STUDIES ON THE EFFECT OF ALTERNATE GROWING SYSTEMS AND IRRIGATION SCHEDULES FOR SOILLESS CULTURE OF SALAD CUCUMBER

By

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(2013 -18- 105)

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2015

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THESIS

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requirement for the degree of

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2015

DECLARATION

I hereby declare that this thesis entitled **“Studies on the Effect of Alternate Growing Systems and Irrigation Schedules for Soilless Culture of Salad Cucumber”** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Place: Tavanur **Sabeena Shahul**
Date : **(2013 -18- 105)**

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Certified that this thesis, entitled **“Studies on the Effect of Alternate Growing Systems and Irrigation Schedules for Soilless Culture of Salad Cucumber”** is a record of research work done independently by **Mrs. Sabeena Shahul (2013- 18- 105)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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DEDICATED
TO
ALMA MATER

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SYMBOLS AND ABBREVIATIONS

CWR	:	Crop Water Requirement
Dept.	:	Department
dS/m	:	deci-siemen per metre
et al.	:	and others
FAO	:	Food and Agricultural Oganisation
Fig.	:	figure
FCRD	:	factorial completely randomized design
FUE	:	fertilizer use efficiency
g	:	gram
g/cc	:	gram per cubic centimeter
J.	:	journal
ha	:	hectare
h	:	hour
Hort.	:	Horticulture
Hp	:	horse power
K	:	potassium
KAU	:	Kerala Agricultural University
KCAET	:	Kelappaji College of agricultural Engineering and Technology
Kc	:	Crop Coefficient
KFUE	:	potassium fertilizer use efficiency
kg	:	kilogram

kg /ha.kg of K	:	kilogram per hectare per kilogram of potassium
kg /ha.kg of N	:	kilogram per hectare per kilogram of nitrogen
kg/ha.mm	:	kilogram per hectare millimeter
km/day	:	kilometer per day
l	:	Litre
LDPE	:	low density polyethylene
lph	:	litre per hour
m	:	Metre
m^2	:	square metre
m^3	:	cubic metre
Meq	:	million equivalent
MJ/m^2/day		mega joules per square meter per day
Mg	:	Magnesium
ml	:	Milliliter
mm	:	millimeter
meql^{-1}	:	milli equivalent per litre
MSL	:	mean sea level
N	:	nitrogen
Na	: :	sodium
ppm	:	parts per million
PVC	:	poly vinyl chloride
Rs.	:	rupees
RH	:	Relative humidity

S	:	second
Sci.	:	science
SO_4	:	sulphate
SPSS	:	Statistical Package for the Social Sciences
T		Tonnes
t ha^{-1}	:	tonnes per hectare
UV	:	Ultraviolet
VPD	:	Vapour Pressure Deficit
viz.	:	namely
WUE	:	water use efficiency
%	:	percentage
µm	:	micrometer
&	:	And
’	:	Minute
”	:	second
=	:	equal to
°	:	degree
°C	:	Degree Celsius

Introduction

CHAPTER 1

INTRODUCTION

Agriculture has been crucial for sustaining life and we are regularly improving technology to increase food production. Technological advances in food production have been ample all over the world. Different methods of farming have strayed from the traditional system of soil based farming to the hydroponic techniques.

Soil is the reservoir for water and nutrients, and it provides anchorage for roots. However, it has created some limitations for plant growth, at times. Presence of nematodes and disease causing organisms, undesirable soil reaction, unfavorable soil compaction, degradation due to erosion, poor drainage etc are some of them. Further, continuous cultivation of crops has resulted in poor soil fertility, which in turn has shortened the opportunities for natural soil fertility build up by microbes. In industrial and urban areas, soil is less available for crop growing, or in some areas, there is shortage of fertile cultivable arable lands due to their unfavourable geographical or topographical conditions.

In addition, conventional crop growing in soil is difficult as it involves more space, large volume of water and lot of labour. Under such circumstances, soil-less culture can be introduced as a viable and successful alternative. The beauty of more advanced methods like hydroponic systems is that it can be used in the narrowest places and without any need for agricultural soil. The system can be placed on rooftop, on terrace or backyard, which helps in producing healthy, fresh and safe food.

Even in areas of adverse growing situations, soilless culture systems (SCS) offers flexibility and intense farming, with high crop yield and high quality produce. It is the modern cultivation system for plants that use either inert organic or inorganic substrate through nutrient solution nourishment. SCS offers means for control over soil-borne pests and diseases, which is especially suitable in the tropics, where the life cycles of these organisms are uninterrupted and so is the threat of infestation. Hence, the time consuming and costly works of soil sterilization and amelioration etc. can be avoided with soilless cultivation systems. Employing labour is easy, as it provides clean working environment and thus soilless culture in bags, pots or trays with light weight medium is simple, easy and economical way of growing crops.

Polyhouse farming as well as other modes of controlled environment cultivation has been evolved to create favourable micro-climates, conducive for crop production, making cultivation possible throughout the year or part of the year as required. Adopting soilless culture in protected cultivation with technical practices like integrated plant protection, fertigation, drip irrigation and climate control ensures better yield and water use efficiency. Therefore, studies over the last few decades have mainly focused on the development and rehabilitation of new or readily available systems especially aiming to provide more water and nutrient saving, increased yield and decreased waste of nutrients. This protected cultivation system can control the growing environment through management of amount and composition of nutrient solution, weather factors and also the growing medium. Modern systems employ manufactured media such as perlite, rock wool, expanded clay and other materials in plastic growbags and containers. Certain organic products, such as coconut coir, rice hulls, saw dust, composted plant material and wood chips etc. also are used successfully for polyhouse soilless culture of vegetables.

Coirpith can be useful in soilless cultivation especially in areas facing different growing constraints such as water shortage, low fertility and poor soil drainage, unsuitable soil reaction, soil salinity, pest and other ecological problems. Besides the use of coirpith in agricultural fields or as water conservant in dry land, coirpith has gained prominence as potting medium. Furthermore, its distinct features like water resistance and enhanced aeration enables the usage for various agricultural purposes. Coirpith is an excellent soil conditioner and is being extensively used as a soilless medium for agro-horticultural purposes such as planting lawns, parks and gardens, golf courses and planting vegetable gardens. Application of coirpith in soil helps in improving the structure and other physical and chemical properties of the soil. Because of its sponge like structure coirpith helps to improve aeration and retain water in root zone.

Proper irrigation management is essential for improving the productivity and quality of crops grown in the greenhouse in which rainfall is blocked by the cover. Exact time and amount of irrigation are two deterministic factors for the efficient irrigation management. In soilless culture, drip irrigation is used to deliver water to crops. Right selection of operating parameters and scheduling of irrigation requirements scientifically can result in better yield in soilless production system. Scheduling water application is very crucial to make the most efficient use of drip irrigation system, as excessive irrigation can reduce yield, while inadequate irrigation causes water stress and reduces production. On the other hand, the intensity of operation requires the water supply to be kept at optimum level to maximize the returns to the farmer. The optimal use of irrigation can be characterized as the supply of sufficient water according to plant needs in the rooting area. Fertigation is a very important requirement in inert substrate culture and optimizing the fertigation levels to suit to the requirements of media and crop can assure commendable results in soilless production.

The development of a method or model to estimate water requirement for vegetable crops also helps to enhance effectiveness of irrigation systems. In order to improve the crop yield and increase the water use efficiency accurate determination of crop water requirement is necessary. Knowing the exact amount of water for irrigation will help not only in saving water but also in providing better yield. To calculate the exact amount of water that is to be applied, use of many complicated equations is required. Development of software would make the process of computation of depth of irrigation water requirement much easier. In this context CROPWAT appears to be increasingly effective which uses the Penman Monteith concept in computation of crop water requirement.

Soilless culture systems generally improve water use efficiency (WUE) and reduce the demand of water. Protected cultivation using soilless culture tremendously reduce the water use and improve the WUE. Particularly coirpith based media has good water holding capacity and high volume of expansion and there is a scope to study the irrigation scheduling on coirpith based media, so that frequency of irrigation and quantity of water applied can be reduced compared to conventional methods. Generally studies on coirpith based media stresses on applying irrigation the same amount as in soil. There have been no reported studies on the irrigation scheduling in coirpith to find out whether lesser amount of application or less frequency of irrigation can sustain the crop without effecting yield. Therefore, the specific investigation was initiated to study the effect of alternate growing systems and irrigation schedules for soilless culture of Salad Cucumber.

The specific objectives of the study are:-

- To determine the crop water requirement for polyhouse cultivation of Salad Cucumber in coirpith media using CROPWAT model.
- To characterize the physico–chemical and engineering properties of coirpith media.
- To study the effect of different growing systems on crop performance.
- To evaluate the effect of varying irrigation schedules on crop performance.
- To determine the water and fertilizer use efficiencies under soilless culture for Salad Cucumber.

Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

Soilless culture is an artificial means of providing plants with support and a reservoir for nutrients and water. Soilless cultivation is intensively used in protected agriculture to improve control over the growing environment and to avoid uncertainties in the water and nutrient status of the soil. It also overcomes the problem of salinity and the accumulation of pests and diseases. Considerable progress has been made recently in the development of media and economically viable soilless systems and a number of growers in different Mediterranean countries are using soilless culture commercially extend of which varies, according to the level of education of the growers, the existing greenhouses facilities and their level of organization.

Soilless culture is based on environmentally friendly technology resulting in higher yields and that too without quality deterioration. An adoption of cultural management to the specific cultural system, as well as crop demand can further result in the improvement of quality and quantity of horticultural products (Gruda, 2009).

Some of the literature relevant to the study are reviewed and presented under the following sub headings.

2.1 MICROCLIMATE INSIDE POLYHOUSE AND ITS EFFECT ON CROP GROWTH

Rise in air humidity stimulates growth and photosynthesis and high humidity levels resulted in an increased photosynthetic rate (Bunce,1984). High humidity increased cucumber total yield, but did not affect the early yield fresh and dry weight, stem length and leaf area, and the final total cucumber yield was positively related to daytime humidity (Bakker *et al.*,1987).

The major aim of a polyhouse is to grow plants, and therefore high transmission of solar radiation in the wave band 400-700 nm is essential to maximize photosynthesis rates. The amount of structural material and the properties of the cladding will influence the proportion of incident radiation transmitted to the plants. The photosynthetically active radiation will be accompanied by radiation at other, mostly longer, wavelengths. All the radiation entering the greenhouse will contribute to the potential elevation of the greenhouse temperature above that of the external air. The greater the insulation properties of the polyhouse the greater will be the elevation, though as general rule those cladding materials that might be chosen for good thermal resistance will also tend to be less good at admitting radiation for plant growth (Day and Bailey, 1999).

Kavitha *et al.* (2003) carried out a study in polyhouse provided with solar module aided spinning disc sprayer and solar energy aided exhaust fan. By attaining specific climatic conditions in the poly-house the crop response could be varied. In case of tomato shoot length was increased by 96% and yield was increased by 27% as compared to control. For brinjal 55% increase in shoot length and 85% increase in yield were observed.

Greenhouse cooling is quite difficult and complicated task, far more difficult than heating, since the cooling devices used in other kind of building demand huge investments and high energy consumption. The net solar radiation in the greenhouse, reaches 500-600 Wm^{-2} during summer. In order to obtain greenhouse air temperatures close to outside ones, a total of about 200-250 Wm^{-2} of sensible heat needs to be removed. Low cost methods such as forced ventilation, cooling pads, fog systems, screens, etc., or in most cases, a combination of the previous methods are used for the removal of redundant energy. The most common methods used for greenhouse cooling in Mediterranean areas are natural or forced ventilation (Kittas *et al*., 2005).

Tropical greenhouses require active evaporative cooling system such as pad-and-fan to assure a suitable microclimate for crop production. Excess heat causes inside temperature becoming hotter than desired resulting in damaging effects to crop growth and production. Temperature and relative humidity of inside greenhouse were investigated at horizontal and vertical profiles. The result of the study showed that, in horizontal direction temperature increased from evaporative pad to exhaust fans while relative humidity shows inverse pattern from temperature and in the vertical direction, temperature increased, while relative humidity decreased from lower level to the upper level. The inside temperature with growing crops however, was slightly lower than the empty greenhouse. (Jamaludin, 2009).

Neelam *et al*. (2010) carried out a study to analyze the effects of climatic variability on evapotranspiration. The objective is achieved through the use of internet based technology. The polyhouse has a direct effect on air temperature, and relative humidity and an indirect effect on soil temperature and soil moisture inside the polyhouse. Web enabled automatic weather station having sensors for real time online measurement of soil temperature, soil moisture, ambient temperature, humidity, leaf wetness and solar insolation was installed inside the polyhouse. Capsicum was transplanted inside the polyhouse and crop evapotranspiration was estimated. The system also allows transmission of process parameters, including sending SMS on a mobile phone. The concept encompasses data acquisition through a sensor network, data storage, post processing and online transmission of data to multiple users logged on to web-browsers. Further, control of process parameters of a polyhouse, Control of pumps and accessories and ventilators in real time was also possible. From, this study it was concluded that the total crop water requirement of capsicum under inside polyhouse was about 20-40 % less than outside the polyhouse.

Parvej *et al*. (2010) conducted an experiment in a covered polyhouse along with an open field to compare the phenological development and production potentials of two tomato varieties *viz.* BARI Tomato-3 and Ratan under polyhouse and open field conditions. Photosynthetically active radiation inside the polyhouse was reduced by about 40% compared to the outside (i.e. open field) while air and soil temperatures always remained higher. Relative humidity had opposite trends with that of air temperature i.e. it was lower inside the polyhouse as compared to open field. The above microclimatic variabilities inside polyhouse favoured the growth and development of tomato plant through increased plant height, number of branches/plant, rate of leaf area expansion and leaf area index over the plants grown in open field. Polyhouse plants had higher number of flower clusters/plant, flowers/cluster, flowers/plant, fruit clusters/plant, fruits/cluster, fruits/plant, fruit length, fruit diameter, individual fruit weight, fruit weight/plant and fruit yield over open field condition.

Rajasekar *et al*. (2013) took up studies to screen ten vegetables for cultivation under shade net house (33% shade) and open field for year round production of vegetables. Tomato, eggplant, chilli, cucumber, cluster bean, radish, amaranthus, coriander and capsicum were grown in the summer and winter. 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, inter nodal length, average fruit weight and yield per plant to be higher in the shade net house than in the open field.

2.2 FAO - CROPWAT MODEL

During the nineties, CROPWAT, a computer program for irrigation planning and management developed by FAO (Smith., 1992), had been gaining particular importance among irrigation engineers. CROPWAT provided the link with climatic data from 3261 meteorological stations of 144 countries worldwide and represented a unique practical tool for estimation of crop water requirements, simulation of irrigation scheduling scenarios and estimation of specific continuous discharge either for one or more crops grown in almost any part of the world. CROPWAT program was developed on the methodologies presented in FAO Irrigation and Drainage Papers No.24 (Crop Water Requirements) and No.33 (Yield response to water) although including the Penman-Monteith formula for crop evapotranspiration estimate. Nevertheless, in the recent years, FAO Irrigation and Drainage paper No. 24 was revised and substituted with No.56 (Allen *et al*., 1998) which recommended a new procedure based on the Penman-Monteith equation as standard method for reference evapotranspiration estimate and introduced dual K_c concept allowing better consideration of soil evaporation and plant transpiration components. Moreover, on-going activities are focused on the revision of FAO Irrigation and Drainage paper No.33 and introduction of a new approach for crop growth modelling and yield response to water.

Smith *et al*. (1992) carried out a study on to assess the applicability of the FAO CROPWAT model for deficit irrigation scheduling. The study utilized data obtained from a joint FAO/IAEA coordinated research project (CRP) on “The use of nuclear and related techniques in assessment of irrigation schedules of field crops to increase effective use of water in irrigation projects,” which was carried out in Turkey and Pakistan on cotton, sugar beet, and potato, respectively. The study revealed that the CROPWAT model can adequately predict the effects of main crop parameters.

The field experimental data from the Hsueh Chia Experimental Station of Chia Nan Irrigation Association in Taiwan were collected, analysed and the results were fed to the CROPWAT irrigation management model that was developed by the Food Agricultural Organization (FAO). The results from CROPWAT model show that the annual potential evapotranspiration and effective rainfall in Hsueh Chia area are 1444 mm and 897 mm, respectively. In the paddy fields, the crop water requirements and deep percolation are respectively 962 mm and 295 mm for the first rice crop and 1114 mm and 296 mm for the second rice crop. The research shows that the irrigation management model can effectively and efficiently estimate the crop water requirements (Kuo, 2001).

Muhammad (2009) conducted a study on CROPWAT simulation under irrigated and rainfed conditions for maize crop, in order to provide information necessary for taking decisions on irrigation management. Simulation results suggests that areas, where the maize water requirements exceeds the water supply, by application of adequate irrigation scheduling the yield losses can be significantly reduced.

Nurul *et al.* (2012) conducted a study for measuring irrigation water requirement of Pedu-muda reservoir for paddy plantation (two seasons) using two different methods, (Blaney Criddle method and CROPWAT model), compare the capability of both methods, and to evaluate the reliability of CROPWAT version 8.0 model in predicting future trend of irrigation water requirement. In this study, the SDSM tool was used to simulate future climate trend from the year 2010 to 2099 and revealed that the temperature and rainfall are estimated to increase in the future year. In the effort to measure the irrigation needed in the region, CROPWAT model was found to be more reliable and capable compared to the Blaney Criddle method. From the year 2010 to 2099, the annual irrigation requirement is estimated to slightly decrease at every interval year even though the ET_{crop} is expected to increase due to the effect of rising temperature in the future.

Sudip *et al.* (2012) carried out a study to assess the impact of climate change on crop water requirement. In this study, potato was taken as the reference crop for its growing period and its high response to irrigation. The ET values from the potato field were measured using field water balance method and the data was used to validate the CROPWAT model. After proper validation of CROPWAT model, the model was used to determine the irrigation requirement of potato using current and future (prediction years: 2020 and 2050) weather data. It was observed that irrigation water requirement will be increased by 7 to 8 % during 2020, while it may increase about 14 to 15 % during 2050.

Ali (2013) conducted a study for the simulation of peanut with CROPWAT model under Irrigated and Rainfed Conditions in order to provide information necessary in taking decisions on irrigation management. Analysis suggests that from the month August the values of soil moisture deficit remained higher than readily available moisture values due to which severe yield reduction in peanut crop occurred (45.6%) in growth stage three of peanut vegetation season. The total yield reduction was 43.6%. Simulation for irrigated field of peanut crop is done using the criteria of fixed interval of 6 days with irrigation application at a fixed depth of 40 mm from the first day of sowing. During the first 3- irrigation application 207.3 mm of water is lost, the first, second and third irrigation lost were 1.1 mm, 102.5 mm and 103.7 mm water respectively. The largest yield reduction 45.4 % occurred in growth stage three of peanut vegetation season. Simulation estimated 39.4 % yield reduction under irrigated condition.

Sabeena *et al.* (2013) conducted a study to determine the crop water requirement and irrigation schedule using CROPWAT model of eleven major crops of a farm in Tavanur region. The CWR of eleven crops *viz.* Amaranthus, Snake gourd, Cowpea, Cucumber, Water melon, Pumpkin, Bhindi, Ashgourd, Sesamum, Banana and Rice were calculated and the results were 187.7 mm, 341.5 mm, 405.9 mm, 418,2 mm, 381.7 mm, 375.5 mm, 398.2 mm, 486.4 mm, 56.7 mm, 118.2 mm and 430.1 mm respectively. From the study it was clear that the computation of total CWR and scheduling irrigation became effortless, less time consuming and more accurate.

2.3 POLYHOUSE VEGETABLE CULTIVATION

Growing vegetables in greenhouse is one of the most intense and demanding forms of all agricultural enterprises. The greenhouse offers the ability to manage the growing environment in order to increase control over productivity and quality.

Protected cultivation has a special importance in the agriculture of Turkey and occupies 42,000 ha, which accounts 50 % of the total land as glass and plastic greenhouses. From that 95 % of them vegetables, 4 % ornamentals and in the remaining seedlings and fruits are grown. Fertigation is the main fertilization system in modern commercial greenhouses. Excess fertilizer use is a very widespread practice, in especially conventional greenhouses (Anac., 2004).

Crop water requirement of drip irrigated tomatoes grown in greenhouse in tropical environment has been investigated in the past. Greenhouse farming system performed better than open farming systems in terms of crop yield, irrigation water productivity and fruit quality. The results revealed that the crop evapotranspiration inside the greenhouse matched 75-80 % of the crop evapotranspiration computed with the climate parameters observed in the open environment. In other words, the greenhouse farming can save about 20-25 % of water compared to the open drip irrigated farming system (Harmantoa *et al*., 2004).

Plasticulture with soilless cultural systems could address several of the serious challenges facing the vegetable industry in Florida and other areas of the world with similar climates. In analysing production systems in this area, it was conceivable to assume that similar production systems would work in the more humid, semi-tropical areas and countries such as India. Florida Plasticulture systems could include the use of soilless culture for crop production and thereby increase water use efficiency. Bag or container production using an inert media such as perlite, vermiculite, peat, or coconut fiber would be an example (Cantliffe *et al.*, 2007).

2.4 PHYSICO - CHEMICAL PROPERTIES OF DIFFERENT SOILLESS CULTURE MEDIA

Atiyeh *et al*. (2001) designed experiments to characterize the physical, chemical and microbial properties of a standard commercial horticultural, greenhouse plant medium (Metro-Mix 360), that had been substituted with a range of increasing concentrations (0 %, 5 %, 10 %, 25 %, 50 % and 100 % by volume) of pig manure vermicompost and to relate these properties to plant growth responses. The growth trials used tomatoes grown in the substituted media for 31 days under glasshouse conditions, with seedling growth recorded in 20 pots for each treatment. The percentage total porosity, percentage air space, pH and ammonium concentrations of the container medium all decreased significantly, after substitution of Metro-Mix 360 with equivalent amounts of pig manure vermicompost; whereas bulk density, container capacity, electrical conductivity, overall microbial activity and nitrate concentrations, all increased with increasing substitutions of vermicompost. Some of the growth enhancement in these mixtures seemed to be related to the combined effects of improved porosity, high nitrate content of the substrate and aeration and water retention in the medium, which produced an increased uptake of nitrogen by the plant.

Kannan *et al*. (2005) conducted a field experiment to study the influence of different organic N sources *viz*, FYM, Vermicompost and coirpith compost with Bioferilizers on the soil physical properties, nutrient availability and biological properties during December - May (2003-2004) with tomato (*Lycopersicon esculentum*. Mill). Application of different organics with azospirillum favourably influences the soil physical, chemical and biological environment such as bulk density, water holding capacity, available nitrogen, organic carbon, ,beneficial bacterial and fungal population over the inorganics alone applied plot. Among the different organic N sources the application 75 per cent Vermicompost with azospirillum was found to be superior in bettering soil health over the other treatments.

Rasool *et al*. (2008) carried out a study on the effects of vermicompost on soil physical and chemical properties in tomato field. The experiment was arranged in a CRBD design with four replications. Different amounts of vermicompost *viz.* 0, 5, 10, and 15 t/ ha were incorporated into the top 15 cm of soil. The soil sampling and measurements were carried out 3 months after the application of vermicompost in soil and the soil samples were collected from depth of 15 cm. The results showed that addition of vermicompost at rate of 15 t /ha significantly ($P < 0.05$) increased contents of soil total organic carbon, total N, P, K, Ca, Zn and Mn substantially compared with control plots. The soils treated with vermicompost had significantly more EC and low pH in comparison to unamended plots. The results of this experiment showed that addition of vermicompost had significant ($P < 0.05$) positive effects on the soil chemical and physical properties.

Coirpith is a mass of heterogeneous particles having broadened physical characteristics. Bulk density was found to be high in small particles (150 µm) and it decreased as particle size increased (2000 µm). In smaller particles, high bulk density of coirpith was found (0.11g/cc) which is low compared to soil. Total porosity and aeration porosity of the coirpith mass formed of specific particle size showed direct relationship with particle size whereas water holding porosity had a negative relation. High bulk density showed by big particles had a low total porosity which would cause reduction in growth and distribution of roots of the plants grown on it. Water absorptive and particle size of coirpith showed a strong negative linear correlation. Smaller particles of coirpith which was compactly arranged and absorbed more water due to infinite micro pores than the coarser particles which contained larger but limited amounts of macro pores. Both surface area as well as specific surface area of coirpith particles decreased with the increase in the average size of the coirpith. As water retention in a medium depends mainly on the number and size of the pores and the specific surface area of the medium, it was observed to be higher in the smaller sized particles. (Maragatham *et al*., 2010)

Duggan-Jones *et al.* (2013) studied on the effect of physical characteristics of coir on the productivity of greenhouse tomatoes. Coir is a relatively new growing media, and little information is known of the relationship between particle size and particle size distribution on crop productivity. Particle size significantly affects the physical properties of coir, particularly the air-water relationships. An experiment was designed to compare the yield, water use efficiency and RGR (relative growth rate) of a tomato crop grown in coir using a range of particle sizes. Seven treatments based on combinations of small (S), medium (M) and large (L) sized particles, together with a commercial ungraded coir dust were used. Two irrigation (low and high) frequencies were adopted. The seven treatments were based on particle size with differences in WHC. A bioassay will be used to compare tomato yield and RGR. The physical properties, governed by particle size, have an effect on tomato yield. As treatments increase in WHC so does yield. An upward linear relationship exists between WHC and yield gained per plant. A relationship was also found between the bioassay and tomato yield trial. Similar to the tomato yield trial, as WHC increased so did the RGR. The relationship between WHC and RGR may have commercial implications for both soilless media manufacturers and growers which require specific physical properties in terms of water and air availability for particular crop types.

Narendar *et al.* (2013) carried out a study to determine the effect of chemical treatment on the mechanical and water absorption properties of coirpith/Nylon/Epoxy sandwich composites. Multi-layered coirpith = nylon fabric = epoxy hybrid composites were fabricated by the hand lay-up technique. Coirpith was subjected to chemical treatment before processing and the volume fraction of coirpith was maintained in the range of 60 – 65 %. The effect of treatment was analysed by scanning electron microscope (SEM) and optical microscopy. The effects of layering and treatment on the mechanical and water transport nature of composite were analysed. The mechanical properties of the composite decreased on exposure to water. However, the retention of impact strength increased with chemical treatment of coirpith.

2.5 ALTERNATE MEDIA FOR SOILLESS CULTURE

Dayananda *et al.* (2001) conducted an experiment to find out the desirable growing media and hydroponic system for cultivation of lettuce under controlled environment. The treatments included 3 growing systems *viz* nutrient flow system, non-circulating system and aggregate system and six growing medias used were coir dust, coir dust + tea refuse, tea refuse + partially burnt paddy husk, tea refuse, coir dust + partially burnt paddy husk and partially burnt paddy husk. Results revealed that the aggregate system had better mean values for all measured growth parameters while coir dust and paddy husk proved to be the best growing media for better plant growth and yield. Hence combination of an aggregate system with either coir dust or partially burnt paddy husk or both would be ideal for cultivation of lettuce under protected environment.

Hochmuth *et al.* (2003) reported that the cucumber and tomato are grown successfully in perlite media. Although the paper focuses on perlite media in lay-flat bags, most of the principles also pertain to other soilless media, such as peat-mix bags and rockwool slabs. In addition, many of these principles apply to using perlite, pine bark, or similar media in containers, such as nursery containers.

Parks *et al*. (2005) investigated the suitability of some locally available materials in Vietnam as soilless substrates as a part of an Australian aid project (AUSAID-CARD). For the production of cucumber and tomato, four media were used as substrates like coir, or mixtures of three components including sugar cane waste, peanut husks, soybean, peat or volcanic rock. For both the tomato and cucumber crop yield was significantly increased by the use of coir as a substrate. The medium of sugar cane waste, peat and volcanic rock proved unsuitable for cucumber production as it produced fruit with lead levels above the maximum residue limit of 0.2 mg/kg in three out of five replicates.

Coirpith is a byproduct of the coir industry, producing more than 7.5 million tonnes annually in India. It can be used as fuel in loose form or in briquettes. This study investigates different physical properties of coirpith with respect to its moisture content (10.1 to 60.2 % w.b.) and particle size (0.098 to 0.925 mm). Porosity and particle density varied from 0.623 to 0.862 and from 0.939 to 0.605 gm/cc respectively. Bulk density and static coefficient of friction against mild steel were in the range of 0.097 to 0.341 gm/cc and 0.5043 to 0.6332 respectively. Models were developed for the above properties (Neethi *et al.,* 2006).

Ayse *et al*. (2007) had conducted a study on the effect of nutrient sources on cucumber production in different substrates. The research was conducted in two successive seasons to compare the effect of nutrient sources, organic manure and inorganic conventional nutrient solution, in cucumber production performed with different local substrates. Results showed that organic manuring decrease the total yield by 22.4 % in comparison to inorganic nutrient solution. In organic manure treatment, vigorous variety (Armada) gave higher yield than less vigorous variety (Gordion). In the spring season, the tested factors were decreased to two and tested as nutrient source [(a) inorganic nutrient solution, (b) solid organic manure, (c) organic nutrient solution] and substrate. Armada was the only cultivar. Compared to that of the inorganic nutrient solution, total yield was reduced by 10.9% in the organic nutrient solution system and 31.3 % in solid organic manure treatment.

Rajarathnam *et al.* (2007) carried out experiments with coirpith for its potential in serving as a growth substrate for the production of species of oyster mushroom. Amendment of coirpith with rice straw and horse gram plant residue tended to greatly modify the physical characteristics of inoculated mushroom. Changes in cellulose, hemicellulose and lignin contents of coirpith amended with rice straw were studied. Cellulose, hemicellulose and protease enzyme activities in the amended coirpith substrate showed continuous increase from inoculation till the end of fructification, whereas laccase activity decreased during fructification, in consonance with decreased lignin degradation during fructification

Albaho *et al*. (2013) investigated the suitability of some locally available materials in Kuwait. Four combinations of media were used as substrates viz. M1-

35 % peat moss/40 % perlite/25 % vermicompost, M2-25 % peat moss/25 % perlite/25 % vermicompost/25 % coco peat, M3- 100 % coco peat and M4- 50 % perlite/50 % peat moss as control. Experiments were carried out in a cooled greenhouse. Experiments with cucumber cultivar ‘Banan’ revealed that the growing media M1 and M2 are the best substrates for use in the growbag technique.

Due to unaffordability of peat media, looking for substitution of materials instead of peat is strictly followed. Hence to achieve the best and most appropriate culture media to produce healthy, strong and homogeneous transplant of greenhouse pepper, a study was conducted with one cultivar of green pepper (called ES 8700) in 5 beds and 9 different combinations in a completely randomized design with 4 replications in Jahrom city. Some traits such as root number, length and diameter of transplants, fresh and dry weight of root and shoot in 4-5 leaf stage were measured. The results revealed that produced seedlings had better conditions in peat moss media and they were in the highest values. In addition, coco-peat and peat moss as pure form or mixed with sand, had better result than other media and cultivation in soil and palm-peat media were not suitable for transplant production (Zabiholah *et al.*, 2013)

2.6 DRIP IRRIGATION AND FERTIGATION IN SOILLESS CULTURE

Harmsen, *et al.* (2002) assessed the pan evaporation method for scheduling irrigation of a sweet pepper (*Capsicum annuum*) crop grown on an Oxisol at the University of Puerto Rico Agricultural Experiment Station at Isabela, PR. Evaluation of the pan method for scheduling irrigation was based on comparison of ET_{pan} with the Penman-Monteith-based evapotranspiration (ET_c), estimates of deep percolation, measured vertical hydraulic gradients, and measured soil moisture distribution. A simulated irrigation schedule using the Penman-Monteith method resulted in even greater seasonal deep percolation (127.7 mm). Vertical hydraulic gradients were found to be downward throughout a significant portion of the season, and observed moisture content distributions below the root zone clearly showed that deep percolation was occurring.

Singandhupe *et al.* (2002) tested fertigation studies and irrigation scheduling in drip irrigation system in tomato crop ,response to urea fertilizer with drip irrigation and compared with conventional furrow irrigation for 2 years (1995 and 1996) at the Research Farm of Water Management Project, Mahatma Phule Agricultural University, Rahuri (Maharashtra), India. Application of nitrogen through the drip irrigation in ten equal splits at 8-days interval saved 20-/40 % nitrogen as compared to the furrow irrigation when nitrogen was applied in two equal splits (at planting and 1 month thereafter). Similarly, 3.7-/12.5 % higher fruit yield with 31-/37 % saving of water was obtained in the drip system. Water use efficiency in drip irrigation, on an average over nitrogen level was 68 and 77 % higher over surface irrigation in 1995 and 1996, respectively.

Harmantoa *et al.* (2004) reported that four different levels of drip fertigated irrigation equivalent to 100, 75, 50 and 25 % of crop evapotranspiration (ETc), based on Penman-Monteith method, were tested 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 % 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 % of ETc provided the maximum crop yields and irrigation water productivity. The distribution uniformity dropped from 93.4 to 90.6 %. The emitter flow rate was also dropped by about 5–10 % over the experimental period.

Miranda (2005) suggests that precise estimation of crop evapotranspiration (ETc) on a daily basis is critical for drip irrigation management in soils with limited water storage capacity. The objective of his study was to determine the evapotranspiration and crop coefficients for Tabasco pepper *(Capsicum frutescens*

L.), in the Northeast region of Brazil. Crop ET was measured daily using a precision weighing lysimeter with a surface area of 2.25 m^2. Reference ET was estimated using the FAO Penman-Monteith equation. The total ETc observed throughout the 300 - day crop season was 888 mm, with maximum daily values of 5.6 mm d^{-1}. Average crop coefficients observed during the first harvest cycle were 0.3, 1.22 and 0.65 for the initial, mid-season and end of the late-season stages, respectively. During the second harvest cycle average crop coefficients were 1.08 and 0.60 for the mid-season and the late-season stages, respectively.

"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. An alternating N (ALT-N) treatment that followed the four growth stages was also included (120- 160- 200- 120 mg/l). In all three seasons, there were no differences among the N treatments for average fruit weights or soluble solids content. Petiole-sap NO_3 -N concentrations during spring and fall 2001 suggested that optimal yields can be achieved if at least 3000 mg/l NO_3 -N was maintained through fruit maturation. When petiole-sap concentrations were less than 2500 mg/l, as in the case of plants receiving 80 or 120 mg/l N, significantly lower yields were obtained (Rodriguez *et al*., 2005).

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

Shahnaz Sarkar *et al. (*2008) conducted a study to determine 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 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. The highest and lowest EC values were 29.6 and 16.1 $dS \cdot m^{-1}$ in Sub × Shizudai and Drip × Enshi treatment, respectively. It was concluded that growth and yield suppression in the sub fertigation system seems to be mainly caused by salinity stress, not by water stress.

Metin *et al.* (2009) conducted a study to determine the optimal irrigation strategy for drip irrigated fresh market tomato grown in different soilless culture in a glasshouse in the Mediterranean Region of Turkey. Volcanic ash, peat and their mixture were used as growth media. Four different irrigation levels (WL1=75 %; WL2=100 %; WL3=125 % and WL4=150 % of Class A Pan evaporation) and two watering frequencies like once and twice daily applications were evaluated. Highest yield and fruit number were obtained from the ash+peat mixture (1:1) with twice a day watering at WL4 irrigation level. Soluble solids of tomato fruit decreased with increasing available water. The highest irrigation water use efficiency (IWUE) value of 121.4 kg m^{-3} was obtained from once a day irrigation WL1 irrigation level with peat+ash (1:1). IWUE decreased in all treatments as the amount of irrigation water increased.

An EC based irrigation strategy was tested in two greenhouse soil-less 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 (Sanchez-Guerrero *et al.,* 2009).

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

Serhat, 2009 studied the effect of deficit irrigation on yield of pepper grown under unheated greenhouse condition. The research was carried out at

Turkey, in 2007. In the study, water was applied to pepper as 100, 75, 50, 25 and 0% (as control) of evaporation from a Class A pan (*K1cp* 1.00, *K2cp* 0.75, *K3cp* 0.50, *K4cp* 0.25, *K5cp* 0.00- control) corresponding to 2 day irrigation frequency. Irrigation water applied to crops ranged from 65 to 724 mm, and water consumption ranged from 115 to 740 mm. The effect of irrigation water level on the yield, fruit height, diameter, weight and dry matter ratio were significant. Crop yield response factor (ky) was 1.07. The highest values for water use efficiency (WUE) and irrigation water use efficiency (IWUE) were 3.13 and 3.39 kg mm^{-1} for the *K2cp* treatment. Under the conditions that water resources are scarce, it can be recommended that *K2cp* treatment is most suitable as a water application level for pepper irrigation by drip irrigation under unheated greenhouse condition.

Xiao *et al.* (2009) recommended that the optimum levels of water and nitrogen for high yield and good quality under the study condition were 90 %, and pure nitrogen rate of 0.58-0.74 g/pot/time

Takele Gadissa *et al*. (2009) conducted a field experiment to investigate the effects of level of irrigation and planting method on water use efficiency, irrigation uniformity and yield of drip irrigated green pepper (*Capsicum annuum*, L.) in Bako area, Ethiopia**.** Three irrigation levels (50 %, 75 % and 100 % of ET$_c$) and two planting methods (normal and paired-row planting) were applied. The maximum and minimum values of the yield and yield components were recorded from treatment plots I$_{100}$P (full irrigation level with paired-row planting method) and I$_{50}$P (50 % of ET$_c$ irrigation level with paired-row planting method), respectively, with the exception of plant height. The results revealed that full irrigation water supply under paired-row planting method (I$_{100}$P) could be used for the production of green pepper in an area with no water shortage. Moreover, it was found that the average yields recorded from the I$_{75}$ under the paired-row planting method is fairly greater than the national average.

The influence of irrigation depth was evaluated on tomato crop hybrid Debora plus for salad in a field experiment in split-block design with five treatments (irrigation depth of 40, 60, 80, 100 and 120 % of crop evapotranspiration - ETc) and four replications. During the experiment, ten plant samples were collected to determine phytomass and leaf area to estimate plant growth parameters for different depths of irrigation. Results showed maximal growth between 70 and 80 days after transplanting in all treatments. Increase in irrigation depth above 80 % of ETc increased crop growth rate (CGR), leaf area index (LAI) and total production of tomato fruits, although same commercial fruit yield was obtained with the lower depths. Therefore, an increase in depth of irrigation above 80 % of ETc promotes higher water and energy consumption, without providing an increase in commercial yield of tomato fruits (Jose *et al.,* 2013).

2.7 EFFECT OF GROWING MEDIA ON PLANT GROWTHPARAMETERS

A comparative study of coirpith and cowdung was carried out at Regional Agricultural Research Station. Jessore, to show the performance of coirpith on growth and yield of summer tomato compared to cowdung. Five treatment combinations viz. T1, 10 t/ha coirpith; T2, 20 t/ha coirpith; T3, 10 t/ha cowdung; T4, 20 t/ha cowdung and T5, control were included in the study. Growth and yield of summer tomato was significantly influenced by the treatments. Maximum number of fruits per plant (30) was obtained from T2 treatment which was higher than T3 treatment (27). Similarly the highest single fruit weight (57 g) was measured in T2 treatment which was higher than T3 treatment (54 g). The highest marketable yield (32.59 t/ha) was recorded from the treatment T1 which was statistically similar to T3 treatment and the lowest marketable yield (13.31 t/ha) was recorded from control. Therefore, coirpith @ 10 t/ha with chemical fertiliser is suitable for summer tomato production at Jessore region in Bangladesh (Hossain *et al.,* 2008).

Francisco *et al.* (2010) reported yield and fruit quality response of sweet pepper genotypes grown under soilless cultivation. Total yield, physical, and phytochemical characterization of three yellow and five red-coloured sweet pepper genotypes were analysed under fully controlled environmental and irrigation conditions under soilless culture. Results showed both greater fruit firmness and pericarp thickness in the red coloured genotypes than in the yellow ones. However, no significant differences between these two colours were found for total yield, shape index and dry matter percentage. Additionally, peroxidase activity, total protein and total phenolic compounds were not modified according with the colour of the genotype. With respect to the genotypes studied, ‘Cierva’, ‘A67’, ‘Traviatta’, ‘Cabezo’ and ‘Limona’ showed the highest yields in the “extra” fruit category whilst ‘Disco’ and ‘Zar’ showed the lowest. Additionally, ‘Cierva’ and ‘Cabezo’ showed higher protein concentration and peroxidase activity than any other genotype.

An investigation was carried out for the evaluation of 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 (rice hull, sycamore pruning waste, cocopeat + perlite (50:50), vermicompost + perlite + coco peat (5:45:50), (15:40:45) and (25:35:40). Measured factors were dry and fresh weight of root and shoot, runner number, petiole length, leaf area, total biomass and root/shoot ratio. Physical and chemical characteristics of different substrate consisting of pH, EC, porosity, bulk density, particle density, % organic material and % inorganic material. According to results of this experiment, for better growth and consequently higher yield, suitable substrate that will have high water holding capacity, suitable bulk density and better porosity must be chosen. Among the cultivars, Camarosa, which is a short day plant, consequently had high vegetative growth, while Mrak, day neutral, had high yield. Also, M4 and M5 were the best in the measured properties. Mrak in M4 had the highest yield (Atefe *et al.*, 2012).

Norrizah *et al.* (2012) conducted an experiment on characterization of plant growth, yield and fruit quality of Rockmelon cultivars planted in soilless culture. In this experiment, three different rockmelon cultivars were selected for the study. Seed morphology, plant growth, yield and fruit quality of rockmelon cultivars (Glamour, Honeymoon and Champion) planted in cocopeat were evaluated. Plants were irrigated through fertigation technique and grown under rain shelter. After five weeks, fruit was harvested and tested for ascorbic acid and Total Soluble Solid (TSS) content. All three rockmelon cultivars were able to survive and grow using soilless culture system. Rockmelon cv. Glamour shows the best seed morphology and plant growth performance. Results revealed that the highest leaf areas contribute to highest plant growth rate. Other than that, highest fruit fresh weight seemed to be influenced by the high fruit diameter because cv. Honeymoon produced heaviest and largest fruit diameter. Rockmelon cv. Champion shows the best fruit preferences with high quality as the fruit mesocarp was thick and nutritive contained with large number of vitamin C and TSS.

Enujeke (2013) carried out a study to evaluate the growth and yield responses of cucumber to five different rates of poultry manure in Asaba area of Delta State, Nigeria. Experiment was conducted in a Randomized Complete Block Design (RCBD) with three replicates. Rates of poultry manure in tons per hectare were 0, 5, 10, 15, and 20. The parameters assessed to achieve the objectives of the study were vine length, number of leaves/plant, fruit diameter, fruit length, and fruit weight of cucumber. The result of the study showed that plants that received 20 tha^{-1} of poultry manure were superior in the parameters tested. Based on the findings of the study, it was recommended that farmers in the study area should apply 20 tha^{-1} of poultry manure for increased growth and yield of cucumber.

2.8 STUDIES ON IRRIGATION SCHEDULING FOR SALAD CUCUMBER

Wang *et al.* (1999) studied the relationship between irrigation amount, yield and quality of cucumber in solar greenhouse. The seedlings were transplanted on 10th, January, 40 days after sowing. In 140 days growing period from transplanting to last harvest, five irrigation treatments with different water amount were designed. The yield increased with irrigation amount, but the quality slightly decreased. Water use efficiency (yield/irrigation quantity) declined with increase of irrigation quantity.

Xiaobo *et al*. (2002) studied the water requirement of cucumber in solar greenhouse. The results indicated that inner light and temperature of solar greenhouse varied with the cropping seasons of winter-spring and autumn-winter. Water requirement was close at plantlet stage with about 0.55 mm/d, but it increased more quickly in winter-spring than in autumn-winter since early bloom. During fruit bearing stage water requirement kept over 2.0 mm/d in winter-spring while about 40 % of this level at the same stage in autumn-winter. At plantlet stage water were scattered through evaporation and at fruit bearing through transpiration in solar greenhouse.

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 treatment peat: vermicompost: sand was found to have a positive influence on plant height, flower characters, and yield per hectare. The highest yield (113.89 t/ha) was registered in peat: vermicompost: sand. 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 (Janapriya *et al.,* 2010).

The effects of different water supply tension i.e. different soil moisture on the growth and development of greenhouse cucumber (*Cucumis sativus* L.) were studied. The result also indicates that the water demand increase with the growing process. The growth will be restricted and yield will be reduced with the shortage of water supply, increased yield at terminal fruiting stage can be obtained by increasing soil water content at fruiting stage of cucumber. The above results indicate that the range of water supply tension from 3-5 kPa are more suitable for greenhouse cucumber growth when the relative soil water content ranges from 67% to 81%. Reduce water supply at seedling stage, control water supply at flowering stage and increase water supply at fruiting stage of cucumber can increase yield and WUE (Shao *et al*., 2010).

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

Soilless culture offers a valuable option to substitute soil based vegetable cultivation and has been widely adopted by specialist growers of greenhouse crops in the world. The problems associated with soil based production such as pests and diseases, salinity, lack of arable soil and water etc. have led to the development of substrate media for soilless cultivation.

In the present study coirpith was selected as substrate media since it is light weight, environmentally friendly and has high water-holding capacity. The high air filled porosity of this media results in very high seed germination rates and produces seedlings with stronger and more fibrous roots. Commercial hydroponic growers worldwide are producing excellent quality and high-yielding vegetable and cut flower crops using coirpith. The most commonly available substitute for soil in Kerala is coirpith. There are several reasons for the popularity of coirpith as potting mixture. It is easy to handle and there is no interaction between the medium and the nutrients hence offering more availability of nutrients to plants. It provides better physical and chemical properties suitable for plant growth and also a pathogen free growing environment. It also enables incorporation of microorganisms used as biopesticide and bionutrients, thus reducing the use of chemicals. Hence this experiment utilises coirpith as soil substitute and studies the effect of alternate growing systems and irrigation schedules for soilless culture of Salad Cucumber. The materials utilized and the methodology adopted for achieving the objectives of the study are enumerated under the following subheadings in this chapter.

3.1 LOCATION OF THE STUDY AREA

The field experiment was conducted inside the naturally ventilated polyhouse in the research plot of Precision Farming Development Centre, situated in the instructional farm of KCAET, Tavanur, Kerala. The site is situated on the cross point of 10^o 51’18” N latitude and 75^o 59’ 11” E longitude at an altitude of 8.54 m above mean sea level.

3.2 CLIMATE OF THE STUDY AREA

Agro - climatically, the area falls within the border line of northern zone and central zone of Kerala. Most part of the rainfall received in this region is from south- west monsoon. The average annual rainfall varies from 2500 mm to 2900 mm. The average maximum temperature of study area is 31ºC and the average minimum temperature is 26ºC.

3.3 CROP WATER REQUIREMENT OF SALAD CUCUMBER

CROPWAT is a decision support system developed by the Land and Water Development Division of FAO for planning and management of irrigation. It is a computer program that uses the FAO Penman-Monteith model to calculate reference evapotranspiration (ET_o), crop water requirements and crop irrigation requirements (FAO 1992). The program allows for the development of irrigation schedules under various management and water supply conditions and to evaluate rainfed production, efficiency of irrigation practices and drought effects (FAO 2002).

The estimation of water requirement of crop is essential for irrigation planning and management and also it is the basis on which irrigation project is designed. The key to effectiveness of irrigation water management lies in proper estimation of crop water requirements, which is primarily based on cropping pattern, rainfall in the area and other climatic factors. Computer model simulation is an emerging trend in the field of water management.

3.3.1 Data Requirements for CROPWAT

Four main datasets are used as inputs in the CROPWAT estimation: climatic, crop, soil and rain. In this study climate and crop data are given as input based on local values. The climatic data include maximum and minimum temperatures (ºC), mean daily relative humidity (%), daily sunshine (hours), wind speed (km/day) and rainfall (mm). The crop parameters include: water stress coefficient (K_s), length of the growing season, critical depletion fraction, and yield response factor (K_y). The soil data include total available soil water content, maximum rooting depth and initial soil water content at the start of the season.

3.3.1.1 Climate Data

Climate module window is as presented in Fig. 3.1. The daily data of rainfall, minimum temperature, maximum temperature, humidity, sunshine hours, and wind speed for twelve months were used to calculate radiation and reference crop evapotranspiration. Data of minimum temperature, maximum temperature and relative humidity inside the naturally ventilated polyhouse were used as input to the climate module (Preenu, 2012). Other data on wind speed and sun shine hours were taken from the Meteorological station at KAU, Thrissur for the year 2012 and suitable correction factors for the polyhouse were applied based on literature due to lack of the year wise polyhouse data. Wind velocity value was reduced by 10% and sunshine hours was assumed to be the same (Neelam *et al.* 2009). Radiation and ET_o were calculated by the model. The monthly average values of climatic parameters and the calculation of radiation and ET_o as done in the CROPWAT model.

3.3.1.1.1 ETo Calculation Using CROPWAT

To calculate reference evapotranspiration (ET_o), using the Penman-Monteith method, monthly mean data are required, including Maximum and minimum temperatures (°C), Sunshine hours (hour), Wind Speed (km/day) and Relative Humidity (%).

The Penman-Monteith form of the combination equation is,

$$ET_0 = \frac{0.408\,\Delta\,(\mathrm{R_n} - \mathrm{G}) + \gamma\,\frac{900}{\mathrm{T} + 273}\,\mathrm{U_2}(\mathrm{e_s} - \mathrm{e_a})}{\Delta + \gamma\,(1 + 0.34\,\mathrm{U_2})}$$

Where,

ET_o : The reference evapotranspiration [mm day^{-1}]

R_n : The net radiation [MJ m^{-2} day^{-1}]

G : The soil heat flux density [MJ m^{-2} day^{-1}]

T : The mean daily air temperature at 2m height [°C]

U_2 : The wind speed at 2m height (km/day)

e_s : The saturation vapour pressure [kPa]

e_a : The actual vapour pressure [kPa]

$(e_s - e_a)$: The vapour pressure deficit of the air [kPa]

Δ : The slope vapour pressure curve [kPa $°C^{-1}$]

γ : The psychometric constant [kPa $°C^{-1}$]

3.3.1.2 Rain Module

Fig. 3.2 shows the rain module window in the CROPWAT software. The input data for the rain module is daily rainfall data. In order to account for the losses due to runoff or percolation, effective rain fall is calculated by empirical method viz USDA method. In polyhouse cultivation rainfall is considered as zero.

3.3.1.3 Crop Module

Fig. 3.3 shows crop module window of the software. The details of crop related to the study such as crop coefficient, critical depletion, yield response, root depth and crop height over different development stages were fed in to this module. The specific details of salad cucumber were collected from FAO paper No. 56 of the Irrigation and Drainage Series (1998).

3.3.1.4 Soil Module

Soil module window is presented in Fig. 3.4. In this study coirpith was the media used. Various parameters include in soil module were total available water (TAW), maximum infiltration rate, maximum rooting depth and Initial soil moisture depletion. Total available water for coirpith was measured using the pressure plate apparatus. TAW of coirpith were calculated by the equation,

TAW = Field capacity – Permanent wilting point

Maximum rooting depth was taken from FAO paper No. 56 of the Irrigation and Drainage Series (1998). Initial soil moisture depletion was fixed at 50 % level.

3.3.1.5 Crop Water Requirement Module

The amount of water required to compensate the evapotranspiration loss from the cropped field is defined as crop water requirement. Crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration. The crop water requirement module includes calculations, producing the irrigation water requirement of the crop on a daily basis and over the total growing season, as the difference between the Crop evapotranspiration under standard conditions (ETc) and the Effective rainfall.

ET_{c} is termed as the crop water requirement (CWR) in mm/day. It is defined as “the depth of water needed to meet the water loss through evapotranspiration of a disease free crop, growing in fields under non-restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment” (Doorenbos and Pruitt, 1977). The model calculates ET_c as,

$ET_c = K_c \times ET_0$ where, K_c is the crop coefficient

The crop water requirement (ET_c) of salad cucumber was computed by multiplying the crop coefficient (K_c) with ET_0 at different growth stages and irrigation requirement is computed as,

Irrigation requirement = ETc - P_{eff}. In this case as under greenhouse conditions P_{eff} was zero therefore irrigation requirement was same as ETc.

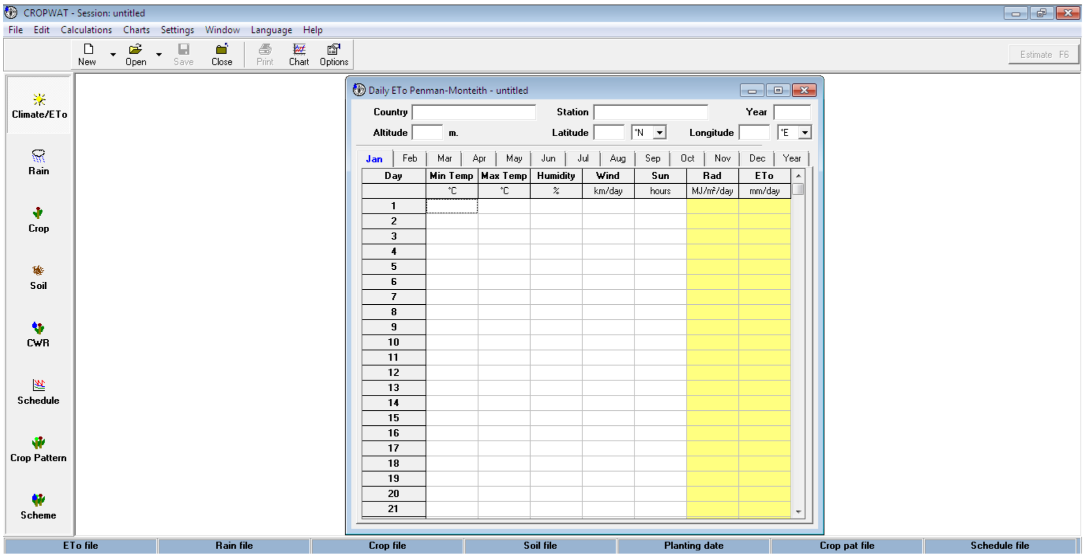
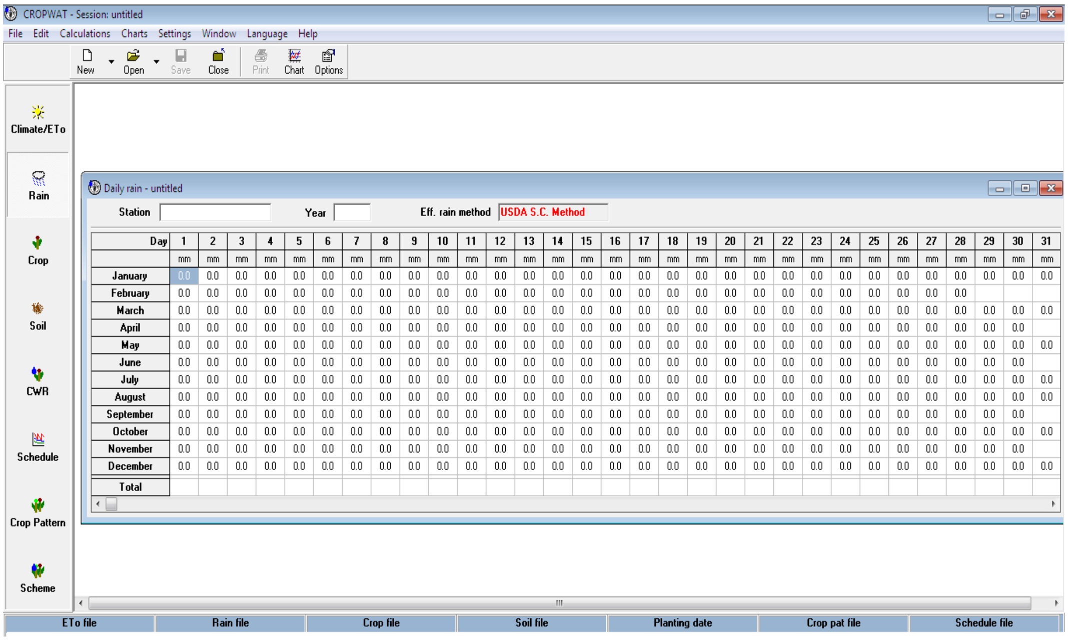


Fig. 3.1 Climate module window



Station

Year

Eff. rain method USDA S.C. Method

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
January	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
February	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
March	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
April	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
June	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
August	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
September	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
October	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
November	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
December	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total																															

Fig. 3.2 Rain module window

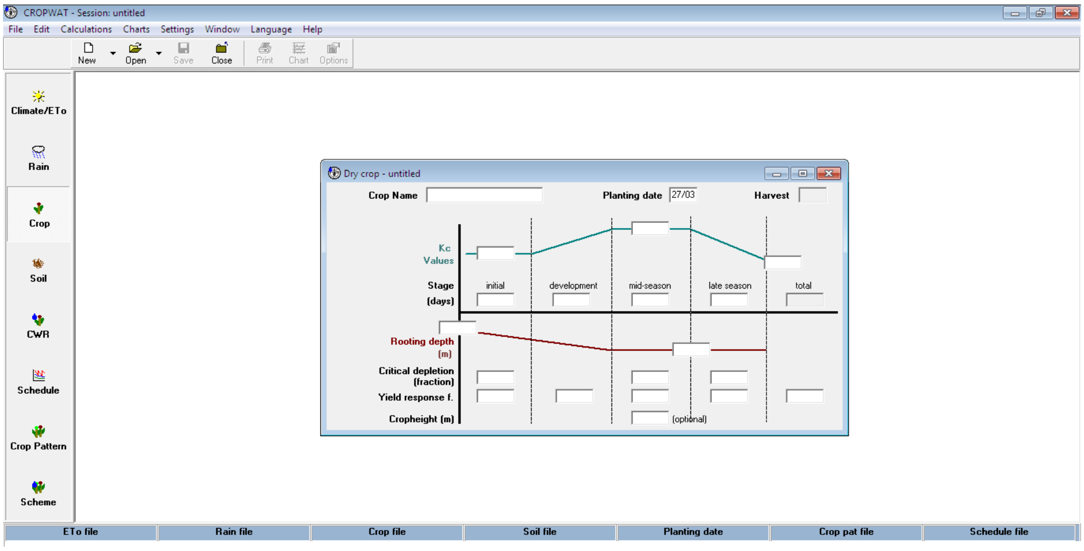


Fig. 3.3 Crop module window

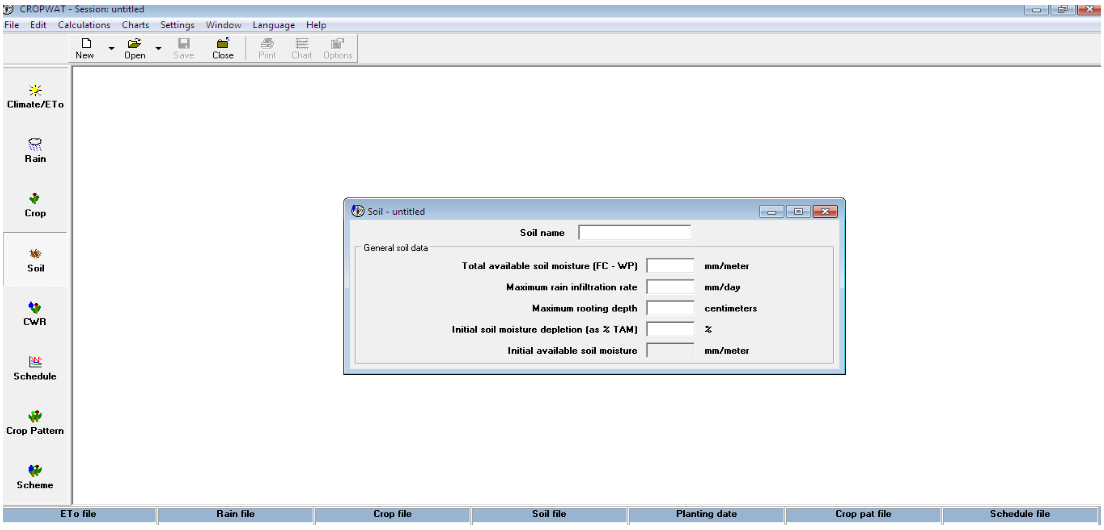


Fig. 3.4 Soil module window

3.4 DETERMINATION OF PHYSICO-CHEMICAL AND ENGINEERING PROPERTIES OF THE MEDIA

3.4.1 Physical Properties

The coirpith used for the study was analysed for physical characteristics like bulk density, particle density, moisture percent in air dry media and volume expansion by using Hilgard Apparatus or Keen Rackzowski Box based on standard procedures.

The keen box is a cylindrical brass box of 5 cm diameter and 2.5 cm height having a perforated bottom as shown in Plate 3.1. The radius and depth of keen box was measured with a vernier caliper. The dish of the keen box was cleaned and dried and it is weighed. Whatman No.1 filter paper is cut and placed at the bottom of the keen box with the help of a split brass ring. The box is filled with coirpith with repeated tapings (20 - 30 timing) on the top of the table for complete and uniform packing. The surface is levelled with the spatula. The keen box with air-dry media is weighed. The box is placed in the soaking tray and gradually filled with water from the side till the water level was about 1 cm above the base of the box. The tray is covered to prevent evaporation from media surface and it is kept for 12 hrs or more for equilibrium. A continuous and shining film of water at the media surface confirms this. The box is carefully removed from the water and wiped dry from outside and weighed quickly. The expanded coirpith (above dish's rim) was cut off with spatula and it was transformed to previously weighed watch glass. The watch glass was weighed with expanded out wet coirpith. The coirpith of watch glass and keen box was dried in the oven at 105^0C and constant weight was recorded. A blank test (only with keen box and filter paper) was also run simultaneously to find the weight of the water absorbed by the filter paper alone. By this method the properties of the coirpith were determined (Viji *et al.* 2011).

The physical properties are determined by using the following formulae. The specimen calculations are shown in Appendix I.

Bulk density of the processed coirpith (g/cm^3) $= \frac{\text{Weight of the coirpith}}{\text{Volume of coirpith with pore space}}$

Particle density of the processed coirpith (g/cm^3) =

$$\frac{\textbf{Weight of coirpith}}{\textbf{Volume of coirpith excluding pore space}}$$

Volume expansion $= \frac{\text{Volume of expanded coirpith}}{\text{Volume of the air dry coirpith}}$

3.4.2 Determination of Porosity Characteristics of Coirpith

Saturation and drainage method was used for the study (Gessert, 1976).

Equipment used

1. Container with a drainage hole at the bottom
2. Waterproof tape for sealing the drainage hole
3. Graduated cylinder for measuring liquid volume
4. Watertight pan wider than the bottom of the container

Procedure

1. Drainage hole in the container was sealed and filled with water. Volume of water in the container was measured and recorded as "container volume."
2. Then the container was emptied, dried and filled with coirpith. The coirpith in the container was slowly saturated by gradually pouring water onto the surface. Water was continuously added over a period of several hours until the coirpith was completely saturated (the surface glistens). The total volume of water added was recorded as "total pore volume."
3. Container was placed over the watertight pan and the seal was removed from the drain holes. The free water was allowed to drain out of the container. The amount of this drainage water was measured and recorded as "aeration pore volume."
4. The total porosity, aeration porosity, and water filled porosity were computed as follows:

$$\text{Total porosity (\%)} = \frac{\text{Total pore volume}}{\text{container volume}} \text{ x } 100\%$$

$$\text{Aeration porosity (\%)} = \frac{\text{Aeration pore volum}}{\text{Container volume}} \text{ x } 100\%$$

Water-filled porosity (%) = Total porosity - Aeration porosity

3.4.3 Determination of Media Moisture Characteristics

Laboratory measurement of media moisture characteristics was done with the pressure plate apparatus (Plate 3.2) developed primarily by Richards (1949, 1954). The apparatus consists of ceramic pressure plate or membranes of high air entry values contained in airtight metallic chambers strong enough to withstand high pressure (15 bars or more). The apparatus enables the development of media moisture characteristic curves in the higher range of metric potential (>1 bar) which is not possible on suction plates.

The procedure for determining soil metric potential and water content relation involves in first saturating the porous plates and then the coirpith media (undisturbed or disturbed) is placed on these plates. The coirpith samples were also saturated and then the plates were transferred to the metallic chambers. The chamber was closed with wrenches to tighten the nuts and bolts with the required torque for ceiling it. Pressure was applied from a compressor through control which helps in maintaining the desired two pressures 1/3 atm & 15 atm which were applied to get field capacity and permanent wilting point. It was ensured that there was no leakage from the chamber. Water starts to flow out from saturated coirpith samples through outlet and continues to trickle till equilibrium against the applied pressure is achieved. After that the coirpith samples were taken out and oven dried for determining moisture content, volume basis. Similarly, the moisture content of the coirpith media can be determined against other pressure values. Calculations are shown in Appendix II (Michael, 2008).

3.4.4 Media pH and EC Variation

The pH values of coirpith media from each treatments were determined by mixing 10 g of media with 50ml distilled water, thoroughly shaking and kept for 24 hours. The mixtures were filtered through Whatman No 1 filter paper and the pH of the extract was determined by using digital pH meter. For determination of EC, 40 g of media was mixed with 80 ml of distilled water shaken for 15 minutes and left for 60 minutes. EC of the filtered extract was estimated with digital EC meter. The electrical conductivity indicates the strength of nutrient solution, as measured by an EC meter. The unit for measuring EC is dS/ m. A limitation of EC is that it indicates only the total concentration of the solution and not the individual nutrient components. Higher EC will prevent nutrient absorption due to osmotic pressure and lower EC severely affect plant health and yield. When plants take up nutrients and water from the solution, the total salt concentration, i.e., the EC of the solution changes. If the EC is higher than the recommended range, fresh water must be added to reduce it. EC can be increased by adding KNO_3.

Variations in the pH and EC values of the media were monitored during the crop growth period at 20 or 30 day intervals.

Plate 3.1 Keen rackzowski box

Plate 3.3 Digital EC and pH meter

Plate 3.2 Pressure plate apparatus for determination of media moisture retention characteristics

3.5 FIELD EXPERIMENT

Performance of salad cucumber with alternate growing systems and three irrigation schedules was studied. The experiment was conducted inside the naturally ventilated polyhouse during 2013 (November 24th) - 2014 (March 10th) and the crop duration was three and half months (107 days). The polyhouse was oriented east–west with an area of 292 m^2 (36 m in length and 8 m in width). A view of the polyhouse is shown in Plate 3.4.

Plate 3.4 A view of the polyhouse

3.5.1 Field Preparation

The land preparation was done. Three raised beds of 10 m length, 1.2 m width and 40 cm height were made (Plate 3.5).

3.5.2 Preparation of Alternate Growing Systems

3.5.2.1 Layflat Growbag Preparation

Lay flat growbags made of UV resistant polyethylene and filled with sterilized coirpith were used for the study. The expanded size of bag was 100 × 20 × 12 cm as shown in Plate 3.6. Three plants can be established per bag.

The growbags were placed in row with the ‘TOP’ logo on the upper side. Then small holes were made with equal spacing on the upper surface of the growbag for establishing the crop. Water was supplied to the media in order to expand the coirpith. Drainage holes were provided on both sides of the grow bag, on the corner between the side and the bottom of the grow bag (on the edge of the grow bag). Each hole was 6-8 cm long, and total six draining holes were made.

3.5.2.2 Vertical Growbag Preparation

Fifteen numbers of 5 kg coirpith blocks were used for media preparation to fill 54 bags (Plate 3.8). Coirpith blocks were soaked in water for 24 hours. Then the coirpith was expanded 5 times by volume and formed like loose soil (Plate 3.9). This media was thoroughly mixed by hand before filling in growbags of size 40 × 24 × 24 cm as shown in Plate 3.7. The bag was made of UV stabilized polyethylene and was white outside and black inside. In order to compare with lay flat grow bag 1/3rd of the weight of the growing media and as filled in lay flat grow bag were used for the filling of vertical grow bag. Drainage holes were already provided by the manufacturers. This was done in order to compare with lay flat grow bags.

A set of three vertical grow bags and a lay flat grow bag were placed alternatively in each row. Hence 18 plants can be grown in one row and 36 plants in a bed as a bed contains two rows.

During the expansion of media calcium nitrate treatment was applied through drip irrigation for buffering. To every expanded cubic meter of coir (1000 litres) 3kg of calcium nitrate was applied. This displaces the sodium and balances the naturally occurring potassium. After the soaking period the media was washed with water. This removes the displaced sodium, leaving the calcium in the coir.

Plate 3.5 Land preparation

Plate 3.6 Layflat growbag

Plate 3.7 Vertical growbag

Plate 3.8 Initial coirpith blocks

Plate 3.9 Expanded coirpith media

3.5.3 Nursery

Salad cucumber variety *Hilton* was chosen for cultivation. Seeds were sown in pro trays and fifteen days old seedlings were transplanted to the main field. For sowing the seeds, the mixture of cocopeat, vermiculite and perlite in a ratio of 3:1:1 were filled in the trays. After sowing the seeds, trays were irrigated with a rose can daily in the morning. Plate 3.10 shows the seedling of salad cucumber before transplanting.

Plate 3.10 Seedling of salad cucumber

3.5.4 Transplanting

Transplanting was done on 24th November. There were 36 plants in each bed. The total plant population was 108 numbers. The view of the plot after transplanting is given in Plate 3.11.

Plate 3.11 Plot after transplanting

3.6 LAYOUT OF THE EXPERIMENT

Two types of grow bags viz lay flat (horizontal type) and open top grow bag (vertical type) with coirpith media were prepared. The experiment was designed under Factorial completely randomized block design. Layout of the experimental plot is shown in Fig. 3.5 and the design details are as furnished in the Table 3.1.

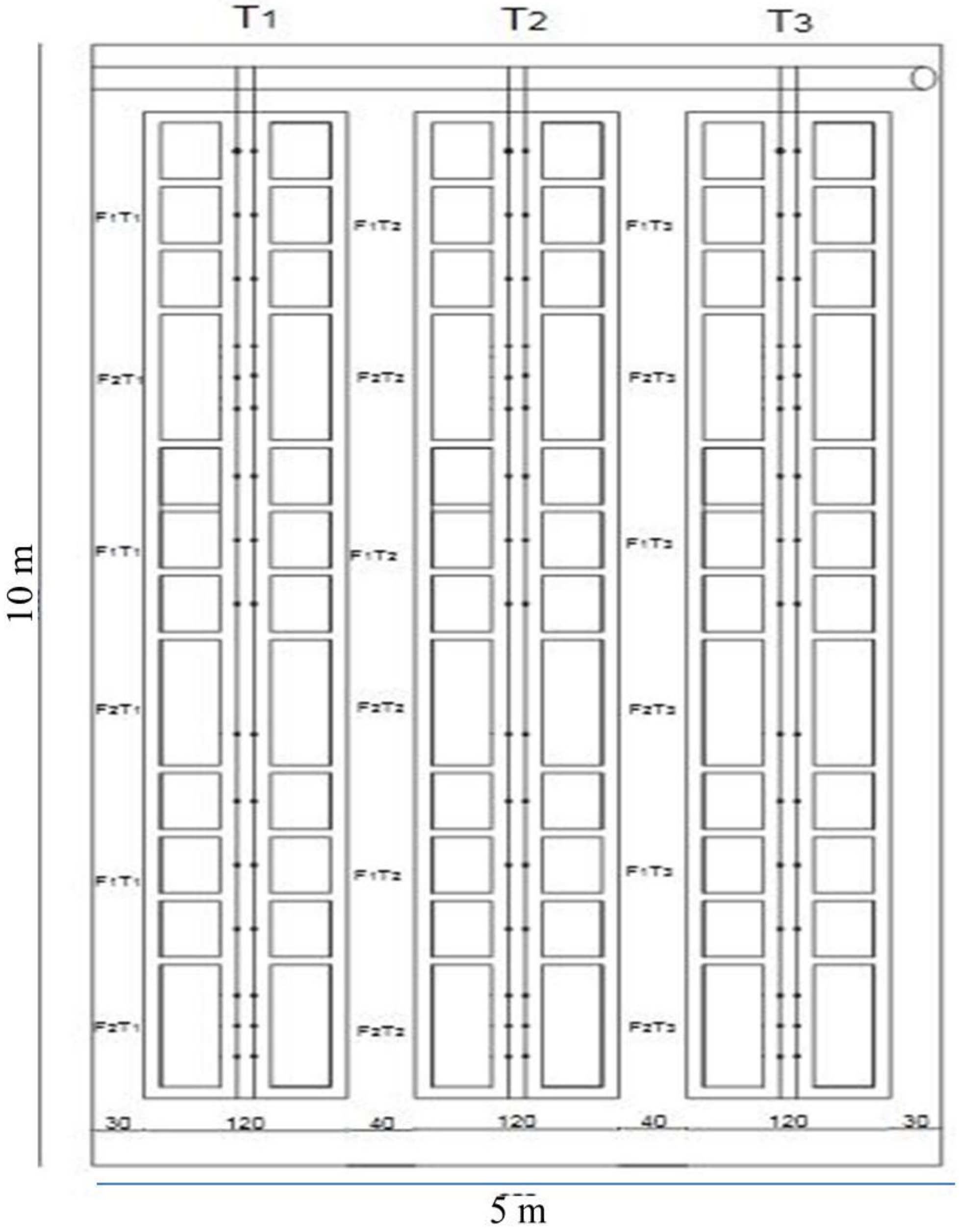


Fig. 3.5 Layout of the experimental plot

Table 3.1 Experiment design details

Crop variety	Salad cucumber, *Hilton*
Experiment design	Factorial CRD
Factors	F_1 - Growing systems F_2 - Irrigation schedules
Number of replications	3
Number of treatment combinations	6
Treatment details	
F1T1	Vertical type growbag bag with daily irrigation
F1T2	Vertical type growbag with alternate day irrigation
F1T3	Vertical type growbag with irrigation once in 3 days
F2T1	Lay flat growbag with daily irrigation
F2T2	Lay flat growbag with alternate day irrigation
F2T3	Lay flat growbag with irrigation once in 3 days

3.7 IRRIGATION SYSTEM

Irrigation water was pumped using a 5 hp pump and conveyed through the main line of 63 mm diameter PVC pipes after filtering through the screen filter. Water source was a nearby bore well. PVC sub main of 50 mm diameter was connected to the main line to which, Low density polyethylene laterals of 12 mm diameter were connected. End caps were provided at the end of laterals. Each lateral was provided with individual taps for controlling irrigation. Along the laterals, microtube of 6 mm diameter and length of 75 cm were connected with thin connector and online drippers of 4 lhr^{-1} were fixed at the other end of microtube at spacing of 30 cm (Plate 3.12).

The irrigation applied to the plant was in a low rate than the actual requirement in order to reduce drainage as no drainage collection and recirculation was done. At the initial stage the crop was irrigated twice daily with application rate of 0.25 litre in the morning and 0.25 litre in the evening. During the development stage the plant requires more water than initial stage. So the water applied was increased from 0.5 to 1 l/day/plant. After mid stage water application rate was increased to 1.5 l/day/plant as the water uptake by plants increases during mid-stage.

3.7.1 Irrigation Water Quality

Irrigation water from bore well was analysed for various parameters like pH, EC, Total alkalinity, Cl_2, Ca, Mg, Na, K, Mg/Ca ratio, Boron, SAR and RSC.

3.8 FERTIGATION IN COIRPITH

Both macro and micro nutrients were applied as water soluble fertilizers from two tanks (tank A and tank B as shown in Plate 3.13) through fertigation system with fertilizer tank and venturi. Tank A having macro nutrients and tank B having micro nutrients. Same quantities of fertilizers were applied in each treatment by maintaining pH and electrical conductivity. A view of the fertilizer unit is shown in Plate 3.14.

Stoke solution was prepared by dissolving the following minerals in 50 litres of water.

Plate 3.12 Grow bags with the drip system laid out

Plate 3.13 Stock solution tank

Plate 3.14 A view of the fertigation system attached to the supply line

Tank A

Calcium Nitrate	: 4.125 kg
Potassium Nitrate	: 0.85 kg

Tank B

Potassium Nitrate	: 1.375 kg
Magnesium Sulphate	: 1.945 Kg
Mono potassium phosphate	: 0.925 kg
Sulphate of potash	: 1.180 kg
Manganese sulphate	: 3.750 g
Zinc sulphate	: 7.650 g
Copper sulphate	: 8.750 g
Sodium molybdenum	: 0.875 g
Borax	: 15.45 g

(Source: Rijk - Zwaan seeds)

Stoke solution was injected with one litre in 100 litres of water. Tank A solution was applied 5 minutes in the morning and tank B solution was applied for 5 minutes in the evening.

3.9 PEST AND DISEASE MANAGEMENT

Cucumber yields are frequently reduced due to sucking insects and pests. Common problems for polyhouse salad cucumber are aphids, thrips, white flies, downy mildew etc. Seedlings have little tolerance to insect attack and relatively small numbers can cause economic damage. Crop protection consisted of controlling the incidence of pest and disease.

Aphids damage cucumber plants by feeding on plant sap, and by spreaded and cause important viral diseases like cucumber mosaic. Small soft bodied insects on underside of leaves and/or stems of plant. Usually green or yellow in colour. Tatamida SL was sprayed at the rate of 3ml/10 litres of water on the leaves for controlling sucking insects like aphids, white fly and thrips.

Downy mildew (*Pseudoperonospora cubensis)* causes fluffy purplish mildew on underside of leaves and yellow spots on the upper side. The fungicide ridomil gold was applied at the rate of 2 g/l for controlling the disease.

3.10 FIELD OBSERVATIONS

3.10.1 Microclimate Inside the Polyhouse

Minimum temperature, maximum temperature and relative humidity inside the polyhouse during the crop season were measured using the Equinox Digital Temperature and Humidity meter at 8 am, 2 pm, and 5 pm everyday at crop canopy level. Data are presented in Appendix III and IV.

3.10.2 Plant Growth and Yield Parameters

Three plants from each treatment was selected at random and tagged for observations on growth and yield characters.

3.10.2.1 Plant Height / Length of the Main Vine

The height of the plant from base level of shoot to the tip was measured at 10 days intervals and expressed in centimetres for each treatment.

3.10.2.2 Number of Leaves

Number of leaves per plant was noted at 10 days intervals in selected plants.

3.10.2.3 Flowering

Days to first flowering and number of female flowers per plant was recorded at 10 days intervals.

3.10.2.4 Plant Dry Weight

The tagged plants were cut into smaller pieces at the end of crop growth period and dried in the oven at 70^0C until constant weight was recorded.

3.10.2.5 Yield Parameters

Harvesting was started 55 days after transplanting at an interval of two or three days.The number of fruits obtained and weight of fruits harvested were noted from the tagged plants for each harvest. The average value of fruit number per plant and fruit weight per plant was accordingly computed from the data of all harvests. Total 16 harvests were done and total yield was taken.

3.10.2.6 Root Length and Root Mass

The tagged plants were uprooted at the end of crop growth period and the root length and root mass were monitored.

3.10.2.7 Fruit Characteristics

The fruit characteristics such as number of fruits, fruit diameter and fruit length were observed. The effects of different treatments on these parameters were studied.

3.11 QUALITY ANALYSIS

Fruit texture of freshly harvested fruits of selected plants was measured using Texture analyser.

Textural properties of the salad cucumber samples were determined using food texture analyser (stable micro systems, UK). The instrument had a micro-processor regulated texture analysis system interfaced to a personal computer. The instrument consists of two separate modules; the test-bed and the control console (keyboard). Both are linked by a cable which route low voltage signal and power through it. The texture analyser measures force, distance and time and hence provide a three-dimensional product analysis. Forces may be measured to achieve set distances and distances may be measured to achieve set forces. The sample was kept on the flat platform of the instrument. The samples were compressed using a cylindrical probe (diameter 5 mm) under measure force in compression mode with a test speed of 10 mm/sec during which various textural parameters were determined. From the force deformation curve, the firmness or hardness (peak force), and toughness (area under the curve) were determined.

3.12 DETERMINATION OF IRRIGATION WATER USE EFFICIENCY

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

$$WUE = \frac{Y}{W.A}$$

Where,

WUE = Water Use Efficiency (kg/ha mm^{-1}) of water used

Y = Yield of the crops (kg ha^{-1})

W.A = Total water applied (mm)

3.13 DETERMINATION OF FERTILIZER USE EFFICIENCY

Fertilizer Use Efficiency (FUE) was calculated for each treatment. Estimation of fertilizer use efficiency includes calculation of Nitrogen use efficiency, Phosphorus use efficiency and Potassium use efficiency. It is the ratio of yield of the crop in kg/ha to the total quantity of Nitrogen, Potassium and Phosphorus applied in kg/ha.

$$FUE = \frac{Y}{F.A}$$

Where,

FUE = Fertilizer Use Efficiency (%)

Y = Yield of the crops (kg ha^{-1})

F.A = Total fertilizer applied (kg ha^{-1})

3.14 STATISTICAL ANALYSIS

Statistical analysis was carried out to study the effects of alternate growing systems, irrigation interval and their interaction effect on crop growth and yield parameters. The experiment was laid as CRD design with three replications and the data collected were analyzed statistically as 2 × 3 factorial experiment. SPSS 16.0 software was used to analyze data. Analysis of variance (ANOVA) was performed using the General linear model (GLM) procedure from SPSS 16.0 software. Least significant differences test (LSD) was used to compare the significant differences among mean of the treatments at 0.05 level of probability.

Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

Results obtained from the field trials on the effect of alternate growing systems and irrigation schedules for soilless culture of Salad Cucumber were analyzed and details are discussed under various headings in this chapter.

4.1 ESTIMATION OF CROP WATER REQUIREMENT BY CROPWAT MODEL

The input data i.e. climate, soil/substrate media and crop related to the study area were fed to the CROPWAT model to estimate the crop water requirement.

4.1.1 Climate Module Input Data

Data of monthly average values of climate data collected from the observatory and the calculated radiation and ETo is given in the Table 4.1.

Fig. 4.1 shows the monthly variation of minimum temperature (°C), maximum temperature (°C), Relative humidity and $ET_{0.}$ The maximum temperature was recorded during the month of February and minimum temperature was recorded during the month of July. From the figure it is evident that ET_0 values vary with temperature and humidity and maximum ET_0 was recorded during the month with maximum temperature.

Fig. 4.2 presents monthly variation of sunshine (hours), ETo (mm/day) and radiation (MJ/m^2/day). The maximum sunshine hours was recorded during the month of February and the minimum sunshine hours was recorded during the month of July. The maximum ETo and radiation were recorded during February and the minimum during the month of July. From the data it is understood that sunshine and radiation influences the reference evapotranspiration.

Table 4.1 Monthly average values of climatic parameters

Month	Min temp °C	Max temp °C	Humidity %	Wind Km/day	Sun hours	Rad MJ/m^2/day	ETo mm/day
January	24.8	34.2	62	15	8.5	19.6	3.76
February	25.9	37.1	63	12	8.7	21.3	4.37
March	25.2	36.1	65	10	7.5	20.7	4.34
April	25.6	35.7	71	10	6.2	19.1	4.17
May	24.3	33.2	75	9	6.1	18.6	4.01
June	22.8	28.6	85	8	2.8	13.4	2.86
July	22.5	28.4	86	8	3.2	14.1	2.87
August	22.9	30.0	85	11	2.9	13.8	2.88
September	23.9	29.9	82	8	4.6	16.3	3.30
October	23.5	33.2	74	10	6.2	17.8	3.59
November	23.8	33.8	54	8	7.0	17.8	3.27
December	24.9	34.7	45	13	7.1	17.2	3.14
Average	24.2	32.9	71	10	5.9	17.5	3.55

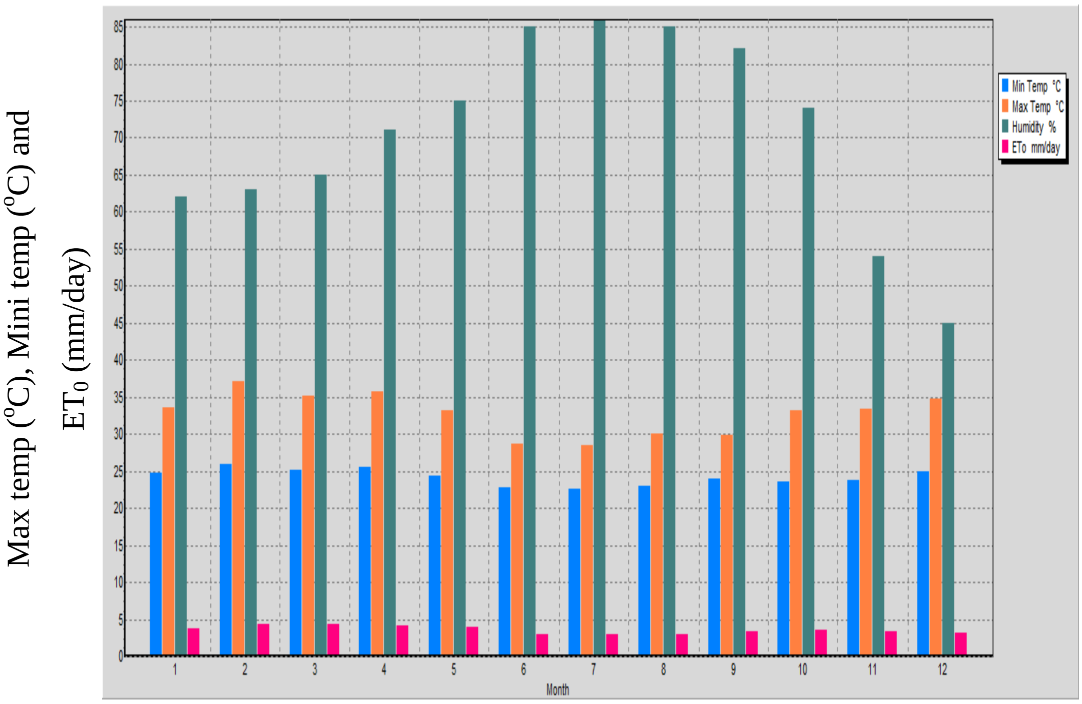


Fig. 4.1 Monthly Variation of Minimum Temperature (ºC), Maximum Temperature (◦C), Relative humidity and ET$_0$ (mm/day)

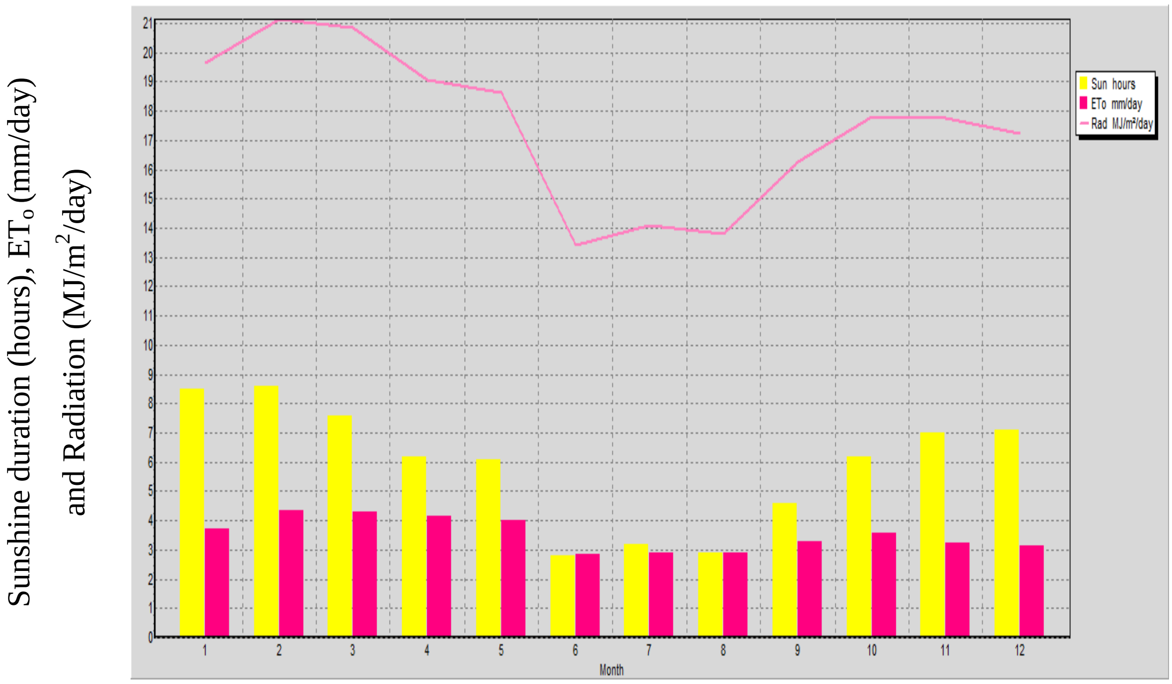


Fig. 4.2 Monthly Variation of Sunshine duration (hours), ET$_o$ (mm/day) and Radiation (MJ/m^2/day)

4.1.2. Crop Module Input Data

The respective primary data related to the crop of the study area is given in the Table 4.2.

Table 4.2 Crop module

Crop name: Salad Cucumber					
Stages (days)	Initial	Develop	Mid	Late	Total
	20	32	35	20	107
K_c values	0.6		1	0.75	
Rooting depth (m)	0.5			0.7	
Critical depletion (fraction)	0.5		0.5	0.5	0.5
Yield response factor	1.1	1.1	1.1	1.1	1.1
Crop height (m)	2.75				

In the crop module data, duration of different stages of growth of salad cucumber in days, K_c values, rooting depth (m), critical depletion (fraction), yield response factor and crop height (m) are given as input to the model. Total duration of the crop was 107 days. Maximum rooting depth comes to 70 cm. Average crop height was taken as 2.75 m. Other data were taken from FAO paper No. 56 of the Irrigation and Drainage Series (1998).

4.1.3. Soil Module Input Data

Physical properties of the proposed coirpith media obtained from the lab analysis were fed as input to this module. The results are presented in section 4.2. The input data to soil module are presented in Table 4.3.

Table 4.3 Soil module

Total available soil moisture (FC -WP)	275.05 mm/meter
Maximum rooting depth	70 cm
Initial soil moisture depletion (as % TAM)	50 %
Initial available soil moisture	137.5 mm/ meter

Available moisture for coirpith was determined using pressure plate apparatus. Good water holding capacity of coirpith causes the high value of total available soil moisture. Maximum rooting depth comes to 70 cm. Initial soil moisture depletion was taken as 50 % of total available moisture. With these values as input to the model, the model calculates the initial available soil moisture.

4.1.4 Crop Water Requirement of Salad Cucumber

Table 4.4 presents the output of CWR calculations for salad cucumber. Total irrigation requirement was computed by adding irrigation requirement of each stage of the salad cucumber and the value obtained was 30.45 cm.

Table 4.4 Estimation of crop water requirement of salad cucumber

ET_0 station : Tavanur					Crop : Salad cucumber Planting date : 24/11		
Month	**Decade**	**Stage**	**K_c**	**ET_c**	**ET_c**	**Eff. Rain**	**Irr. Req.**
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Nov	3	Init	0.60	1.86	13.0	0.0	13.0
Dec	1	Init	0.60	1.90	19.0	0.0	19.0
Dec	2	Deve	0.62	1.96	19.6	0.0	19.6
Dec	3	Deve	0.71	2.21	24.3	0.0	24.3
Jan	1	Deve	0.79	2.92	29.2	0.0	29.2
Jan	2	Mid	0.86	3.24	32.4	0.0	32.4
Jan	3	Mid	0.86	3.29	36.2	0.0	36.2
Feb	1	Mid	0.86	3.65	36.5	0.0	36.5
Feb	2	Mid	0.86	3.77	37.7	0.0	37.7
Feb	3	Late	0.79	3.50	28.0	0.0	28.0
Mar	1	Late	0.70	2.86	28.6	0.0	28.6
					304.5		304.5

(In CROPWAT model ‘decade’ represents 10 days)

Even though, Coirpith media is characterized by good physical properties such as high water-holding capacity and high air filled porosity, the water requirement of salad cucumber for polyhouse cultivation with coirpith media as computed by CROPWAT model was almost same as that in open field. This may be because, for polyhouse cultivation, rain input to the module was given as nil and effective rainfall component was nil. Other weather parameters like wind speed, radiation etc are less inside polyhouse which would contribute to lesser water requirement value.

The advantages of low wind speed include low evapotranspiration rate that means lesser water requirements (Abou-Hadid *et al.,* 1994). The plants inside the polyhouse received about 18-20 % less energy as net solar radiation form than the outside condition. The type of roof material used causes the reduction of the total solar radiation inside the polyhouse. The reduction of solar energy received by the plants also results in the reduced evapotranspiration (Neelam *et al.*, 2009).

4.2 PHYSICO CHEMICAL AND ENGINEERING PROPERTIES OFCOIRPITH

4.2.1 Physical Properties

Bulk density, particle density, moisture percent in air dry media and volume expansion of coirpith were analyzed using Keen Rackzowski box and the results are presented in Table 4.5.

Table 4.5 Physical properties of coirpith

Bulk density	0.12 g/cc
Particle density	0.17 g/cc
Moisture percent in air dry media	8.21 %
Volume expansion	38.25 %

The value of bulk density and particle density were observed as 0.12 and 0.17g/cc, which is low as compared to other substrates. Bulk density is one of the factor that determines the successful functioning of a growing medium. High intensity greenhouse production generally prefers low bulk density media as mixing and transportation is easier (Raviv *et al*. 2008).

The moisture percent in the air dry media was 8.21 % and volume expansion was as high as 38.25 %.

4.2.2 Porosity Characteristics

The values of total porosity, aeration porosity and water holding porosity of coirpith were determined using saturation and drainage method and the results are presented as follows;

Total porosity : 87.50 %

Aeration porosity : 28.12 %

Water-holding porosity : 59.38 %

Total porosity and aeration porosity of coirpith were observed as 87.50 % and 28.12 % respectively, which is very high as compared to other substrates. These values were found to be in close agreement with the results reported by Ronald (2012), in which total porosity and aeration porosity of coirpith were 83± 9 % and 28.1 % as reported in the study conducted in Tamilnadu.

Water filled porosity was also high as 59.38 %. This value was found to be in close agreement with the result reported by Venu (2014), in which the value was 60 %. Coirpith has a phenomenal high water holding capacity. It can hold water upto six times or more of its dry weight and has high moisture retention. It improves the physical and biological condition of soil and also improves aeration and reduces frequency of irrigation (Mariamma, 2010).

4.2.2 Media Moisture Constants

The values of field capacity and permanent wilting point for coirpith samples were obtained using pressure plate apparatus and the results were as follows. Sample calculation is given in Appendix II.

Field Capacity : 510.30 %

Permanent Wilting Point : 235.25 %

Available Water : 275.05 %

Available moisture in coirpith was high (275.05 %). The improvement in soil available moisture by adding coirpith as admixture is in the range of 110 to 168 %. From the point of view of water retention for plant growth, coirpith is the most acceptable admixture not only to increase the plant available water but also the irrigation interval, bringing in considerable saving in irrigation water (Bandyopadhyay *et al.*, 1988).

4.2.3 Chemical Characteristics

4.2.3.1 pH Variation of Coirpith During Crop Growth Period

The variation of pH value of media during the crop growth period was observed and the results are presented in Table 4.6 and Fig. 4.3.

The pH is an important factor in the availability and the uptake of nutrients. Changes in pH of less than 0.1 unit are not significant. Thus pH control is a necessity in soilless culture. The pH range of 6.2 to 6.8 is optimal for the availability of nutrients from nutrient solutions for salad cucumber (Waters *et al.*, 1970).

Table 4.6 pH variation of coirpith during the crop growing season

	DAYS AFTER TRANSPLANTING				
Treatments	**15**	**30**	**50**	**70**	**100**
F1TI	6.6	6.5	6.2	6.3	5.8
F1T2	6.7	6.6	6.5	6.4	5.9
F1T3	6.9	6.7	6.4	6.5	6.2
F2T1	6.2	6.5	6.8	6.7	6.5
F2T2	7.2	7.3	6.8	6.8	6.7
F2T3	6.9	6.9	7.1	6.8	6.8

4.2.3.2. Variation of media EC value during crop growth period

Table 4.7 Variation of EC (dS/m) of coirpith during crop growing season

	DAYS AFTER TRANSPLANTING				
Treatments	**15**	**30**	**50**	**70**	**100**
F1TI	2.05	1.36	1.85	2.24	1.98
F1T2	1.26	1.06	1.73	1.75	2.03
F1T3	1.30	1.24	1.50	1.82	2.18
F2T1	1.25	0.92	1.27	1.48	1.85
F2T2	0.94	0.85	1.30	1.51	1.83
F2T3	1.12	1.15	1.28	1.13	1.65

Fig. 4.3 shows the variation of pH value of media during different stages of crop growth. From the figure it can be seen that, in all the five stages, the highest value of pH was observed for treatment F2T2 (7.3), followed by F2T2 (7.1) and F2T3 (7.1).The lowest value was observed in F1T1 (5.8) followed by the other F1 treatments. The pH values were found to decrease towards the later stage of crop growth period in almost all treatments.

In this study the pH range was within the satisfactory limits for the treatments F1T1, F1T2 and F1T3. Soil pH influences the solubility of nutrients. It also affects the activity of micro-organisms responsible for breaking down organic matter and for most chemical transformations in the soil.

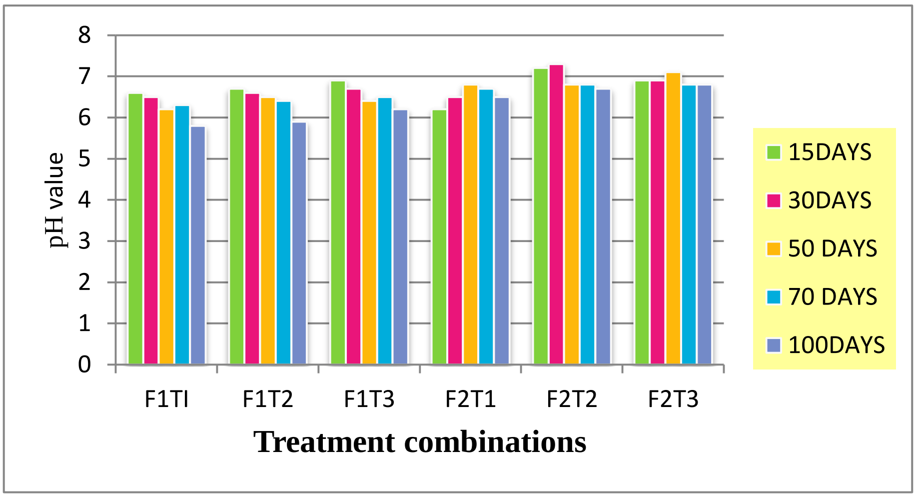


Fig. 4.3 pH variation of coirpith during the crop growing season

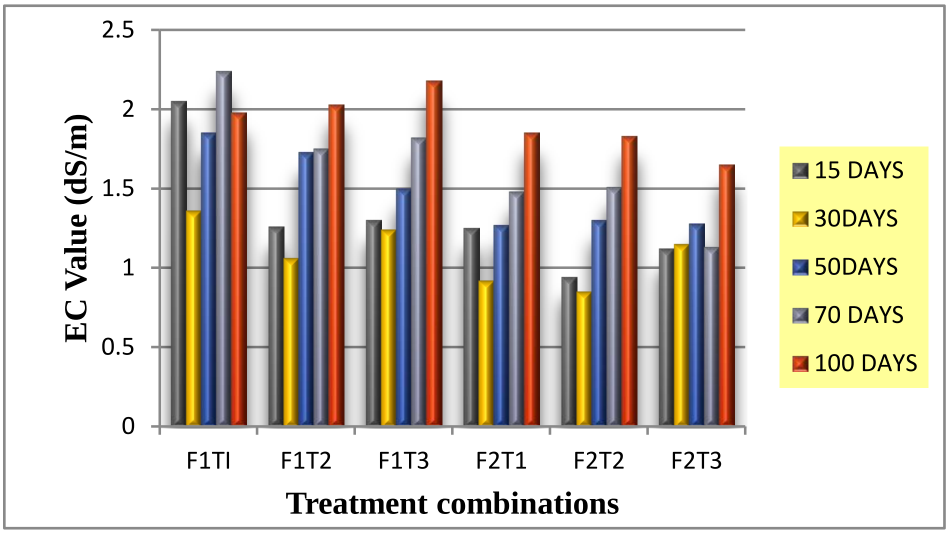


Fig. 4.4 EC (dS/m) variation of coirpith during crop growth period

Fig. 4.4 shows the fluctuation of electrical conductivity (dS/m) during crop growing season. The highest EC (dS/m) was observed in F1T1 (2.24) 70 days after transplanting. In this treatment EC was high in the initial stage also and the amendment with fresh water had to be given. The lowest EC was obtained in F2T2 (0.85) and F2T1 (0.92) 30 days after transplanting. EC values were high in F1 treatments and washing with fresh water was required occasionally.

The optimum level of EC for salad cucumber was 0.8 (initial stage), 1.2 (flowering stage) and 1.5 or 1.8 (fruiting stage). Higher EC will prevent nutrient absorption due to osmotic pressure and lower EC severely affect plant health and yield (Aatif *et al*., 2014).

From the Fig. 4.4 it is clear that almost all the values of EC for F2 treatments during different crop growth stages were within the ideal range.

4.3 FIELD EXPERIMENT

Evaluation of the effect of alternate growing systems and irrigation schedules on salad cucumber (variety *Hilton*) was performed as per the procedure explained in section 3.10. The various observations made during the crop growth period are as follows.

4.3.1 Irrigation Water Quality

Irrigation water quality analysis was done and the results are presented in the Table 4.8.

Table 4.8 Quality of irrigation water

Sl.No	**Parameters**	**Quantity**	**Remarks**
1	pH	6.3	Neutral
2	Electrical Conductivity (dS/m)	0.19	Safe
3	Carbonates (me/L)	Nil	Safe
4	Bicarbonates (me/L)	2.0	Moderate
5	Copper (Cu) (mg/L)	ND	Safe
6	Zinc (Zn) (mg/L)	ND	Safe
7	Iron (Fe) (mg/L)	0.031	Safe

Table 4.8 continued

Sl.No	**Parameters**	**Quantity**	**Remarks**
8	Manganese (Mn) (mg/L)	0.298	Safe
9	Calcium (Ca) (mg/L)	3.615	Safe
10	Magnesium (Mg) (mg/L)	4.604	Safe
11	Mg /Ca ratio	1.27	Safe
12	Sodium (Na) (mg/L)	11.7	-
13	Potassium (K) (mg/L)	3.2	Safe
14	SAR	0.96	Safe
15	RSC (me/L)	1.44	Moderate
16	Boron (mg/L)	ND	Safe

Most of values were within the safe limits for the irrigation water used for the study.

4.3.2 Measurement of climatic parameters inside the polyhouse

Microclimate inside the polyhouse was recorded during the crop growth period. Temperature and relative humidity were observed as per the procedure detailed in section 3.10.1.

Fig. 4.5 shows variation of temperature inside the polyhouse during crop growing season. The maximum temperature was recorded in the month of February (38.32^{o}C) and higher values were recorded during the last days of crop production period. The minimum temperature inside polyhouse was recorded in the month of December (24.03^{o}C) and the minimum temperature ranges from 24 to 27^{o}C. The afternoon temperature was high during the months of February and March.

In this study the high temperature inside polyhouse compared to open field was found to be an advantage as it benefitted the early maturity and yield. Cheema *et al.* (2004) reported that the early and higher yield of different vegetable crops inside the polyhouse was mainly because of better microclimate such as higher temperature (4-9°C more than the nearby open field) observed during winter months.

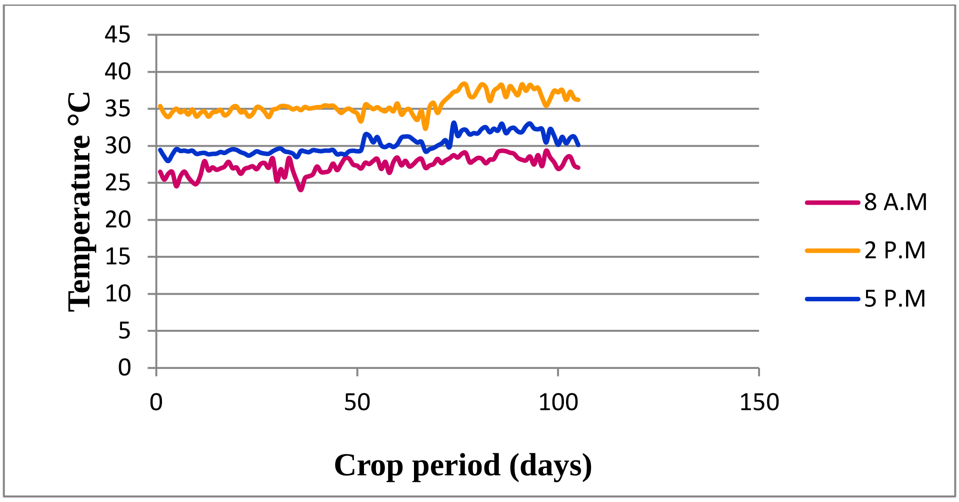


Fig. 4.5 Temperature variation observed inside the polyhouse during the crop period

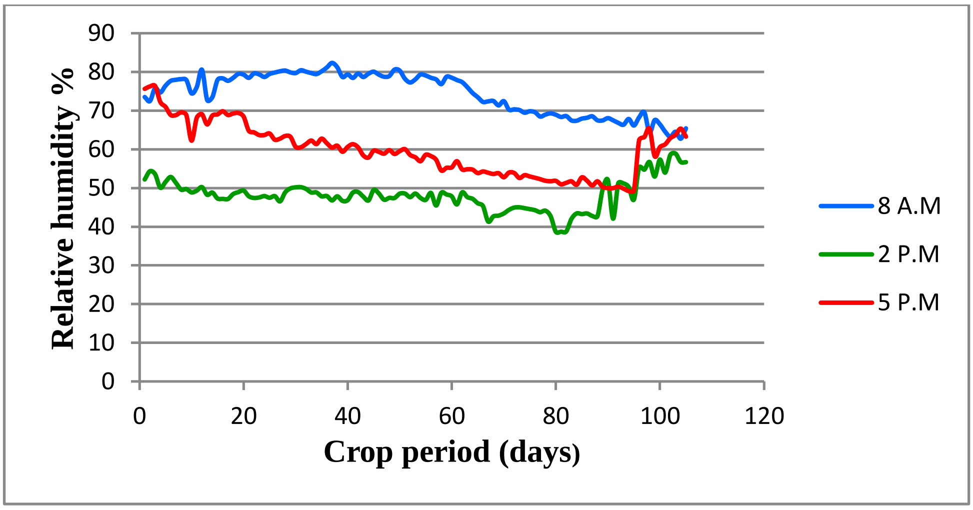


Fig. 4.6 Relative humidity variation recorded inside the polyhouse during the crop period

Fig. 4.6 shows variation of relative humidity during the crop period. From the figure it can be seen that the relative humidity was lower at noon hours and, higher relative humidity was recorded at morning and evening hours (8 am &

5 pm). The maximum relative humidity monitored was 82.35% (December) and minimum was 38.68 % (February).

The RH inside the polyhouse was always 5-10 % lower than that of the nearby open field. Parvej *et al*. (2010) had reported that better growth, development and yield of crop inside polyhouse were attained due to the higher (optimum) temperature and lower relative humidity during the winter months (December to February), which positively influenced the morpho-phenological and physiological events. In this study also, higher temperature and lower humidity were experienced inside polyhouse which benefitted crop growth positively.

4.3.3 Observation on Crop Growth and Yield Parameters

Data on biometric observations viz, length of main vine, number of leaves, number of flowers, number of fruits, mean fruit weight, fruit length, fruit diameter, yield per plant, root length and root mass for each treatment were observed during different stages of crop growth. The data were statistically analysed and the results are enumerated as three separate sections; effect of alternate growing systems used, effect of irrigation frequency and the interaction effect.

4.3.3.1 Effect of Alternate Growing Systems

Two types of growbags were used viz. vertical type growbag and lay flat type growbag. The effect of alternate growing systems on the crop growth and yield parameters are given in the following tables and the corresponding graphs are also included.

4.3.3.1.1 Length of Main Vine

The data on length of main vine at different stages of crop growth after transplanting as influenced by the effect of alternate growing systems are presented in the Table 4.9 and Fig. 4.7.

Table 4.9 Effect of alternate growing systems on the length of main vine during different growth stages

Type of grow bag	Length of main vine (cm)				
	10 DAT	**20 DAT**	**30 DAT**	**40 DAT**	**50 DAT**
F1	14.61^a	63.87^a	107.42^a	158.22^a	285.22^a
F2	14.76^a	62.56^a	106.07^a	156.44^a	282.66^a

(In each column, mean values followed by the same letter do not differ significantly at P = 0.05 according to the Post hoc tests).

From Table 4.9 and Fig. 4.7, it is clear that average length of main vine increased with crop growth and reached a maximum value of 285.22 cm in vertical type grow bag and 282.66 cm for lay flat type grow bag. Length of vine varied minimally at the last stages. The statistical results indicate that the length of main vine of cucumber plant at different growth stages did not differ significantly with respect to alternate growing systems.

4.3.3.1.2 Number of Leaves

Table 4.10 Effect of alternate growing systems on number of leaves during different growth stages

Type of grow bag	Number of leaves					
	10 DAT	**20 DAT**	**30 DAT**	**40 DAT**	**45 DAT**	**50 DAT**
F1	3^a	10^a	15^a	25^a	32^a	37^a
F2	3^a	10^a	14^a	24^a	31^a	36^a

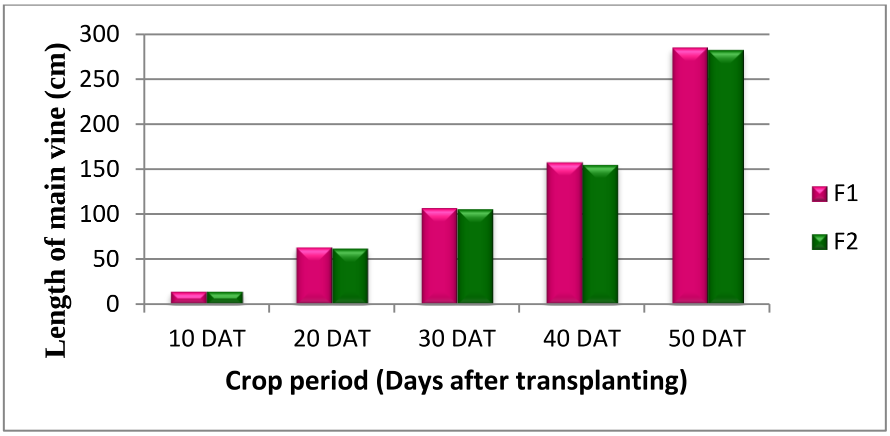


Fig. 4.7 Effect of alternate growing systems on length of main vine during different growth stages

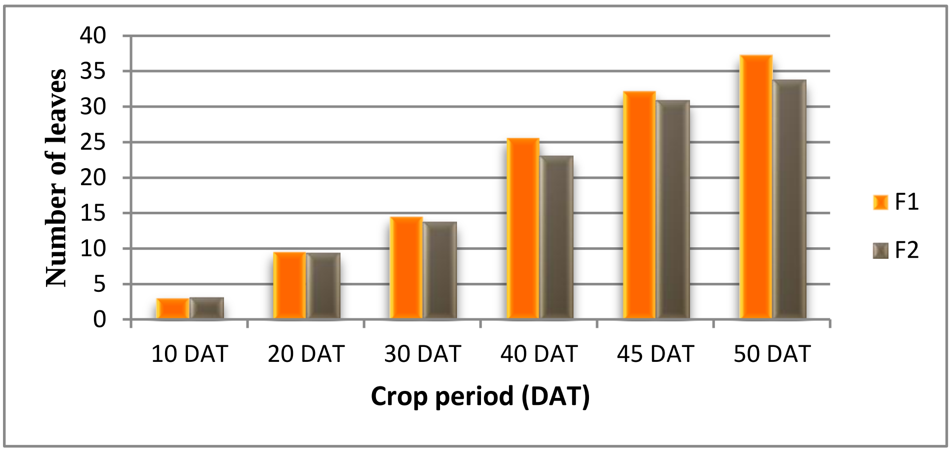


Fig. 4.8 Effect of alternate growing systems on number of leaves during different growth stages

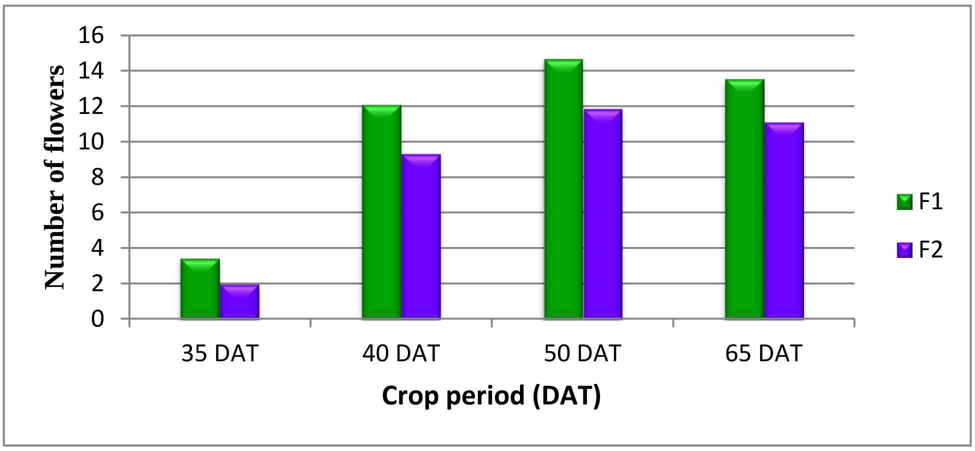


Fig. 4.9 Effect of alternate growing systems on number of flowers during different growth stages

Table 4.10 and Fig. 4.8 shows the variation of number of leaves during different growth stages. It is clear that vertical grow bag is found to give slightly better performance than lay flat type grow bag. The Number of leaves at the initial stages were almost equal and after mid stage, vertical type grow bag was found to have more leaves than lay flat type. The statistical results indicate that the number of leaves at different growth stages did not differ significantly with respect to alternate growing systems and all the treatments seem to be on par.

4.3.3.1.3 Number of Flowers

Table 4.11 Effect of alternate growing systems on number of flowers during different growth stages

Type of grow bag	**Number of flowers**			
	35 DAT	**40 DAT**	**50 DAT**	**65 DAT**
F1	4^a	12^a	15^a	14^a
F2	2^b	9^b	12^b	11^b

The number of flowers arising from plants in each treatments were counted at regular intervals and expressed as number of flowers per plant. The data are presented in the Table 4.11 and Fig. 4.9.

The number of flowers at different growth stages varied significantly with respect to alternate growing systems. From Fig. 4.9, It was observed that number of flowers in the vertical type grow bags were greater than lay flat grow bag. The maximum number of flowers observed was 15 for the F1 and 12 for F2, 50 days after transplanting (Table 4.11).

4.3.3.1.4 Fruit Quality Parameters and Yield

The number of fruits, mean values of fruit weight, fruit length, fruit diameter and total yield per plant are presented in the Table 4.12.

Table 4.12 Effect of alternate growing systems on fruit quality parameters and yield

Type of grow bag	Number of fruits per plant	Mean fruit weight per plant (kg)	Mean fruit length per plant (cm)	Mean fruit diameter per plant (cm)	Total yield per plant (kg)
F1	24^a	0.278^a	17.67^a	15.83^a	6.67^a
F2	23^b	0.239^b	15.87^b	14.41^b	5.55^b

All the fruit quality parameters and yield were found to vary significantly with respect to alternate growing systems. The Table 4.12 reveals that number of fruits per plant in vertical grow bag (24) was more than that in lay flat grow bag (23) and mean fruit weight per plant in vertical grow bag was found to be higher (0.278 kg) than that in lay flat grow bag (0.239 kg).

As in case of number of mean fruit weight per plant, the mean fruit length and diameter in vertical growbag was also found to be more (17.67 cm and 15.83 cm) than that in lay flat grow bag (15.87 cm and 14.41 cm).

The yield of crops from vertical type growbag was found to be better (6.67 kg) undoubtedly than lay flat type (5.55 kg) as all other vegetative parameters represented good performance. The statistical results indicate that the total yield per plant differs significantly with respect to types of growing systems. This might be due to better root development of crops grown in the vertical type grow bag, because it was filled with loose granular media which allow root to penetrate easily than that in lay flat type where the media was slightly compact.

4.3.3.1.5 Root Length and Root Mass

From Table 4.13, root length was observed to be high in vertical grow bag than that in lay flat type. This may be due to loose granular structure and larger depth of media in vertical type growbag compared to lay flat type where media was in slightly compacted form.

Table 4.13 Effect of alternate growing systems on root length and root mass per plant

Type of grow bag	**Mean root length per plant (cm)**	**Mean root mass per plant (g)**
F1	67.38^{a}	11.07^{b}
F2	48.55^{b}	12.95^{a}

Prince (2000) reported that addition of composted coirpith in other substrate produced significant increase in the number of roots and length of roots of plants. Coirpith was the substitute media used in this trial and root development might have improved due to this.

Table 4.13 shows that crops belonging to lay flat grow bags resulted in higher root mass compared to vertical type grow bag. It has been observed that types of root system were different for different types of growbag. Crops grown in layflat type growbags were found with denser, thick root system because of the compressed form of media. Lighter hairy roots were identified in crops raised in vertical growbag where the media was loose.

Regarding fruit quality parameters there was significant difference between alternate growing systems F1 and F2 and the values were better for F1 and yield wise there was significant difference between F1 and F2, the yield being higher for F1. Root mass was more for F2 but for remaining parameters, F1 was high.

The statistical results indicate that most of the biometric observations showed no significant difference between alternate growing systems. But quality parameters such as total number of fruits per plant, mean fruit length, mean fruit weight, mean fruit diameter and total yield per plant differ substantially between alternate growing systems. The number of flowers per plant and root length also showed significant variation.

4.3.3.2 Effect of Irrigation Interval

The water holding capacity of coirpith media is more and due to this the number of irrigations has been reduced and higher water use efficiency could be achieved. The influence of different irrigation treatment combinations on the crop growth and yield parameters are discussed in the following tables and the corresponding graphs are also included. The treatments in the experiments were;

T1 – Daily irrigation

T2 – Alternate day irrigation

T3 – Irrigation once in three days.

4.3.3.2.1 Length of Main Vine

Table 4.14 Effect of irrigation interval on length of main vine during different growth stages

Treatments	**Length of main vine (cm)**				
	10 DAT	**20 DAT**	**30 DAT**	**40 DAT**	**50 DAT**
T1	14.43^{a}	61.21^{c}	105.63^{c}	157.66^{ab}	283.23^{ab}
T2	14.65^{a}	63.41^{b}	109.11^{b}	158.83^{a}	284.66^{a}
T3	14.68^{a}	66.03^{a}	112.50^{a}	156.00^{b}	282.34^{b}

From Table 4.14 and Fig. 4.10 it can be observed that average lengths of vine increased with crop growth and reached a maximum value of 284.66 cm in alternate day irrigation (T2). In the initial stage length of main vine was on par for all the treatments. But towards the later stages length of main vine was better in T2 and T1 than T3.

4.3.3.2.2 Number of Leaves

As shown in Tables 4.15 and Fig. 4.11, it is seen that the number of leaves increased with crop growth and reached a maximum value of 37 at the maturity stage. The statistical results did not show significant difference at the initial stages but 20 days after transplanting there was significant difference between the values of number of leaves per plant in T1 and T3 and the difference of T1 and T2 were least significant.

Table 4.15 Effect of irrigation interval on number of leaves during different growth stages

Treatments	Number of leaves					
	10 DAT	20 DAT	30 DAT	40 DAT	45 DAT	50 DAT
T1	3.00^{a}	10^{a}	14^{b}	25^{b}	32^{ab}	36^{ab}
T2	3.00^{a}	10^{a}	14^{b}	26^{b}	34^{a}	37^{a}
T3	3.00^{a}	10^{a}	15^{a}	28^{a}	30^{b}	34^{b}

4.3.3.2.3 Number of Flowers

Table 4.16 Effect of irrigation interval on number of flowers during different growth stages

Treatments	Number of flowers			
	35 DAT	40 DAT	50 DAT	65 DAT
T1	3^{b}	10.00^{b}	13^{ab}	12^{ab}
T2	4^{a}	12.00^{a}	15^{a}	14^{a}
T3	4^{a}	12.00^{a}	12^{b}	11^{b}

Table 4.16 and Fig. 4.12 shows the effect of irrigation interval on number of flowers during different growth stages. The maximum number of flowers observed was 15 (50 days after transplanting) for alternate day irrigation trial. The statistical results indicate that the number of flowers at different growth stages differ significantly with respect to irrigation interval.

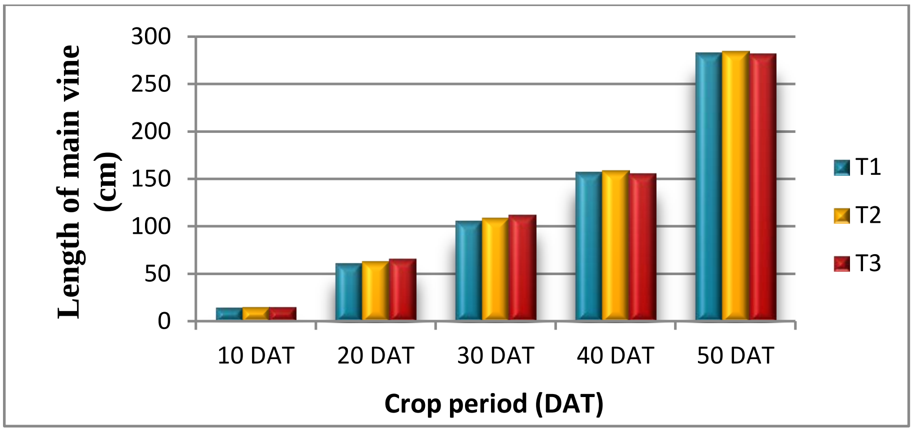


Fig. 4.10 Effect of irrigation interval on length of main vine during different growth stages

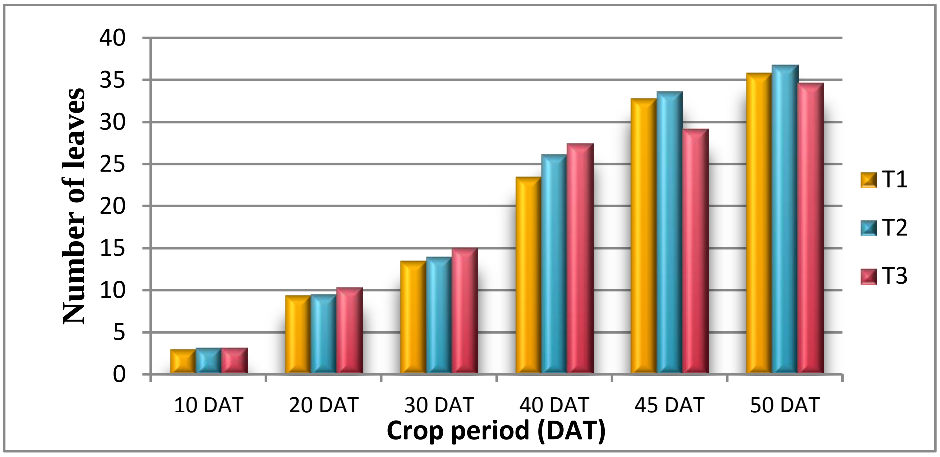


Fig. 4.11 Effect of irrigation interval on number of leaves during different growth stages

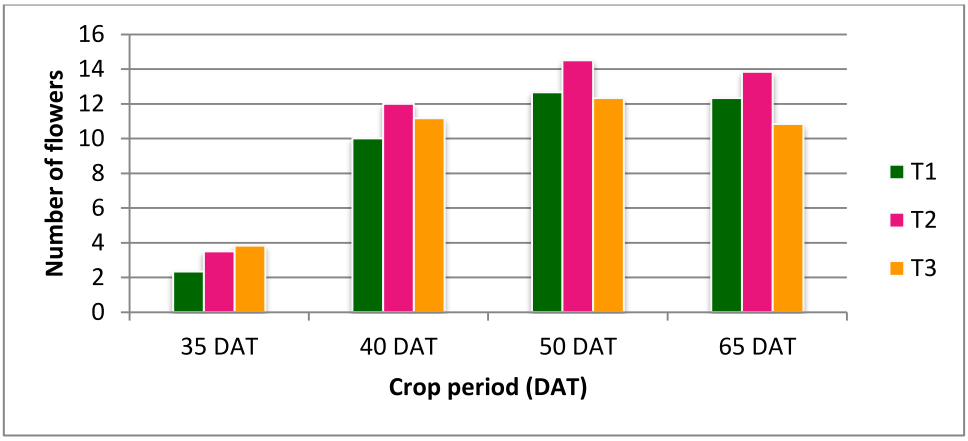


Fig. 4.12 Effect of irrigation interval on number of flowers during different growth stages

4.3.3.2.4 Fruit Quality Parameters and Yield

Table 4.17 Effect of irrigation interval on fruit quality parameters and yield

Treatments	**Number of fruits per plant**	**Mean fruit weight per plant (kg)**	**Mean fruit length per plant (cm)**	**Mean fruit diameter per plant (cm)**	**Total yield per plant (kg)**
T1	23^{ab}	0.252^{a}	16.71^{a}	14.79^{a}	5.82^{ab}
T2	26^{a}	0.265^{a}	17.25^{a}	15.54^{a}	6.81^{a}
T3	22^{b}	0.249^{a}	16.63^{a}	15.16^{a}	5.48^{b}

The maximum number of fruits observed was 26 for the alternate day irrigation trial followed by 23 for daily irrigation trial and 22 for irrigation once in three days interval. The statistical results indicate that the number of fruits differ significantly with respect to irrigation interval.

The maximum values of mean fruit weight, mean fruit length, mean fruit diameter and total yield per plant were observed and alternate day irrigation trial gave higher values 0.265 kg, 17.25 cm, 15.54 cm and 6.81 kg per plant respectively. Regarding fruit weight, fruit length and fruit diameter the treatments were all on par. But yield wise there was significant difference between T2 and T3 and the yield was the highest for T2 (Table 4.17).

4.3.3.2.5 Root Length and Root Mass

Table 4.18 shows that the effect of irrigation interval on mean root length and root mass. Maximum root length observed was 62.75 cm for alternate day irrigation. Shortest length was recoded as 54.91 cm for irrigation once in three days because when irrigation duration varies quantity of water applied will be varied accordingly and so does the water uptake. The root development will also be changed accordingly. In case of root mass also alternate day irrigation gives higher value (13.25 g). The results showed significant difference between treatments in the case of mean root length and mean root mass per plant and varied significantly between T2 and T3 but no significant difference with T1 (daily irrigation). So there is no need to suggest daily irrigation for the sake of root development.

Table 4.18 Effect of irrigation interval on mean root length and root mass per plant

Treatments	**Mean root length per plant (cm)**	**Mean root mass per plant (g)**
T1	58.75^{b}	12.04^{ab}
T2	62.75^{a}	13.25^{a}
T3	54.91^{c}	10.95^{b}

High water-holding capacity and high air filled porosity are the desirable qualities of coirpith media and it enhanced root and shoot development throughout crop period. So it reduces the frequency of irrigation as there was a scope to reduce the quantity of water application. The crop was transplanted into growbags during winter season. Along with this during initial stage the crop needs less amount of water. For that reason crops grown under once in three days irrigation were found with better vegetative growth till flowering stage. But after flowering stage the season changed to summer in which crop water requirement was high due to increased evapotranspiration rate. So at this stage crops with alternate day irrigation resulted in better performance.

Similar result was reported by Shao *et al.* (2010) that reduce water supply at seedling stage, control water supply at flowering stage and increase water supply at fruiting stage of cucumber can increase yield and WUE.

Xiabo *et al.* (2012) reported that water requirement was close at plantlet stage with about 0.55 mm/d, but it increased more quickly in winter-spring than in autumn-winter since early bloom. During fruit bearing stage water requirement kept over 2.0 mm/d in winter-spring while about 40% of this level at the same stage in autumn-winter.

Compared to crops under alternate day irrigation, crops grown under daily irrigation schedule resulted in reduced yield and other growth parameters like length of main vine, number of leaves, number of flowers, fruit parameters, root length etc followed by crops under once in three days irrigation.

4.3.3.3 Effect of alternate growing systems and irrigation interval on crop performance

The influence alternate growing systems and irrigation interval on the crop growth and yield parameters are discussed in the following sections.

4.3.3.3.1 Length of Main Vine

Table 4.19 Effect of alternate growing systems and irrigation interval on length of main vines during different growth stages

Treatment combinations	**Length of main vine (cm)**				
	10 DAT	**20 DAT**	**30 DAT**	**40 DAT**	**50 DAT**
F1T1	14.23^{a}	62.30^{ab}	97.03^{b}	152.33^{b}	281.67^{ab}
F1T2	14.56^{a}	63.30^{ab}	106.90^{ab}	159.33^{a}	288.00^{a}
F1T3	14.83^{a}	65.03^{a}	116.33^{a}	161.00^{a}	290.00^{a}
F2T1	14.34^{a}	58.13^{c}	94.23^{b}	153.00^{ab}	282.00^{ab}
F2T2	14.42^{a}	63.53^{ab}	107.33^{ab}	158.33^{a}	283.33^{ab}
F2T3	14.73^{a}	66.03^{a}	102.67^{ab}	155.00^{ab}	278.67^{b}

From the Table 4.19 and Fig. 4.13 it can be observed that lengths of main vine increased with crop growth and reached a maximum value of 290 cm in vertical type grow bag with irrigation once in three days followed by 288 cm in vertical type grow bag with alternate day irrigation. In the initial stage length of main vine was on par for all the treatments. but towards the later stages length of main vine was better in F1T2 and F1T3 than all the treatments of layflat grow bag.

4.3.3.3.2 Number of Leaves

Table 4.20 Effect of alternate growing systems and irrigation interval on number of leaves during different growth stages

Treatment combinations	**Number of leaves**					
	10 DAT	**20 DAT**	**30 DAT**	**40 DAT**	**45 DAT**	**50 DAT**
F1T1	3^{a}	9^{ab}	14^{ab}	24^{ab}	33^{a}	42^{a}
F1T2	3^{a}	8^{b}	14^{ab}	23^{ab}	28^{b}	41^{a}
F1T3	3^{a}	1^{a}	16^{a}	28^{a}	36^{a}	41^{a}
F2T1	3^{a}	9^{ab}	13^{b}	23^{b}	33^{ab}	35^{ab}
F2T2	3^{a}	9^{ab}	14^{ab}	23^{ab}	30^{ab}	35^{ab}
F2T3	3^{a}	10^{ab}	14^{ab}	25^{ab}	30^{ab}	33^{b}

The Table 4.20 and Fig. 4.14 gives the data of number of leaves during different growth stages based on interaction effect. Maximum number of leaves was observed to be 42 in F1T1 followed by 41 (F1T3 and F1T2) and 35 (F2T1). In the initial stage, number of leaves was on par for all the treatments. But towards the later stages number of leaves was better in all the irrigation treatments with vertical growbag than the treatments of layflat type growbag.

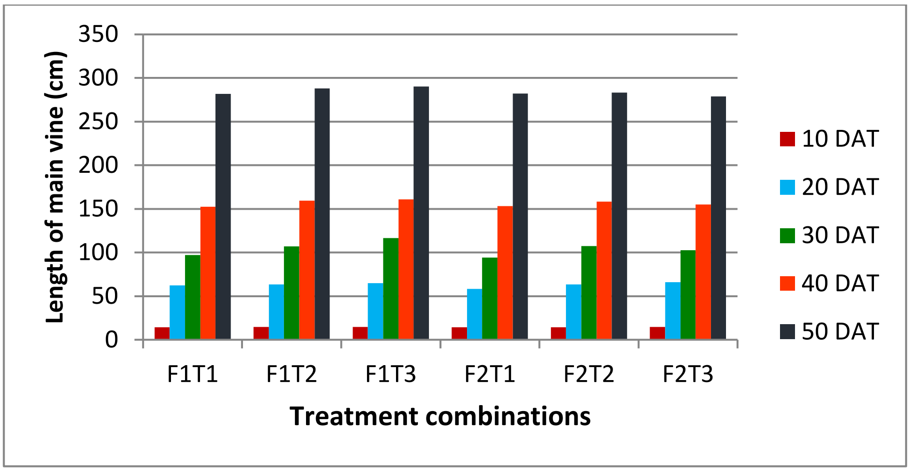


Fig 4.13 Effect of alternate growing systems and irrigation interval on length of main vine during different growth stages

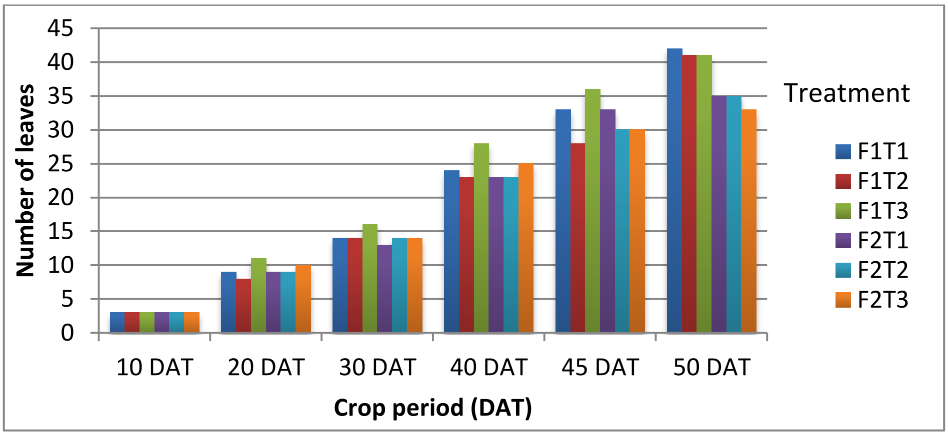


Fig. 4.14 Effect of alternate growing systems and irrigation interval on number of leaves during different growth stages

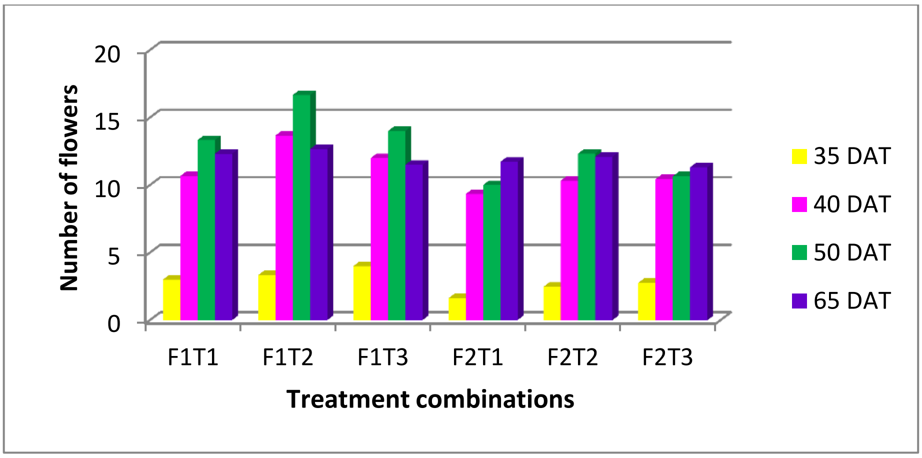


Fig. 4.15 Effect of alternate growing systems and irrigation interval on number of flowers during different growth stage

4.3.3.3.3 Days to First Flowering

Table 4.21 Effect of alternate growing systems and irrigation interval on days to first flowering

Treatment combinations	Days to first flowering
F1T1	20
F1T2	18
F1T3	15
F2T1	21
F2T2	19
F2T3	22

In polyhouse with coirpith media the earliest flowering was observed in F1T3 after 15 days of transplanting and F1T2 was late by three days. Remaining treatments have no significant difference in first flowering. Crop at the flowering stage is shown in Plate 4.1.

4.3.3.3.4 Number of Flowers

Table 4.22 Effect of alternate growing systems and irrigation interval on number of flowers during different growth stages

Treatment combinations	Number of flowers			
	35 DAT	40 DAT	50 DAT	65 DAT
F1T1	3.00^{ab}	11^{ab}	13^{ab}	12^{ab}
F1T2	3.00^{ab}	13^{a}	17^{a}	13^{a}
F1T3	4.00^{a}	12^{a}	14^{ab}	12^{ab}
F2T1	2.00^{b}	10^{b}	10^{d}	12^{ab}
F2T2	3.00^{ab}	10^{b}	12^{bc}	12^{ab}
F2T3	3.00^{ab}	11^{ab}	10^{cd}	11^{b}

Table 4.22 and Fig. 4.15 shows the combined effect of alternate growing systems and irrigation schedules on the number of flowers during different growth

stages. The highest number of flowers was for F1T2 (17) followed by F1T3 (14). Both values were observed 50 days after transplanting.

Plate 4.1 Crop at the flowering stage

Plate 4.2 Crop at fruiting stage

4.3.3.3.5 Fruit Quality Parameters and Yield

Table 4.23 Effect of alternate growing systems and irrigation interval on fruit parameters and yield

Treatment combinations	**Number of fruits per plant**	**Mean fruit weight per plant (kg)**	**Mean fruit length per plant (cm)**	**Mean fruit diameter per plant (cm)**	**Total yield per plant (kg)**
F1T1	22^{ab}	0.275^{ab}	17.67^{ab}	15.83^{a}	6.34^{b}
F1T2	26^{a}	0.292^{a}	18.50^{a}	16.32^{a}	7.56^{a}
F1T3	24^{ab}	0.265^{ab}	16.83^{ab}	15.37^{ab}	6.20^{bc}
F2T1	21^{b}	0.248^{c}	15.16^{c}	13.73^{b}	5.43^{bc}
F2T2	25^{a}	0.251^{bc}	16.00^{bc}	14.33^{ab}	6.07^{bc}
F2T3	22^{ab}	0.262^{ab}	16.43^{ab}	15.16^{ab}	5.03^{c}

From the Table 4.23 it can be observed that number of fruits was highest in vertical type grow bag with alternate day irrigation (26) followed by F2T2 (25) and F1T3 (24). The mean fruit weight per plant was observed in this experiment. The highest fruit weight was recorded in F1T2 (292 kg) followed by F1T1 (275 kg) F1T3 (265 kg) and F2T3 (262 kg).

From the Table 4.23 it can be understood that mean fruit length was maximum in F1T2 (18.50 cm) and minimum length was observed in F2T1 (15.16 cm).

The highest diameter was for F1T2 (16.32 cm) followed by F1T1 (15.83 cm). The next higher value was for F1T3. In all cases the fruits from vertical type growbag were observed to be having higher diameter.

Table 4.23 and Fig. 4.16 shows the combined effect on total yield per plant. The highest yield was for F1T2 (7.56 kg/plant) followed by F1T1 (6.34 kg/plant). The next higher value was for F1T3. In all cases the vertical type growbag proved to be superior in terms of yield. Harvested salad cucumber is shown in Plate 4.3.

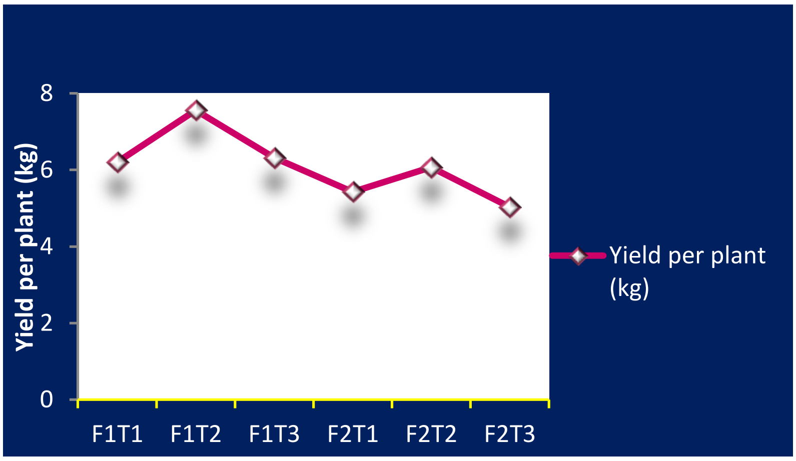


Fig. 4.16 Effect of alternate growing systems and irrigation interval on total yield per plant

Plate 4.3 Harvested salad cucumber

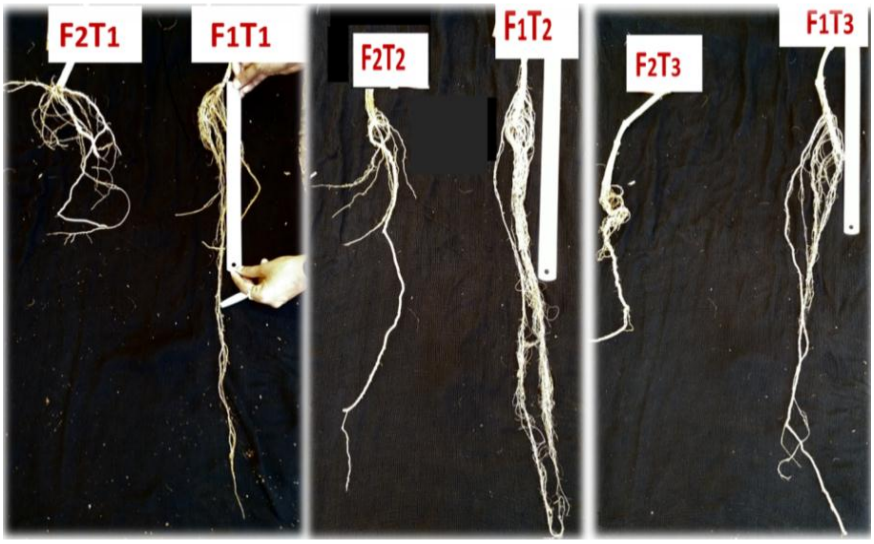


Plate 4.4 Root system for different treatment combinations

4.3.3.3.6 Root Length and Root Mass

Table 4.24 Effect of growing systems and irrigation interval on mean root length and root mass per plant

Treatment combinations	**Mean root length per plant (cm)**	**Mean root mass per plant (g)**
F1T1	66.67^{a}	09.25^{c}
F1T2	70.33^{a}	09.40^{c}
F1T3	63.16^{ab}	08.96^{c}
F2T1	48.83^{cd}	12.83^{a}
F2T2	50.16^{c}	13.50^{a}
F2T3	43.67^{d}	10.93^{ab}

Plate 4.4 shows the root systems for different treatment combinations. From Table 4.24 the variation of root length and root mass with alternate growing systems and irrigation schedules can be observed. The maximum root length observed was 70.33 cm for F1T2 followed by 66.67 cm for F1T1. Next higher length was 63.16 cm for F1T3. Shortest length observed was 43.67 cm for F2T3. In all the cases vertical grow bag gave higher value than lay flat growbag. But in case of root mass lay flat growbag gave better performance than vertical growbag. Highest root mass recorded was 13.50 g for lay flat growbag with alternate day irrigation (F2T2) followed by F2T1 (12.83 g) and F2T3 (10.93 g). It may be due to the fact that crops grown in layflat type growbags were found with denser and thicker root system because of the compressed form of media present. More lighter and hairy root system was identified in crops raised in vertical growbag where the media was loose and of larger depth.

4.3.3.3.7 Plant Dry Weight

The Table 4.25 shows the effect of growing systems and irrigation interval on plant fresh and dry weight. The maximum fresh and dry weight was obtained in F1T1 with 465 g and 56 g. Minimum dry weight was observed in F2T3 (36 g).

Table 4.25 Effect of growing systems and irrigation interval on plant fresh and dry weight

Treatment combinations	**Plant fresh weight (g)**	**Plant dry weight (g)**
F1T1	465	56
F1T2	420	47
F1T3	395	41
F2T1	458	53
F2T2	405	45
F2T3	390	36

The statistical analysis of the number of flowers, mean yield, mean fruit weight, mean fruit length and diameter showed that there was a significant difference between both growing systems and irrigation interval in all the measured parameters using the Tukey post-hoc test. It is clear that the type of growing systems causes a big difference in plant growth. Strong, healthy plants require media with good structure and texture, the proper pH level, and the proper nutrients. Well-balanced media will produce beautiful plants with lush foliage, brilliant blooms and abundant, healthy fruits. The right type of media is really the key to healthy plant growth. Vertical type growbag filled with coirpith showed better performance than lay flat type growbag.

In case of irrigation interval crops under once in three days irrigation showed better performance in the initial stage (winter season). But during mid-season stage (summer season) alternate day irrigation resulted in better growth and yield than once in three days irrigation. During initial stage the crop needs less amount of water. For that reason crops under once in three days irrigation were found with better vegetative growth till flowering stage. But after flowering stage the season were changed to summer and water uptake of plant increased. Crop water requirement was high due to increased evapotranspiration rate. So at this stage crops with alternate day irrigation resulted in better performance. The results of this experiment showed that it is possible to obtain satisfactory yields of hybrid cucumber grown under polyhouse conditions in coirpith filled vertical growbags and alternate day irrigation.

Rockwool is being replaced with coirpith growbags because it performs as well and its disposal has no harmful environmental problems (Noguera *et al*., 2000; Abad *et al.*, 2001).

Commercial hydroponic growers worldwide are producing excellent quality and high-yield vegetable and cut flower crops using coco peat. (Noguera *et al*., 2000).

Preenu (2013) reported that cultivation of salad cucumber in naturally ventilated polyhouse with fertigation trials in soil as media gave average length of vine 273 cm, maximum number of leaves was 40, and maximum number of flowers was 19. These values were found to be in agreement with the results of this study. But yield wise Preenu came up with 2.92 kg/plant whereas a remarkable difference was noticed in this study as the yield was 7.56 kg/plant.

4.3.4 Quality Analysis

The texture of salad cucumber was determined by conducting compression tests using the texture analyzer and the results are shown in the Table 4.26 and Fig. 4.17. The texture is defined by two general terms namely, firmness and toughness. The Fig. 4.19 indicates that the firmness and toughness of salad cucumber is not varying with respect to treatment.

From Fig. 4.17 it was observed that the maximum value of firmness and toughness was recorded as 24.69 N and 59.38 N.sec respectively and in all the treatments the values of firmness and toughness shows almost same value. So it is clear that texture of salad cucumber was not significantly influenced by alternate growing systems and varying irrigation schedules. Similar findings were observed by Preenu, (2013).

Table 4.26 Effect of growing systems and irrigation interval on texture of salad cucumber

Treatments	Firmness (N)	Toughness (N.sec)
F1TI	23.34	57.66
F1T2	24.69	59.38
F1T3	23.91	59.19
F2T1	24.68	58.21
F2T2	25.18	59.97
F2T3	24.59	59.09

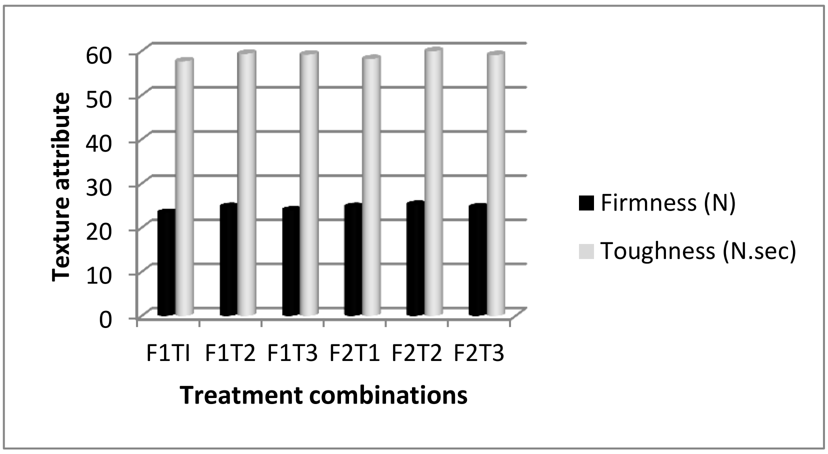


Fig 4.17 Effect of treatments on texture of salad cucumber

4.3.5 Irrigation Water Use Efficiency

Table 4.27 and Fig. 4.18 shows the water use efficiency values obtained under the various treatments. Water use efficiency is greatly improved by scheduling irrigation when plants can utilize the water more effectively.

From the Fig. 4.18 it is seen that irrigation interval significantly affected irrigation water use efficiency (IWUE). The highest IWUE was for F1T3 (2590 kg/ ha.mm) with once in three days irrigation and lowest was F2T1 (446.14 kg/ ha.mm) with daily irrigation. In an area with water shortage as well as problematic soil, cultivation using coirpith with once in three days irrigation can be suggested as WUE was observed very high for the crops under once in three days irrigation compared to other two. Even though crops under alternate day irrigation were identified with remarkable yield, once in three days irrigation can be suggested in the areas experiencing water shortage.

The soilless culture demands 10 times less water than traditional cultivation for the same yield (Melgarejo and Martinez., 2007).

Table 4.27 Variation of irrigation water use efficiency for different treatments

Treatments	**Yield (kg/ha)**	**Water used (mm)**	**Water use efficiency (kg/ha.mm)**
F1TI	136566.63	263	519.26
F1T2	163361.35	131	1247
F1T3	133973.59	87.67	2590
F2T1	117334.93	263	446.14
F2T2	131164.47	131	1001.255
F2T3	108691.47	87.67	1239.78

4.3.6 Fertilizer Use Efficiency

The efficiency with which the fertilizers are being used up by plants is indicated by the FUE values. Nitrogen, Phosphors, and Potassium are essential nutrients for crop production. The values for this study are presented in Table 4.28 and Fig. 4.19.

Table 4.28 Variation of fertilizer use efficiency for different treatments

Treatments	**Yield (kg/ha)**	**NFUE (kg/ha.kg N)**	**PFUE (kg/ha.kg P)**	**KFUE (kg/ha.kg K)**
F1TI	136566.63	735.61	1419.61	382.92
F1T2	163361.35	879.94	1698.14	458.05
F1T3	133973.59	721.63	1392.65	375.65
F2T1	117334.93	632.02	1219.69	329.00
F2T2	131164.47	706.51	1363.45	367.77
F2T3	108691.47	585.46	1129.84	304.76

From Fig. 4.19 it is clear that Nitrogen FUE was highest for F1T2 (879.94 kg/ha.kg N) and then for F1T1 and F1T3. (735.61 and 721.63 kg/ha.kg N) respectively. Phosphorus FUE (1698.14 kg/ha.kg P) and potassium FUE (458.05 kg/ha.kg K) were also greater in F1T2. The figure gives a clear indication on the difference in ranges of each efficiency. Potassium was applied in greater quantities compared to the Nitrogen and Phosphorus and hence KFUE is in low ranges.

In soilless culture use of drip irrigation with fertigation allows growers to improve the synchronization between nutrient application and crop nutrient uptake which leads to higher water and fertilizer use efficiencies (Metin *et al.*, 2010).

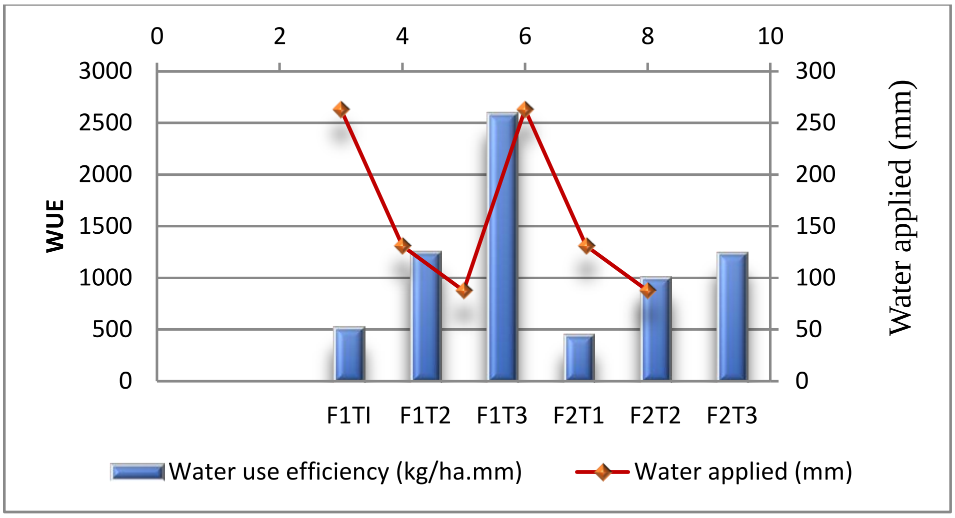


Fig. 4.18 Variation of irrigation water use efficiency for different treatments

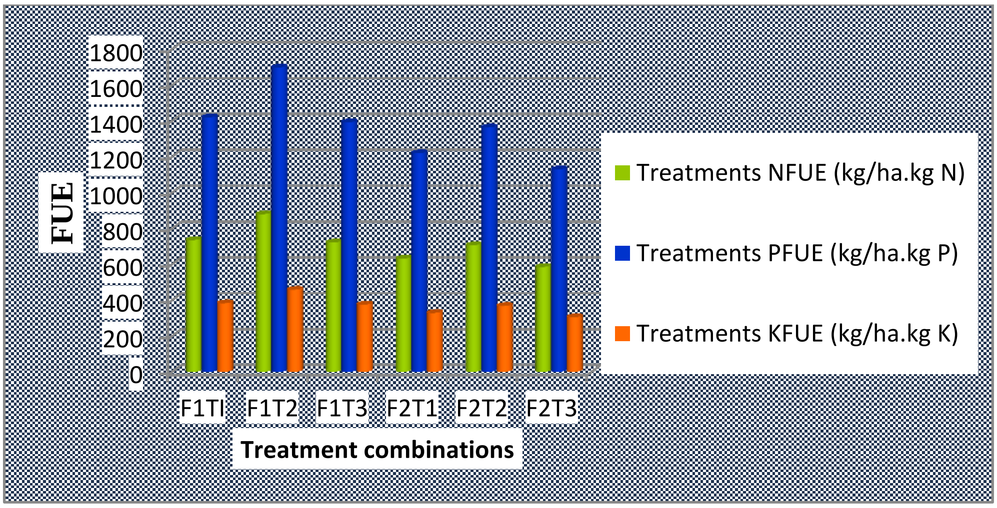


Fig. 4.19 Variation of fertilizer use efficiency for different treatments

4.4 CONSOLIDATED DATA ON THE EFFECT OF ALTERNATE GROWING SYSTEMS AND IRRIGATION SCHEDULES ON CROP PERFORMANCE

Table 4.29 shows consolidated data on the effect of alternate growing systems and irrigation schedules on crop performance.

Table 4.29 Consolidated data on the effect of alternate growing systems and irrigation schedules on crop performance

Treatments	Length of main vine in cm	Number of leaves	Number of flowers	Number of fruits /plant	Mean fruit weight /Plant	Mean fruit length /Plant)	Mean fruit diameter/ plant	Total yield/plant	Water Use Efficiency Kg/ha	Nitrogen Fertilizer Use Efficiency in Kg/ ha KgN	Phosphorous Fertilizer Use Efficiency in Kg/ ha KgP	Potassium Fertilizer Use Efficiency in Kg/ ha KgK	Root length/plant	Root mass/plant
F1	**285.22**	**36**	**15**	**24**	**0.278**	**17.67**	**15.83**	**6.67**					**67.38**	11.07
F2	282.66	36	12	23	0.239	15.87	14.41	5.55					48.55	**12.95**
T1	283.23	36	13	23	0.252	16.71	14.79	5.82					58.75	12.04
T2	**284.66**	**37**	**15**	**26**	**0.265**	**17.25**	**15.54**	**6.81**					**62.75**	**13.25**
T3	282.34	35	12	22	0.249	16.63	15.16	5.48					54.91	10.95
F1TI	281.67	**41**	13	22	0.275	17.67	15.83	6.34	519	735	1419	382.92	66.67	09.25
F1T2	288.00	41	**17**	**26**	**0.292**	**18.50**	**16.32**	**7.56**	1247	**879**	**1698**	**458.05**	**70.33**	9.40
F1T3	**290.00**	41	14	24	0.265	16.83	15.37	6.20	**2590**	721	1392	375.65	63.16	08.9
F2T1	282.0	35	10	21	0.248	15.16	13.73	5.43	446	632	1219	329.00	48.83	12.83
F2T2	283.33	35	12	25	0.251	16.00	14.33	6.07	1001	706	1363	367.77	50.16	**13.50**
F2T3	278.67	33	11	22	0.262	16.43	15.16	5.03	1239	585	1129	304.76	43.67	10.93

So the overall analysis of the effect of alternate growing systems reveals that all the vegetative parameters as well as yield of crops of ordinary vertical type growbag was found to be better than lay flat type. Even though lay flat type growbag is a novel growing system no additional advantages were found. Compared to crops under daily and once in three days irrigation alternate day irrigation resulted in best performance in all the growth parameters and yield. The growth parameters were found to be better in crops under once in three days irrigation compared to daily irrigation except number of flowers and yield.

This study revealed that salad cucumber *Hilton* variety with once in three days irrigation at initial stage followed by alternate day irrigation during mid-season stage and late stage in vertical type grow bag results in good performance in terms of crop growth and produce quality.

Even though crops under alternate day irrigation were identified with remarkable yield, for an area with water shortage as well as problematic soil, cultivation using coirpith with once in three days irrigation can be suggested. The WUE was observed very high for the crops under once in three days irrigation compared to daily and alternate day irrigation. In an area with sufficient amount of water alternate day irrigation can be suggested.

Suggestions for Future Research

- Vertical growbag with different crops can be used for further irrigation scheduling studies.

- Research by incorporating coarser fraction as drainage layer beneath the coirpith to improve the performance.

- Water use efficiency studies with different media mixes can be done for getting better results.

Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

Field experiment on the effect of alternate growing systems and irrigation schedules for soilless culture of Salad Cucumber under drip irrigation were conducted inside the naturally ventilated polyhouse in the research plot of Precision Farming Development Centre in the instructional farm of KCAET, Tavanur, during November 2014 to March 2015. In the present study coirpith was selected as substrate media and data on climatic parameters, plant morphological parameters, physico-chemical and engineering properties of media and yield parameters were recorded. The summary of the results obtained from the experiments and the conclusions drawn out of field experimentation are presented in this chapter.

The crop water requirement of salad cucumber was determined using the CROPWAT model. Four main datasets were used as inputs in the CROPWAT estimation: climate, crop, soil and rainfall. The details of these parameters were fed to the CROPWAT model to estimate the crop water requirement. The total crop water requirement of salad cucumber obtained was 30.45 cm.

The polyhouse was oriented east–west with an area of 292 m^2 (36 m length and 8 m width) and the study area was 50 m^2. In this experiment, the land was levelled and beds were raised. Salad cucumber variety *Hilton* was chosen for cultivation. The experiment was laid out in factorial completely randomized block design. The plot was divided into 3 rectangular sections having three treatments with three replications and two factors. Two factors were two types of grow bags viz. open top grow bag F1 (vertical type) and lay flat growbag F2 (horizontal type) with coirpith media. Six salad cucumber plants were planted under each replication. Treatment details consisted of F1T1 (Black poly bag with daily irrigation), F1T2 (Black poly bag with alternate day irrigation), F1T3 (Black poly bag with irrigation once in 3 days), F2T1 (Lay flat grow bags with daily irrigation), F2T2 (Lay flat grow bags with alternate day irrigation), and F2T3 (Lay flat grow bags with irrigation once in 3 days).

Bulk density, particle density, moisture percent in air dry media and volume expansion of coirpith were analyzed using Keen Rackzowski box. The value of bulk density and particle density were observed as 0.12 and 0.17 g/cc, which is low as compared to other substrates. The moisture percent in the air dry media was 8.21 % and volume expansion was high (38.25 %). Porosity characteristics of coirpith were determined using saturation and drainage method. The values of total porosity, aeration porosity and water filled porosity were 87.50, 28.12 and 59.38 % respectively. The values of Field capacity and Permanent wilting point for coirpith samples were obtained using pressure plate apparatus. Available water for coirpith was monitored high (275.05 %). The variation of pH value of media during the crop growth period was observed using digital pH meter. The highest value of pH was observed for treatment F2T2 (7.3), followed by F2T2 (7.1) and F2T3 (7.1).The lowest value was observed in F1T1 (5.8) followed by the other F1 treatments. The pH values were found to decrease towards the later stage of crop growth period in almost all treatments. The fluctuation of electrical conductivity (dS/m) during crop growing season was observed using digital EC meter. The highest EC (dS/m) was observed in F1T1 (2.24) 70 days after transplanting. In this treatment EC was high in the initial stage also and the amendment with fresh water had to be given. The lowest EC was obtained in F2T2 (0.85) and F2T1 (0.92) 30 days after transplanting. EC values were high in F1 treatments and washing with fresh water was required occasionally. The optimum level of EC for salad cucumber was 0.8 (initial stage), 1.2 (flowering stage) and 1.5 or 1.8 (fruiting stage). Almost all the values of EC for F2 treatments during different crop growth stages were within the ideal range.

Fertigation in coirpith include both macro and micro nutrients applied as water soluble fertilizers from two tanks (tank A and tank B) through fertigation system with fertilizer tank and venturi. Tank A having macro nutrients and tank B having micro nutrients. Same quantities of fertilizers were applied in each treatment by maintaining pH and electrical conductivity.

The data on micro climate such as temperature and relative humidity were periodically recorded in polyhouse. Higher humidity was observed inside the polyhouse during morning hours and value gradually decreased in the afternoon because of increase in temperature. The maximum temperature was recorded in the month of February (38.32 ^{o}C) and the higher values were recorded during the last days of crop production period.

Data on vegetative parameters like length of main vine, number of leaves, number of flowers, number of fruits, mean values of fruit weight, fruit length and fruit diameter, total yield per plant, root length and root mass for each treatment were observed during different stages of crop growth. Statistical analyses of the results were carried out in three separate sections based on the effect of alternate growing systems used, effect of irrigation frequency and their interaction effect.

From the effect of alternate growing systems (F1- Vertical growbag and F2-Horizontal growbag) on these crop growth and yield parameters, length of main vine and number of leaves increased with growth stages and maximum value was obtained in vertical growbag. But the values did not differ significantly with respect to alternate growing systems. Number of flowers in the vertical type grow bags were greater than lay flat grow bag and maximum number of flowers observed was 15 for F1 and 12 for F2. Number of fruits per plant in vertical grow bag (24) was more than that in lay flat grow bag (23). Mean fruit weight per plant, mean fruit length and mean fruit diameter were also larger in vertical grow bag than that in lay flat grow bag. The yield of crops from vertical type growbag was found to be better (6.67 kg) undoubtedly than lay flat type (5.55 kg) as all other vegetative parameters resulted in good performance.

Root length was observed to be high in vertical grow bag than that in lay flat type. This may be due to loose granular structure and larger depth of media in vertical type growbag compared to lay flat type where media was in slightly compacted form. Crops belonging to lay flat grow bags resulted in higher root mass compared to vertical type grow bag. It has been observed that types of root system was different for different types of growbag. Crops grown in layflat type growbags were found with denser, thick root system because of the compressed form of media. Lighter hairy roots were identified in crops raised in vertical growbag where the media was loose.

Regarding fruit quality parameters there was significant difference between alternate growing systems F1 and F2 and the values were better for F1 and yield wise there was significant difference between F1 and F2, the yield being higher for F1. Root mass was more for F2 but for remaining parameters, F1 was high.

From the analyses of the influence of different irrigation treatment combinations [Daily irrigation (T1), Alternate day irrigation (T2) and Irrigation once in three days (T3)] on the crop growth and yield parameters, the average lengths of vine increased with crop growth and reached a maximum value of 284.66 cm in alternate day irrigation (T2). In the initial stage length of main vine was on par for all the treatments. But towards the later stages length of main vine was better in T2 and T1 than T3. The number of leaves increased with crop growth and reached a maximum value of 36.84 at the maturity stage. The statistical results did not show significant difference at the initial stages but 20 days after transplanting in every stages there was significant difference between the values of number of leaves per plant in T1 and T3 and the difference of T1 and T2 were least significant. The maximum number of fruits observed was 25.58 for the alternate day irrigation trial followed by 23.37 for daily irrigation trial and 22.40 for irrigation once in three days interval. The statistical results indicate that the number of fruits differ significantly with respect to irrigation interval.

The maximum values of mean fruit weight, mean fruit length, mean fruit diameter and total yield per plant were observed and alternate day irrigation trial gave higher values 0.265 kg, 17.25 cm, 15.54 cm and 6.81 kg per plant respectively. Regarding fruit weight, fruit length and fruit diameter the treatments were all on par. But yield wise there was significant difference between T2 and T3 and the yield was high for T2. Maximum root length observed was 62.75 cm for alternate day irrigation. Shortest length was recoded as 54.91 cm for irrigation once in three days because when irrigation duration and quantity of water applied varies, the water uptake will be varied and hence the root development will also be changed. In case of root mass also alternate irrigation shows higher value (13.25 g). The results showed significant difference between treatments in the case of mean root length. Mean root mass per plant varied significantly between T2 and T3 but no significant difference was obtained with T1 (daily irrigation). So there is no need to suggest daily irrigation for the sake of root development. Compared to crops under alternate day irrigation, crops grown under daily irrigation schedule resulted in reduced yield and other growth parameters like length of main vine, number of leaves, number of flowers, fruit parameters, root length etc followed by crops under once in three days irrigation.

The combined effect of alternate growing systems and irrigation interval on the crop growth and yield parameters were analyzed. In the initial stage length of main vine and number of leaves were on par for all the treatments. But towards the later stages length of main vine was better in F1T2 and F1T3 than all the treatments of layflat grow bag. The earliest flowering was observed in F1T3 after 15 days of transplanting and F1T2 was late by three days. The highest number of flowers was for F1T2 (16.67) followed by F1T3 (14). Both values were observed 50 days after transplanting. In case of all the fruit quality parameters vertical type grow bag with alternate day irrigation gave best result. The highest yield was for F1T2 (7.56 kg/plant) followed by F1T1 (6.34 kg/plant). The next higher value was for F1T3. In all cases the vertical type growbag with alternate day irrigation proved to be superior in terms of yield. From the quality analysis by texture analyzer it was clear that the different growing systems and irrigation interval had no significant effect on quality of fruits in terms of firmness and toughness.

The statistical analysis of the number of flowers, mean yield, mean fruit weight, mean fruit length and diameter showed that there was statistically significant differences between both growing systems and irrigation interval in all the measured parameters using the Tukey post-hoc test. It is clear that the type of growing systems caused a considerable difference in plant growth. Strong, healthy plants require media with good structure and texture, proper pH level, and proper nutrients. The right type of media is really the key to healthy plant growth. In this study, vertical type growbag filled with coirpith showed better performance than lay flat type growbag.

Irrigation interval significantly affected irrigation water use efficiency (IWUE). The highest IWUE was F1T3 (2590 kg/ha.mm) and lowest was F2T1 (446.14 kg/ha.mm). Even though crops under alternate day irrigation were identified with remarkable yield, once in three days irrigation can be suggested in the areas experiencing water shortage, since it has resulted in higher water use efficiency with a value 2590 kg/ha.mm. Nitrogen, phosphorus and potassium use efficiency were estimated to get an idea as to how effectively the macronutrients were used by the crop under different treatments during the field trial. Nitrogen FUE was highest for F1T2 (879.94 kg/ha.kg N) and then for F1T1 and F1T3. (735.61 and 721.63 kg/ha.kg N) respectively. Phosphorus use efficiency (1698.14 kg/ha.kg P) and potassium use efficiency (458.05 kg/ha.kg K) were also greater in F1T2. Potassium was applied in greater quantities compared to Nitrogen and Phosphorus and hence KFUE is in low ranges.

The results of this experiment showed that it is possible to obtain satisfactory yields of hybrid cucumber *Hilton* variety grown under polyhouse conditions in coirpith filled vertical growbags. The study also reveals that crop with once in three days irrigation at the initial stage followed by alternate day irrigation during mid-stage and late stage in vertical type grow bag results in best performance. Using inert growing media like coirpith demands full fertigation with all macro and micro nutrients for good FUE.

References

REFERENCES

Aatif, H., Kaiser, I., Showket, A., Prasanto, M., and Negi, A. K. 2014. A review on the science of growing crops without soil (Soilless Culture) – A novel alternative for growing crops. *Int. J. Agric. Crop. Sci.* 11:833-842.

Abad, M., Noguera, P., Puchades, R., Maquieira, A., and Noguera, V. 2001. Physico-chemical properties of some coconut coir dusts for use as a peat substitute for containerised ornamental plants. *Bioresour. Technol*. 82(3): 241-245.

Abou-Hadid, A.F., El-Shinawy, M.Z., El-Oksh, I., Gomaa, H., and El-Beltagy, A.S. 1994. Studies on water. *Acta Hort*. 366(45): 365-372.

Albaho, M., Bhat, N., Thomas, B.N., Isathali, S., George, P., and Ghloum, D. 2013. Alternative Growing Media for Production of Cucumber Cultivar 'Banan' for Soilless Culture in Kuwait. *Acta Hort*. 1004: 115-122.

Ali, A. G. 2013. Simulation of Peanut (Arachis hypogaea L.) with Cropwat Model in Irrigation Condition and Rainfed. *J. Sci. Agric*. 2(3): 54-59.

Allen, R.G., Pereira, P.L., Raes D., Smith, M., 1998. Crop Evapotranspiration on-Guidelines for Computing Crop Water Reguirements. FAO Irrigation and Drainage Paper 56.

Anaç, D. 2004. Nutrient Management in the Protected Agriculture of Turkey. IPI regional workshop on Potassium and Fertigation development in West Asia and North Africa, Rabat, Morocco.

Atefe, A., Ali, T., Mahmoud, S., and Gholam, H. 2012. Effect of substrate and cultivar on growth characteristic of strawberry in soilless culture system. *Afr. J. Biotechnol.* 11(56): 11960-11966.

Atiyeh, R. M., Edwads, C. A., Subler, S., and Metzger, J. D. 2001. Pig manure vermicompost as a component of a horticultural bedding plant medium:

effects on physical properties and plant growth. *Bioresour. Technol.* (78):11-20.

Ayse, G., Funda, K., and Dileka. 2007. Effect of nutrient sources on cucumber production in different substrates. *J. Sci. Hortic.* 113(2): 216-220.

Bakker, J.C., Welles, G. W. H., and Uffelen, J. A. M. 1987. The effects of day and night humidity on yield and quality of glasshouse cucumbers. *J. Hortic. Sci*. 62: 363-370.

Bandyopadhyay, S.K. and Ray, S.B. 1988. Changes in some physical properties of sandy loam soil as influenced by Jalsakthi. *Indian. J. Agron*. 33: 447-450.

Bernstein, N., Bar, T. A., and Friedman, H. 2006. Application of treated waste water for cultivation of roses (Rosa hybrida) in soil-less culture. *Sci. Hortic*.108:185–193.

Cantiffe, D. J., Funes, J., Jovicich, E., Paranjpe, A.,Rodriguez, J., and Shaw, N. 2007. Media and containers for greenhouse soil less grown cucumbers, melons, peppers and strawberries. *Acta Hort*. 614: 199-203.

Cheema, D.S., Kaur, P., and Kaur, S. 2004. Off-season cultivation of tomato under net house conditions. *Acta Hort*. 659: 177-181.

Day, W. and Bailey, B. J. 1999. Green house technology and management. Chapter 3. Ecosystems of the world 20. ELSEVIER, Amsterdam.

Dayananda, M. A. I. and Wahundeniya, W. M. K. B. 2001. Effect of different systems and media on growth of lettuce (Lactuca sativa) under protected culture.

Doorenbos, J. and Pruitt, W. O. 1977. FAO. *Guidelines for predicting crop water requirement.* Irrigation and Drainage Paper 24. Rome.

Duggan, D. I., Nichols, M. A., and Woolley, D. J. 2013. Effect of Physical Characteristics of Coir on the Productivity of Greenhouse Tomatoes. *Acta. Hort*. 1004p.

Enujeke, E. C. 2013. Growth and yield responses of cucumber to five different rates of poultry manure in Asaba area of Delta state, Nigeria. *J. Int. Res.* 3(11): 369-375.

Francisco, M. A. and Maria, D. G. 2010. Agronomical response and water use efficiency of sweet pepper plants grown in different greenhouse substrates. *Hortic. Sci*. 44(3): 810-814.

Gessert, G. 1976. Measuring air space and water-holding capacity. *Ornamentals Northwest.* 3:59-60.

Gruda, N. 2009. Do soilless culture systems have an influence on product quality of vegetables. *J. Appl. Bot. and Food Qual.* 82: 141 – 147.

Gul, A. and Sevgican, A. 1994. Suitability of various soil less media for long term greenhouse tomato growing. *Acta Hort.* 366: 437-444.

Harmantoa, V.M., Salokhea, M.S. Babelb., and Tantau, H. J. 2004. Water requirement of drip irrigated tomatoes grown in greenhouse in tropical environment. *Agric. Water Manag.* 71:225–242.

Harmsen, E., Joel, C .T., Carmen, L. A., and Dionel, C. R. 2002. Evaluation of percolation and nitrogen leaching from a sweet pepper Crop grown on an oxisol soil in northwest Puerto Rico. *J. Trop. Agric. Res*. Vol.39.

Hochmuth, G. and Hochmuth, R. 2003. Open-field Soilless Culture of Vegetables. University of Florida Cooperative Extension Service, *Inst. Food and Agric. Sci,* EDIS.

Hossain M. F., Uddin, M. R., and Ara Nand, M. S. (2012) Comparative study of coirpith and cowdung on growth and yield of summer tomato, *Bull. Inst. Trop. Kyushu Univ.* 35: 47-51.

Jamaludin, D. 2009. *Effect of Temperature and Relative Humidity on Crop Yield in Tropical Greenhouse with Evaporative Cooling System*, University Putra, Malaysia.

Janapriya, S., Palanisamy, D., and Mohanalakshmi, M. 2010. Evaluation of soil less media on growth parameters of cucumber (*Cucumis satvus* L.) under naturally ventilated polyhouse. *Green Farming*. 3(1): 5-7.

Jose, A. M., Daniel, F.C., Leonardo, O. M., Leonardo, D. B., and Carlos, P. 2013. Growth analysis and yield of tomato crop under different irrigation depths. *Revista Brasileira de Eng. Agríc. e Ambient*. 17: 926-931.

Kannan, P., Saravanan, A., Krishnakumar and S. Natarajan 2005. Biological Properties of Soil as Influenced by Different Organic Manures. *Res. J. Agric. and Biol. Sci.* 1(2): 181-183.

Kavitha, E. R., Vijayaraghavan, N., and Tajuddin. A. 2003. Response of Vegetable Crops in a Solar aided Poly-house Ecosystem. *J. Inst. Eng. India.* 84: 52-55.

Kittas, c., Karamanis, M., and katsolas, N. 2005. Air temperature regime in a forced ventilated greenhouse with rose crop. Energy and Building. (37):807-812

Kuo, S. F., Ho, S. S., and Liu, C. W. 2001. Estimation irrigation water requirements with derived crop coefficients for upland and paddy crops in chianan irrigation association, Taiwan. *J. Agric. Water. Manag*. 82: 433-451.

Maragatham, D. and Samuel, P. R. 2010. Physical characteristics of coirpith as a function of its particle size to be used as soilless medium. *Am. Eur. J. Agric. And Environ. Sci*. 8(4): 431-437.

Mariamma, J. 2010. A study on the water retention characteristics of soils and their improvements. Phd. (Civil) theses, Cochin University of Science and Technology, Cochin, 217p.

Melgarejo, P. and Martınez, J. J. 2007. Preliminary results on fig soil-less culture. *Sci. Hortic*. 111: 255–259.

Metin, S. S., gulendam, C., Attila, y., Servet, T., and Burcak, K. 2010. Effect of irrigation management on yield and quality of tomatoes grown in different soilless media in a glasshouse. *Sci. Res. Essay.* 5(1): 41-48.

Michael, A. M. 2008. *Irrigation Theory and Practice* (2nd Ed.).Vikas Publishing House Pvt. Ltd, Noida, 768p.

Miranda, F. R., Gondim, R. S., and Costa, C. A. G. 2005. Evapotranspiration and crop coefficients for tabasco pepper (*Capsicum frutescens* L.). *J. Agric. Water. Manag.* 82: 237-246.

Muhammad, N. 2009. Simulation of maize crop under irrigated and rainfed conditions with cropwatmodel. ARPN J. Agric. Biological Sci. Available: www.arpnjournals.com. ISSN 1990-6145.

Narendar , R and K. Priya, D. 2013. Effect of Chemical Treatment on the Mechanical and Water Absorption Properties of Coirpith/Nylon/Epoxy Sandwich Composites. *Int. . Polymer. Anal. Charact.,* 18: 369–376.

Neelam, P. and Rajput, T. B. S. 2010. environment monitoring and estimation of water requirement inside a polyhouse through internet.

Neethi, M. and Subramanian, P. 2006.study of physical properties of coirpith. *Int. J. Green. Energy.* 3: 397- 406.

Noguera, M., Abad, P., Noguera, V., Puchades, R. E., Maquieira, A., 2000. Coconut coir waste, a new and ecologically-friendly peat substitute. *Acta Hort*. 517: 279-286.

Norrizah, J. F., saiyidah, N. H., Yaseer, S. M., and Shamsiah, A. 2012. Chararacterization of plant growth, yield and fruit quality of rock cultivars planted on soilless culture. *J. Plant Sci. 7: 186-193.*

Nurul, N. A., Sobri, H., and Shamsuddin S. 2012. Comparison of different methods in estimating potential evapotranspiration at Muda Irrigation Scheme of Malaysia. *J. Agric.Rural. Dev.Trop. Subtrop*.113:77-85.

Parks, S., Newman, N., Pham, L.M., and Tran, T.K..2005. Exploratory data for improving food safety in Vietnam using soilless vegetable production. *Acta Hortic*. 648: 129-133.

Parvej, M.R., Khan, M. A. H., and Awal, M. A.2010. Phenological development and production potentials of tomato under polyhouse climate. *J. Agric. Sci,* 5(1): 19-31.

Prince, W. S., Sivakumar., Ravi, V., and Subburam, V. 2000. The effects of coirpith compost on the growth and quality of leaves of the mulberry plant *Morus alba* L. *Bioresour. Technol.* 72: *9*5- 97.

Preenu, N. P. 2014. Effect of microclimate on the performance of salad cucumber under naturally ventilated polyhouse. M.Tech.(Ag) theses, Kerala Agricultural University, Thrissur, 93p.

Rajarathnam,S .and Shashirekha,M.N. 2007. Bioconversion and biotransformation of coirpith for economic production of Pleurotus florida: chemical and biochemical changes in coirpith during the mushroom growth and fructification. *World. J. Microbiol. Biotechnol*. 23: 1107 -1114.

Rajasekar, M. T., Arumugam., and Ramesh Kumar, S. 2013. Influence of weather and growing environment on vegetable growth and yield. *J. Hortic. For*. 5(10): 160-167.

Rasool, A., Mousa, T. G., and Rahim, D. T. 2008. Influence of vermicompost on soil chemical and physical properties in tomato (Lycopersicum esculentum) field. *Afr. J. Biotechnol.* 7 (14): 2397-2401.

Raviv, M. and Lieth, J. H. 2008. *Soilless culture: theory and practice*. Elsevier Science Ltd, London, 566p.

Rema, K. P. 2012. Techno- economic evaluation of soilless culture techniques for vegetable crops. Phd. (Ag) theses, Tamilnadu Agricultural University, Coimbatore, 154p.

Rodriguez, J. C., Cantlifee, D. J., and Shaw, N. L. 2006. Soilless media and containers for greenhouse production of 'Galia' type muskmelon. *Hortic. Sci.* 41(5):1200-1205.

Ronald, R. P., Paramanandham, J., Thenmozhi, P., Abhirami, K. S., and Muthulingam, M. 2012. Determination of physico chemical properties of coir pith in relation to particle size suitable for potting medium. *Int. J. Res. Environ. Sci. Technol.* 2(2): 45-47.

Sabeena, S. and Megha, P. 2012. Crop water requirement and irrigation scheduling of K.C.A.E.T. Instructional farm using CROPWAT model. B.Tech.(Ag) project. Kerala Agricultural University, Thrissur,104p.

Sanchez-Guerrero, M.C., Lorenzo, P., Medrano, E., Baille, A., and Castilla, N. 2009. Effects of EC-based irrigation scheduling and CO2 enrichment on water use efficiency of a greenhouse cucumber crop. *Agric. water manag.* 96: 429 – 436.

Savvas, D., Giotis, D., Chatzieustratiou, E., Bakea, M., Patakioutas, G., 2009. Silicon supply in soilless cultivations of zucchini alleviates stress induced by salinity and powdery mildew infections. J. Biol. Environ. Sci. 65: 11–17.

Serhat, A. and Çigdem, D. 2009. Deficit irrigation effects on pepper (*Capsicum annuum* L. Demre) yield in unheated greenhouse condition. *J. Food, Agric. & Environ.*7: (3&4) : 989-993.

Shahnaz, S., Yoshikazu, K., Masanobu, E., Tomoya, K., and Akira N. 2008. Effect of Fertigation Management and the Composition of Nutrient Solution on the Yield and Quality of High Soluble Solid Content Tomatoes. *J.Japan. Soc. Hortic. Sci*. 77 (2): 143–149.

Shao Guang-Chenga, Zhang Zhan-Yua, Liu Nac, Yu Shuang-Ena, and Xing Weng-Gang. 2010. Comparative effects of deficit irrigation (DI) and partial root zone drying (PRD) on soil water distribution, water use, growth and yield in greenhouse grown hot pepper. *Sci. Hortic.* 119: 11–16.

Singandhupe, *R.* B., Rao, G. G. S. N., Patil, N. G., and Brahmanand, P. S. 2002. Fertigation studies and irrigation scheduling in drip irrigation system in tomato crop (*Lycopersiconesculentum* L.). *Eur. J. Agron*. 19: 327-340.

Smith, M., Allen, R .G., Monteith, J. L., Perrier, A., Pereira, L., and Segeren, A. 1992. Report of the expertconsultation on procedures for revision of FAO guidelines for prediction of crop water requirements.UN-FAO, Rome, Italy, 54 p.

Sudip, K. C., Saon, B., and Mridul, B. 2012. Climate Change Impact on Crop Water Requirement in Ganga River Basin, West Bengal, India, *Environ. and Chem*. 46: 22-24.

Takela, G. and Desalegn, C. 2009. Effect of drip irrigation level and planting method on water use efficiency, Irrigation uniformity and yield in green pepper (Capsicum annum L.) in Bako, Ethopia. *J.agwat.* 96: 11-96.

Vavrina, C. S., Armbrester, K., Mireia, A., and Pena, M. Coconut coir as an alternative to peat media for vegetable transplant production. University of Florida. SWFREC Station Report - VEG 96.7.

Venu, S. A., Senthil, K. G., and Bali, V. B. 2014. Determination of some physical properties of insulation materials and for selected vegetables to design a low cost evaporative cooling system. *Plant Archives.* 14(1): 507-510.

Viji, R. and Prasanna, P. R. 2011. Assessment of water holding capacity of major soil series of lalgudi, Trichy, India. *J.Environ. Res. Develop*. 7: 393-398.

Wang, X.,, Li Dengshun and Zhang, X. 1999. Relationship between irrigation amount and yield of cucumber in solar greenhouse. *J. China Veg.*

Waters, W. E., Flewellyn, W., and Smith, J. 1970. The chemical, physical and salinity characteristics of twenty-seven soil media. *Proc. Flor. State Hort. Soc*. 83: 482-488.

Xiaobo, P., Zhang, F., and Gao, L. 2002. Study on water requirement of cucumber of different cropping in solar greenhouse. *J. Chin. Agric. Sci. Bull.*

Xiao, Z., W. Jiang, H. Yu and M. Wang. 2009. Substrate water content and nitrogen interactions in growing media: yield, fruit quality, water consumption and water use efficiency on tomato. *Acta Hort.* 843:57-64.

Zabihoah, R., Abdolhossein, A., Abdolrasoul, Z. 2013. Comparison of different medium for production of Sweet pepper transplant. *Int. Res. J. Appl. Basic. Sci.* 4(2): 307-310.

Appendices

APPENDIX I

Physical Properties of coirpith by Keen Rackzowski Box

Calculations

Weight of Box + filter paper : 33.43 g

Weight of Box + dry coirpith media : 42.00 g

Weight of Box + saturated coirpith media : 85.29 g

Weight of Box + media after removing expanded portion : 83.43 g

Weight of Box + media after drying in oven : 39.15 g

Weight of empty dish : 12.85 g

Weight of dish + expanded wet media : 14.71 g

Weight of dish + coirpith after drying in oven : 13.12 g

Internal radius of box : 2.5 cm

Internal height of coirpith : 2.5 cm

Volume of box : 49.06 cm^3

Weight of coirpith media : 5.91 g

Bulk density, particle density and volume expansion were determined by using the following formulas

Bulk density of the processed coirpith (g/cm^3) =

$$\frac{\text{Weight of the coirpith}}{\text{Volume of coirpith with pore space}}$$

$$5.91/49.06 = 0.12 \text{ g/cc}$$

Particle density of the processed coirpith (g/cm^3) =

$$\frac{\text{Weight of coirpith}}{\text{Volume of coirpith excluding pore space}}$$

$$= 5.91/34.76 = 0.17 \text{ g/cc}$$

Volume expansion = (volume of the expanded coirpith /volume of the dry air coirpith) × 100 = (1.85/ 4.86) × 100

= 38.25 %

APPENDIX II

Media moisture constants of coirpith using pressure plate apparatus

		Mass of container (g)	Mass of wet media (g)	Mass of dry media (g)	Moisture content (%)	Available water (%)
FC	F1	10.5	14.03	2.3	510.15	275.27
PWP	P1	15	13.56	4.05	234.88	
FC	F2	14	13.99	2.3	508.82	274.84
PWP	P2	15	13.68	4.11	233.98	

APPENDIX III

Daily Temperature (^{0}C) recorded inside the polyhouse during crop period

Date from Transplanting	**Temperature (^{0}C)**		
	8 A.M	**2 P.M**	**5 P.M**
24/11/14	26.50	35.38	29.45
25/11/14	25.45	34.36	28.55
26/11/14	26.22	33.89	27.96
27/11/14	26.46	34.56	28.82
28/11/14	24.54	35.03	29.56
29/11/14	25.87	34.53	29.32
30/11/14	26.52	34.78	29.35
01/12/14	25.73	34.23	29.25

Appendix III Continued

02/12/14	25.10	34.93	29.35
03/12/14	24.86	33.96	28.92
04/12/14	26.02	34.45	29.00
05/12/14	27.94	34.67	29.05
06/12/14	26.69	33.95	28.86
07/12/14	27.09	34.52	28.92
08/12/14	26.77	34.61	28.95
09/12/14	26.96	34.87	29.17
10/12/14	27.20	34.12	29.05
11/12/14	27.84	34.43	29.35
12/12/14	26.98	35.21	29.54
13/12/14	27.08	35.32	29.45
14/12/14	26.23	34.54	29.15
15/12/14	26.88	34.67	28.96
16/12/14	27.06	33.96	28.68
17/12/14	27.24	34.32	28.94
18/12/14	26.85	35.23	29.26
19/12/14	27.56	35.12	29.07
20/12/14	27.67	34.57	28.96
21/12/14	27.04	33.89	28.94
22/12/14	28.32	34.86	29.27
23/12/14	25.22	35.01	29.54
24/12/14	26.85	35.36	29.63
25/12/14	25.76	35.38	29.25
26/12/14	28.37	35.24	29.15

Appendix III Continued

27/12/14	26.65	34.93	28.95
28/12/14	25.22	35.12	28.48
29/12/14	24.03	34.83	29.32
30/12/14	25.64	35.26	29.24
31/12/14	25.89	35.04	29.15
01/01/15	26.17	35.12	29.42
02/01/15	27.21	35.22	29.35
03/01/15	26.48	35.25	29.28
04/01/15	26.45	35.47	29.36
05/01/15	26.63	35.38	29.35
06/01/15	27.60	35.43	29.44
07/01/15	26.72	34.96	28.86
08/01/15	27.54	34.45	28.94
09/01/15	28.34	34.86	28.85
10/01/15	28.26	35.03	29.26
11/01/15	27.47	34.67	29.34
12/01/15	27.32	34.36	29.28
13/01/15	26.95	33.32	29.43
14/01/15	27.72	35.54	31.50
15/01/15	27.55	35.32	31.36
16/01/15	27.97	34.96	30.48
17/01/15	28.24	35.22	31.19
18/01/15	26.88	34.87	30.07
19/01/15	27.85	34.68	29.84
20/01/15	26.35	35.15	30.12

Appendix III Continued

21/01/15	27.79	34.67	29.85
22/01/15	28.42	35.73	30.23
23/01/15	27.37	34.22	31.11
24/01/15	27.98	34.82	31.26
25/01/15	27.21	34.95	31.22
26/01/15	27.53	34.05	30.82
27/01/15	28.08	33.52	30.45
28/01/15	28.24	34.74	30.54
29/01/15	27.02	32.30	29.24
30/01/15	27.35	35.24	29.54
01/02/15	27.54	35.82	29.72
02/02/15	28.24	34.44	30.04
03/02/15	27.67	35.62	30.32
04/02/15	28.04	36.24	30.76
05/02/15	28.32	36.72	29.86
06/02/15	28.74	37.27	33.12
07/02/15	28.42	37.46	31.34
08/02/15	28.92	38.24	32.06
09/02/15	29.05	38.30	32.17
10/02/15	27.78	36.74	31.54
11/02/15	28.02	36.65	31.72
12/02/15	28.36	37.56	31.68
14/02/15	28.25	38.31	32.28
15/02/15	27.65	37.89	32.52
16/02/15	28.14	36.05	31.84

Appendix III Continued

17/02/15	28.22	37.41	32.32
18/02/15	29.16	37.84	32.05
19/02/15	29.34	38.22	33.00
20/02/15	29.28	36.59	31.72
21/02/15	29.08	38.05	32.28
22/02/15	28.94	37.45	32.44
23/02/15	28.36	36.86	31.94
24/02/15	28.12	38.32	31.87
25/02/15	28.04	37.45	32.66
26/02/15	28.56	38.25	33.02
27/02/15	27.48	37.68	32.36
28/02/15	28.75	37.84	32.24
01/03/15	27.26	36.54	32.28
02/03/15	29.34	35.42	30.45
03/03/15	28.46	36.32	32.28
04/03/15	27.78	37.45	31.36
05/03/15	26.89	37.24	30.14
06/03/15	27.28	37.56	31.22
07/03/15	28.32	36.22	30.34
08/03/15	28.54	37.32	31.08
09/03/15	27.36	36.42	31.24
10/03/15	27.05	36.22	30.12

APPENDIX IV

Daily Relative Humidity (%) recorded inside the polyhouse during crop period

Date from Transplanting	Relative Humidity (%)		
	8 A.M	2 P.M	5 P.M
24/11/14	73.50	52.20	75.61
25/11/14	72.45	54.34	76.23
26/11/14	75.80	53.56	76.34
27/11/14	74.65	50.06	72.22
28/11/14	76.43	51.56	70.95
29/11/14	77.67	52.85	68.85
30/11/14	77.95	51.32	68.84
01/12/14	78.12	49.56	69.54
02/12/14	77.88	49.73	68.82
03/12/14	74.43	48.85	62.22
04/12/14	76.06	49.32	68.14
05/12/14	80.56	50.23	69.06
06/12/14	72.74	48.24	66.42
07/12/14	73.46	48.83	68.72
08/12/14	77.93	47.28	69.02
09/12/14	78.32	47.19	69.82
10/12/14	77.69	47.17	68.85
11/12/14	78.46	48.44	69.24
12/12/14	79.48	48.94	69.37
13/12/14	79.28	49.35	68.45
14/12/14	78.45	47.86	64.78
15/12/14	79.59	47.43	64.37

Appendix IV Continued

16/12/14	79.34	47.56	63.67
17/12/14	78.68	47.92	63.68
18/12/14	79.46	47.48	64.08
19/12/14	79.83	47.91	62.47
20/12/14	80.15	46.54	62.75
21/12/14	80.34	48.89	63.44
22/12/14	79.86	49.90	63.22
23/12/14	79.69	50.17	60.63
24/12/14	80.42	50.22	60.53
25/12/14	80.05	49.76	61.35
26/12/14	79.69	48.84	62.26
27/12/14	79.43	48.85	61.34
28/12/14	80.15	47.84	62.76
29/12/14	81.13	47.93	61.56
30/12/14	82.35	46.78	60.43
31/12/14	81.18	47.85	60.93
01/01/15	78.67	46.67	59.36
02/01/15	79.35	46.85	60.62
03/01/15	78.43	48.82	61.32
04/01/15	79.56	48.95	60.50
05/01/15	78.67	47.76	58.42
06/01/15	79.53	46.78	57.86
07/01/15	80.05	49.52	59.65
08/01/15	79.28	48.57	59.32
09/01/15	78.74	46.96	58.87

Appendix IV Continued

10/01/15	78.92	47.46	59.78
11/01/15	80.58	47.42	58.79
12/01/15	80.32	48.54	59.52
13/01/15	78.22	48.56	60.04
14/01/15	77.25	47.64	58.54
15/01/15	78.06	48.56	57.93
16/01/15	79.33	47.44	56.92
17/01/15	79.05	46.92	58.59
18/01/15	78.48	48.73	58.24
19/01/15	78.04	45.47	57.29
20/01/15	76.83	48.78	54.50
21/01/15	78.75	48.32	55.22
22/01/15	78.48	47.84	55.32
23/01/15	77.88	45.76	56.93
24/01/15	77.34	48.88	54.78
25/01/15	76.03	47.64	54.85
26/01/15	74.54	47.21	54.74
27/01/15	73.45	46.05	53.85
28/01/15	72.23	45.34	54.27
29/01/15	72.38	41.32	53.94
30/01/15	72.48	42.67	53.62
01/02/15	71.34	42.86	53.82
02/02/15	72.44	43.42	52.78
03/02/15	70.23	44.36	54.00
04/02/15	70.32	44.94	53.87

Appendix IV Continued

05/02/15	70.15	45.01	52.58
06/02/15	69.45	44.78	53.32
07/02/15	69.82	44.54	52.98
08/02/15	69.56	44.27	52.64
09/02/15	68.45	43.75	52.28
10/02/15	68.96	44.14	51.86
11/02/15	69.28	42.71	51.75
12/02/15	68.92	38.68	51.84
14/02/15	68.34	38.71	50.96
15/02/15	68.58	38.77	51.34
16/02/15	67.45	42.01	51.72
17/02/15	67.38	43.43	50.83
18/02/15	67.92	43.26	52.76
19/02/15	68.14	43.42	51.87
20/02/15	68.52	42.78	50.65
21/02/15	67.48	42.71	51.72
22/02/15	67.46	49.67	50.26
23/02/15	68.05	52.06	49.98
24/02/15	67.48	42.06	49.96
25/02/15	66.82	51.24	50.36
26/02/15	66.34	51.18	49.83
27/02/15	67.83	50.25	49.22
28/02/15	66.14	47.00	49.36
01/03/15	68.24	55.32	62.32

02/03/15	69.56	54.73	63.14

Appendix IV Continued

03/03/15	64.36	56.72	65.28
04/03/15	67.54	52.94	58.18
05/03/15	66.44	57.35	60.56
06/03/15	64.56	53.96	61.27
07/03/15	63.22	58.56	62.87
08/03/15	64.54	58.89	63.72
09/03/15	62.73	56.72	65.34
10/03/15	65.41	56.68	63.27

STUDIES ON THE EFFECT OF ALTERNATE GROWING SYSTEMS AND IRRIGATION SCHEDULES FOR SOILLESS CULTURE OF SALAD CUCUMBER

By

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ABSTRACT

Submitted in partial fulfillment of the
requirement for the degree of

MASTER OF TECHNOLOGY
IN
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(Soil and Water Engineering)

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TAVANUR - 679573, MALAPPURAM
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ABSTRACT

Field study on the effect of alternate growing systems and irrigation schedules for soilless culture of salad cucumber under drip irrigation was conducted inside the naturally ventilated polyhouse in the research plot of Precision Farming Development Centre, in the Instructional Farm of KCAET, Tavanur, during November 2013 to March 2014. In this study coirpith was the media used. The crop water requirement of salad cucumber was determined using CROPWAT model. The data on micro climate inside the polyhouse were periodically recorded on daily basis.

The physico chemical and engineering properties of coirpith were studied. The experiment was laid out in a two factor completely randomized block design. The plot was divided into three rectangular sections with three treatments each replicated thrice. The treatments were F1T1 (Black poly bag with daily irrigation), F1T2 (Black poly bag with alternate day irrigation), F1T3 (Black poly bag with irrigation once in 3 days), F2T1 (Lay flat grow bags with daily irrigation), F2T2 (Lay flat grow bags with alternate day irrigation), and F2T3 (Lay flat grow bags with irrigation once in 3 days).

Fertigation in coir pith include both macro and micro nutrients applied as water soluble fertilizers from two tanks (tank A and tank B) through fertigation system with venturi. Data about vegetative parameters for each treatment were observed during different stages of crop growth. The results on the effect of alternate growing systems used, irrigation frequency and their combined effect on crop growth and yield parameters were statistically analyzed. Analyzing the effect of alternate growing systems, it was found that vertical type growbag filled with

coirpith showed better performance than lay flat type growbag. In case of irrigation interval, crops under once in three days irrigation showed better performance at the initial stage (winter season). But during mid-season (summer season) alternate day irrigation resulted in better growth and yield than once in three days irrigation. The highest yield was for F1T2 (7.56 kg/plant) followed by F1T1 (6.34 kg/plant).

Irrigation interval significantly affected irrigation water use efficiency (IWUE). The highest IWUE was for F1T3 (2590 kg/ ha.mm) and lowest was for F2T1 (446.14 kg/ ha.mm). Even though crops under alternate day irrigation were identified with remarkable yield, once in three days irrigation can be suggested in the areas experiencing water shortage.

The results of this experiment showed that it is possible to obtain satisfactory yields of hybrid cucumber *Hilton* variety grown under polyhouse conditions in coirpith filled vertical growbags. The study also revealed that crops with once in three days irrigation at initial stages followed by alternate day irrigation during mid-stage and late stage in vertical type growbag resulted in better performance. Using inert growing media like coirpith demands full fertigation with all macro and micro nutrients for good FUE.

സംഗ്രഹം

തുള്ളിജലസേചനരീതി അവലംബിച്ച് സലാഡ് വെള്ളരി വിവിധ വളർത്തു രീതിയിലും ജലസേചന പദ്ധതിയിലും കൃഷി ചെയ്യുന്നതിനുള്ള ഒരു പഠനം, കെ.സി.എ.ഇ.ടി. ഫാമിലെ പി. എഫ്.ഡി.സി യുടെ കീഴിലുള്ള പ്രകൃതിദത്ത വായു സഞ്ചാരമുള്ള പോളിഹൗസിൽ 2013 നവംബർ മുതൽ 2014 മാർച്ച് വരെ നടന്നു. മണ്ണിനു പകരം ചകിരിച്ചോർ ആണ് വളർത്തു മാധ്യമമായി ഉപയോഗിച്ചത്. സലാഡ് വെള്ളരിക്കാവശ്യമായ ജലത്തിന്റെ അളവ് ക്രോപാറ്റ് (CROPWAT) സോഫ്റ്റ്വെയർ ഉപയോഗിച്ച് കണ്ടുപിടിച്ചു. പോളിഹൗസിനകത്തുള്ള കാലവസ്ഥയുടെ വിവരം നിത്യേന രേഖപ്പെടുത്തിയിരുന്നു. ചകിരിച്ചോറിന്റെ ഭൗതീക-സാങ്കേതിക ഗുണങ്ങൾ പരീക്ഷണങ്ങളിലൂടെ കണ്ടെത്തി. ഫാക്ടറിയിൽ കംപ്ലീറ്റ്ലി റാണ്ടമൈസ്ട് ഡിസൈൻ ആണ് പരീക്ഷണത്തിനായി തിരഞ്ഞെടുത്തത്.

പരീക്ഷണ ഭൂഭാഗത്തെ ദീർഘചതുരത്തിലുള്ള മൂന്നു മൺതിട്ടകളാക്കി തിരിച്ചാണ് മൂന്നു രീതിയിലുള്ള ജലസേചന പദ്ധതിയെ വിഭജിച്ചത്. കുത്തനെയും തിരശ്ചീനമായും സജ്ജീകരിച്ച പോളിബാഗുകളിൽ പ്രതിദിനവും ഒന്നിടവിട്ട ദിവസങ്ങളിലും മൂന്നു ദിവസത്തിലൊരിക്കലുമുള്ള ജലസേചനം ക്രമീകരിച്ചു. എഫ്.വൺ.ടി.വൺ-(കുത്തനെയുള്ള (സാധാരണ രീതിയിലുള്ള) പോളിബാഗും പ്രതിദിന ജലസേചനവും.), എഫ്.വൺ.ടി.ടു- (കുത്തനെയുള്ള പോളിബാഗും ഏകാന്തരരീതിയിലുള്ള ജലസേചനവും), എഫ്.വൺ.ടി.ത്രി- (കുത്തനെയുള്ള പോളിബാഗും മൂന്നു ദിവസത്തിലൊരിക്കലുള്ള ജലസേചനവും), എഫ്.ടു.ടി.വൺ- (തിരശ്ചീനമായ പോളിബാഗും പ്രതിദിന ജലസേചനവും), എഫ്.ടു.ടി.ടു- (തിരശ്ചീനമായ പോളിബാഗും ഏകാന്തരരീതിയിലുള്ള ജലസേചനവും), എഫ്.ടു.ടി.ത്രി- (തിരശ്ചീനമായ പോളിബാഗും മൂന്നു

ദിവസത്തിലൊരിക്കലുള്ള ജലസേചനവും) എന്നിവയാണ് പഠനത്തിൽ ഉൾപ്പെടുത്തിയിട്ടുള്ള പരീക്ഷണങ്ങൾ.

ആവശ്യ മൂലകങ്ങളും സസ്യങ്ങളുടെ വളർച്ചക്കാവശ്യമായ മറ്റു മൂലകങ്ങളും വെള്ളത്തിൽ ലയിപ്പിച്ച് എല്ലാ ചെടികൾക്കും ഒരേപോലെ ലഭ്യമാകുന്ന രീതിയിലാണ് ഫെർട്ടിഗേഷൻ ക്രമീകരിച്ചത്. തെരഞ്ഞെടുക്കപ്പെട്ട ചെടികളിൽ നിന്നും ചെടിയുടെ ഓരോ വളർച്ചാ ഘട്ടത്തിലുമുള്ള വിവിധ ഘടകങ്ങൾ നിരീക്ഷിക്കുകയും രേഖപ്പെടുത്തുകയും ചെയ്തു.

വളർത്തുരീതിയെ ആസ്പദമാക്കി നടത്തിയ പഠനങ്ങളിൽ ചകിരിച്ചോർ മാധ്യമമായി കുത്തനെയുള്ള പോളിബാഗിൽ പരിചരിച്ച ചെടികൾ തിരശ്ചീനമായ പോളിബാഗിൽ വളർത്തിയ ചെടികളെക്കാളും മികച്ചതായി കണ്ടു.ജലസേചന ഇടവേളയെ ആസ്പദമാക്കി നടത്തിയ പഠനങ്ങളിൽ മൂന്നു ദിവസത്തിലൊരിക്കലുള്ള ജലസേചനം നടത്തിയ ചെടികൾ പ്രാരംഭ ഘട്ടത്തിൽ മികച്ചതായി കണ്ടെങ്കിലും വളർച്ചയുടെ പാതിഘട്ടങ്ങളിൽ എത്തിയപ്പോഴേക്കും ഒന്നിടവിട്ട ദിവസങ്ങളിൽ ജലസേചനം നടത്തിയ ചെടികൾ കൂടുതൽ വളർച്ചയും വിളവും ഉള്ളതായി കണ്ടു. മേൽ നടത്തിയ പഠനങ്ങളിൽ നിന്നും ഏറ്റവും കൂടുതൽ വിളവ് ലഭിച്ചത് എഫ്.വൺ.ടി.ടു (7.56 കിലോഗ്രാം/പ്ലാന്റ്) ആയിരുന്നു.

ജലസേചന ഇടവേള ജലസേചന കാര്യക്ഷമതയെ ബാധിക്കുന്നതായി കണ്ടെത്തി. ഒന്നിടവിട്ട ദിവസങ്ങളിലുള്ള ജലസേചനരീതി വിളയുടെ കാര്യത്തിൽ ശ്രധിക്കപ്പെട്ടെങ്കിലും ജലക്ഷാമമുള്ള പ്രദേശങ്ങളിൽ മൂന്നുദിവസത്തിലൊരിക്കലുള്ള ജലസേചനം ശുപാർശ ചെയ്യാവുന്നതാണ്.