that the polyhouse cultivation of cucumber using soilless media has most benefit than open field condition, in terms of yield, quality, water use efficiency, fertilizer use efficiency and benefit cost ratio. The supreme performance of cultivation of cucumber under polyhouse in soilless media can be attributed to the prevalence of optimum microclimatic conditions created by the protected structure as well as the ideal growing medium.

Rodriguez *et al.* (2006) worked out that the different combination of media (coarse perlite, medium perlite and pine bark) and containers (polyethylene bags and plastic pots) were used for hydroponics production of ‘Galia’ muskmelon (Cucumis melon L.) to determine their effect on fruit yield and quality and their influence on costs of production. Marketable yields obtained for ‘gal-152’ in the spring 2001 and 2002 were 25.5 kg m^{-2} and 39.0 kg m^{-2} respectively. When data were combined for 2001 and 2002, fruit yield and fruit quality unaffected by any combination of media and container. Average soluble solids content was generally greater than 10^0 Brix. It was determined that the use of pine bark media and plastic pots instead of perlite and bags would save $18,200 per year (two crops) a feasible option for reducing costs of producing ‘Galia’ muskmelons in greenhouse using soil less culture without loss of yield and fruit quality.

Selda and Omer Anapali (2010) carried out the experiment to determine the effect of soil addition to perlite medium on strawberry cultivation. Five different levels of soils i.e. 10, 20, 30, 40 and 50 per cent by volume were added to perlite and 100 per cent perlite was used as a control. Results showed that soil addition caused a decrease of macro pores in the growing media while the vegetative parameters of the strawberry plant improved during cultivation period.

Ahmad *et al.* (2011) conducted experiment and compared some growing indexes of greenhouse tomato in coco peat + perlite (v/v=50 per cent), date-palm peat + perlite (v/v=50 per cent), perlite (100 per cent) and date-palm peat (100 per cent). The result shows that date-palm peat is an appropriate media for soilless culture with suitable physical and chemical properties, availability and low cost. Therefore, it can be a new substrate that is introduced for replacing other media.

Shaaban (2012) conducted experiment to evaluate the three organic wastes (composted bark, composted filter mud and peat moss) and in combination with each other as media (substrates) for seedlings production of fodder beet. Prepared media were: A-bark, B-filter mud, C-peat, D: J- mixtures of A, B and C at the ratio 1:1:1, 2:1:1, 1:2:1, 1:1:2, 2:2:1, 2:1:2 and 1:2:2(w/w), respectively. Results showed that volume of air and easily available water (EAW) for imported peat moss were very low (7.50 and 18 volume per cent). This means that growing plants will suffer from suffocation due to the very low content of large pores responsible for aeration. Easily available water (EAW) for the other substrates is in the range of 20 to 23 per cent which means sufficiency of available water to plants. Improvement of peat hydro physical properties was occurred by mixing it with composted bark and composted filter mud substrates. Consequently, root length of fodder beet increased by 29, 31, 33, 7, 38, 17 and 22 per cent that of peat moss substrate for substrates D to J. In addition, all vegetative growth parameters and dry matter production took the same trend.

Atefe *et al.* (2012) studied the effect of substrate and cultivar on growth characteristic of strawberry in soilless culture system. Experimental treatment consisted of three strawberry cultivars (Camarosa, Mrak and Selva) and six growing media like rice hull, sycamore pruning waste, cocopeat + perlite (50:50), vermicompost + perlite + cocopeat (5:45:50), (15:40:45) and (25:35:40).The cultivars responded differently to different substrates. Camarosa cultivar had the highest leaf area, length of petiole, runner number and total biomass. Mrak cultivar had the highest yield.

Murumkar *et al.* (2012) conducted experiment in naturally poly house. There were eight different media levels comprising of coirpith, perlite, vermiculite and peat separately as treatments T_1 to T_4 and treatments T_5 to T_8 with vermicompost as 50 per cent on volume basis with three replications. Result shows that in terms of growth, yield and quality the best results were observed in treatment with peat: vermicompost (T_8) in the ratio of 1:1 on volume basis, highest water use efficiency and benefit cost ratio were recorded.

Kashif waseem *et al.* (2013) conducted pot experiment at Faculty of Agriculture, Gomal University, Dera Ismail Khan, KPK, Pakistan to investigate the effect of different growing media on the growth and development of stock (Matthiola incana). Seven different growing media including soil (100 per cent), leaf mold (100 per cent), coconut husk (100 per cent), soil + leaf mold (50:50), soil + coconut husk (50:50), leaf mold + coconut husk (50:50) and soil + leaf mold + coconut husk (33:33:33) were used to check the growth of stock plants in pots. Data was recorded for different parameters including days to flower initiation, days to flowering, plant height (cm), leaves per plant, branches per plant, flowering clusters per plant, flowers per cluster, flowers per plant and flower persistence life (days), during the course of study. The overall performance of Stock was better in media having leaf mold as it took least days to flower initiation (75.83), maximum plant height (21.43 cm), flowering clusters per plant (4.11), number of flowers per cluster (8.45 days), flowers per plant (34.66). For better growth and flowering of stock plant, leaf mold can be used as growing media in pots.

Panj *et al.* (2014) carried out study under protected conditions with different growing media combinations *viz.* soil, sand, FYM, vermicompost, coco peat and rice husk. Significant relationships were observed between different growing media parameters with flower quality and yield parameters of gerbera. To evaluate the apparent strength of the relationship and to explain the variations on dependent variable (crop yield) multiple regression models were developed. In conclusion, it was found that the most important variables explaining the variations in the yield of gerbera were Water Holding Capacity (per cent) (initial), pH (initial), Available N (per cent) (initial), Available P (per cent) (initial), pH (end), Available N (per cent) (end) and Available P (per cent) (end).

Ahmad Mohammadi Ghehsareh (2013) conducted an experiment regards use of different organic and inorganic substrates which helps in nutrient uptake optimize water use and oxygen holding. This work was carried out using a completely randomized design with six treatments and six replications. The treatments were pure palm peat, pure rice hull, soil + 5 per cent (weight) palm peat, soil + 5 per cent (weight) rice hull, soil + 5 per cent (weight) palm peat + 5 per cent (weight) rice hull and pure soil. Results showed that amount of porosity, water holding capacity (WHC) and cation exchange capacity (CEC) in date-palm peat was higher than soil and rice hull but amount of bulk density in date-palm peat was lower than the others. Also the results showed that many growth parameters were affected by the culture media. Most amount of yield and plant height in each was related to palm waste (100 per cent) and had significant difference at 5 per cent level as compared with the others. Results showed that plant growing indices for cucumber plant were sufficient when cultured only in date palm waste and rice hull substrates and when these materials were added to the soil, although it amended physiochemical properties of media but decreased the plant growing indices.

2.3. Standardization of growing media

Use of suitable growing media or substrates is essential for production of quality horticultural crops. It directly affects the development and later maintenance of the extensive functional rooting system. A good growing media would provide sufficient anchorage or support to the plant, serve as reservoir for nutrients and water, allow oxygen diffusion to the roots and permit gaseous exchange between the roots and atmosphere outside the root substrate.

Green house plants for their proper growth and development require a growing media with good physical and chemical properties. The current trend is towards the use of locally available organic waste materials as growing media components. Recent investigations on the use of different substrates and their effect on crops are reviewed in this chapter.

Walter Chavez *et al.* (2008) observed that the use of alternative soilless media for the production of crops requires knowledge of their physical and chemical characteristics to result in the best conditions for plant growth.

2.4. Drip irrigation and fertigation in soilless culture

In soilless culture, drip irrigation is used to deliver water to crops. Irrigation is an important factor for crop production where growing season coincides with a period of high evaporative demand. The amount of irrigation applied and its timing throughout the crop cycle influence both yield and fruit quality.

Harmanto *et al.* (2005) tested four different levels of drip fertigated irrigation equivalent to 100, 75, 50 and 25 per cent of crop evapotranspiration (ETc), based on Penman–Monteith (PM) method, for their effect on crop growth, crop yield and water productivity. Tomato (Troy 489 variety) plants were grown in poly-net greenhouse. The distribution uniformity, emitter flow rate and pressure head were used to evaluate the performance of drip irrigation system with emitters of 2, 4, 6 and 8 l/h discharge. The results revealed that the optimum water requirement for the Troy 489 variety of tomato is around 75 per cent of the ETc. Based on this, the actual irrigation water for tomato crop in tropical greenhouse could be recommended between 4.1 and 5.6 mm/day or equivalent to 0.3-0.4 l/plant/day. Drip irrigation at 75 per cent of ETc provided the maximum crop yields and irrigation water productivity. The distribution uniformity dropped from 93.4 to 90.6 per cent. The emitter flow rate was also dropped by about 5-10 per cent over the experimental period. This is due to clogging caused by minerals of fertilizer and algae in the emitters. It was recommended that the cleaning of irrigation equipment (pipe and emitter) should be done at least once during the entire cultivation period.

Bernstein *et al.* (2006) conducted a study to investigate the effect of irrigation with treated sewage water on roses cultivated in two soil-less medium, perlite, an inert mineral medium and Choir (coconut fibers), an organic medium of high ion absorption capacity. Cl contents increased 47 per cent in perlite and 73 per cent in Choir grown plants reaching levels characteristic of exposure to moderate salinity. Mn, Cu and B contents increased as well under cultivation in both perlite and Choir under irrigation with treated sewage water.

Metin sezen *et al.* (2006) carried out the study to determine the most suitable irrigation scheduling of fresh market tomato grown on volcanic ash, peat and their mixture (1:1) under plastic house. The quality and yield response of Fantastic-144 to trickle irrigation was also investigated. Four different irrigation levels (WL_1=75 per cent, WL_2=100 per cent, WL_3=125 per cent and WL_4=150 per cent of class A pan evaporation) and two irrigation frequencies (once and twice daily applications) were evaluated. Highest yield and fruit number were obtained from the ash + peat (1:1) with irrigation once a day at WL_4 and ash + peat (1:1) with twice a watering at WL_3 and WL_4 irrigation levels. Soluble solids of tomato fruit decreased with increasing available water. The highest WUE value of 67.5 kg m^{-3} was obtained from WL_1 with peat + ash (1:1). WUE decreased in all treatments as the amount of irrigation water increased.

Melgarejo *et al.* (2007) conducted an experiment in a greenhouse, the soil-free culture may allow irrigated farms to boost their fig productions from 4500 kg/ha-year up to 81,000 kg/ha-year; that is an 18-fold yield increase compared to traditional farming. A 90 per cent water reduction was achieved by applying this growing technique.

Shao Guang-Chenga *et al.* (2008) conducted a study to compare two water-saving practices, deficit irrigation (DI) and partial root zone drying (PRD), and examined how they affected soil water distribution, water use, growth and yield of greenhouse grown hot pepper compared to commercial irrigation (CI). The results showed mean soil volumetric water content of DI75, DI50, 1PRD and 2PRD were lower by 21.06, 28.32, 24.48 and 34.76 per cent, respectively than that of CI after starting the experiment. Water consumption showed some significant effect of irrigation treatments during the growing period of drought stress application and therefore decreased in DI75, DI50, 1PRD and 2PRD to a level around 75 and 50 per cent of CI. All the DI and PRD treatments resulted in a reduction of total dry mass of 7.29-44.10 per cent, shoot biomass of 24.97-47.72 per cent compared to CI, but an increase in the root–shoot ratio of 12.50-35.42 per cent compared to the control and with significant differences between 2PRD, 1PRD, DI50 and CI. The yield of 1PRD was significantly reduced by 23.98 per cent compared to CI (19,566 kg hm^2) over a period of 109 days after transplanting. However, the 1PRD treatment had 17.21 and 24.54 per cent additional yield over the DI50 and 2PRD treatments and had 52.05 per cent higher irrigation water use efficiency (IWUE) than CI treatment.

Chun Zhi Zeng *et al.* (2009) conducted studies to determine the optimum irrigation water amounts for muskmelon (Cucumis melo L.) in plastic greenhouse. The results showed that plant growth, fruit production and quality were significantly affected under different irrigation water amounts. Plant height and stem diameter decreased as well as fruit yield from treatment T_{100} to T_{70}. Fruit quality was the best in the (T_{90} treatment). The irrigation water use efficiency (IWUE) values found in this experiment showed that the lower the amount of irrigation water applied, the higher the irrigation water use efficiency obtained. Hence, based on the quality and quantity of muskmelon yield, the regime for 90 per cent of field water capacity (T_{90}) is the suitable soil irrigation treatment (T_{90}) which can save irrigation water and improve the quality of fruit.

Sanchez-Guerrero *et al.* (2009) conducted an experiment to test EC-based irrigation strategy in two greenhouse soilless cucumber crops. One of the crops was subjected to CO_2 enrichment using a dynamic control strategy, while the other one was not enriched. It is concluded that CO_2 enrichment combined to an EC-based irrigation scheduling lead to synergistic beneficial effects on the overall water use efficiency of soilless greenhouse cropping systems and to a drastic reduction of the leaching fraction.

Dunage *et al.* (2009) reported that the total water requirements for tomato under net house conditions using 60, 80, 100 and 120 per cent evapotranspiration (ET) levels of drip irrigation were 52.720, 61.451, 69.607 and 79.524 L per plant respectively. The mean application efficiency of the system was 91.75 per cent, while the mean distribution efficiency was 94.27 per cent. Within the drip irrigation treatments, the highest WUE of 11.90 t ha cm^{-1} was obtained under the treatment of irrigation at 60 per cent and the least in 120 per cent ET (7.45 t ha cm^{-1}). In water scarcity areas and where the land availability is not a constraint, drip irrigation at 60 per cent ET could be resorted to as it would command an additional area of 0.32 ha (using the same quantity of water consumed in 100 per cent ET per ha) and fetch an increased net return of Rs. 42,559 per ha. The payback period of the investment in net house cultivation of tomato using drip irrigation was found out to be one and a half years (three seasons) by which time the system became beneficial.

Meric *et al.* (2011) conducted a research to determine the effects of nutrition systems and irrigation programs on soilless grown tomato plants under polyethylene covered unheated greenhouse conditions. Two nutrition systems (open and closed) and three irrigation programs (high, medium and low) has been used. WUE of treatments varied between 33-55 kg m^{-3} in autumn and 26-35 kg m^{-3} in spring. Highest WUE values have been determined in (4 MJ m^{-2}) and in the closed system in both growing seasons. Results showed that the closed system and infrequent irrigations increased water use efficiency while decreasing yield and discharged nutrient solution.

Fertigation

Sharma *et al.* (1994) noticed that fertigation of greenhouse tomatoes with nitrogen fertilizers and potassium fertilizers especially K_2SO_4 produced excellent results in improvement of plant quantitative characters.

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

Rodriguez *et al.* (2005) conducted study on “Galia” muskmelons which was originally developed for open-field cultivation in the desert regions of Israel. Nitrogen fertilization recommendations for ‘Galia’ production include altering N concentrations through four stages of plant growth: seeding to flowering, flowering to fruit set, fruit development and fruit ripening through final harvest. In the present work, “Galia” muskmelons were grown in a passively ventilated greenhouse during three seasons in Gainesville, Florida using polyethylene-bag perlite culture. Nitrogen concentrations were applied with every irrigation at 80, 120, 160, 200 and 240 mg l^{-1}. An alternating N (ALT-N) treatment that followed the four growth stages was also included (120- 160-200-120 mg l^{-1}). In all three seasons, there were no differences among the N treatments for average fruit weights or soluble solids content. In spring 2001, plants receiving N in relation to their growth stage produced the greatest number of fruit per plant and per square meter at 6.4 and 15.5 fruits, respectively. In fall 2001, plants receiving 80 and 120 mg L^{-1} N produced significantly lower fruit numbers than those produced by all other N treatments. There was no difference among plants receiving 160, 200, 240 mg l^{-1}, and the ALT-N treatment for fruit number per plant, each averaging 4.8 fruits. Petiole-sap NO_3-N concentrations during spring and fall 2001 suggested that optimal yields can be achieved if at least 3000 mg l^{-1} NO_3-N was maintained through fruit maturation. When petiole-sap concentrations were less than 2500 mg l^{-1}, as in the case of plants receiving 80 or 120 mg l^{-1} N, significantly lower yields were obtained.

Gulshan Mahajan and Singh (2006) conducted study at Ludhiana to investigate the effect of irrigation and fertigation on greenhouse tomato. Drip irrigation at 0.5 * E pan along with fertigation of 100 per cent recommended nitrogen resulted an increase in fruit yield by 59.5 per cent over control (recommended practices) inside the greenhouse and by 116.2 per cent over control (recommended practices) outside the greenhouse, respectively. The drip irrigation at 0.5 * E pan irrespective of fertigation treatments gave a saving of 48.1 per cent of irrigation water and resulted in 51.7 per cent higher fruit yield as compared to recommended practices inside the greenhouse.

Saadet Sevil Kilinc *et al.* (2007) determined the effects of different nutrient solution formulations on the growth of nursery fig trees in soil-less culture techniques. The trials were conducted in two different growing conditions, namely, high-tunnel and open-field conditions in substrate culture. It was concluded that the use of Hewitt’s and Hoagland’s nutrient solution formulations led to increased growth of nursery fig trees in high-tunnel and open-field conditions, respectively.

Shahnaz Sarkar *et al.* (2008) conducted a study to clarify the effects of different fertigation systems (drip or sub fertigation) in combination with 2 formulae of nutrient solution (modified Enshi formulation or Shizudai tomato formulation) at EC 4 dS m^{-1} on the response of "High soluble solid content tomato" grown in soilless culture systems from September, 2005 to February, 2006. The growth, total yield and size of fruit decreased in the sub fertigation system regardless of the nutrient solution formulation. On the other hand, the soluble solid content was higher in the sub fertigation system. Sub fertigation inhibited water uptake compared to drip fertigation. EC of the medium solution was higher in the sub fertigation than drip fertigation system and higher with the Shizudai than the Enshi formulation. The highest and lowest EC values were 29.6 and 16.1 dS m^{-1} in Sub Shizudai and Drip Enshi treatment, respectively. The matric potential of medium in the sub fertigation system was higher than that in the drip fertigation system. The proline concentration of leaves taken on November 17 and December 2 was higher in the sub fertigation than the drip fertigation system regardless of the nutrient solution formulation. Judging from the above results, growth and yield suppression in the sub fertigation system seems to be mainly caused by salinity stress, not by water stress.

Savvas *et al.* (2009) indicated that the supply of at least 1mm of Silicon via the nutrient solution is capable of enhancing both tolerance to salinity and resistance to powdery mildew in soilless cultivations of zucchini squash.

2.5 Physical and chemical properties of different soilless media.

Container grown plants have their root system confined to a limited mass of medium. A substrate must have enough water and aeration for optimal plant growth, which is achieved depending on the physical and chemical properties of the medium.

2.5.1 Physical properties of different soilless media.

Bunt (1971) and Kaukovirta (1972) recommended that container grown plants have their root system confined to a limited mass of medium. A substrate must have enough water and aeration for optimal plant growth, which is achieved depending on the physical properties of the medium.

Murumkar *et al.* (2013) conducted an experiment in natural poly house. Chemical and physical characteristics of four types of growing medias comprising of coirpith, perlite, vermiculite and peat as separately and combination with vermicompost as 50 per cent on volume basis were determined and their suitability as growing media was tested using beet root (*nobo*l). The results indicated that certain chemical and physical properties of selected soilless media can be improved through incorporation of vermicompost and its positive effect was clearly reflected in the yield of beet root.

2.5.1.1 Bulk density

Quintero *et al.* (2009) reported that bulk density ranges between 0.77 g cm^{-3} for burnt rice husks and 0.81 g cm^{-3} for the 65:35 mixture of bulk density is highest on burnt rice husks (0.26 g cm^{-3}) and lowest on coconut fiber (0.13 g cm^{-3}), mixtures show proportional intermediate values. Coconut fiber displayed bigger particle size (from >2.5 to 0.63 mm), whereas burnt rice husk has higher values of fine particle size (0.63 to <0.08 mm). These differences in particle size affect the water retention curve and the water types for each substrate type. Air content and easily available water might help to define adequate water management and efficiency on different substrates.

2.5.1.2 Porosity

Nagavallemma *et al.* (2006) worked out that adding of vermicompost in soilless medias will increases macropore space ranging from 50 to 500 µm, resulting in improved air-water relationship in the soilless media which favorably affect plant growth.

Yahya *et al.* (2009) experimented that media comprising of 70 per cent cocopeat: 30 per cent burnt rice hull contained higher air content. Incorporation of burnt rice hull and perlite into cocopeat increased water absorption ability of the media. Addition of burnt rice hull (30 per cent) to cocopeat elevated the Air-Filled Porosity (AFP) of the media. The growth and flowering of *Celosia cristata* were the greatest when grown in a mixture of 70 per cent cocopeat: 30 per cent burnt rice hull and perhaps linked with a good balance in the aeration and moisture relationship of the media.

2.5.1.3 Water holding capacity

Miguel *et al.* (2009) observed that use of wetting agent in the nutrient solution would improve wettability and some other physical properties of growing media. The total water holding capacity increased with the wetting agent. With 2 mg wetting agent content there was an important and significant increase in the easily available water (over 600 per cent) in substrates (including the reused ones). The substrate reutilized after one crop, reduces the air capacity and increases the easily available water and total water-holding capacity. 2 mg L^{-1} is the wetting agent concentration more adequate in coir waste and rock wool.

Nichols and Savidov (2009) examined that coir (cocopeat) is obtained from the husk of the coconut and is essentially a waste product. It has been used for at least 10 years as a potting medium and is slowly gaining acceptance as a growing medium because of its excellent aeration and water holding characteristics. Grading coir for particle size by sieving and then appropriately mixing the different size grades provides an opportunity to optimize the physical characteristics of the mix and thus match the medium to the crop and thus enhance crop productivity.

2.5.2. Effect of substrates on chemical properties of growing media

Besides physical properties of the media, chemical standards such as pH and electrical conductivity are important parameters for optimum growth of soilless crops.

2.5.2.1. pH

Seemann and Critchley, (1985) and Yeo *et al.* (1985) recommended pH ranges for soilless media depending on crop species. The response of plant growth and yield to salinity is the resultant of various salt effects, including reduced carbon fixation due to specific ion toxicity and restriction of photosynthesis due to partial stomata closure.

2.5.2.2. Electrical conductivity

Cuartero and Fernandez-Munoz (1999) found that root biomass could be negatively affected by cell growth restriction. For tomato at EC above 4-6 dS m^{-1} plants have a significantly reduced water uptake.

Dietmar Schwarz and Rita Grosch (2003) pointed out that fresh and dry mass of shoots and roots, total root length, number of adventitious roots and all tap root laterals decreased with increasing nutrient solution EC. Dry matter content of roots and tap root diameter were not influenced while shoot dry matter content increased with increasing EC.

Magan *et al.* (2008) conducted experiment to know the effect of salinity on fruit yield, yield components and fruit quality of tomato grown in soilless culture in plastic greenhouses. Total and marketable yield decreased linearly with increasing salinity above a threshold EC value (ECt). There were only small effects of climate and cultivar on the ECt value for yield. Average threshold EC values for total and marketable fruit yield were, respectively, 3.2 and 3.3 dS m^{-1}. The linear reductions of total and marketable yield with EC above ECt showed significant differences between experiments. The decrease of fresh fruit yield with salinity was mostly due to a linear decrease of the fruit weight of 6.1 per cent per dS m^{-1} from an ECt of 3.0 dS m^{-1} for marketable fruits. Reduction in fruit number with salinity made a smaller relative contribution to reduced yield.

2.6. Effect of growing media on plant parameters

2.6.1. Plant height

NeSmith and Duval (1998) conducted a study on transplants for both vegetable and floral crops produced in a number of various sized containers or cells. Varying container size alters the rooting volume of the plants, which can greatly affect plant growth. Container size is important to transplant producers as they seek to optimize production space. Transplant consumers are interested in container size as it relates to optimum post-transplant performance. The following is a comprehensive review of literature on container size, root restriction, and plant growth, along with suggestions for future research and concern.

Momirovic *et al.* (2000) observed the significant effect of different organic media on plant growth of greenhouse-grown sweet pepper.

Arenas *et al.* (2002) reported that for Tomato the transplant growth with more than 50 per cent coir in growing medium exhibited reduced plant growth compared to peat grown plants.

Gruda and Schnitzle (2004) concluded that there were no significant differences observed for the absolute and relative growth rate of tomato transplants cultivated in wood fibre substrates as compared to white peat.

Ranawana *et al.* (2008) conducted an experiment on cultivation of cauliflower under open-field conditions in hot and humid regions. For the purpose of identifying the most appropriate hydroponics system for cauliflower cultivation, grow-bag culture (coco peat based) (T_1) and trough culture (liquid) (T_2) were compared with conventional soil culture under greenhouse (T_3) and open field conditions (T_4) for growth, nutrient uptake and the flower (curd) yield. Grow-bag culture (T_1) was found superior to other hydroponics systems with respect to vegetative growth, reproductive growth and the yield. Profusely branched root system could be the contributive factor for the higher nutrient uptake leading to relatively higher yield in T_1. Higher K dosage in T_1 and T_2 (N:K = 1:2) appeared to be favourable for K uptake during the stage of curd development. T_1 was more efficient in water and fertilizer usage. Hence grow-bag culture (T_1) appeared to be the best growing (hydroponics) system for cauliflower under tropical greenhouse conditions.

Bairwa *et al.* (2009) conducted study on fruit at Department of Horticulture, College of Agriculture, Udaipur, Rajasthan. The fruit yield was increased 29.30 per cent over control along with highest benefit cost ratio (3.19) in this treatment. Similarly, total chlorophyll content of leaves at 30 and 60 DAT (0.311 and 0.390 mg g^{-1} fresh weight) respectively. Nitrogen (2.275 per cent), phosphorus (1.060 per cent) and potassium contents of leaves (1.443 per cent) and protein content of fruit (1.86 g 100 g^{-1}) were also highest with the same integrated nutrient management treatment. Integrated nutrient management emerged as the best over the nutrient management through both sole inorganic and organic sources.

Hamdy *et al.* (2009) pointed that in cauliflower crop, the plant and root dry weight was significantly higher on the plants grown on pozzolana (PZ). While no significant differences were found between perlite (PR) and gravel (GR) substrates.

Maboko *et al.* (2009) found that plants in the soilless system developed faster with higher total yield compared with in-soil cultivation.

2.6.2. Fruit weight

Servetvaris and Tancerozyyman (1994) concluded that fruit weight varied greatly among the perlite combinations and ordinary soil + compost mixture in greenhouse grown tomatoes.

Maher and Prasad (1995) observed that cucumber plants grown in rock wool, soft nuggets and pumice produced fruit of higher average than using moss peat.

Baskar and Saravanan (1997) reported on increase in single fruit weight of tomato with coir pith as growing medium.

Hamdy *et al.* (2009) indicated that average fruit weight was higher on pozzolana (PZ) (1200 g) with respect to the other two substrates perlite (PR) and gravel (GR), (900-980 g).

2.6.3. Fruits per plant

Dobrimilska (1998) found that no significant effect of growing medium on number of fruits, when tomato plants were grown in greenhouse with a media composition of peat, soil, cattle manure, sand and brown coal.

Servetvaris and Tancerozyyman (1994) obtained significant different among different perlite combinations in total fruit number per plant.

Mokrzecka (2000) reported that tomato plants grown in 3:1 mixture of sawdust and soil and fertigated with 0.8 g nitrogen cm^{-3} gave the highest fruits per plant.

Cantliffe *et al.* (2001) concluded that plants grown in a mixture of 2 peat: 1 perlite produced a higher marketable fruit number and fruit weight per plant compared to pine bark or perlite regardless of growing system or plug type.

Majid Fandi *et al*. (2008) conducted study during 2001 and 2002 growing seasons at the Jordan Valley to evaluate the use of locally available tuff and sand substrates in comparison with soil for growing tomato (Lycopersicum esculentum [Mill] L. cv. Hana) using an open soilless culture. Tomato plants grown in soil or tuff gave higher total yield and yield/plant in both seasons. Fruit weight was not affected by the substrates in the first season, but it was the highest in soil in the second season. Total soluble solid was higher for tuff or sand substrates for both seasons. This study indicated that open soilless system using tuff as a substrate may be suitable for tomato production without dramatic changes in yield or fruit quality.

2.6.4. Fruit size

Abak *et al.* (1994) reported that there is no significant effect on fruit size when greenhouse tomatoes were grown in rockwool, peat and spent mushroom compost combinations.

Gul and Savgican (1994) reported that in greenhouse grown tomato, the growing media had significant effect on fruit size.

Hardgrave and Harimanna (1995) found that cucumber fruit size was reduced on peat and bark. Largest fruit size was obtained where the plants grown on wheat straw.

2.6.5 Chlorophyll content

Suharja and Sutarno (2009) conducted a study in the village of Gatak, Karangnongko sub-district, Klaten District, Central Java, Indonesia. This study aims to determine the influence of various fertilization treatments on biomass, chlorophyll and nitrogen content of leaves from two varieties of chili, Sakti (large chili) and Fantastic (curly chili). The results showed that on the *Fantastic* chili fertilizer treatment affected the biomass and chlorophyll *a*, but gave no effect on chlorophyll *b*, total chlorophyll and leaf nitrogen. On the curly chilli, fertilizer treatment effected plant fresh weight, chlorophyll *a* and total chlorophyll, but gave no effect on dry weight, fresh fruit weight, and chlorophyll *b* and leaf nitrogen. It is, therefore, recommended to use the formulation of manure + chemical fertilizer (SP-36: KCl = 1: 1) + liquid organic fertilizer in the cultivation of chili.

Malik *et al.* (2011) conducted an study at two locations of Experimental Farm of the Division of Olericulture, SKUAST-K, Shalimar and Regional Research Station, Faculty of Agriculture, Wadura (Sopore), during Kharif 2007. Observations were recorded on growth, yield, and fruit quality. The colour of fruit is an important determinant of the quality status of any vegetable. The chief pigment of fruits and vegetables which impart the green colour is chlorophyll. Different treatments were found to promise the effect on total chlorophyll content of capsicum fruits at edible stage. As a result, it revealed that the maximum chlorophyll (732.66 mg /100 g) was recorded in the treatment 9 (N=150 kg ha-1; P2O5 = 120 kg ha-1; K2O = 60 kg ha-1; FYM = 40 t ha-1) to improve the growth and yield attributing traits than other treatment combinations.

2.7 Cost economics

Raman *et al.* (1997) worked out the cost of construction of greenhouse depending upon the materials used and degree of automation and it is raised from Rs.125/- to Rs. 2000 m^{-2}.

Kariyanna (1998) conducted that various factors like availability of fund, water, electricity and other utilities such as crops to be grown, labour requirement, marketing facility and type of business wholesale or retail, personal linking etc. are to be considered while selecting the type and size of the greenhouse.

Mandhar *et al.* (1999) concluded that bigger greenhouse will cost less per square metre than smaller greenhouse by approximate cost per square metre of floor area of different types of greenhouses and net houses without including cost of irrigation, misting, fogging, computer systems and rolling benches etc.

Islam *et al.* (2010) conducted an experiment at the Horticultural farm of the Bangladesh Agricultural Research Institute. There were seven levels of sowing dates viz. September 1, September 15, October 1, October 15, October 30, November 15 and November 30. The results shows that the highest yield (19.36 t ha^{-1}) of fruit was recorded from the earlier sowing (October 1) with the spacing (50×30 cm) which also gave the highest benefit cost ratio (4.58). Considering the yield of fruits per hectare, cost of production and net return, the treatment combinations of October 1 sowing appeared to be recommendable for the cultivation of sweet pepper.

Murumkar *et al.* (2012) conducted an experiment during December 2008 to February 2009 to study the effect of growing media under polyhouse condition as a package in beet root (variety Nobol). There were eight different media levels comprising of coirpith, perlite, vermiculite and peat separately as treatments T_1 to T_4 and treatments T_5 to T_8 with vermicompost as 50 per cent on volume basis with three replications. Among the growing media treatments, the best performance in terms of growth, yield and quality were observed in treatment with peat: vermicompost (T_8) in the ratio of 1: 1 on volume basis. The highest water use efficiency (6.15×10^{-3} kg mm^{-1} per root) and benefit cost ratio (2.11) recorded in treatment T_8.

III. MATERIAL AND METHODS

The experiments were conducted during *rabi,* season of 2013 to study the different soilless growing media on yield and quality parameters of bell pepper **(***Capsicum annuum* var. *grossum*) cv. Indira under shade house. The details of material used and methodology followed during the field experiment and analytical techniques followed during the course of investigations are presented under this section.

3.1 Field location

The experiment was conducted in New Orchard of Main Agriculture Research Station, UAS Raichur, which is located in North Eastern Dry Zone *viz*., zone-II of region-I in Karnataka state. The georeference of study area is 16°15' latitude and 77° 20' longitude with elevation of 389 m above Mean Sea Level (MSL). The climate is semi-arid and average annual rainfall is 722 mm. The experimental plot was laid out in a spilt plot design with 2 main treatments, 7 sub treatments and 2 replications.

3.1.1 Weather parameter

The daily climatologically data during the study was collected from the meteorological observatory at the Main Agricultural Research Station, Raichur. The data on daily maximum and minimum temperature, relative humidity and evaporation from October 2013 to March 2014 are presented in Appendix. I. It has seen that during the study period, the highest maximum temperature of 35.4 °C was recorded in the month of March, 2014 and the lowest maximum temperature of 23.8 °C was recorded in the month of February, 2014. The highest minimum temperature of 24.4 °C was recorded in the month of October, 2013 and the lowest minimum temperature of 9.4 °C was recorded in the month of November, 2013. The maximum average relative humidity of 100.0 per cent was recorded in the month of October, 2013 and the minimum average relative humidity of 47 per cent was observed in the month of March, 2014. The maximum evaporation of 10 mm/day was recorded in the month of March, 2014 and the minimum evaporation of 0.6 mm/day in the month of November, 2013.

3.1.2 Crop and variety

The bell pepper hybrid Indira from Syngenta company was chosen for the study since it has a vibrant market potential in domestic market. The duration of the crop is 150 days.

3.1.3 Irrigation source

The source of irrigation water was from nearby bore well. The water was analyzed for pH, EC, total alkalinity, Cl_2, SO_4, Ca, Mg, Na, K, SAR and total soluble salts. The details of quality of irrigation water are presented in Table.3.1

3.2 Methods

3.2.1 Experimental layout

The experiments were carried out in a natural ventilated shade house of 28 m length and 8 m width with center height of the shade house of 4 m (Plate 3.1 and Plate 3.2). The floor area of the shade house was divided in to 28 beds each of 3 m length and 1 m width and 40 cm depth. The pits were all lined with thick polyethylene sheet on all sides and small holes are provided for drainage purpose. The detailed layout of beds are shown in (Fig. 3.1).

3.2.2 Transplanting

Bell pepper seedlings were transplanted in double row with spacing of 45 x 60 cm. Bell pepper production under shade house was taken up in seven types of growing media viz. cocopeat, rice husk, sawdust, vermicompost and their combinations replicated twice. The experimental and treatment details are given in Table 3.2.

3.2.3 Cultural practices

Gap filling was done one week after transplanting with the reserved plants of the same variety. Thinning was done 10 days after transplanting.

3.2.4 Treatments

The details of treatments taken for present study are given below.

Table 3.1 Quality of irrigation water

Water quality parameters	Content
pH	6.73
EC (dS/m)	1.756
Carbonate (CO_3) (meq/lit)	---
Bi-carbonate (HCO_3) (meq/lit)	7.2
Chloride (Cl_2) (meq/lit)	5.6
Calcium (Ca) (meq/lit)	9.6
Magnesium (Mg) (meq/lit)	6.6
Sodium (Na) (meq/lit)	40.0
Potassium (K) (meq/lit)	4.3
SAR (Sodium Adsorption Ratio)	0.61

Plate 3.1 Layout of natural shade house

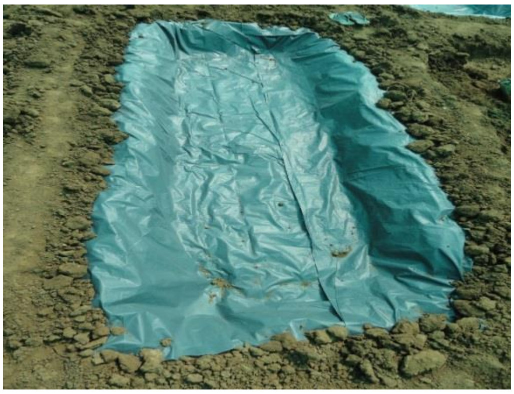

Plate 3.2 Pit and cover with polyethylene sheet

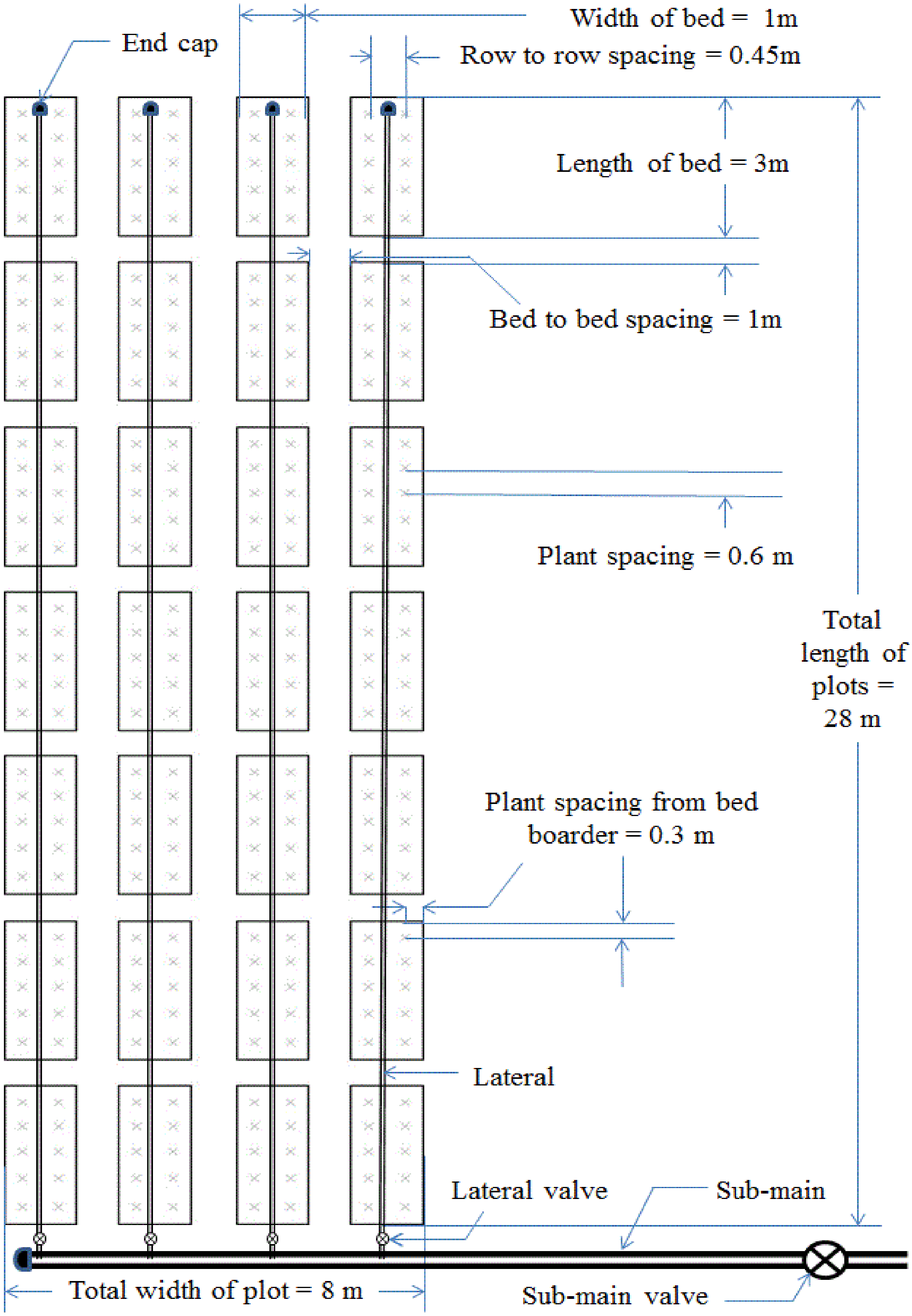

Fig. 3.1 Detailed layout of the experimental plot

Table 3.2 The experiment and treatment details are furnished below

Components	Details
Crop	Bell Pepper
Variety	Indira
Date of sowing	11-09-2013
Date of transplanting	10-10-2013
Spacing	45 x 60 cm
Number of main treatments	02
Number of sub-treatments	07
Replication	02
Duration	6 months
No. of plants under each treatment in one replication	10

A) Main treatments

I_1 - 100 per cent ET irrigation level

I_2 - 80 per cent ET irrigation level

B) Sub treatment (growing media)

Seven different growing media were selected for the study and the sandy loam soil was taken up as control (Plate 3.3). The different combinations of media on volume basis are given below.

M_1 - Cocopeat

M_2 - Rice husk

M_3 - Sawdust

M_4 - Cocopeat + vermicompost (1:1)

M_5 - Rice husk + vermicompost (1:1)

M_6 - Sawdust + vermicompost (1:1)

M_7 - Sandy loam soil

Replication: 2

3.3 Irrigation system

The irrigation system consists of mains, screen filter, sub mains, inline laterals and other accessories required for drip irrigation.

3.3.1 Pumping source

A 5 hp submersible pump was used to lift the water from bore well and supply to drip irrigated plots. The specification of the pump used was as follows.

Make	:	Atlanta
Speed	:	2900 rpm
Power	:	5 hp
Voltage	:	425 V
Stage	:	8
Total head	:	65 m

Plate 3.3 General view of the experimental plot

3.3.2 Pipeline manifold

The main and sub main pipelines used for drip irrigation were made of PVC of 63 mm and 50 mm diameter respectively.

3.3.3 Filter unit

A single mesh screen (125 µ) with a maximum capacity of 25 m^3 h^{-1} was used to filter the irrigation water for drip irrigation. The filter unit was fitted on the main pipeline of drip irrigation system.

3.3.4 Laterals and emitters

J-turbo line emitting pipes of 16 mm diameter were used for laterals in drip irrigation treatments. Drippers at 2.6 litres per hour (l h^{-1}) capacity were in the inline dripper at a spacing of 30 cm for drip irrigation treatments.

3.4 Irrigation scheduling

Drip irrigation for bell pepper was designed by careful analysis of the design capacity, optimum size of the pipelines, discharge rate of drippers, capacity of filter and pump capacity. The operating pressure at the main pipe of the drip system was maintained as 1 kg cm^{-2}. This pressure head was sufficient for irrigating the experimental area with paired row crop system with drip irrigation. To lift the water 5 hp submersible pump were used and conveyed to the field using 63 mm diameter PVC pipe. After filtering through the screen filter the water was conveyed to the field using 50 mm sub main. From the sub main, laterals of 16 mm diameter LLDPE pipes were installed. Each lateral was provided with individual tap control for imposing irrigation. Irrigation was given to all the treatments immediately after transplanting**.** Evening time was preferred for irrigation since evaporation was less at that time.

With the above mentioned design, first irrigation was given immediately after transplanting and subsequent irrigations were scheduled once in day based on the following formula and applied each time as per the treatment schedule.

Total water requirement of bell pepper is (287.1 lit per plant) and irrigation scheduling during study period is presented.

$$\text{Total water requiermen t (mm/day)} = \frac{\text{Number of plants} \times \text{Depth of water applied}}{\text{Water requiermen t} \times \text{Area of pit}}$$

3.5 Assessment of water requirement

The quantities of irrigation water applied to various treatments were based on daily temperature. The maximum and minimum temperature was measured inside the shade house. The evapotranspiration (ET) of shade house were correlated and arrived at before the beginning of the experiment. The daily evapotranspiration inside the shade house was calculated using modified Blaney-Criddle method (Michael, 1977) (Appendix-II).

Among the various approaches for irrigation scheduling, according to Jadhav *et al*. (2002) the water requirement of a plant was determined for drip irrigation by equation 3.1.

$$WR = \frac{A \times B \times C}{E} \qquad \text{... 3.1}$$

Where,

WR = Water requirement of a plant, (l $day^{-1} plant^{-1}$)

A = Reference Evapotranspiration (ET) in the shade house

ET = C [P (0.46 T + 8.18)]

Where,

T = mean daily temperature ($^{\circ}$C)

P = Mean daily percentage of total annual day time hours (per cent)

C = n/N

n = actual sunshine hours (h)

N = maximum sunshine hours (h)

B = Amount of area covered with foliage (canopy factor), fraction

C = Crop co-efficient, fraction

E = Efficiency of drip irrigation, (considered as 90 per cent)

The reference evapotranspiration was calculated using Blaney-Criddle method (Michael, 1977). A sample calculation for estimation of daily ET rate per plant is given in Appendix-III.

The water requirement for each drip treatment was worked out based on above equation and the same was considered for making supply of irrigation.

3.5.1 Crop factor (C)

The values of the crop factor for different stages of the bell pepper were selected based on the values suggested by Jain Irrigation Systems Manual (Anonymous, 2008). Accordingly the crop factor values used were 0.35, 0.67, 1.02 and 0.85 respectively for the initial stage (1 to 25 days), vegetative stage (25 to 45 days), fruiting stage (45 to 120 days) and harvest stage (120 to 150 days) of the bell pepper crop with total duration of 150 days. These crop values were utilized in determining the daily water requirement of the bell pepper crop under each treatment.

3.5.2 Canopy factor (B)

According to Jain Irrigation Manual (Anonymous, 2008) the canopy factors of bell pepper of initial stage, vegetative stage, fruiting stage and harvest stage were 0.4, 0.65, 0.9 and 0.8 respectively and the same have been used in the present study.

3.5.3 Duration of irrigation

The quantity of water to be applied was computed every day as explained in above. For the known discharge rate of emitters (2.5 l h^{-1}), the duration of irrigation water application was calculated using the following formula.

$$\text{Duration of irriagtion} = \frac{\text{Dripper discharge (l h}^{-1})}{\text{Dripper spacing} \times \text{Inline spacing (m)}} \qquad \text{... 3.2}$$

3.6 Fertigation

Water soluble fertilizers were used in this experiment. The recommended soluble fertilizers were applied simultaneously in a combined form to the plant root zone. NPK (19:19:19) and mono ammonium phosphate (12:61:0) in the form of water soluble fertilizers were applied manually throughout the crop duration.

3.6.1 Fertilizer application

The recommended levels of fertilizer for capsicum crop are as follows.

Nitrogen : 150 kg ha^{-1}

Phosphorus : 75 kg ha^{-1}

Potassium : 50 kg ha^{-1}

The fertilizer was applied manually as a basal dose.

3.6.2 Plant protection

The Table 3.3 presents the pesticides used during the experiment along with schedule of sprays and applied dose.

3.6.3 Harvesting

The crop was harvested manually depending upon the maturity of the bell pepper.

3.7. Physical and chemical characteristics of different soilless media

3.7.1. Physical properties

The selected growing media were analyzed for physical characteristics like bulk density, particle density and porosity by the below formula.

The bulk density was determined using pycnometer method. A empty container was weighed using digital balance. The container was filled with sample; the container and the sample were then weighed. The bulk density was calculated using following formula.

$$\text{Bulk Density (g/cc)} = \frac{\text{Mass of sample}}{\text{Volume of pycnometer}} \qquad \text{... 3.3}$$

The particle density was determined using pycnometer method. A clean empty bottle was weighed using digital balance. Fill a 10g of sample in the container weight it and fill half of the water. Expel the entrapped air by shaking and gentle boiling of the contents. Allow the contents to cool to room temperature and fill the pycnometer to the brim with boiled and cooled distilled water. Remove the contents of the pycnometer clean it with filter paper and weight it.

$$\text{Particle Density (g/cc)} = \frac{\text{Weight of particle}}{\text{Final volume} - \text{Initial volume}} \qquad \text{... 3.4}$$

$$\text{Porosity} = (1 - \frac{BD}{PD}) \times 100 \qquad \text{… 3.5}$$

(Murumkar *et al*. 2013)

Table 3.3 Pesticides used during the experiment

Chemical name	Trade name	No. of sprays	Dose
Imidacloprid 17.8% SL	Confidor	2	0.3 ml l^{-1}
Chlorantraniliprole 18.5 SC	Coragen	1	0.25 ml l^{-1}
Emamectin benzoate 5% SG	Proclaim	1	0.25 gm l^{-1}
Dicofol 18.5% SL	Kelthane	1	2.5 ml l^{-1}
Difenthiuron 50% WP	Peguses	2	1 gm l^{-1}
Pyromite	---	1	1 gm l^{-1}
Hexaconozoli 5% EC	Kantaf	1	1 gm l^{-1}

3.7.2 Water Holding Capacity (WHC) of different soilless media

The Water Holding Capacity (WHC) of different soilless media is determined by using procedure followed by Yahya *et al.* 2009.

Water holding capacity was determined by using a pressure plate apparatus. Ten grams of fresh media was placed in a retaining ring. The samples were saturated for 24 h by keeping the water level just below the edge of the ring in a tray. The plates with media sample were then placed inside the corresponding pressure chamber connected to an outflow tube. Different levels of pressure were applied on each sample. The samples were taken out when there were no dripping detected. The samples were then weighted and oven-dried for 24 h and their dry weights recorded. The water holding capacity expressed as a percentage.

3.7.3 Chemical characteristics

The media samples were collected from each treatment plot. The samples were dried under shade, powdered and sieved through 2 mm sieve and analysis was done using following procedure.

3.7.3.1 Total NPK status

The various soilless media samples were analyzed for available NPK content as per the standard procedure.

Available nitrogen was estimated by using alkaline potassium permanganate method (Subbiah and Asija, 1956). Available phosphorus was estimated by using Klett Summerson Calorimeter with red filter at 600 nm (Olsen *et al.* 1954). Available potassium was estimated using neutral normal ammonium acetate.

3.7.3.2 pH and EC

The pH and EC of all treatments were measured using pH and EC meters before transplanting and after harvesting.

3.8 Growth parameters

For periodical field observations, five plants were selected randomly from each treatment and were tagged. Observations such as number of days to flowering, number of 50 per cent flowering, plant height, number of branches, root length, average fruit weight, number of fruits per plant, yield per plant and yield per hectare were taken from selected five plants. The observations were taken at 30 DAT, 60 DAT, 90 DAT, 120 DAT and 150 DAT.

3.8.1 Days taken for flower initiation

Number of days taken for first flower appearance in each treatment was recorded.

3.8.2 Days to 50 per cent flowering

The number of days taken after planting for 50 per cent of the plants for first flowering was recorded as days to 50 per cent flowering.

3.8.3 Plant height

The height of the plant was recorded in centimeter (cm) at different stages (30, 60, 90,120 DAT and final harvesting). The height was measured from the ground level to the tip of the growing point from the tagged individual plant and average was worked out.

3.8.4 Number of branches per plant

The number branches were recorded at different stages (30, 60, 90, 120 DAT and final harvesting).

3.8.5 Root length

The length of the taproot was measured after final harvest and expressed in centimeters.

3.9 Yield parameters

3.9.1 Number of fruits per plant

The weight of fruits harvested from each plant was measured and then mean value worked out.

3.9.2 Average fruit weight

The average fruit weights were recorded from each treatment and then mean value worked out and expressed in grams.

3.9.3 Yield per plant

The weight of fruits from each plant over all the harvests was recorded and expressed in kilograms.

3.9.4 Yield per hectare

Total weight of matured fruit harvested from each picking in each replication was recorded till final harvest and the total yield of fruits per hectare under different treatments computed in tonne per hectare.

3.10 Quality analysis

3.10.1 Fruit length (mm)

Five fruits from each treatment were taken and the length was recorded from the stem end of the fruit to the distal end of the fruit using vernier caliper and mean calculated and recorded in millimetres.

3.10.2 Fruit width (mm)

The width of five fruits from each treatment was recorded at the point of maximum width by using vernier caliper and mean was calculated and recorded in millimetres.

3.10.3 Rind thickness (mm)

The selected fruits were sliced at the equatorial plane to measure the rind thickness with the help of vernier caliper and the mean was computed and recorded in millimetre.

3.10.4 Total soluble solids

The total soluble solids content of fruit was estimated using a refractometer and corrected to 21 $^{\circ}$C and expressed in $^{\circ}$Brix.

3.10.5 Chlorophyll content

Leaf chlorophyll content was measured by a portable Spad meter. In each leaf five readings were taken the average values are recorded and expressed in percentage.

3.10.6 Moisture content of fruit

The moisture content of the bell pepper samples was determined by following AOAC (2005) method. Accurately 5 g of bell pepper slice was kept in a pre-dried moisture box. The initial mass of the sample was recorded as W_1 and the box was placed in the hot air oven maintained at 105 $^{\circ}$C for 24 hours. The sample box was kept in the desiccator for cooling and then weighed. The mass of the dried sample was recorded as W_2. The moisture content of the sample was calculated by using the following equation. All the measurements were replicated thrice and the average moisture content was calculated.

$$\text{Moisture content (\%)} = \frac{W_1 - W_2}{W_2} \times 100 \qquad \text{... 3.6}$$

Where,

W_1 = Initial weight of the sample (g)

W_2 = Dry weight of the sample (g)

3.10.7 Total ash

The total ash content of the bell pepper slice samples was determined as per the standard procedure (AOAC, 2005) by using muffle furnace. Accurately 5 g of the sample was weighed into a crucible. The crucible was placed in a muffle furnace and heated at 600°C for about 5 h till all the material was completely charred. It was then cooled in a desiccator and weighed. The percentage of ash was calculated by using the following expression.

$$\text{Total ash (\%)} = \frac{\text{Weight of ash (g)}}{\text{Weight of sample (g)}} \times 100 \qquad \text{... 3.7}$$

3.10.8 Volume of fruit

The volume of bell pepper was determined using platform scale method. The fruit is first weighed on digital weighing balance and then forced into the water by means of a sinker rod. The second reading of the scale with the fruit submerged minus the weight of the container and water is the weight of the displaced water which will be used in the following equation (Mohsenin Nuri, 1986).

$$\text{Volume of fruit (cm}^{-3}) = \frac{\text{Weight of displaced water (g)}}{\text{Weight density of water (g cm}^{-3})} \quad \ldots 3.8$$

3.11 Field application efficiency

The application efficiency of drip irrigation was computed using the equation given by Nakayam and Bucks (1986), and the equation is expressed as follows.

$$e_a = \frac{e \times q_{min} \times T}{V} \times 100 \quad \ldots 3.9$$

Where,

e_a = Application efficiency, (per cent)

e = Total number of emitters,

q_{min} = Minimum emitters flow rate, ($l\ h^{-1}$)

T = Total irrigation time, (h)

V = Total volume of water applied, (l)

3.12 Determination of water use efficiency

Water Use Efficiency (WUE) was calculated for each treatment, which is the ratio of yield of the crop per kg and total water used in mm.

$$\text{WUE (kg m}^{-3}) = \frac{Y}{W.A} \quad \ldots 3.10$$

Where,

WUE = Water Use Efficiency, kg m^{-3} of water used.

Y = Yield of the crop per kg.

W.A = Total water utilized, m.

3.13 Cost economics

Economics of bell pepper production under shade house was worked out in terms of total expenditure. The total return was arrived at based on realized yield and Benefit Cost Ratio was calculated.

$$\text{Benefit Cost Ratio} = \frac{\text{Gross income ha}^{-1}}{\text{Total cost of cultivatio n ha}^{-1}} \quad \ldots 3.11$$

3.14 Statistical analysis

The data on the observations made and characters studied were statistically analyzed using Split Plot Design, the procedure described by Gomez and Gomez (1976). Wherever the results are significant, the critical difference at 5 per cent level was worked out and presented.

IV. EXPERIMENTAL RESULTS

The study was conducted during 2013-14 at the MARS, Raichur with a view to study the drip irrigation for bell pepper cultivation under shade house with different soilless media and to compare the performance of the crop in respect of growth, yield and quality parameters. The experiments also involved study on the effect of different levels of drip irrigation on irrigation efficiencies and cost economics. The results of the work are presented in this chapter.

4.1 Water requirement of bell pepper crop

Before start of the experiment irrigation water was delivered under drip irrigation as per treatments and the crop was irrigated at variable frequency (100 per cent ET).

The amount of water delivered to bell pepper under different levels of drip irrigation are presented in Table 4.1. It was observed that in case of irrigation at 80 per cent ET the water applied in l day^{-1} plant^{-1} varied from 0.2 to 0.9 during the month of October, 0.2 to 2.4 during November, 1.6 to 2.7 during December, 0.8 to 3.2 during January,1.3 to 2.4 during February, 0.7 to 2.1 during March. In case of drip irrigation at 100 per cent ET the water applied varied from 0.2 to 0.9 l day^{-1} plant^{-1} during the month of October, 0.2 to 3.0 during November, 2.0 to 3.3 during December, 0.9 to 4.0 during January, 1.6 to 3.0 during February, and 0.9 to 2.7 during March respectively.

The amount of water applied per month for different levels of drip irrigation are presented in Table 4.2. For drip irrigation at 80 per cent ET the monthly water requirement varied from 1.7 l in October to 70.9 l in December, for 100 per cent ET the water requirement varied from 2.1 l in October to 88.7 l in December.

It is also observed that the water requirement was maximum during the month of December and minimum during the month of October.

The quantities of water delivered per day averaged on monthly basis are presented in Table 4.3. It is observed from table that, the daily water requirement averaged on monthly basis varied from 0.1 l in October to 2.3 l in December under drip irrigation at 80 per cent ET. Similarly for 100 per cent ET, it varied from 0.1 l in October to 2.9 l in December.

Table 4.1 Amount of water applied to bell pepper crop under different levels of drip irrigation

Date	Amount water applied through drip irrigation at different irrigation levels, mm day^{-1}		
	ET	**I_1 (100 per cent ET)**	**I_2 (80 per cent ET)**
11/10/2013*	0.12	0.0	0.0
12/10/2013*	0.13	0.0	0.0
13/10/2013*	0.12	0.6	0.6
14/10/2013*	0.13	0.0	0.0
15/10/2013*	0.13	0.0	0.0
16/10/2013*	0.13	0.0	0.0
17/10/2013*	0.21	0.9	0.9
18/10/2013	1.70	0.3	0.2
19/10/2013	1.24	0.2	0.2
20/10/2013	1.71	0.3	0.2
21/10/2013	1.22	0.2	0.2
22/10/2013**	0.00	0.0	0.0
23/10/2013**	0.00	0.0	0.0
24/10/2013**	0.00	0.0	0.0
25/10/2013**	0.00	0.0	0.0
26/10/2013**	0.00	0.0	0.0
27/10/2013**	0.00	0.0	0.0
28/10/2013**	0.00	0.0	0.0
29/10/2013	2.11	0.3	0.2
30/10/2013	2.09	0.3	0.3
31/10/2013	2.35	0.4	0.3
01/11/2013	2.39	0.4	0.3
02/11/2013	2.42	0.4	0.3
03/11/2013	1.52	0.2	0.2
04/11/2013	1.89	0.3	0.2
05/11/2013	2.17	1.0	0.8
06/11/2013	2.21	1.1	0.9

Date	Amount water applied through drip irrigation at different irrigation levels, mm day^{-1}		
	ET	**I_1 (100 per cent ET)**	**I_2 (80 per cent ET)**
07/11/2013	3.14	1.5	1.2
08/11/2013	3.06	1.5	1.2
09/11/2013	1.40	0.7	0.5
10/11/2013	1.35	0.7	0.5
11/11/2013	1.33	0.6	0.5
12/11/2013	1.31	0.6	0.5
13/11/2013	1.31	0.6	0.5
14/11/2013	2.89	1.4	1.1
15/11/2013	2.80	1.4	1.1
16/11/2013	2.79	1.3	1.1
17/11/2013	2.64	1.3	1.0
18/11/2013	2.62	1.3	1.0
19/11/2013	2.14	1.0	0.8
20/11/2013	3.13	1.5	1.2
21/11/2013	2.99	1.4	1.2
22/11/2013	2.99	1.4	1.2
23/11/2013	2.87	1.4	1.1
24/11/2013	2.91	1.4	1.1
25/11/2013	2.52	1.2	1.0
26/11/2013	2.91	3.0	2.4
27/11/2013	2.84	2.9	2.3
28/11/2013	2.49	2.5	2.0
29/11/2013	2.12	2.2	1.7
30/11/2013	0.00	0.0	0.0
01/12/2013	1.95	2.0	1.6
02/12/2013	2.04	2.1	1.7
03/12/2013	2.44	2.5	2.0
04/12/2013	2.78	2.8	2.3
05/12/2013	2.91	3.0	2.4

Date	Amount water applied through drip irrigation at different irrigation levels, mm day^{-1}		
	ET	I_1 (100 per cent ET)	I_2 (80 per cent ET)
06/12/2013	2.82	2.9	2.3
07/12/2013	2.84	2.9	2.3
08/12/2013	2.70	2.8	2.2
09/12/2013	2.88	2.9	2.4
10/12/2013	2.49	2.5	2.0
11/12/2013	2.56	2.6	2.1
12/12/2013	2.60	2.6	2.1
13/12/2013	2.63	2.7	2.1
14/12/2013	2.73	2.8	2.2
15/12/2013	2.87	2.9	2.3
16/12/2013	2.91	3.0	2.4
17/12/2013	2.84	2.9	2.3
18/12/2013	2.91	3.0	2.4
19/12/2013	2.87	2.9	2.3
20/12/2013	2.57	2.6	2.1
21/12/2013	3.01	3.1	2.5
22/12/2013	3.20	3.3	2.6
23/12/2013	3.26	3.3	2.7
24/12/2013	3.11	3.2	2.5
25/12/2013	3.13	3.2	2.6
26/12/2013	2.92	3.0	2.4
27/12/2013	3.06	3.1	2.5
28/12/2013	2.67	2.7	2.2
29/12/2013	3.05	3.1	2.5
30/12/2013	3.04	3.1	2.5
31/12/2013	3.17	3.2	2.6
01/01/2014	1.45	1.5	1.2
02/01/2014	2.91	3.0	2.4
03/01/2014	2.64	2.7	2.2

Date	Amount water applied through drip irrigation at different irrigation levels, mm day^{-1}		
	ET	**I_1 (100 per cent ET)**	**I_2 (80 per cent ET)**
04/01/2014	2.80	2.9	2.3
05/01/2014	2.99	3.1	2.4
06/01/2014	2.80	2.9	2.3
07/01/2014	2.90	3.0	2.4
08/01/2014	3.11	3.2	2.5
09/01/2014	3.14	3.2	2.6
10/01/2014	2.99	3.0	2.4
11/01/2014	3.93	4.0	3.2
12/01/2014	0.95	1.0	0.8
13/01/2014	2.76	2.8	2.2
14/01/2014	1.33	1.4	1.1
15/01/2014	2.88	2.9	2.4
16/01/2014	3.20	3.3	2.6
17/01/2014	3.11	3.2	2.5
18/01/2014	3.06	3.1	2.5
19/01/2014	2.80	2.9	2.3
20/01/2014	2.79	2.8	2.3
21/01/2014	2.56	2.6	2.1
22/01/2014	2.79	2.8	2.3
23/01/2014	2.75	2.8	2.2
24/01/2014	1.04	1.1	0.8
25/01/2014	2.21	2.3	1.8
26/01/2014	2.22	2.3	1.8
27/01/2014	1.99	2.0	1.6
28/01/2014	1.90	1.9	1.6
29/01/2014	0.85	0.9	0.7
30/01/2014	1.76	1.8	1.4
31/01/2014	0.96	1.0	0.8
01/02/2014	1.56	1.6	1.3

Date	Amount water applied through drip irrigation at different irrigation levels, mm day^{-1}		
	ET	I_1 (100 per cent ET)	I_2 (80 per cent ET)
02/02/2014	1.59	1.6	1.3
03/02/2014	1.62	1.7	1.3
04/02/2014	1.68	1.7	1.4
05/02/2014	1.96	2.0	1.6
06/02/2014	2.12	2.2	1.7
07/02/2014	2.27	2.3	1.9
08/02/2014	2.94	3.0	2.4
09/02/2014	2.89	2.2	1.7
10/02/2014	2.99	2.3	1.8
11/02/2014	2.96	2.2	1.8
12/02/2014	3.14	2.4	1.9
13/02/2014	2.92	2.2	1.8
14/02/2014	2.94	2.2	1.8
15/02/2014	3.06	2.3	1.9
16/02/2014	3.04	2.3	1.8
17/02/2014	2.66	2.0	1.6
18/02/2014	3.02	2.3	1.8
19/02/2014	2.98	2.3	1.8
20/02/2014	2.89	2.2	1.7
21/02/2014	2.78	2.1	1.7
22/02/2014	2.87	2.2	1.7
23/02/2014	2.67	2.0	1.6
24/02/2014	3.29	2.5	2.0
25/02/2014	2.33	1.8	1.4
26/02/2014	2.60	2.0	1.6
27/02/2014	3.36	2.5	2.0
28/02/2014	3.06	2.3	1.9
01/03/2014	3.53	2.7	2.1
02/03/2014	3.02	2.3	1.8

Date	Amount water applied through drip irrigation at different irrigation levels, mm day^{-1}		
	ET	I_1 (100 per cent ET)	I_2 (80 per cent ET)
03/03/2014	3.04	2.3	1.8
04/03/2014	3.05	2.3	1.8
05/03/2014	3.04	2.3	1.8
06/03/2014	2.93	2.2	1.8
07/03/2014	1.19	0.9	0.7
08/03/2014	3.07	2.3	1.9
09/03/2014	2.79	2.1	1.7
10/03/2014	2.80	2.1	1.7
11/03/2014***	1.60	1.2	1.0

* Less amount of water so applied for 3 days

** No irrigations was applied from 22nd October to 28th October 2013 since there was adequate rainfall.

*** After 11th March 2013 irrigation was stopped.

Table 4.2 Monthly amount of water applied to bell pepper under different levels of drip irrigation

	Amount of water applied through drip irrigation at different irrigation levels, mm	
Month	**I_1 (100 per cent ET)**	**I_2 (80 per cent ET)**
October (21 days)	2.1	1.7
November	36.3	29.0
December	88.7	70.9
January	77.1	61.7
February	60.2	48.2
March (11 days)	22.7	18.2
Total	**287.1**	**229.7**

I_1- Water application at 100 per cent of ET using drip irrigation

I_2- Water application at 80 per cent of ET using drip irrigation

Table 4.3 Amount of water applied in litre per day drip irrigation averaged on monthly basis

Month	Daily average water applied under drip irrigation	
	I_1 (100 per cent ET)	I_2 (80 per cent ET)
October (21 days)	0.1	0.1
November	1.2	1.0
December	2.9	2.3
January	2.5	2.0
February	2.5	1.7
March (11 days)	2.1	1.7

I_1- Water application at 100 per cent of ET using drip irrigation

I_2-Water application at 80 per cent of ET using drip irrigation

Amount of water applied under drip irrigation methods based on crop growth stages are presented in Table 4.4. The highest water requirement was recorded during fruiting stage at 100 per cent ET (192.4 l) and lowest was found in 80 per cent ET (153.9 l).

4.1.1 Irrigation capacity (duty) and delta

The capacity of unit quantity of water to irrigate a crop is an important factor for any irrigation system. Table 4.5 presents the capacity of one m^3 of water to irrigate bell pepper crop during its growth period. It can be seen from the table that, with increase in the level of irrigation the amount of water applied also showed an increasing trend, whereas the irrigation capacity was found on a decreasing pattern. It was also observed that, the irrigation capacity was lowest (0.00010 ha m^{-3}) for 100 per cent ET irrigation. The highest irrigation capacity of 0.00013 ha m^{-3} was obtained for the treatment water application at 80 per cent ET.

Delta is the depth of irrigation (expressed in cm) required during the crop period. Delta of water for different treatments is presented in Table 4.5. It is observed from the table that delta was highest (95.7 cm) for 100 per cent ET irrigation and lowest (76.6 cm) for water application at 80 per cent ET.

4.2 Physical characteristics

4.2.1 Bulk density, particle density and porosity

Bulk density, particle density and porosity of different medias were analyzed and the results are presented in Table 4.6. The maximum (0.434 g/cc) bulk density was noticed in vermicompost followed by sawdust + vermicompost (0.356 g/cc) and minimum (0.100 g/cc) was found in rice husk.

In case of particle density maximum (1.112 g/cc) was noticed in cocopeat + vermicompost followed by sawdust + vermicompost (0.902 g/cc) and the minimum (0.199 g/cc) was found in cocopeat.

The maximum porosity was noticed in cocopeat + vermicompost (73.56 %) followed by rice husk + vermicompost (67.34 %) and minimum was found in vermicompost (36.73 %).

Table 4.4 Amount of water applied under drip irrigation methods based on crop growth stages

Crop growth stage	Stage wise water applied under drip irrigation, mm	
	I_1 (100 per cent ET)	**I_2 (80 per cent ET)**
Initial	3.4	2.7
Vegetative	24.5	19.6
Fruiting	192.4	153.9
Final	66.9	53.5
Total	287.1	229.7

I_1- Water application at 100 per cent of ET using drip irrigation

I_2- Water application at 80 per cent of ET using drip irrigation

Table 4.5 Irrigation capacity (duty) of 1m^3 of water and delta of water for different treatments for the crop period

Treatment	Irrigation water applied (l plant^{-1})	Irrigation water applied (l plot^{-1})	Irrigation water applied (m^3 ha^{-1})	Irrigation capacity (ha m^{-3})	Delta (cm)
I_1	287.1	2871.0	9570.1	0.00010	95.7
I_2	229.7	2296.8	7656.1	0.00013	76.6

I_1- Water application at 100 per cent of ET using drip irrigation

I_2- Water application at 80 per cent of ET using drip irrigation

Table 4.6 Bulk density of different media

Growing media	Bulk density (g/cc)	Particle Density (g/cc)	Porosity (%)
Cocopeat	0.115	0.199	42.21
Rice husk	0.100	0.279	64.20
Sawdust	0.260	0.660	60.60
Vermicompost	0.434	0.686	36.73
Cocopeat + Vermicompost (1:1)	0.294	1.112	73.56
Rice husk + Vermicompost (1:1)	0.280	0.857	67.34
Sawdust + Vermicompost (1:1)	0.356	0.902	60.53

4.2.2 Water holding capacity of different media

The water holding capacity of different growing media was analyzed and results are presented in Table 4.7. The highest water holding capacity was found in rice husk (88.00 %) followed by sawdust (75.40 %) and least was found in sawdust + vermicompost (42.20 %).

4.3 Chemical characteristics

4.3.1 N, P and K analysis

The N, P and K of the different medias were analyzed and results are presented in Table 4.8. The highest nitrogen was found in sandy loam soil (128.8 ppm) followed by vermicompost (0.518 ppm) and least was found in sawdust (0.238 ppm). In the phosphorus highest was found in sandy loam soil (363.12 ppm) followed by vermicompost (0.093 ppm) and least was found in rice husk (0.013 ppm) and lastly in case of potassium the highest potassium was found in soil (483 ppm) and least was found in sawdust (0.089 ppm)

4.4 Growth parameters

The effects of different drip irrigation levels and soilless media on the growth (biometric) parameters of bell pepper crop are presented below.

4.4.1 Days taken for flower initiation

The results on the number of days taken for flower initiation as influenced by irrigation levels and soilless growing media and their interaction are presented in Table 4.9 and Fig. 4.1

Among the different irrigation levels, the maximum (25.5) number of days taken for flower initiation was noticed in 100 per cent ET, followed by 80 per cent ET (23.5) which was statistically significant with each other.

Among the different media, the maximum number of days (33.0) taken for flower initiation was observed in sandy loam soil (M_7), which was statistically on par with cocopeat (M_1) (28.3) but superior over the other treatments. The least number of days taken flower initiation was in (19.5) was noticed in case of rice husk (M_2).

Table 4.7 Water holding capacity of different media

Growing media	Water holding capacity (per cent)
Cocopeat	49.05
Rice husk	88.00
Sawdust	75.40
Vermicompost	45.00
Cocopeat + Vermicompost	56.31
Rice husk + Vermicompost	67.24
Sawdust + Vermicompost	42.20

Table 4.8 N, P and K values of different growing media

Growing media	N (ppm)	P (ppm)	K (ppm)
Cocopeat	0.490	0.071	0.493
Rice husk	0.350	0.013	0.313
Sawdust	0.238	0.054	0.089
Vermicompost	0.518	0.093	0.179
Soil	128.8	363.12	483

The interaction effects due to different drip irrigation levels and soilless media on days to take flower initiation were found to be non-significant.

4.4.2 Days to 50 per cent flowering

The data regarding number of days taken for 50 per cent flowering as influenced by irrigation levels and soilless growing media and their interaction are presented in Table 4.9 and Fig. 4.1

Among the different irrigation levels, the maximum (46.5) number of days to 50 per cent flowering was noticed in 100 per cent ET followed by 80 per cent ET (44.1) which was statistically significant.

Among the different media, the maximum number of days (50.5) to 50 per cent flowering was observed in sandy loam soil (M_7), which was statistically on par with cocopeat (M_1) (49.5) but superior over the other treatments. The least number of days to 50 per cent flowering was (40.3) noticed in case of rice husk (M_2).

The interaction effects due to different drip irrigation levels and soilless media on days to 50 per cent flowering were found to be non-significant.

4.4.3 Plant height

The data on plant height (cm) at different stages (30, 60, 90,120 DAT and at final harvest) of crop growth as influenced by different drip irrigation levels and soilless media as well as their interaction are presented in the Table 4.10 and Fig. 4.2.

The highest plant heights of 18.4 cm (30 DAT), 40.0 cm (60 DAT), 49.3 cm (90 DAT), 61.1 cm (120 DAT) and 71.6 cm (150 DAT) were observed in treatments of 100 per cent ET (I_1). On the contrary, lowest plant heights were observed in case of 80 per cent ET (I_2) (16.8, 37.6, 45.6, 57.9 and 63.1 cm respectively).

Among the media, the sandy loam soil (M_7) appeared to be better exhibited the highest plant height (31.7, 68.3, 81.9, 107.2 and 119.5 cm respectively at 30, 60, 90,120 and 150 DAT), followed by cocopeat (M_1) (28.2, 59.8, 65.7, 92.5 and 96.1 cm respectively) which were on par and superior over the rest of the treatments. While, the lowest plant heights (5.1, 9.0, 14.2, 18.2 and 21.8 cm respectively) were observed in the treatment of rice husk (M_2) at different stages of plant growth.

Table 4.9 Effect of different drip irrigation levels and growing media on days taken for flowering, days to 50 per cent flowering

Treatment	Days taken for flowering initiation	Days to 50% flowering
M: Drip irrigation levels		
I_1:100 % ET	25.5	46.5
I_2:80 % ET	23.5	44.1
Mean		
S.Em.±	0.10	0.10
C.D.at 5 %	1.81	1.81
S: Media		
M_1:Cocopeat	28.3	49.5
M_2:Rice husk	19.5	40.3
M_3:Sawdust	22.8	42.8
M_4:Cocopeat + Vermicompost	22.3	45.5
M_5:Rice Husk + Vermicompost	23.0	45.3
M_6:Sawdust + Vermicompost	22.8	43.3
M_7:Sandy loam soil	33.0	50.5
Mean		
S.Em.±	1.58	0.80
C.D.at 5 %	4.88	2.47
Interaction		
I × M		
S.Em.±	2.24	1.13
C.D.at 5 %	**NS**	**NS**
I at the same or different M		
S.Em.±	3.17	1.60
C.D.at 5 %	**NS**	**NS**

Table 4.10 Plant height (cm) of bell pepper at various growth stages as influenced by different drip irrigation levels and growing media

Treatment	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT
M: Drip irrigation levels					
I_1:100 % ET	18.4	40.0	49.3	61.1	71.6
I_2:80 % ET	16.8	37.6	45.6	57.9	63.1
Mean					
S.Em.±	0.06	0.13	0.01	0.15	0.38
C.D.at 5 %	1.08	2.35	0.18	2.81	6.89
S: Media					
M_1:Cocopeat	28.2	59.8	65.7	92.5	96.1
M_2:Rice husk	5.1	9.0	14.2	18.2	21.8
M_3:Sawdust	12.7	26.2	32.2	41.4	49.9
M_4:Cocopeat + Vermicompost	18.6	44.4	55.5	63.9	76.7
M_5:Rice Husk + Vermicompost	14.8	38.2	45.3	53.5	60.1
M_6:Sawdust + Vermicompost	12.4	25.9	37.6	39.9	47.6
M_7:Sandy loam soil	31.7	68.3	81.9	107.2	119.5
Mean					
S.Em.±	2.14	4.57	5.68	4.86	8.06
C.D.at 5 %	6.55	14.10	17.50	14.98	24.84
Interaction					
I × M					
S.Em.±	3.0	6.47	8.03	6.88	11.40
C.D.at 5 %	**NS**	**NS**	**NS**	**NS**	**NS**
I at the same or different M					
S.Em.±	3.97	8.47	10.51	9.00	14.93
C.D.at 5 %	**NS**	**NS**	**NS**	**NS**	**NS**

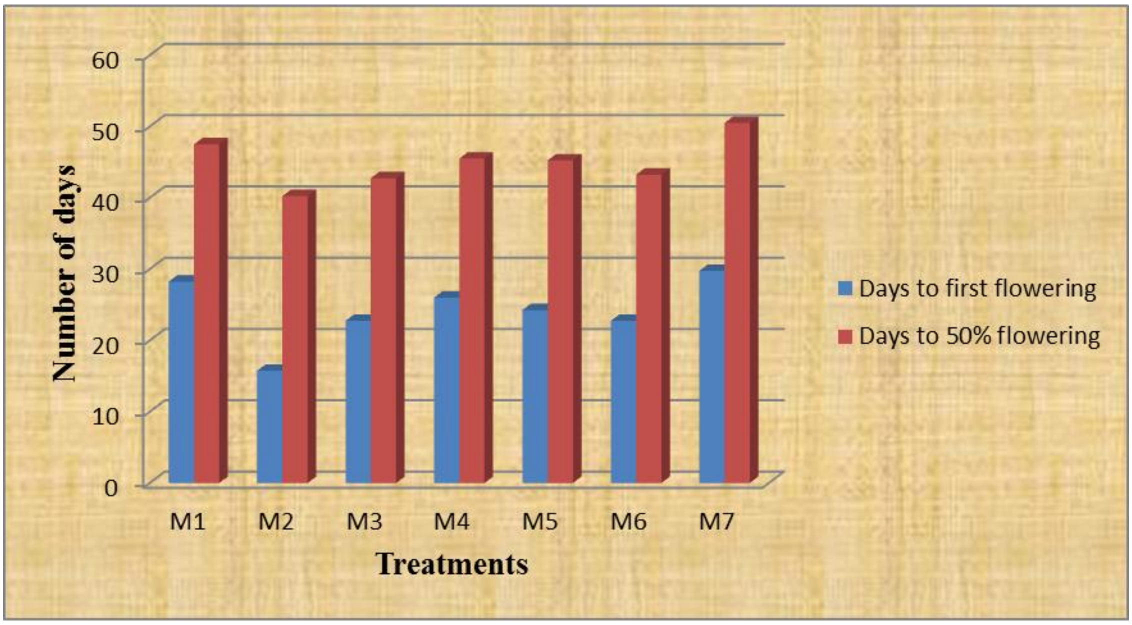

Fig. 4.1 Effect of soilless media on number of days taken for flowering and days to 50 per cent flowering of bell pepper

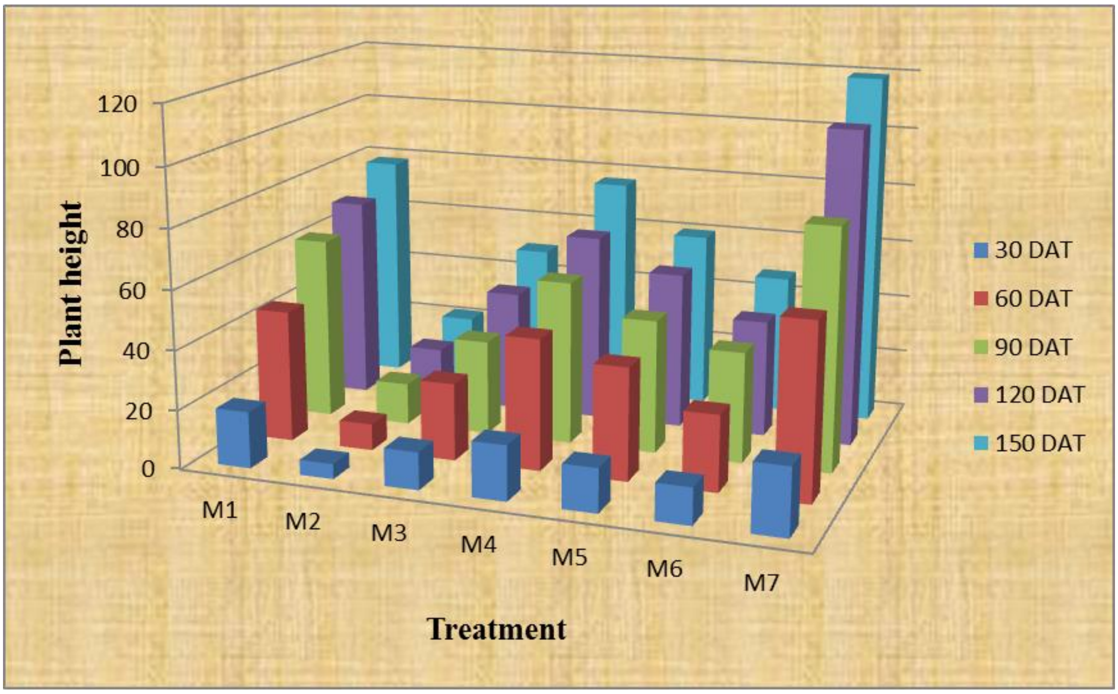

Fig. 4.2 Effect of soilless media on plant height for bell pepper

The interaction effects due to different drip irrigation levels and soilless on plant height of bell pepper were found to be non-significant at all the stages of crop growth.

4.4.4 Number of branches per plant

The data on number of branches per plant at 30, 60, 90, 120 DAT and at final harvest of the crop as influenced by different drip irrigation levels and soilless media and their interaction are presented in Table 4.11 and Fig. 4.3.

Significantly, the highest number of branches of 5.3 cm (30 DAT), 7.5 cm (60 DAT), 8.9 cm (90 DAT), 9.7 cm (120 DAT) and 11.3 cm (150 DAT) were observed in treatment 100 per cent ET (I_1). On the contrary, the lowest number of branches were observed in case of 80 per cent ET (I_2) (5.0, 7.0, 8.2, 8.7 and 10.2 cm respectively).

Among the media, the number of branches of bell pepper per plant with sandy loam soil (M_7) was highest (11.2, 13.8, 15.3, 16.8 and 18.3), followed by cocopeat (M_1) (9.2, 10.7, 12.7, 13.2 and 16.0) at 30, 60, 90, 120 and 150 DAT respectively. They were on par with each other, but superior over the other treatments. The least number of branches (1.5, 2.4, 3.0, 3.4 and 3.5 respectively) at all growth stages in bell pepper was noticed in case of rice husk (M_2).

The interaction effects due to different drip irrigation levels and soilless media on number of branches per plant of bell pepper were found to be non-significant at all the stages of crop growth.

4.4.5 Root length

The results on the root length after harvesting as influenced by irrigation levels and soilless growing media and their interaction are presented in Table 4.12

Among the different irrigation levels, the maximum (24.8) root length was noticed in 100 per cent ET, followed by 80 per cent ET (21.1) which was statistically significant.

Among the different soilless media, the maximum root length (34.0) was observed in cocopeat + vermicompost (M_4), which was statistically on par with cocopeat (M_1) (32.2) but superior over the other treatments. The least root length was in (14.7) in bell pepper was noticed in case of sawdust (M_3)

Table 4.11 Number of branches per plant of bell pepper at various growth stages as influenced by different drip irrigation levels and growing media

Treatment	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT
M: Drip irrigation levels					
I_1:100 % ET	5.3	7.5	8.9	9.7	11.3
I_2:80 % ET	5.0	7.0	8.2	8.7	10.2
Mean					
S.Em.±	0.02	0.03	0.01	0.04	0.04
C.D.at 5 %	0.27	0.54	0.18	0.73	0.73
S: Media					
M_1:Cocopeat	9.2	10.7	12.7	13.2	16.0
M_2:Rice husk	1.5	2.4	3.0	3.4	3.5
M_3:Sawdust	2.7	6.3	6.6	7.6	8.0
M_4:Cocopeat + Vermicompost	3.8	6.7	7.8	7.4	11.9
M_5:Rice Husk + Vermicompost	5.4	6.4	8.4	8.8	9.9
M_6:Sawdust + Vermicompost	2.4	4.6	6.1	7.5	8.1
M_7:Sandy loam soil	11.2	13.8	15.3	16.8	18.3
Mean					
S.Em.±	1.00	1.17	1.20	1.29	1.33
C.D.at 5 %	3.07	3.60	3.70	3.97	4.09
Interaction					
I × M					
S.Em.±	1.41	1.65	1.70	1.82	1.88
C.D.at 5 %	**NS**	**NS**	**NS**	**NS**	**NS**
I at the same or different M					
S.Em.±	1.99	2.33	2.40	2.57	2.65
C.D.at 5 %	**NS**	**NS**	**NS**	**NS**	**NS**

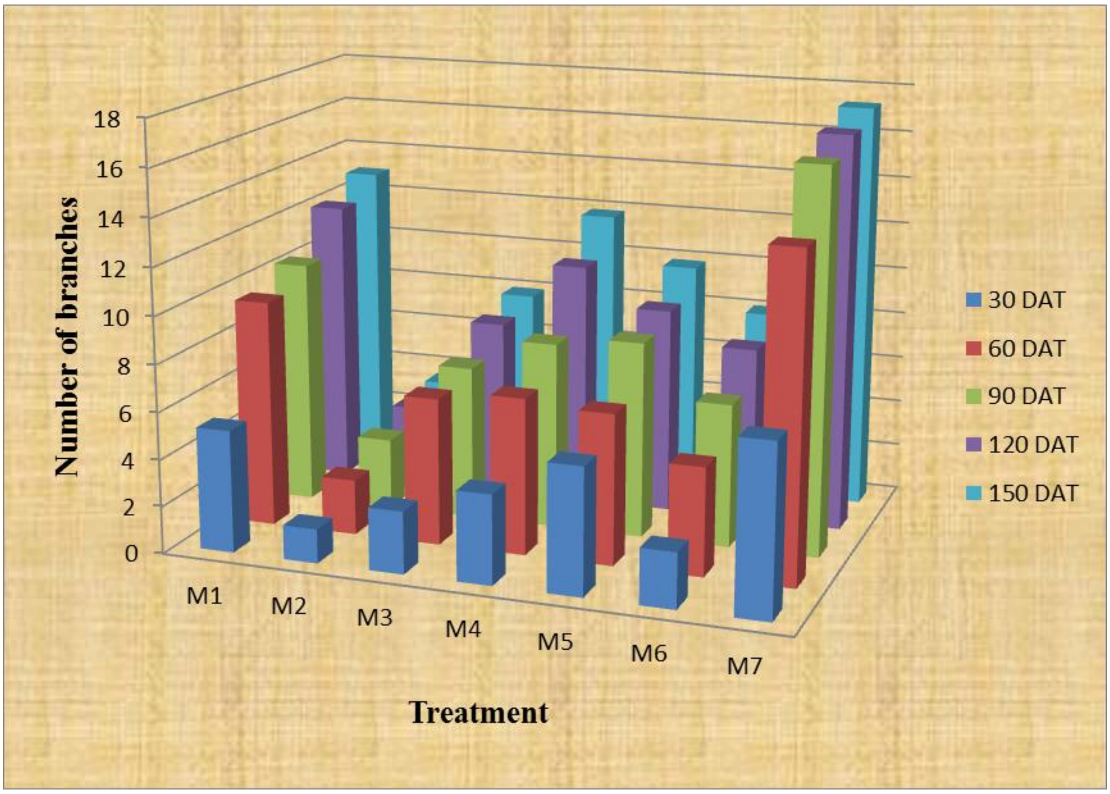

Fig. 4.3 Effect of soilless media on number branches for bell pepper

Table 4.12 Root length (cm) of bell pepper as influenced by different drip irrigation levels and growing media

Treatments	Root length (cm)
M: Drip irrigation levels	
I_1:100 % ET	24.8
I_2:80 % ET	21.1
Mean	
S.Em.±	0.19
C.D.at 5 %	3.53
S: Media	
M_1:Cocopeat	32.2
M_2:Rice husk	21.0
M_3:Sawdust	14.7
M_4:Cocopeat + Vermicompost	34.0
M_5:Rice Husk + Vermicompost	21.8
M_6:Sawdust + Vermicompost	17.4
M_7:Sandy loam soil	19.8
Mean	
S.Em.±	1.33
C.D.at 5 %	4.12
Interaction	
I × M	
S.Em.±	1.89
C.D.at 5 %	**NS**
I at the same or different M	
S.Em.±	2.68
C.D.at 5 %	**NS**

The interaction effects due to different drip irrigation levels and soilless media on root length of bell pepper were found to be non-significant at all the stages of crop growth.

4.5 Yield parameters

The effects of different drip irrigation levels and soilless media on the yield parameters of bell pepper crop are presented below.

4.5.1 Number of fruits per plant

The data pertaining to number of fruits per plant are presented in Table 4.13. Among the different irrigation levels, the highest number of fruits per plant (48.41) was observed in plants 100 per cent ET treatment, followed by the treatment with 80 per cent (45.85) which were statistically significant with each other.

Among the different media, the highest number of fruits per plant (68.35) was observed in sandy loam soil and was significantly higher compared to other treatments, but was statistically significant difference with cocopeat (53.55). On the other hand, the lowest number of fruits per plant (28.10) was noticed in rice husk which was statistically on par with each other.

The interaction effects due to different drip irrigation levels and soilless media with respect to number of fruits per plant were found to be non-significant.

4.5.2 Average fruit weight

The effects of different drip irrigation levels and soilless growing media on the average fruit weight (g) are presented in Table 4.13. Among the different irrigation levels, significantly, the highest (83.93 g) average fruit weight was recorded in the treatment of 100 per cent ET (I_1), followed by 80 per cent ET (I_2) (79.57 g), which was statistically significant with each other.

Among the different media, significantly highest average fruit weight (104.00 g) was noticed in sandy loam soil. Whereas, the other treatments of cocopeat (92.25 g), rice husk + vermicompost (87.00 g), cocopeat + vermicompost (84.75 g), sawdust + vermicompost (77.75 g), rice husk (72.50 g) and sawdust (54.00 g) were statistically found to be on par with each other.

The interaction effects due to different drip irrigation levels and soilless growing with respect to average fruit weight were found to be non-significant.

4.5.3 Yield per plant

The data regarding yield per plant are presented in Table 4.13. Among the different irrigation levels, the highest yield per plant was observed in 100 per cent ET (4.06 kg), followed by 80 per cent ET (3.64 kg) which were statistically significant with each other.

Among the different media, the highest yield per plant (7.09 kg) was observed in sandy loam soil, followed by cocopeat (4.96 kg) which were statistically significant and other treatments are on par with each other. On the other hand, the lowest yield per plant (1.67 kg) was noticed in sawdust which was statistically on par with rice husk (2.03 kg).

The interaction effects due to different drip irrigation levels and soilless media with respect to yield per plant were found to be non-significant.

4.5.4 Yield per ha

The results on total yield per hectare are presented in Table 4.13. Among the different drip irrigation levels, the highest yield was observed in the treatment 100 per cent ET (50.75t ha^{-1}), followed by 80 per cent (45.50 t ha^{-1}) which were statistically significant with each other.

Among the different media, the sandy loam soil was recorded significantly the highest yield (88.62 t ha^{-1}) followed by cocopeat (62.00 t ha^{-1}) which were statistically significant and other treatments are on par each other. On the contrary, the least yield was observed in sawdust (20.87 t ha^{-1}) which was on par with that of rice husk (25.37 t ha^{-1}).

The interaction effects due to different drip irrigation levels and soilless media with respect to yield per ha were found to be non- significant.

4.6 Quality analysis

4.6.1 Fruit length (mm)

The results on fruit length are presented in Table 4.14 and Fig. 4.4 Among the different drip irrigation levels, the highest fruit length was observed in the treatment

Table 4.13 Yield and yield parameters of bell pepper as influenced by different drip irrigation levels and growing media

Treatment	No. of fruits per plant	Average fruit weight (g)	Yield per plant (kg)	Yield (t ha^{-1})
M: Drip irrigation levels				
I_1:100 % ET	48.41	83.93	4.06	50.75
I_2:80 % ET	45.85	79.57	3.64	45.50
Mean				
S.Em.±	0.05	0.15	0.01	0.31
C.D. (5 %)	1.00	2.72	0.32	3.98
S: Media				
M_1:Cocopeat	53.55	92.25	4.96	62.00
M_2:Rice husk	28.10	72.50	2.03	25.37
M_3:Sawdust	31.00	54.00	1.67	20.87
M_4:Cocopeat + Vermicompost	53.13	84.75	4.48	56.00
M_5:Rice Husk + Vermicompost	51.30	87.00	4.46	55.75
M_6:Sawdust + Vermicompost	44.50	77.75	3.45	43.12
M_7:Sandy loam soil	68.35	104.00	7.09	88.62
Mean				
S.Em.±	2.89	6.54	0.02	5.29
C.D.at 5 %	8.92	20.18	0.45	16.32
Interaction				
I × M				
S.Em.±	4.10	9.26	0.42	7.49
C.D.at 5 %	**NS**	**NS**	**NS**	**NS**
I at the same or different M				
S.Em.±	5.79	13.10	0.60	10.60
C.D.at 5 %	**NS**	**NS**	**NS**	**NS**

100 per cent ET (55.6 mm), followed by 80 per cent (54.9 mm) which were statistically significant with each other.

Among the different media, the sandy loam soil was recorded significantly the highest fruit length (77.1 mm) followed by cocopeat (67.8 mm) which were statistically on par with each other. On the contrary, the least fruit length was observed in rice husk (26.1 mm) which was on par with that of sawdust (49.8 mm).

The interaction effects due to different drip irrigation levels and soilless media with respect to fruit length were found to be non- significant.

4.6.2 Fruit width (mm)

The results on fruit width are presented in Table 4.14 and Fig.4.5. Among the different drip irrigation levels, the highest fruit width was observed in the treatment 80 per cent ET (46.6 mm), followed by 100 per cent (45.0 mm) which were statistically significant with each other.

Among the media, the sandy loam soil recorded significantly the highest fruit width (59.5 mm) followed by cocopeat + vermicompost (53.2 mm) which were statistically on par with each other. On the contrary, the least fruit width was observed in sawdust + vermicompost (27.4 mm) which was on par with that of rice husk (35.5 mm).

The interaction effects due to different drip irrigation levels and soilless media with respect to fruit width were found to be non- significant.

4.6.3 Rind thickness (mm)

The results obtained on rind thickness as influenced by irrigation levels and soilless growing media are presented in Table 4.15 and depicted in Fig. 4.6. Among the different drip irrigation levels, the highest rind thickness was observed in the treatment 80 per cent ET (3.0 mm), followed by 100 per cent (2.9 mm) which were statistically significant with each other.

Among the media, the sandy loam soil was recorded significantly the highest rind thickness (3.7 mm) followed by sawdust (3.5 mm) which were statistically on par with each other. On the contrary, the least rind thickness was observed in rice husk (1.3 mm) which was on par with that of sawdust + vermicompost (1.8 mm).

Table 4.14 Fruit length (mm) and fruit width (mm) of bell pepper as influenced by different drip irrigation levels and growing media

Treatment	Fruit length	Fruit width
M: Drip irrigation levels		
I_1:100 % ET	55.6	45.0
I_2:80 % ET	54.9	46.6
Mean		
S.Em.±	0.04	0.05
C.D.at 5 %	0.72	0.92
S: Media		
M_1:Cocopeat	67.8	50.8
M_2:Rice husk	26.1	35.5
M_3:Sawdust	49.8	42.1
M_4:Cocopeat + Vermicompost	66.1	53.2
M_5:Rice Husk + Vermicompost	64.6	52.2
M_6:Sawdust + Vermicompost	35.5	27.4
M_7:Sandy loam soil	77.1	59.5
Mean		
S.Em.±	8.58	6.02
C.D.at 5 %	26.45	18.55
Interaction		
I × M		
S.Em.±	12.14	8.52
C.D.at 5 %	**NS**	**NS**
I at the same or different M		
S.Em.±	5.05	3.61
C.D.at 5 %	**NS**	**NS**

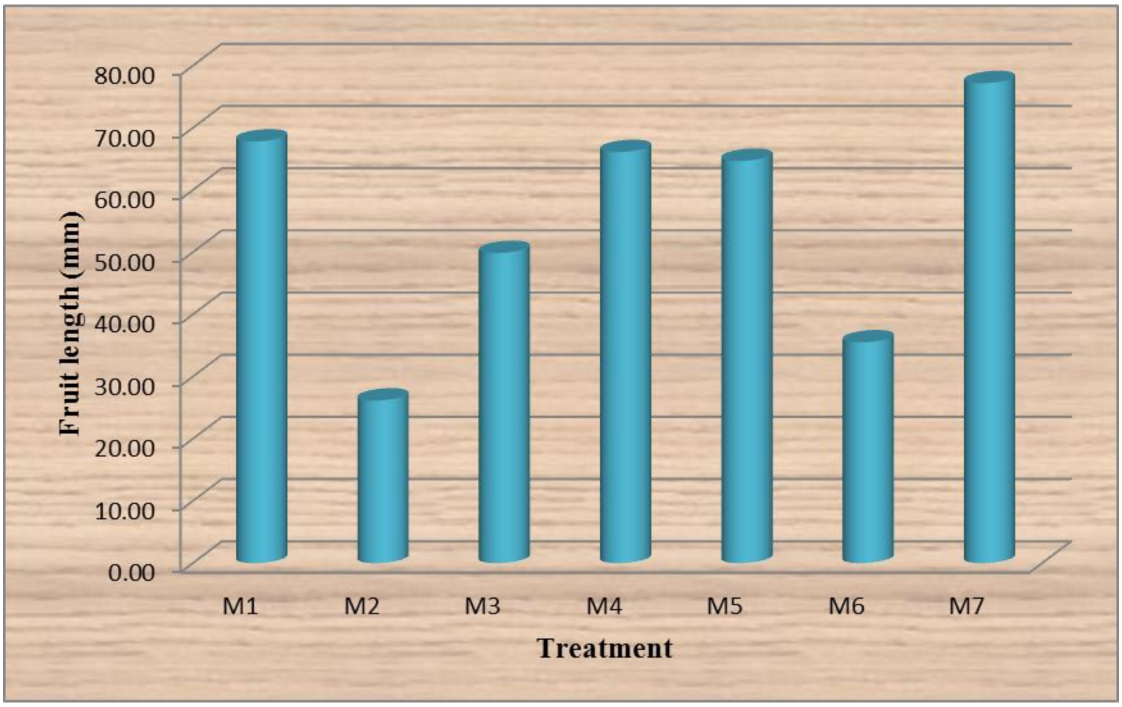

Fig. 4.4 Effect of soilless media on fruit length for bell pepper

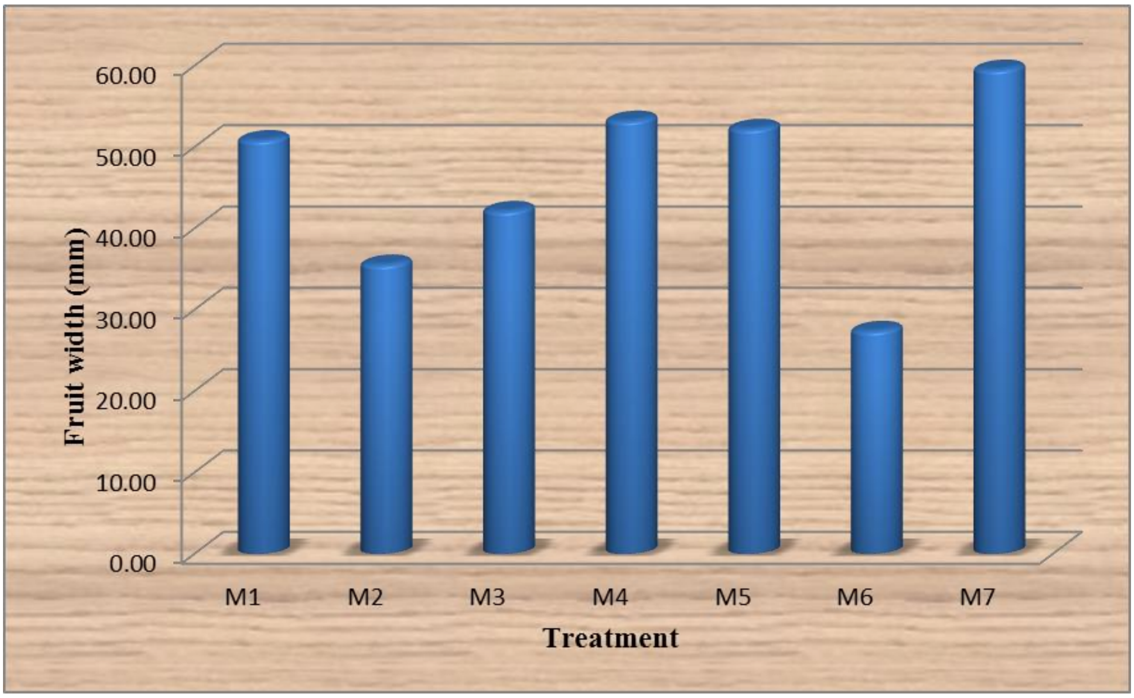

Fig. 4.5 Effect of soilless media on fruit width for bell pepper

The interaction effects due to different drip irrigation levels and soilless media with respect to rind thickness were found to be non- significant.

4.6.4 Volume of fruit

The data regarding volume of fruit for different irrigation levels and soilless media are given in table 4.15 and Fig.4.7. Among the different drip irrigation levels, the highest volume of fruit was observed in the treatment 100 per cent ET (103.2), followed by 80 per cent (101.3) which were statistically significant different. In the sub plot the different media sandy loam soil was recorded the maximum volume of fruit (141.5) and minimum volume of fruit was found in rice husk (56.3) which were statistically on par with each other.

The interaction effects due to different drip irrigation levels and soilless media on volume of fruit for bell pepper were found to be non-significant.

4.6.5 Total soluble solids (TSS)

The effect of drip irrigation levels and soilless media on TSS of bell pepper crop are presented Table 4.16, it can be seen that from table the treatment 100 per cent ET levels shows the highest TSS value (3.5 ^{o}brix) which was statistically significant difference with 80 per cent ET (3.4 ^{o}brix). In the sub plot the among all the media sandy loam soil recorded the maximum TSS (4.4 ^{o}brix) and minimum TSS was found in rice husk (1.8 ^{o}brix) which were statistically on par with each other.

The interaction effects due to different drip irrigation levels and soilless media with respect to TSS were found to be non- significant.

4.6.6 Chlorophyll content

The data pertaining to chlorophyll content on leaf for bell pepper crop are presented in Table 4.17. Among the different drip irrigation levels, the highest chlorophyll was observed in the treatment 100 per cent ET (51.4), followed by 80 per cent (48.3) which were statistically significant with each other. In the sub plot the among all media sandy loam soil recorded the maximum chlorophyll (68.3) and minimum chlorophyll was found in rice husk (24.7) which were statistically on par with each other.

The interaction effects due to different drip irrigation levels and soilless media with respect to chlorophyll content were found to be non- significant.

Table 4.15 Effect of different drip irrigation levels and growing media on rind thickness (mm) and fruit volume (cc/fruit)

Treatments	Rind thickness (mm)	Fruit volume (cc/fruit)
M: Drip irrigation levels		
I_1:100 % ET	2.9	103.2
I_2:80 % ET	3.0	101.3
Mean		
S.Em.±	0.009	0.084
C.D.at 5 %	0.163	1.524
S: Media		
M_1:Cocopeat	3.2	109.9
M_2:Rice husk	1.3	56.3
M_3:Sawdust	3.5	101.7
M_4:Cocopeat + Vermicompost	3.2	121.1
M_5:Rice Husk + Vermicompost	3.3	93.6
M_6:Sawdust + Vermicompost	1.8	91.6
M_7:Sandy loam soil	3.7	141.5
Mean		
S.Em.±	0.54	14.71
C.D.at 5 %	1.67	45.33
Interaction		
I × M		
S.Em.±	0.77	20.81
C.D.at 5 %	**NS**	**NS**
I at the same or different M		
S.Em.±	1.08	29.42
C.D.at 5 %	**NS**	**NS**

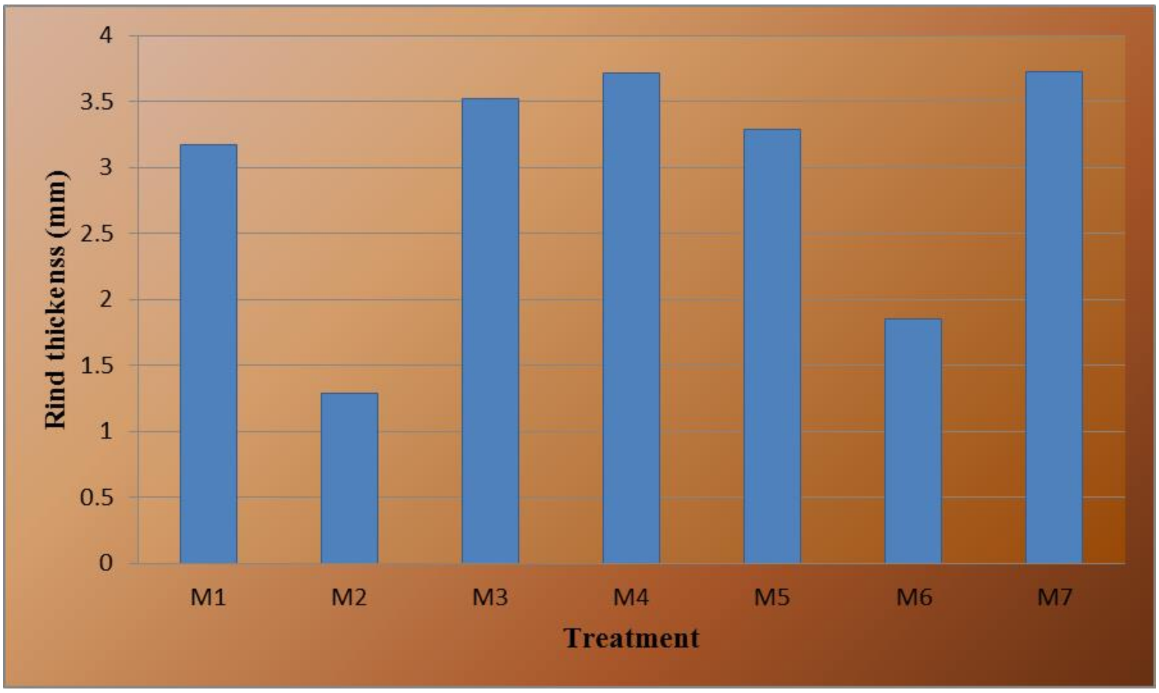

Fig. 4.6 Effect of soilless media on fruit rind thickness for bell pepper

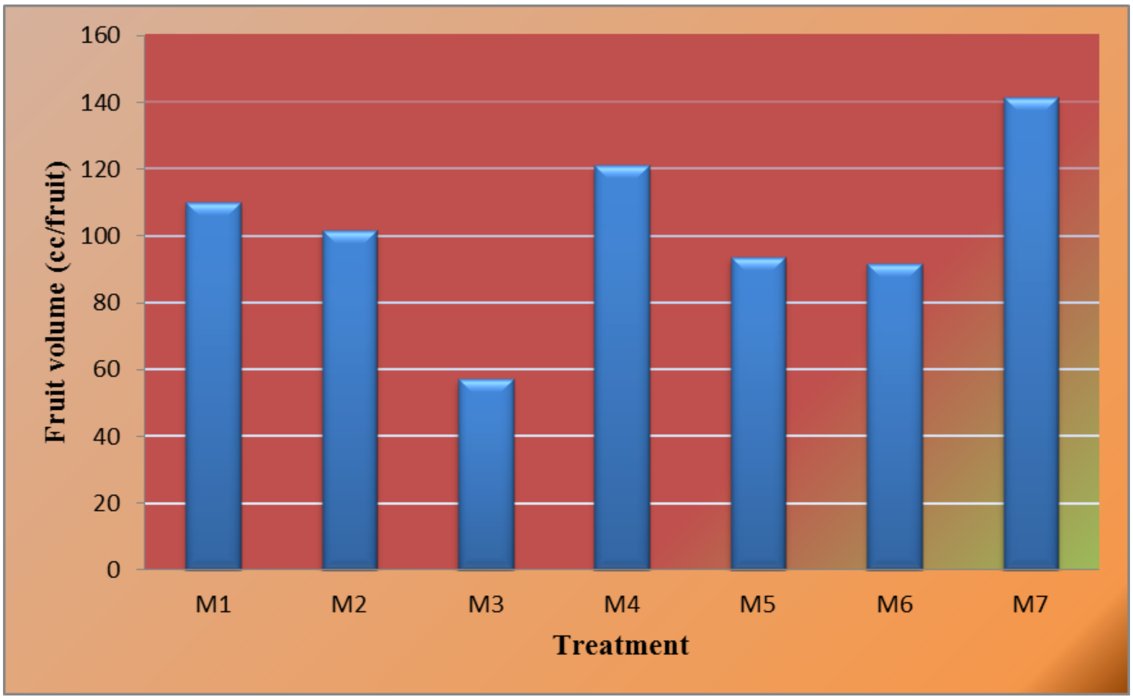

Fig. 4.7 Effect of soilless media on fruit volume for bell pepper

Table 4.16 Total soluble solids (per cent) of capsicum as influenced by different drip irrigation levels and growing media

Treatments	TSS
M: Drip irrigation levels	
I_1:100 % ET	3.5
I_2:80 % ET	3.4
Mean	
S.Em.±	0.005
C.D.at 5 %	0.090
S: Media	
M_1:Cocopeat	4.0
M_2:Rice husk	1.8
M_3:Sawdust	3.5
M_4:Cocopeat + Vermicompost	4.1
M_5:Rice Husk + Vermicompost	3.0
M_6:Sawdust + Vermicompost	3.6
M_7:Sandy loam soil	4.4
Mean	
S.Em.±	0.505
C.D.at 5 %	1.558
Interaction	
I × M	
S.Em.±	0.72
C.D.at 5 %	**NS**
I at the same or different M	
S.Em.±	1.01
C.D.at 5 %	**NS**

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Table 4.17 Chlorophyll content of bell pepper as influenced by different drip irrigation levels and growing media

Treatments	Chlorophyll
M: Drip irrigation levels	
I_1:100 % ET	51.4
I_2:80 % ET	48.3
Mean	
S.Em.±	0.16
C.D.at 5 %	2.94
S: Media	
M_1:Cocopeat	61.7
M_2:Rice husk	24.7
M_3:Sawdust	42.1
M_4:Cocopeat + Vermicompost	60.4
M_5:Rice Husk + Vermicompost	60.5
M_6:Sawdust + Vermicompost	31.1
M_7:Sandy loam soil	68.3
Mean	
S.Em.±	7.84
C.D.at 5 %	24.17
Interaction	
I × M	11.10
S.Em.±	**NS**
C.D.at 5 %	
I at the same or different M	4.64
S.Em.±	NS
C.D.at 5 %	

4.6.7 Moisture content of fruit

The results of moisture content of fruit for different irrigation levels and soilless media for bell pepper crop are presented Table 4.18 and Fig.4.8. Among the different drip irrigation levels, the highest moisture content of fruit was observed in the treatment 100 per cent ET (90.1), followed by 80 per cent (86.2) which were statistically significant with each other. In the sub plot among all the media sandy loam soil recorded the maximum fruit moisture content (91.8) and minimum fruit moisture content was found in rice husk (84.3) which were statistically on par with each other.

The interaction effects due to different drip irrigation levels and soilless media with respect to moisture content of fruit were found to be non- significant.

4.6.8 Total ash

The results on ash content of fruit for different irrigation levels and soilless media are presented in Table 4.18 and Fig. 4.9. Among the different drip irrigation levels, the highest ash content of fruit was observed in the treatment 100 per cent ET (8.4), followed by 80 per cent (7.3) which were statistically significant with each other. In the sub plot the different media sandy loam soil recorded the maximum ash content of fruit (9.4) and minimum ash content of fruit was found in rice husk (4.5) which were statistically on par with each other.

The interaction effects due to different drip irrigation levels and soilless media on ash content of fruit for bell pepper were found to be non-significant.

4.7 Irrigation efficiencies

The results of the various irrigation efficiencies for different drip irrigation levels under the shade house conditions are presented in this section.

4.7.1 Application efficiency

Application efficiency shows how well the irrigation water is applied to the field; the percentage of water applied is stored in the crop root zone as required and available for plant use. The application efficiency for different treatments are given in Table 4.19. It is observed that application efficiency was higher in 80 per cent ET (98.5) and lowest in 100 per cent ET (88.4). This shows that the application efficiencies were higher in 80 per cent ET as compared with the 100 per cent ET irrigation treatment.

Table 4.18 Effect of different drip irrigation levels and growing media on moisture content (per cent) and ash content (per cent)

Treatments	Moisture content	Ash content
M: Drip irrigation levels		
I_1:100 % ET	90.1	8.4
I_2:80 % ET	86.2	7.3
Mean		
S.Em.±	0.202	0.008
C.D.at 5 %	3.630	0.145
S: Media		
M_1:Cocopeat	89.8	8.4
M_2:Rice husk	84.3	4.5
M_3:Sawdust	87.3	7.5
M_4:Cocopeat + Vermicompost	89.5	8.7
M_5:Rice Husk + Vermicompost	87.0	7.9
M_6:Sawdust + Vermicompost	87.5	8.5
M_7:Sandy loam soil	91.8	9.4
Mean		
S.Em.±	1.228	0.909
C.D.at 5 %	3.785	2.803
Interaction		
I × M		
S.Em.±	1.74	1.29
C.D.at 5 %	**NS**	**NS**
I at the same or different M		
S.Em.±	2.46	1.81
C.D.at 5 %	**NS**	**NS**

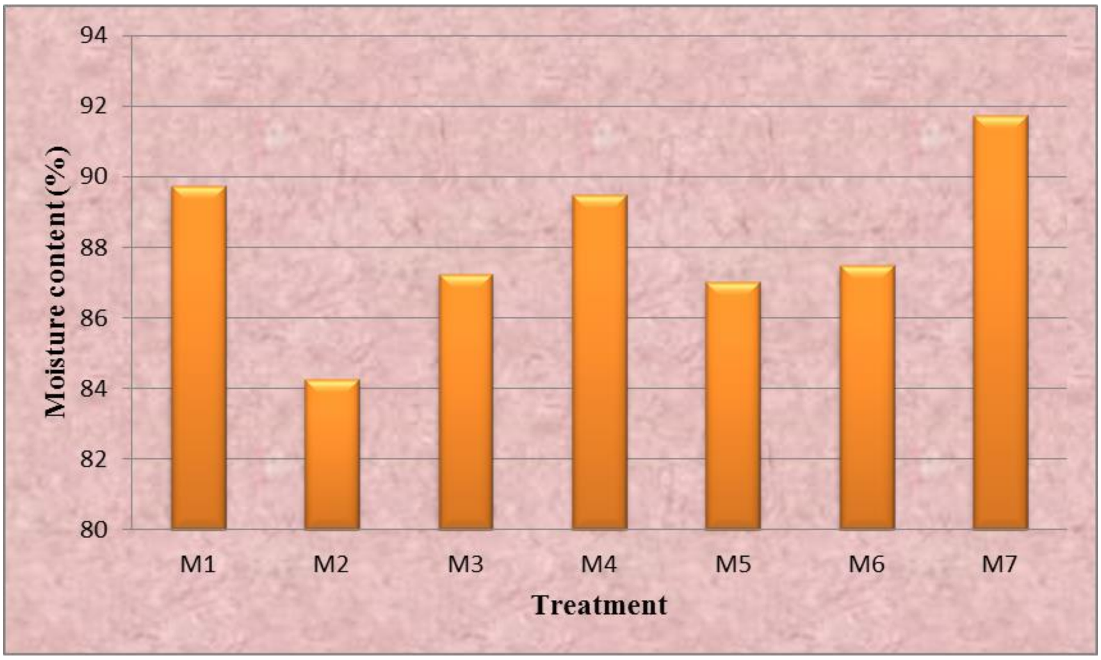

Fig. 4.8 Effect of soilless media on fruit moisture content for bell pepper

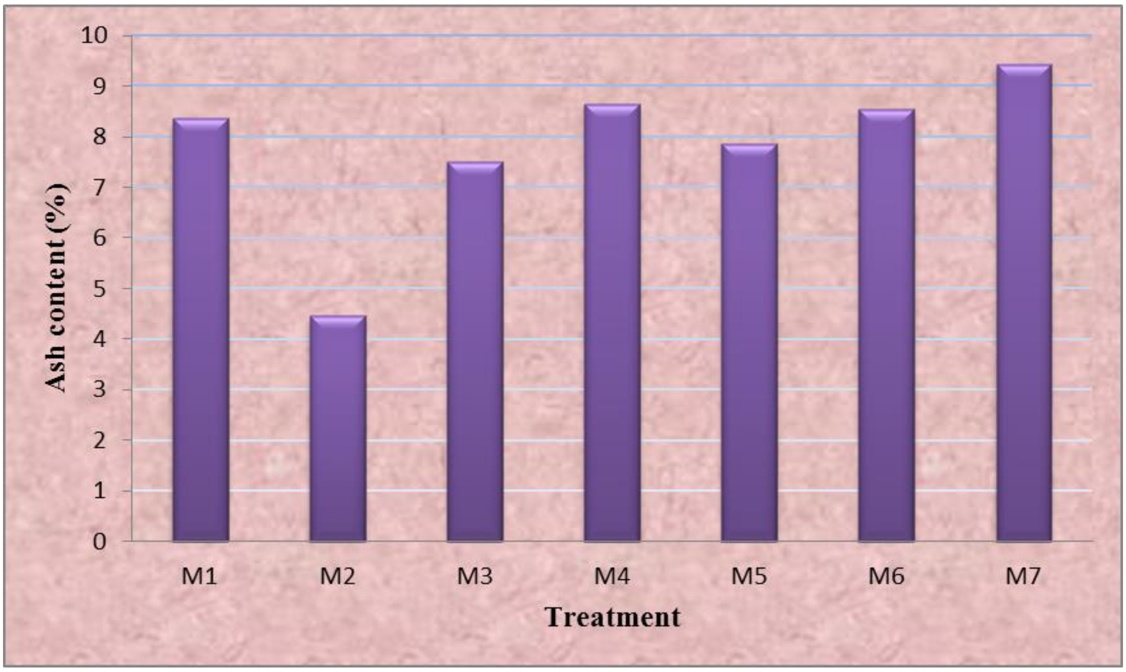

Fig. 4.9 Effect of soilless media on fruit ash content for bell pepper

Table 4.19 Effect of growing media and different levels of irrigation on application efficiency

Treatments	Application efficiency (per cent)
I_1	88.4
I_2	98.5

I_1 - Water application at 100 per cent ET using drip irrigation

I_2 - Water application at 80 per cent ET using drip irrigation

4.7.2 Water use efficiency

The effect of different irrigation levels and soilless media on water use efficiency are presented in Table 4.20. The results indicated that among the irrigation level of 100 per cent ET resulted maximum water use efficiency (6.0 kg m^{-3}) than the 80 per cent ET (5.7 kg m^{-3}). And on the other side among different media, the sandy loam soil was recorded the maximum water use efficiency (10.2 kg m^{-3}) followed by cocopeat (7.3 kg m^{-3}), cocopeat + vermicompost (6.6 kg m^{-3}), rice husk + vermicompost (6.5 kg m^{-3}), sawdust + vermicompost (5.1 kg m^{-3}) and rice husk (3.0 kg m^{-3}). The minimum water use efficiency was found in saw dust (2.4 kg m^{-3}).

4.8 Cost economics

The data on cost of cultivation, fixed cost, gross and net income and water used for different treatments for bell pepper crop are presented in Appendix IV.

The life of the pipe materials were taken as ten years. Interest at twelve per cent of fixed cost was taken into consideration to work out the cost economics. The economics of the system of irrigation under study was worked out in Rs. per ha.

4.6.1 Net returns and benefit: cost ratio

The net returns and benefit-cost ratio for soilless culture with different drip irrigation levels are presented in Table 4.21. It can be seen from the results that among all the media treatments the highest net return of Rs. 33,22,197.93 per ha was obtained from treatment of sandy loam soil with 100 per cent ET, followed by the treatment of sandy loam soil with 80 per cent ET (Rs. 21,43,222.93 per ha) and the lowest net return was obtained in sawdust + vermicompost treatment with 100 per cent ET (Rs. 56,597.93 per ha.).

It is also seen from the Table 4.21. Among all the media with highest benefit: cost ratio of (9.03) was obtained in sandy loam soil with 100 per cent ET followed by sandy loam soil with 80 per cent ET (5.82). The lowest benefit-cost ratio was found in sawdust + vermicompost with 100 per cent ET (0.04) followed by sawdust + vermicompost with 80 per cent ET (0.10).

Table 4.20 Effect of different irrigation levels and soilless media on water use efficiency

Treatments	Water use efficiency (kg m^{-3})
M: Drip irrigation levels	
I_1:100 % ET	6.0
I_2:80 % ET	5.7
Mean	
S.Em.±	0.008
C.D.at 5 %	0.15
S: Media	
M_1:Cocopeat	7.3
M_2:Rice husk	3.0
M_3:Sawdust	2.4
M_4:Cocopeat + Vermicompost	6.6
M_5:Rice Husk + Vermicompost	6.5
M_6:Sawdust + Vermicompost	5.1
M_7:Sandy loam soil	10.2
Mean	
S.Em.±	0.59
C.D.at 5 %	1.75
Interaction	
I × M	
S.Em.±	0.81
C.D.at 5 %	**NS**
I at the same or different M	
S.Em.±	1.13
C.D.at 5 %	**NS**

Table 4.21 Economics of bell pepper as influenced by different drip irrigation levels and growing media

Treatments	Crop yield t ha^{-1}	Total returns Rs ha^{-1}	Total cost of cultivation Rs ha^{-1}	Net returns Rs ha^{-1}	Benefit cost ratio
I_1M_1	62.51	21,87,850.00	6,03,527.08	15,84,322.93	2.63
I_1M_2	25.75	9,01,250.00	5,33,027.08	3,68,222.93	0.69
I_1M_3	23.88	8,35,625.00	5,55,527.08	2,80,097.93	0.57
I_1M_4	56.31	19,70,850.00	11,36,777.08	8,34,072.93	0.73
I_1M_5	57.94	20,27,725.00	11,01,527.08	9,26,197.93	0.84
I_1M_6	41.88	14,65,625.00	14,09,027.08	56,597.93	0.04
I_1M_7	105.44	36,90,225.00	3,68,027.08	33,22,197.93	9.03
I_2M_1	61.50	21,52,325.00	6,03,527.08	15,48,797.93	2.57
I_2M_2	25.06	8,77,100.00	5,33,027.08	3,44,072.93	0.65
I_2M_3	17.94	6,27,725.00	5,55,527.08	72,197.93	0.13
I_2M_4	55.69	19,48,975.00	11,36,777.08	8,12,197.93	0.71
I_2M_5	53.42	18,69,700.00	11,01,527.08	7,68,172.93	0.70
I_2M_6	44.44	15,55,225.00	14,09,027.08	1,46,197.93	0.10
I_2M_7	71.75	25,11,250.00	3,68,027.08	21,43,222.93	5.82

I_1: Drip irrigation at 100 per cent ET

I_2: Drip irrigation at 80 per cent ET

M_1: Cocopeat

M_2: Ricehusk

M_3: Sawdust

M_4: Coco peat + vermicompost (1:1)

M_5: Rice husk + vermicompost (1:1)

M_6: Sawdust + vermicompost (1:1)

M_7: Sandy loam soil

V. DISCUSSION

The results on effect of soilless media along with different level of drip irrigation on various parameter such as water requirement, biometric parameter, yield, quality parameter, efficiency parameters and economics are discussed in this section.

5.1 Water requirement

The amount of water delivered to bell pepper crop under drip irrigation was maximum during the month of December. This may be attributed to growth stage of the crop and higher temperature, wind velocity and evaporation during this month. From Table 4.4 total seasonal water requirements of bell pepper crop per ha were 287.1 and 229.7 mm for drip irrigation at 100 and 80 per cent ET levels respectively. For bell pepper cultivated inside the shade house under different agro-climatic conditions. These comparisons were taken as partial validation of the water requirement of bell pepper grown in this study under semi-arid region. Not only the microclimatic parameters affect the crop water requirement, but also it depends very much upon crop variety, crop season and the method of bell pepper cultivation (Harmanto *et al.* 2005).

The current research results provided appropriate tool to decide on watering crops inside the shade house. The daily water requirement for bell pepper fluctuated and was in accordance with the microclimate on the respective day and growing stage of plants. Therefore, the results may be used as guidelines and not as exact values.

5.2 Plant height and number of branches

The plant height and number of branches are the most important growth parameters which determine the canopy of plant. The productivity is directly related to canopy of crops. From the Table 4.10 and 4.11 it can be seen that the crop under sandy loam soil has higher plant height and number of branches than the soilless media.

The maximum plant height was found in sandy loam soil and followed by cococpeat. This may be due to the potassium nutrient increase the plant height. Higher potassium uptake in sandy loam soil is an evidence for this (Table 4.10). Similar results were found by Ranawana *et al*. (2008).

The soil media was more fertile as compare to soilless media. This may be due to the macro and micro nutrients, as well as the improved soil condition which conduced to stimulate metabolic processes and encourage growth, synthesis and accumulation of more metabolites in plant tissue. The result showed a tendency to produce more number of branches per plant. Several investigators mentioned similar results on different plants such as Kumar and Kohli (2005) in capsicum, Natarajan (2005) in tomato, Bairwa *et al*. (2009) in okra and Sumita Roy *et al*. (2011) in capsicum.

5.3 Yield parameter

The fruit volume and Chlorophyll play an important role in increasing the total yield in bell pepper. From the Table 4.13 it can be seen that the yield was higher in sandy loam soil (88.62 t ha^{-1}) followed by cocopeat (62.00 t ha^{-1}). This may be due to maximum air temperature during the growing season which affects the substrate temperature and increasing the difference between day and night temperatures at the root zone may negatively affect the substrate yields. That is because roots rely upon aerial part for photosynthates, while aerial parts rely on the root for water and nutrients (NeSmith and Duval, 1998). This delicate balance can be upset when the root temperature affects plant growth. Similar results were found in Majid fandi *et al.* (2008).

5.4 Quality parameters

From the Table 4.15 shows that fruit volume was highest in sandy loam soil and lowest in rice husk. This was due to the increased length and breadth of fruit. And also high uptake of nutrients and build-up of sufficient photosynthesis enabled the increase in size of fruits (length and breadth). Similar findings were recorded by Kurubetta Yellavva (2008).

The colour of fruit is an important determinant of the quality status of any vegetable. The chief pigment of fruits and vegetables which impart the green colour is chlorophyll. Different treatments were found to promise the effect on total chlorophyll content of bell pepper fruit. As a result, from Table 4.17 it is revealed that the maximum chlorophyll was recorded in sandy loam soil (68.3) and minimum in rice husk (24.7). The chlorophyll is an essential component for photosynthesis occurs in chloroplasts a green pigments in all photosynthetic plant tissues, so more chlorophyll content in plants may be attributed to more uptake of nitrogen by the plants. Similar results were found by Malik *et al.* (2011).

5.5 Irrigation efficiencies

5.5.1 Water use efficiency

Water use efficiency is the relation between yield and quantity of irrigation water. Table 4.20 shows total fruit yields and total irrigation amounts for each treatment. Water use efficiency was the highest in 100 per cent ET (6.0) followed by 80 per cent ET (5.7).

Among the media highest water use efficiency was in sandy loam soil (10.2) followed by cocopeat (7.3) and lowest water use efficiency was found in saw dust (2.4) followed by rice husk (3.0).

The soilless culture demands 10 times less water than traditional cultivation for the same yield (Melgarejo, 2007). The irrigation scheduling in soilless media lead to synergistic beneficial effects on the overall water use efficiency of soilless greenhouse cropping system. Meric *et al*. 2011 reported that higher water use efficiency in frequent irrigation conditions can explain the increase in the rate of applied nutrient solution volumes and total yield. Regarding 1 and 4MJ m^{-2} with which minimum and maximum values were observed, following these values increase in applied nutrient solution volume appeared 3.4 times of the increase in total yield in autumn and 2 times of that in spring.

5.6 Economics

In order to study the feasibility of cultivation of bell pepper under shade house with soilless media, cost of pits, cost of cultivation and revenue were estimated and are given in Table 4.21. One of the main constraints under soilless media and drip irrigation is its high initial investment. Drip irrigation requires mains, sub mains, laterals, filter and other accessories to design the unit. The economic analysis of bell pepper crop under soilless media with drip irrigation was made by considering fixed cost, cost of cultivation, water used and yields obtained.

The initial cost of soilless media and installing the drip irrigation system for vegetable crops is high but over a period of time the cost could be recovered.

The highest benefit cost ratio of 9.03 recorded in I_1M_7 and the lowest benefit cost ratio of 0.04 was recorded in I_1M_6 under poly house.

Suggestions for future work

1) Studies need to be conducted for various soilless media under shade house conditions in semi - arid region of Raichur to arrive at appropriate drip irrigation schedules and nutrient levels including fertigation for achieving optimum yields and higher net returns.

2) Combination of soilless growing media for better growth of the crop.

VI. SUMMARY AND CONCLUSIONS

A field experiment was conducted at New Orchard, MARS, University of Agricultural Sciences, Raichur during winter from October 2013 to March 2014 on sandy loam soil to study the effect of irrigation level on different soilless media on yield and water use efficiency for bell pepper. The experiment was laid out in Split Plot Design with two main treatments, seven sub treatments and two replications. The experiment comprised of irrigation levels at 80 per cent ET and 100 per cent ET in main plots and soilless media in sub-plots *i.e* cocopeat, rice husk, sawdust and combination with vermicompost in 1:1 ratio on volume basis and filled in pits. Other than soilless media, control plot was sandy loam soil.

In the experiment comparison was made in terms of growth, yield and quality parameters between different soilless media and different levels of drip irrigation.

CONCLUSIONS

- The water requirement of bell pepper crop was low (3.36 mm) at initial stage in 100 per cent ET. At vegetative stage it was 24.47 mm, 192.39 mm at fruiting stage and followed by 66.88 mm at final stage. The net amount of water applied during the crop period under different drip irrigation levels per plant were found to be 287.10 l for 100 per cent ET and 229.7 l for 80 per cent ET of water applied.
- The growth components like plant height and number of branches per plant were significantly influenced by different media. The maximum plant height and number of branches per plant was recorded under sandy loam soil (control treatment) when compared to others soilless media treatments throughout the growing period.
- The highest yield (88.62 t ha^{-1}) was obtained under sandy loam soil followed by cocopeat (62.00 t ha^{-1}) with significant difference. The lowest yield (20.87 t ha^{-1}) was noticed in sawdust treatment.
- The quality of bell pepper produced in different media with different irrigation levels was assessed in terms of TSS content in fruit. Among the different media, the highest TSS content (4.4 ºbrix) was found in the bell pepper grown in sandy

loam soil followed by cocopeat + vermicompost (4.1 ^{o}brix) treatment. The lowest TSS (1.8 ^{o}brix) was observed in the bell pepper grown in rice husk treatment.

- Among the irrigation levels 100 per cent ET gave maximum chlorophyll of 51.4 followed by chlorophyll of 48.3 in 80 per cent ET. Within different media, sandy loam soil gave maximum chlorophyll content (68.3) which was closely followed by cocopeat (61.7). The lowest chlorophyll (24.7) was observed in bell pepper grown in the rice husk treatment.
- Among the irrigation levels 100 per cent irrigation level gave maximum water use efficiency of 6.0 kg m^{-3} followed 5.7 kg m^{-3} in 80 per cent irrigation levels.
- Within different growing media, highest water use efficiency of 10.2 kg m^{-3} was noted in sandy loam soil followed by cocopeat (7.3 kg m^{-3}). The least water use efficiency (2.4 kg m^{-3}) was found in sawdust.
- The highest benefit cost ratio (9.03) was recorded in I_1M_7 treatment (100 per cent ET + sandy loam soil) followed by 5.82, 2.63 and 2.57 in I_2M_7 (80 per cent ET + sandy loam soil), I_1M_1 (100 per cent ET + cocopeat) and I_2M_1 (80 per cent ET + cocopeat) treatments respectively. The benefit cost ratio of less than one was observed in the remaining interaction treatments.

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APPENDIX - I

Daily meteorological data MARS, Raichur during the study period, October 2013 to March 2014.

Date	Temperature in ^{0}C		RH, per cent	Evaporation mm day^{-1}
	Maximum	Minimum		
11/10/2013	31.4	21.0	80.0	3.7
12/10/2013	31.4	22.4	75.0	4.0
13/10/2013	31.0	21.6	90.0	3.0
14/10/2013	31.8	22.4	84.0	3.0
15/10/2013	32.0	24.4	84.0	3.0
16/10/2013	31.8	22.5	90.0	2.2
17/10/2013	33.0	20.6	77.0	4.0
18/10/2013	33.2	22.6	79.0	5.3
19/10/2013	32.8	19.9	78.0	4.0
20/10/2013	32.8	18.9	80.0	5.2
21/10/2013	31.8	19.8	75.0	4.0
22/10/2013	31.2	23.1	91.0	2.2
23/10/2013	30.0	21.9	93.0	1.0
24/10/2013	29.6	21.6	96.0	3.2
25/10/2013	25.2	22.4	98.0	2.0
26/10/2013	26.0	22.1	98.0	1.2
27/10/2013	29.5	21.8	95.0	0.0
28/10/2013	28.9	20.7	98.0	0.6
29/10/2013	32.2	20.9	100.0	2.2
30/10/2013	31.2	19.1	91.0	4.0
31/10/2013	31.4	18.1	72.0	4.8
01/11/2013	30.5	20.4	82.0	4.4
02/11/2013	30.5	21.3	88.0	4.4
03/11/2013	31.5	21.3	85.0	2.0
04/11/2013	32.4	20.6	72.0	4.0
05/11/2013	32.4	20.6	72.0	4.7
06/11/2013	30.0	18.4	79.0	5.1
07/11/2013	31.0	19.9	76.0	3.8
08/11/2013	30.4	20.5	83.0	5.3
09/11/2013	30.1	19.8	79.0	4.0
10/11/2013	29.8	17.1	82.0	4.0
11/11/2013	29.4	15.9	73.0	4.0
12/11/2013	30.0	14.2	74.0	4.0
13/11/2013	30.0	14.5	69.0	4.0

14/11/2013	30.4	14.2	83.0	3.4
15/11/2013	29.0	13.0	72.0	4.0
16/11/2013	28.7	13.0	71.0	6.4
17/11/2013	29.4	19.0	60.0	5.0
18/11/2013	29.8	18.1	78.0	4.8
19/11/2013	30.4	18.0	87.0	4.0
20/11/2013	31.2	18.4	85.0	4.0
21/11/2013	31.4	14.1	75.0	5.0
22/11/2013	32.0	13.6	76.0	4.0
23/11/2013	30.4	13.8	78.0	4.2
24/11/2013	30.8	14.6	82.0	5.0
25/11/2013	31.0	7.8	84.0	4.4
26/11/2013	31.0	20.0	85.0	3.0
27/11/2013	32.0	17.0	92.0	4.0
28/11/2013	31.4	13.4	78.0	4.8
29/11/2013	29.2	18.4	86.0	2.4
30/11/2013	24.0	19.2	91.0	0.6
01/12/2013	31.6	19.0	89.0	4.0
02/12/2013	33.0	21.7	85.0	4.0
03/12/2013	32.0	21.5	86.0	4.2
04/12/2013	29.6	19.8	79.0	3.8
05/12/2013	30.2	19.6	80.0	4.0
06/12/2013	31.4	16.8	72.0	4.2
07/12/2013	31.8	12.6	70.0	4.4
08/12/2013	28.6	11.4	71.0	4.4
09/12/2013	30.9	10.2	69.0	4.5
10/12/2013	30.4	9.7	68.0	4.0
11/12/2013	30.7	9.4	58.0	5.0
12/12/2013	31.4	12.3	57.0	5.8
13/12/2013	30.9	12.6	73.0	4.2
14/12/2013	30.3	13.9	90.0	4.0
15/12/2013	30.1	10.7	54.0	5.0
16/12/2013	31.0	10.9	83.0	3.2
17/12/2013	29.4	10.6	78.0	5.0
18/12/2013	29.0	12.9	83.0	3.8
19/12/2013	28.0	12.6	74.0	3.8
20/12/2013	29.2	11.1	76.0	2.8
21/12/2013	31.4	12.3	57.0	5.8
22/12/2013	30.0	16.7	56.0	4.0
23/12/2013	28.6	17.6	80.0	5.6
24/12/2013	28.2	17.1	73.0	4.0
25/12/2013	28.8	19.2	72.0	4.0

26/12/2013	29.2	17.4	70.0	5.0
27/12/2013	28.5	17.4	64.0	5.4
28/12/2013	28.9	14.6	82.0	4.4
29/12/2013	29.0	17.9	75.0	4.0
30/12/2013	29.1	16.4	77.0	4.2
31/12/2013	28.6	17.4	75.0	4.2
01/01/2014	28.6	15.7	71.8	4.0
02/01/2014	28.8	14.4	79.0	4.4
03/01/2014	28.5	13.1	89.0	4.4
04/01/2014	29.0	14.4	87.0	4.6
05/01/2014	30.8	17.1	85.0	4.8
06/01/2014	31.0	15.9	84.0	4.4
07/01/2014	31.8	18.1	88.0	4.8
08/01/2014	30.9	16.9	69.0	5.2
09/01/2014	30.2	18.6	85.0	5.2
10/01/2014	30.4	17.4	82.0	5.0
11/01/2014	31.0	17.6	88.0	2.0
12/01/2014	31.2	16.2	88.0	5.8
13/01/2014	31.3	16.6	90.0	6.0
14/01/2014	31.4	16.5	88.0	5.6
15/01/2014	30.4	16.6	82.0	4.8
16/01/2014	30.9	19.5	75.0	5.0
17/01/2014	31.4	17.5	78.0	5.2
18/01/2014	30.6	18.2	85.0	5.2
19/01/2014	30.1	17.9	80.0	6.0
20/01/2014	30.9	19.5	85.0	4.0
21/01/2014	31.0	16.8	82.0	5.6
22/01/2014	29.4	18.2	78.0	6.0
23/01/2014	29.0	17.4	73.0	5.0
24/01/2014	30.4	16.3	74.0	5.0
25/01/2014	30.0	17.9	74.0	4.0
26/01/2014	30.4	18.2	82.0	6.0
27/01/2014	31.0	16.3	78.0	6.0
28/01/2014	30.0	16.6	75.0	4.6
29/01/2014	30.4	16.8	78.0	4.8
30/01/2014	29.3	18.1	82.0	4.0
31/01/2014	30.0	18.8	81.0	4.0
01/02/2014	30.2	16.2	77.0	3.0
02/02/2014	30.2	18.0	77.0	3.0
03/02/2014	31.2	18.5	87.0	5.6
04/02/2014	31.6	15.6	86.0	5.0
05/02/2014	32.9	16.2	86.0	4.0

06/02/2014	33.7	17.4	89.0	6.0
07/02/2014	34.1	17.5	83.0	6.0
08/02/2014	31.1	20.5	84.0	6.0
09/02/2014	32.1	20.2	83.0	6.6
10/02/2014	31.3	20.8	84.0	6.0
11/02/2014	32.8	20.6	84.4	6.0
12/02/2014	33.9	21.8	86.0	5.6
13/02/2014	33.3	22.5	82.0	6.0
14/02/2014	33.0	19.9	64.0	2.0
15/02/2014	35.5	22.6	84.0	6.8
16/02/2014	35.8	20.2	83.0	6.2
17/02/2014	30.4	16.9	94.0	6.4
18/02/2014	31.7	16.9	94.0	7.6
19/02/2014	31.2	19.4	82.0	8.0
20/02/2014	31.6	19.6	82.0	4.4
21/02/2014	31.7	20.6	82.4	4.6
22/02/2014	38.9	22.3	75.0	5.4
23/02/2014	33.8	20.1	82.0	7.2
24/02/2014	39.1	23.8	74.0	6.4
25/02/2014	23.8	17.7	86.0	6.6
26/02/2014	32.8	18.5	84.0	5.6
27/02/2014	38.9	22.5	80.0	5.8
28/02/2014	34.4	20.0	82.4	6.2
01/03/2014	38.7	21.5	78.0	7.4
02/03/2014	32.2	21.5	81.2	7.2
03/03/2014	33.0	21.5	84.0	6.2
04/03/2014	33.4	21.5	84.2	6.6
05/03/2014	33.4	21.0	84.4	6.4
06/03/2014	31.6	19.5	80.0	6.8
07/03/2014	30.4	18.5	78.4	7.0
08/03/2014	25.5	19.0	86.4	6.6
09/03/2014	31.1	20.5	82.0	6.8
10/03/2014	32.0	20.2	83.0	7.2
11/03/2014	31.2	20.8	82.4	6.8

APPENDIX II

Sample calculation of water requirement of Bell pepper crop

1) The daily water requirement of Bell pepper crop for drip irrigation was calculated by using the following equation.

   Amount of water required,

$$Q = \frac{AxBxC}{E}$$

Where,

WR = Water requirement of a plant, (l $day^{-1}plant^{-1}$)

A = Reference Evapotranspiration (ET) in the shade house

ET= C [P (0.46 T + 8.18)]

Where,

T = mean daily temperature (^{o}C)

P = Mean daily percentage of total annual day time hours (%)

C = n/N

n = actual sunshine hours (h)

N = maximum sunshine hours (h)

B = Amount of area covered with foliage (canopy factor), fraction

C = Crop co-efficient, fraction

E= Efficiency of drip irrigation, (considered as 90 per cent)

Sample calculation maximum evapotranspiration (100% ET):

C = n/N = 9.9/11.3

P = 7.94

T = 20.27

ET= ((9.9/11.3) (7.94 (0.46 × 20.27 + 8.18)))/31 = 3.92 mm day^{-1}

Then,

A = 3.92

B = 0.90

C = 1.02

$$Q = \frac{3.92 \times 0.90 \times 1.02}{0.9}$$

$$Q = 4.00 \text{ mm day}^{-1}$$

APPENDIX – III

Daily temperature, sunshine hours and calculated reference Evapotranspiration data under shade house condition during study period.

Date	Temp. in shade house (°C)			P, Per cent	n, hr	N, hr	ET mm day^{-1}
	Max.	Min.	Avg. temp.				
11/10/2013	25.7	18.1	21.9	8.24	0.3	11.8	0.12
12/10/2013	25.7	19.3	22.5	8.24	0.3	11.8	0.13
13/10/2013	25.4	18.6	22.0	8.24	0.3	11.8	0.12
14/10/2013	26.1	19.3	22.7	8.24	0.3	11.8	0.13
15/10/2013	26.2	21.0	23.6	8.24	0.3	11.8	0.13
16/10/2013	26.1	19.4	22.7	8.24	0.3	11.8	0.13
17/10/2013	27.1	17.7	22.4	8.24	0.5	11.8	0.21
18/10/2013	27.2	19.4	23.3	8.24	4.0	11.8	1.70
19/10/2013	26.9	17.1	22.0	8.24	3.0	11.8	1.24
20/10/2013	26.9	16.3	21.6	8.24	4.2	11.8	1.71
21/10/2013	26.1	17.0	21.6	8.24	3.0	11.8	1.22
22/10/2013	25.6	19.9	22.7	8.24	0.0	11.8	0.00
23/10/2013	24.6	18.8	21.7	8.24	0.0	11.8	0.00
24/10/2013	24.3	18.6	21.4	8.24	0.0	11.8	0.00
25/10/2013	20.7	19.3	20.0	8.24	0.0	11.8	0.00
26/10/2013	21.3	19.0	20.2	8.24	0.0	11.8	0.00
27/10/2013	24.2	18.7	21.5	8.24	0.0	11.8	0.00
28/10/2013	23.7	17.8	20.8	8.24	0.0	11.8	0.00
29/10/2013	26.4	18.0	22.2	8.24	5.1	11.8	2.11
30/10/2013	25.6	16.4	21.0	8.24	5.2	11.8	2.09
31/10/2013	25.7	15.6	20.7	8.24	5.9	11.8	2.35
01/11/2013	25.0	17.5	21.3	7.72	6.1	11.4	2.39
02/11/2013	25.0	18.3	21.7	7.72	6.1	11.4	2.42
03/11/2013	25.8	18.3	22.1	7.72	3.8	11.4	1.52
04/11/2013	26.6	17.7	22.1	7.72	4.7	11.4	1.89

05/11/2013	26.6	17.7	22.1	7.72	5.4	11.4	2.17
06/11/2013	24.6	15.8	20.2	7.72	5.8	11.4	2.21
07/11/2013	25.4	17.1	21.3	7.72	8.0	11.4	3.14
08/11/2013	24.9	17.6	21.3	7.72	7.8	11.4	3.06
09/11/2013	24.7	17.0	20.9	7.72	3.6	11.4	1.40
10/11/2013	24.4	14.7	19.6	7.72	3.6	11.4	1.35
11/11/2013	24.1	13.7	18.9	7.72	3.6	11.4	1.33
12/11/2013	24.6	12.2	18.4	7.72	3.6	11.4	1.31
13/11/2013	24.6	12.5	18.5	7.72	3.6	11.4	1.31
14/11/2013	24.9	12.2	18.6	7.72	7.9	11.4	2.89
15/11/2013	23.8	11.2	17.5	7.72	7.9	11.4	2.80
16/11/2013	23.5	11.2	17.4	7.72	7.9	11.4	2.79
17/11/2013	24.1	16.3	20.2	7.72	6.9	11.4	2.64
18/11/2013	24.4	15.6	20.0	7.72	6.9	11.4	2.62
19/11/2013	24.9	15.5	20.2	7.72	5.6	11.4	2.14
20/11/2013	25.6	15.8	20.7	7.72	8.1	11.4	3.13
21/11/2013	25.7	12.1	18.9	7.72	8.1	11.4	2.99
22/11/2013	26.2	11.7	19.0	7.72	8.1	11.4	2.99
23/11/2013	24.9	11.9	18.4	7.72	7.9	11.4	2.87
24/11/2013	25.3	12.6	18.9	7.72	7.9	11.4	2.91
25/11/2013	25.4	6.7	16.1	7.72	7.4	11.4	2.52
26/11/2013	25.4	17.2	21.3	7.72	7.4	11.4	2.91
27/11/2013	26.2	14.6	20.4	7.72	7.4	11.4	2.84
28/11/2013	25.7	11.5	18.6	7.72	6.8	11.4	2.49
29/11/2013	23.9	15.8	19.9	7.72	5.6	11.4	2.12
30/11/2013	19.7	16.5	18.1	7.72	0.0	11.4	0.00
01/12/2013	25.9	16.3	21.1	7.9	4.8	11.2	1.95
02/12/2013	27.1	18.7	22.9	7.9	4.8	11.2	2.04
03/12/2013	26.2	18.5	22.4	7.9	5.8	11.2	2.44
04/12/2013	24.3	17.0	20.7	7.9	6.9	11.2	2.78
05/12/2013	24.8	16.9	20.8	7.9	7.2	11.2	2.91
06/12/2013	25.7	14.4	20.1	7.9	7.1	11.2	2.82

07/12/2013	26.1	10.8	18.5	7.9	7.5	11.2	2.84
08/12/2013	23.5	9.8	16.6	7.9	7.5	11.2	2.70
09/12/2013	25.3	8.8	17.1	7.9	7.9	11.2	2.88
10/12/2013	24.9	8.3	16.6	7.9	6.9	11.2	2.49
11/12/2013	25.2	8.1	16.6	7.9	7.1	11.2	2.56
12/12/2013	25.7	10.6	18.2	7.9	6.9	11.2	2.60
13/12/2013	25.3	10.8	18.1	7.9	7.0	11.2	2.63
14/12/2013	24.8	12.0	18.4	7.9	7.2	11.2	2.73
15/12/2013	24.7	9.2	16.9	7.9	7.9	11.2	2.87
16/12/2013	25.4	9.4	17.4	7.9	7.9	11.2	2.91
17/12/2013	24.1	9.1	16.6	7.9	7.9	11.2	2.84
18/12/2013	23.8	11.1	17.4	7.9	7.9	11.2	2.91
19/12/2013	23.0	10.8	16.9	7.9	7.9	11.2	2.87
20/12/2013	23.9	9.5	16.7	7.9	7.1	11.2	2.57
21/12/2013	25.7	10.6	18.2	7.9	8.0	11.2	3.01
22/12/2013	24.6	14.4	19.5	7.9	8.2	11.2	3.20
23/12/2013	23.5	15.1	19.3	7.9	8.4	11.2	3.26
24/12/2013	23.1	14.7	18.9	7.9	8.1	11.2	3.11
25/12/2013	23.6	16.5	20.1	7.9	7.9	11.2	3.13
26/12/2013	23.9	15.0	19.5	7.9	7.5	11.2	2.92
27/12/2013	23.4	15.0	19.2	7.9	7.9	11.2	3.06
28/12/2013	23.7	12.6	18.1	7.9	7.1	11.2	2.67
29/12/2013	23.8	15.4	19.6	7.9	7.8	11.2	3.05
30/12/2013	23.9	14.1	19.0	7.9	7.9	11.2	3.04
31/12/2013	23.5	15.0	19.2	7.9	8.2	11.2	3.17
01/01/2014	0.0	0.0	0.0	7.94	7.8	11.3	1.45
02/01/2014	23.6	12.4	18.0	7.94	7.8	11.3	2.91
03/01/2014	23.4	11.3	17.3	7.94	7.2	11.3	2.64
04/01/2014	23.8	12.4	18.1	7.94	7.5	11.3	2.80
05/01/2014	25.3	14.7	20.0	7.94	7.6	11.3	2.99
06/01/2014	25.4	13.7	19.5	7.94	7.2	11.3	2.80
07/01/2014	26.1	15.6	20.8	7.94	7.2	11.3	2.90

08/01/2014	25.3	14.5	19.9	7.94	7.9	11.3	3.11
09/01/2014	24.8	16.0	20.4	7.94	7.9	11.3	3.14
10/01/2014	24.9	15.0	19.9	7.94	7.6	11.3	2.99
11/01/2014	25.4	15.1	20.3	7.94	9.9	11.3	3.93
12/01/2014	0.0	0.0	0.0	7.94	5.1	11.3	0.95
13/01/2014	25.7	14.3	20.0	7.94	7.0	11.3	2.76
14/01/2014	0.0	0.0	0.0	7.94	7.2	11.3	1.33
15/01/2014	24.9	14.3	19.6	7.94	7.4	11.3	2.88
16/01/2014	25.3	16.8	21.1	7.94	7.9	11.3	3.20
17/01/2014	25.7	15.1	20.4	7.94	7.8	11.3	3.11
18/01/2014	25.1	15.7	20.4	7.94	7.7	11.3	3.06
19/01/2014	24.7	15.4	20.0	7.94	7.1	11.3	2.80
20/01/2014	25.3	16.8	21.1	7.94	6.9	11.3	2.79
21/01/2014	25.4	14.4	19.9	7.94	6.5	11.3	2.56
22/01/2014	24.1	15.7	19.9	7.94	7.1	11.3	2.79
23/01/2014	23.8	15.0	19.4	7.94	7.1	11.3	2.75
24/01/2014	0.0	0.0	0.0	7.94	5.6	11.3	1.04
25/01/2014	24.6	15.4	20.0	7.94	5.6	11.3	2.21
26/01/2014	24.9	15.7	20.3	7.94	5.6	11.3	2.22
27/01/2014	25.4	14.0	19.7	7.94	5.1	11.3	1.99
28/01/2014	24.6	14.3	19.4	7.94	4.9	11.3	1.90
29/01/2014	0.0	0.0	0.0	7.94	4.6	11.3	0.85
30/01/2014	24.0	15.6	19.8	7.94	4.5	11.3	1.76
31/01/2014	0.0	0.0	0.0	7.94	5.2	11.3	0.96
01/02/2014	24.8	13.9	19.3	7.3	4.5	11.6	1.56
02/02/2014	24.8	15.5	20.1	7.3	4.5	11.6	1.59
03/02/2014	25.6	15.9	20.7	7.3	4.5	11.6	1.62
04/02/2014	25.9	13.4	19.7	7.3	4.8	11.6	1.68
05/02/2014	27.0	13.9	20.5	7.3	5.5	11.6	1.96
06/02/2014	27.6	15.0	21.3	7.3	5.8	11.6	2.12
07/02/2014	28.0	15.1	21.5	7.3	6.2	11.6	2.27
08/02/2014	25.5	17.6	21.6	7.3	8.0	11.6	2.94

09/02/2014	26.3	17.4	21.8	7.3	7.8	11.6	2.89
10/02/2014	25.7	17.9	21.8	7.3	8.1	11.6	2.99
11/02/2014	26.9	17.7	22.3	7.3	7.9	11.6	2.96
12/02/2014	27.8	18.7	23.3	7.3	8.2	11.6	3.14
13/02/2014	27.3	19.4	23.3	7.3	7.6	11.6	2.92
14/02/2014	27.1	17.1	22.1	7.3	7.9	11.6	2.94
15/02/2014	29.1	19.4	24.3	7.3	7.8	11.6	3.06
16/02/2014	29.4	17.4	23.4	7.3	7.9	11.6	3.04
17/02/2014	24.9	14.5	19.7	7.3	7.6	11.6	2.66
18/02/2014	26.0	14.5	20.3	7.3	8.5	11.6	3.02
19/02/2014	25.6	16.7	21.1	7.3	8.2	11.6	2.98
20/02/2014	25.9	16.9	21.4	7.3	7.9	11.6	2.89
21/02/2014	26.0	17.7	21.9	7.3	7.5	11.6	2.78
22/02/2014	31.9	19.2	25.5	7.3	7.1	11.6	2.87
23/02/2014	27.7	17.3	22.5	7.3	7.1	11.6	2.67
24/02/2014	32.1	20.5	26.3	7.3	8.0	11.6	3.29
25/02/2014	19.5	15.2	17.4	7.3	7.1	11.6	2.33
26/02/2014	26.9	15.9	21.4	7.3	7.1	11.6	2.60
27/02/2014	31.9	19.4	25.6	7.3	8.3	11.6	3.36
28/02/2014	28.2	17.2	22.7	7.3	8.1	11.6	3.06
01/03/2014	31.7	18.5	25.1	8.42	7.9	12.0	3.53
02/03/2014	26.4	18.5	22.4	8.42	7.2	12.0	3.02
03/03/2014	27.1	18.5	22.8	8.42	7.2	12.0	3.04
04/03/2014	27.4	18.5	22.9	8.42	7.2	12.0	3.05
05/03/2014	27.4	18.1	22.7	8.42	7.2	12.0	3.04
06/03/2014	25.9	16.8	21.3	8.42	7.2	12.0	2.93
07/03/2014	24.9	15.9	20.4	8.42	3.0	12.0	1.19
08/03/2014	20.9	16.3	18.6	8.42	8.1	12.0	3.07
09/03/2014	25.5	17.6	21.6	8.42	6.8	12.0	2.79
10/03/2014	26.2	17.4	21.8	8.42	6.8	12.0	2.80
11/03/2014	25.6	17.9	21.7	8.42	3.9	12.0	1.60

APPENDIX IV

1) Initial cost of drip irrigation system, Rs ha^{-1}

Sl. No.	Particulars	Cost, (Rs ha^{-1})
1	Nethouse + construction + maintenance	2,250,000.00
2	Submersible pump	20,000.00
3	Screen filter (25 m^3 hr^{-1})	2,500.00
4	Main line PVC (63 mm)	1,755.00
5	Sub main PVC (50 mm)	4,200.00
6	Lateral (16 mm)	52,500.00
8	Control valve (50 mm)	900.00
9	Flush valve (50 mm)	180
10	Gromate takeoff (16 mm)	300
11	End cap	250
12	PVC fittings and accessories	800
13	Installation charges	1200
Total		2,334,585.00

Cost economics of bell pepper crop under drip and soilless media

Fixed cost for drip irrigation

a) Interest on initial cost @ 12% — Rs. 2, 80,150.2

b) Depreciation on
- a) Shade house — Rs. 1, 35,000
- b) Pump — Rs. 1200
- c) PVC — Rs. 535.95

Total — Rs. 4, 16,886.15

The system can be used for two seasons in a year. Therefore, the fixed cost for one season would be Rs.416886.15/2 = Rs. 208443.07

2) Operating cost of Cocopeat with drip irrigation

Sl No.	Particulars	Cost Rs.
1	Bed preparation	50000
2	Planting	900
3	Plastic mulch	100000
4	Fix the Sheet in the soil and making hole	1674
5	Plant protection chemicals	10500
6	Spraying	1200
7	Harvesting	1500
8	Electricity charges	1000
9	Seed	9000
10	Fertilizers	8810
11	Cocopeat	235500
	Variable cost	4,20,084
	Fixed cost	2,08,443.1
	Total operating cost	6,28,527.1

3) Operating cost of Rice husk with drip irrigation

Sl No.	Particulars	Cost Rs.
1	Bed preparation	50000
2	Planting	900
3	Plastic mulch	100000
4	Fix the Sheet in the soil and making hole	1674
5	Plant protection chemicals	10500
6	Spraying	1200
7	Harvesting	1500
8	Electricity charges	1000
9	Seed	9000
10	Fertilizers	8810
11	Rice husk	165000
	Variable cost	3,49,584
	Fixed cost	2,08,443.075
	Total operating cost	5,58,027.075

4) Operating cost of Sawdust with drip irrigation

Sl No.	Particulars	Cost Rs.
1	Bed preparation	50000
2	Planting	900
3	Plastic mulch	100000
4	Fix the Sheet in the soil and making hole	1674
5	Plant protection chemicals	10500
6	Spraying	1200
7	Harvesting	1500
8	Electricity charges	1000
9	Seed	9000
10	Fertilizers	8810
11	Sawdust	187500
	Variable cost	3,72,084
	Fixed cost	2,08,443.075
	Total operating cost	5,80,527.075

5) Operating cost of Cocopeat + Vermicompost with drip irrigation

Sl No.	Particulars	Cost Rs.
1	Bed preparation	50000
2	Planting	900
3	Plastic mulch	100000
4	Fix the Sheet in the soil and making hole	1674
5	Plant protection chemicals	10500
6	Spraying	1200
7	Harvesting	1500
8	Electricity charges	1000
9	Seed	9000
10	Fertilizers	8810
11	Cocopeat + Vermicompost	768750
	Variable cost	9,53,334
	Fixed cost	2,08,443.075
	Total operating cost	11,61,777.075

6) Operating cost of Rice husk + Vermicompost with drip irrigation

Sl No.	Particulars	Cost Rs.
1	Bed preparation	50000
2	Planting	900
3	Plastic mulch	100000
4	Fix the Sheet in the soil and making hole	1674
5	Plant protection chemicals	10500
6	Spraying	1200
7	Harvesting	1500
8	Electricity charges	1000
9	Seed	9000
10	Fertilizers	8810
11	Rice husk + Vermicompost	733500
	Variable cost	9,18,084
	Fixed cost	2,08,443.075
	Total operating cost	11,26,527.075

7) Operating cost of Sawdust + Vermicompost with drip irrigation

Sl No.	Particulars	Cost Rs.
1	Bed preparation	50000
2	Planting	900
3	Plastic mulch	100000
4	Fix the Sheet in the soil and making hole	1674
5	Plant protection chemicals	10500
6	Spraying	1200
7	Harvesting	1500
8	Electricity charges	1000
9	Seed	9000
10	Fertilizers	8810
11	Saw dust + Vermicompost	1041000
	Variable cost	12,25,584
	Fixed cost	2,08,443.075
	Total operating cost	14,34,027.075

8) Operating cost of Soil with drip irrigation

Sl No.	Particulars	Cost Rs.
1	Bed preparation	50000
2	Planting	900
3	Plastic mulch	100000
4	Fix the Sheet in the soil and making hole	1674
5	Plant protection chemicals	10500
6	Spraying	1200
7	Harvesting	1500
8	Electricity charges	1000
9	Seed	9000
10	Fertilizers	8810
	Variable cost	1,84,584
	Fixed cost	2,08,443.075
	Total operating cost	3,93,027.075

EVALUATION OF DIFFERENT SOILLESS GROWING MEDIA UNDER SHADE HOUSE FOR BELL PEPPER (*Capsicum annuum* var. *grossum*)

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Major advisor

2014

ABSTRCT

Soil is a natural resource for cultivation of many crops but it has limitations like soil borne diseases, poor nutrient levels *etc*. to overcome these problems, the new methods are being used *viz.*, soilless culture and cultivation of crop under protected environments (shade house). The present experiment was conducted to evaluation of different soilless growing media under shade house for bell pepper under different levels of irrigation though drip at 100% (I_1) and 80% (I_2) of Evapotranspiration (ET)) at research farms of University of Agricultural Sciences, Raichur. The seven different soilless growing media were selected such as cocopeat, rice husk, sawdust separately as M_1, M_2 and M_3 treatments and these medias were mixed with vermicompost on volume basis (1:1) as M_4, M_5 and M_6 treatments with sandy loam soil media as M_7 (control) treatment in two replications. The results revealed that, the maximum monthly water requirement was found as 70.9 l and 88.7 l at 80% ET and 100% ET, respectively in December. The response of plants in respect of plant height, number of branches, root length and yield (t ha^{-1}) was found better in sandy loam soil followed by cocopeat which are on par with each and superior to other treatments. Among the drip irrigation levels, the response of plants was better in case of 100% ET followed by 80% ET. The highest Water Use Efficiency (WUE) of 10.2 kg m^{-3} was found in sandy loam soil followed by cocopeat (7.3 kg m^{-3}) whereas lowest (2.4 kg m^{-3}) was found in sawdust. The highest benefit cost ratio (9.03) was recorded in I_1M_7 treatment (100 per cent ET + sandy loam soil) followed by 5.82, 2.63 and 2.57 in I_2M_7 (80 per cent ET + sandy loam soil), I_1M_1 (100 per cent ET + cocopeat) and I_2M_1 (80 per cent ET + cocopeat) treatments, respectively. But the benefit cost ratio was less than one observed in the remaining interaction treatments. In conclusion, out of all medias, the sandy loam soil was having better yield with irrigation level of 100% ET.