COMPARATIVE EVALUATION OF EVAPOTRANSPIRATION PARAMETERS OF OKRA IN POLYHOUSE FOR ALTERNATE GROWING MEDIA

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PROJECT REPORT

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2018

DECLARATION

We hereby declare that this project entitled **"COMPARITIVE EVALUATION OF EVAPOTRANSPIRATION PARAMETERS OF OKRA IN POLYHOUSE FOR ALTERNATE GROWING MEDIA"** is a bonafide record of project done by us during the course of academic programme in the Kerala Agricultural University and that the report has not previously formed the basis for the award to us for any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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DEDICATED TO OUR PROFESSION

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SYMBOLS AND ABBREVATIONS

CWR	Crop Water Requirement
%	Percentage
&	And
”	Second
“	Minute
=	Equal to
°	Degree
°C	Degree Celsius
Dept.	Department
ET	Evapotranspiration
et al.	And others
ETc	Crop evapotranspiration
ET_0	Reference evapotranspiration
FAO	Food and Agricultural Organisation
Fig.	Figure
g/cc	Gram per cubic centimetre
Hort.	Horticulture
J.	Journal
KAU	Kerala Agricultural University
Kc	Crop coefficient

KCAET	Kelappaji College of Agricultural Engineering and Technology
Km/day	Kilometre per day
L	Litre
l/day/plant	Litre per day per plant
LDPE	Low Density Polyethylene
Lph	Litre per hour
M	Metre
m^2	Square metre
m^3	Cubic metre
$MJ/m^2/day$	Mega joule per square metre per day
Mm	Millimetre
MSL	Mean sea level
PVC	Poly vinyl chloride
RH	Relative humidity
s	Second
Sci.	Science
UV	Ultraviolet
Viz.	Namely
WUE	Water use efficiency

Introduction

CHAPTER 1

INTRODUCTION

Water is considered as a critical resource for agriculture and supplying the right amount in the right time is essential for healthy plants and optimum productivity. This objective can be met only through scientific water management and judicious water application, which in turn requires proper scheduling of irrigation events. Irrigation scheduling is the process of determining when to irrigate and how much quantity of water to apply per irrigation. To schedule irrigation effectively, a farmer must know the atmospheric demand for surface water. In order to obtain profitable level of crop yield, soil water depletion level should not exceed the predetermined levels mainly during critical periods of crop. Application of excess or deficit amounts of water at the crop development stage causes crop damage and yield reduction.

Evapotranspiration (ET), which combines the processes of evaporation and transpiration in the return of surface moisture to the atmosphere, is one of the most important hydrological and meteorological components of the water cycle in nature. ET simultaneously involves flux of mass and energy as latent heat. Information on crop water requirements is very vital in the planning and operation of soil and water management strategies. Besides planning and design of irrigation systems, knowledge of crop water use is required when planning erosion control measures such are terracing and contour bunding, planning and design of micro- and macro-catchment rain/runoff water harvesting systems, surface and subsurface drainage systems, and other soil moisture conservation techniques. Most of the systems mentioned above are usually required to manage soil and water in rainy season. Information on crop water requirements in literature are largely those used for the purpose of irrigation, and were most probably developed during the dry season. Since the micro-climate during the wet season differs from that of the dry season, it is most expected that crop water requirements for irrigation should differ from that under rain-fed condition.

One of the challenges of determining crop water requirement represented by the crop consumptive use (also commonly referred to as evapotranspiration) at field level under rain-fed condition is the fact that the other output components of the soil water balance (e.g. runoff, deep percolation, and capillary movement) are very volatile and difficult to measure. However, this challenge can be overcome with the use of Mini lysimeters. A Mini lysimeter is a device which enables the isolation of a soil column for the purpose of studying water inflow and outflow in the system.

The first report on the use of lysimeters was from France in 1668 where, La Hire used lead containers filled with soil to observe water loss. A lysimeter is a device which enables the isolation of a soil column for the purpose of studying water inflow and outflow in the system. Field studies using lysimetric data acts as an accurate tool in the determination of water balance variables, representing the existing field conditions. Lysimeters if designed to adequately approximate the physical system, can be used as a research tool to study plant-water relationships.

Mini-lysimeters are characterized by reduced soil volume (less than 1 m^3), and have been recently adopted due to reduced installation and management costs and good accuracy of measurement. They have the advantage that they permit the measurement of the evaporative flux from smaller areas. They create fewer disturbances to the cropped area during installation. Non-weighing mini-lysimeters are used to estimate ET by computing the water balance. The water balance involves measuring all the water inputs and outputs to and from the lysimeter and the change in storage over a stipulated period of time. The lysimeters provide viable estimates of ET_c for longer periods such as weekly or monthly.

Crop evapotranspiration (ET_c) is the most important component regarding water balance in arid and semi-arid areas and is a key factor for computing proper irrigation scheduling and for increasing water use efficiency in irrigated agriculture. ET_c differs from the reference crop evapotranspiration (ET_o), since the ground cover, canopy properties and aerodynamic resistance of the crop are different from grass.The actual rate of water uptake by the crop from the soil in relation to its crop evapotranspiration (ET_c) is influenced by whether, the available water in the soil is adequate or whether the crop will suffer from stress induced by water deficit.

For most of the agricultural crops a relationship can be found between evapotranspiration and climate by introducing a crop coefficient (K_c), which is the ratio of crop evapotranspiration (ET_c) to reference crop evapotranspiration (ET_o). The K_c value relates to evapotranspiration of a disease free crop grown in large areas under optimum soil water and fertility conditions and achieving full production potential under the given growing environmental conditions (Allen *et al*.,1998). It serves as a combination of the physical and physiological differences between crops and the reference grass. Differences between evaporation and transpiration of field crops and the reference grass surface can be integrated in a single K_c value. Factors affecting K_c include crop type, crop growth stage, climate and soil moisture. Crop coefficient is normally expressed as a function of time. Therefore, most of the authors have reported values of K_c as a function of days after transplanting which helps to denote K_c for different crop development stages.

Soil based cultivation faces serious challenges in regions with problem soils *viz*. poor fertility, salinity, weed and other disease infestations etc. Soilless culture is an alternative in such areas to sustain crop production with minimum inputs and not compromising on yield. It is an artificial means of providing plants with support and a reservoir for nutrients and water. The simplest and oldest method for soilless culture is a vessel of water in which inorganic chemicals are dissolved to supply all of the nutrients that plants require. Soilless culture has many advantages over standard agricultural practices. Weed and soil diseases are not a problem in soilless culture and yield is of high quality. Cultivating crops in any region even in regions where poor soil conditions prevail is also possible. Since, soil less media like coir pith has high water holding capacity, the water requirement is less. In the present study, mini lysimeters are provided with soil less media so that the evapotranspiration parameters can be compared with that in soil.

Polyhouse farming as well as other modes of controlled environment cultivation have 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 soil less 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 focussed 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. The protected cultivation systems 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 grow bags 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 soil less culture of vegetables.

Soil less culture systems generally improve water use efficiency (WUE) and reduce the demand of water. Particularly coir pith based media has good water holding capacity and high volume expansion and there is a need to conduct studies on water requirement of coir pith based media, so that frequency of irrigation and quantity of water applied can be reduced compared to conventional methods. Generally studies on coir pith based media indicates applying irrigation water in the same amount as in soil. There are only limited studies on the scheduling of irrigation in coir pith to find out whether lesser amount of application or less frequency of irrigation can sustain the crop without effecting yield.

Hi-tech horticultural systems use protected cultivation with soil and soil less media as substrates. Evapotranspiration in open field and inside of polyhouse will differ due to the micro climatic variation. Water balance components in the mini lysimeter will be influenced by the atmospheric condition and the media used in the mini lysimeter. At present water requirement for open field vegetable cultivation is adopted as such as in polyhouse cultivation. Hence there is a need to study the consumptive use of crops in soil and soilless media inside the polyhouse. Considering the above facts, the study was proposed with the following objectives:-

- To determine ET parameters of Okra in a naturally ventilated polyhouse for soil and soilless media.
- To compare ET parameters of Okra for the selected media.
- To determine crop coefficients of Okra in poly house for soil and soilless media.
- To compare crop performance of Okra in soil and soil less media inside poly house.

Review of literature

CHAPTER 2

REVIEW OF LITERATURE

Evapotranspiration (ET), the most important component of hydrological cycle, is a widely studied parameter throughout the world. Evapotranspiration is the combination of two separate processes – evaporation of water from the ground surface or wet surfaces of plants; and transpiration of water through the stomata of leaves. Measurement of ET is needed for many applications in agriculture, hydrology and meteorology. In agriculture, ET estimates are needed for scheduling irrigation particularly in arid and semiarid areas, in planning the farm irrigation systems, in the design of irrigation projects, in water resources development, in yield prediction and also is an important component of soil erosion models. ET estimates are also required for defining the geographical limit of economic rainfed farming. Hence, for judicious application of precious water resources in arid and semiarid areas, it is almost necessary to have accurate estimation of ET.

By comparing the evapotranspiration rates of plants in soil and soil less media, we can analyse the crop water requirement in both the media so that we can use the best medium and schedule irrigation, since water is a scarce resource. Soil less culture is an artificial means of providing plants with support and a reservoir for nutrients and water. Soil less cultivation is intensively 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. Soil less culture is based on environmentally friendly technology resulting in good yield and that too without quality deterioration.

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

2.1 SIGNIFICANCE OF EVAPOTRANSPIRATION (ET)

Evapotranspiration (ET), also known as consumptive use or actual evapotranspiration (AET), is the sum of the amount of water returned to the atmosphere through the processes of evaporation and transpiration (Hansen *et al*., 1980). It is the most important processes in the hydrological cycle for irrigation planning and water management (Allen *et al*., 1998).

Raki *et al*. (2007) reports that one of the most important concepts regarding water balance in arid and semi-arid areas is crop evapotranspiration (ET_c) which is a key factor for determining proper irrigation scheduling and for improving water use efficiency in irrigated agriculture. Accurate determination of evapotranspiration component is considered as a major part of irrigation system planning and designing but, accurate spatial determination is crucial to reach sustainable agriculture.

Irmak (2009) explains that evapotranspiration (ET) is the major component of the hydrologic cycle, given that most precipitation that falls on land is returned to the atmosphere. Worldwide, about 60% of yearly precipitation falling over the land surface is consumed by ET. Determination of ET is used for crop production, water resources management, and environmental assessment. In agriculture, accurate estimation of ET is important for effective and efficient irrigation management.

2.2 POLYHOUSE MICROCLIMATE AND EVAPOTRANSPIRATION

The main aim of a polyhouse is to raise plants, and therefore high transmission of solar radiation in the wave band 400-700 nm is necessary to increase the photosynthesis rates. The amount of structural material and the properties of the cladding material will control the rate of incident radiation transmitted to the plants. All the radiation trapped inside the greenhouse will add to the possible elevation of the greenhouse temperature above that of the outside air. The better the insulation properties of the polyhouse, better will be the elevation, although as universal rule, those cladding material that may be chosen for good quality thermal resistance will also tend to be less good at admitting radiation for plant growth (Day and Bailey, 1999).

The use of greenhouses in arid regions decreases crop water requirement by reducing evapotranspiration. The plastic cover utilized on these structure changes locally the radiation balance and creates an obstacle to moisture losses. As a result evapotranspiration is decreased by 60 to 85% compared to outside the greenhouse (Fernandes *et al*., 2003)which may lead to clear reduction in water demand when compared to open field farming. Thus greenhouse farming provides a way of increasing crop water use efficiency.

Production of vegetable crops under protected conditions provides high water and nutrient use efficiency under varied agro climatic conditions. This technology has good potential especially in peri-urban areas adjoining to the major cities which are fast growing markets of the country, since it can be profitably used for growing high value vegetable crops like, tomato, cheery tomato, colored peppers, parthenocarpic cucumber, healthy and virus free seedlings in agri-entrepreneurial models (Singh *et al*., 2010).

2.3 ROLE OF LYSIMETERS IN WATER BALANCE STUDIES

A lysimeter is a device that separates soil and water hydrologically from its surroundings, but still represents the adjoining soil as closely as possible. Lysimeters are capable to be used as a research tool to study plant-water relations if they are designed sufficiently to approximate the physical system (Chow, 1964).

In a Lysimeter, a soil column can be separated from the adjoining fields using a container of normal shape and planted with crop. The water input to grow the crop can be calculated and the crop water use and other output variables of the soil water balance (runoff, deep percolation and moisture retained in the soil column) can also be computed. The lysimeter tank could be of any dimension, but Clark and Reddell (1990) noted that depth and the surface area of the lysimeter tanks are to be large enough adequately to minimize plant root limitations

Mini-lysimeters have greater advantages that they permit the measurement of the evaporative flux from smaller areas, create fewer disturbances to the environment during installation, and are considerably cheaper to construct and install. Mini-Lysimeters (ML), characterized by reduced soil quantity (less than 1 m^3), have been recently accepted due to the reduced installation and managements costs and good accuracy of measurements (Oke, 2004).

Field studies using lysimetric data acts as an accurate tool in the determination of water balance variables, representing the existent field conditions. Lysimeters are usually more accurate for evaluating the water balance when compared to the use of soil water sensors. Lysimeters are used for determining actual evapotranspiration and groundwater recharge and therefore for setting up a water balance. The original sense of lysimeters gained more and more importance in the last decades and lysimeters are used not only for quantitative but qualitative aspects also (Loos *et al*., 2007).

Henry E Igbadun(2010)conducted the estimation of crop water use of rain fed maize and groundnut using minilysimeters in Ahmadu Bello University, Kadurastate, Nigeria. This paper reports the use of weighing-type minilysimeters to estimate the crop water use of rainfed maize and groundnut. The mini lysimeters were assembled using readily available materials which include plastic containers as the mini lysimeter tank and vehicular tubes filled with water connected to a manometer glass tubes for the weighing system. The mini lysimeters were planted to maize and groundnut, and were installed in the midst of fields cultivated to the respective crops. The daily displacement of water in the manometer tube due to change in weight as water enters or leaves the mini lysimeter tanks were translated to crop water use. The results showed that the average daily water use of the maize crop increased from 2.70 mm/day at the early crop growth stages to 6.00 mm/day at mid-season and declined to 3.30 mm/day at the end of the season. The average daily water use of the groundnut crop was also found to increase from 2.66 mm/day at the early growth stage of the crop to 4.83 mm/day at the mid-season and declined to about 2.70 mm/day at the end of the season. The water use of both crops compared closely with estimates from weather data-crop coefficient with mean differences of 2.75 and 3.15 mm/week for the maize and groundnut crops, respectively.

2.4 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 world wide 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.

The field experimental data from the Hsueh Chia experimental station of Chia Nan irrigation association in Taiwan were collected, analyzed and the results were fed to the CROPWAT irrigation management model that was developed by the Food Agricultural Organization (FAO). The results from the 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, inorder to provide information necessary for taking decision on irrigation management. Simulation results suggest that areas, where the maize water requirements exceeds the water supply, by application of adequate irrigation scheduling the yield losses can be significantly reduced.

2.5 PHYSICO - CHEMICAL PROPERTIES OF DIFFERENT SOIL LESS CULTURE MEDIA

Kannan *et al.* (2005) conducted a field experiment to study the influence of different organic N sources *viz*, FYM, vermicompost and coirpith compost with Biofertilizers on the soil physical properties, nutrient availability and biological properties during December- May(2003-04) 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.

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

2.6 ALTERNATE MEDIA FOR SOIL LESS CULTURE

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 soil less 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

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 (10.1-60.2% w.b.) and particle size (0.098 – 0.925mm). Porosity and particle density varied from 0.623 -0.862 and from 0.939 -0.605 g/cc respectively. Bulk density and static coefficient of friction against mild steel were in the range of 0.097 to 0.341 g/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 substrate. Research was conducted in 2 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 the organic manuring decreased the total yield by 22.4% in comparison to inorganic nutrient solution. In orcanig 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 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.

Albaho *et al.* (2013) investigated the suitability of locally available materials in Kuwait. Four combinations of media were used as substrate *viz.* M1- 35% peat moss/ 40% perlite/ 25% vermicompost, M2-25% pat moss / 25% perlite / 25% vermicompost / 25% coco peat, M3-100% coco peat and M4- 50% perlite/50

% peat moss as controlled. Experiments were carried out in a cooled greenhouse. Experiments with cucumber cultivar ‘Banan’ revealed that the growing media M1 and M2 are the best substrate for use in the grow bag technique.

D. Wang*et al.* (2016)conducted studies for comparing characteristics of growing soil less media mixtures in strawberry.The objectives of the study were to characterise the chemical and hydraulic properties of a number of selected growing media mixes and to evaluate them in 2 year field study for strawberry production in open field. The growing media mixes were 100% coconut coir , a peat-perlite (PP) mix, a peat –rice hull(PR) mix and a peat-coir-rice hull (PCR) mix. Among these media mixes , 100% coir showed the highest water content values at saturation and after free drainage. Strawberry yields in coir and peat-perlite were comparable to grower standard.

2.7 DRIP IRRIGATION AND FERTIGATION IN SOIL LESS CULTIVATION

Harmsen ,*et al.* (2002) assessed the pan evaporation method for scheduling irrigation of sweet pepper (*Capsicum annuum*) crop grown on an oxisol at the University of Puerto Rico Agricultural Experimental Station at Isabela, PR. Evaluation of the pan method for scheduling irrigation was based on comparison of ET_{pan} with the Penman-Montieth-based evapotranspiration (ET_c), estimates of deep percolation, measured vertical hydraulic gradients and measured soil moisture distribution. A simulated irrigation schedule using the Penman-Montieth method resulted in even greater seasonal deep percolation (127.7mm). 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.

Harmantoa *et al.* (2004) reported that four different levels of drip fertigated irrigation equivalent to 100,75,50 an 25% of crop evapotranspiration (ET_c), based on Penman-Montieth method, were tested for their effect on crop growth, crop yield and water productivity. Tomato (Troy 489 variety) plants were grown in polynet green house. 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/hour discharge. The result revealed that the optimum water requirement for the Troy 489 variety of tomato is around 75 % of the ET_C. Based on this, the actual irrigation water for tomato crop in tropical green house could be recommended between 4.1 and 5.6 mm/day or equivalent to 0.3 to 0.4 l/plant/day. Drip irrigation at 75% of ET_c 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 to 40% over the experimental period.

Metian *et al.* (2009) conducted a study to determine the optimal irrigation strategy for drip irrigated fresh market tomato grown in different soil less culture in a glass house 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.

2.8 COMPUTATION OF ET_c AND ET_0

Junzeng*et al.* (2008) conducted Lysimeter experiments to investigate tomato and cowpea crop evapotranspiration inside the greenhouse in Eastern China. The results showed remarkable reduction in crop evapotranspiration inside greenhouse as compared to outside, and ET increased with the growth stage of the crop and varied in accordance with the temperature inside the greenhouse.

Hashim M.A.A, *et al.* (2012) of King Saud university, Riyadh, Saudi Arabia conducted experiments for determining water requirement and crop water productivity of crops grown in the Makkah region of Saudi Arabia. Neutron probe and mini lysimeter measured Evapotranspiration (ET) data acquired at different crop growth stages were used to assess the total water requirements of different crops for an entire growing season. The crops included in the study encompassed seasonal crops (wheat, corn, broad beans, millet, cowpea, okra and eggplant) and forage crops (alfalfa, blue panic grass, rhodes grass and Sudan grass) grown in Makkah region, Saudi Arabia. The investigations were carried out at the Research Farm of King Abdul-Aziz University, Hoda Al-Sham, Makkah area. Results revealed that crop water requirements were found to vary from 303 to 727.8 mm in seasonal crops and from 436.7 to 1821.94 mm in forage crops. In addition, crop water productivity (CWP) of summer season crops (1.478 kg/m3) was found to be higher than the values associated with forage (1.079 kg/m3) and winter season (0.942 kg/m3) crops. The lowest value of CWP was observed in corn (0.794 kg/m3), while the highest value of 1.724 kg m-3 was associated with okra.

Ali and Rehman (2016) conducted a study on the design and construction of low-cost raised-bed drainage lysimeter for crop water hydrological studies and relations. Collection of complete data of all the parameters of water balance equation was possible for one week or 10 days duration with the help of a non-weighing lysimeter. ‘Bangladesh Institute of Nuclear Agriculture’, Bangladesh has designed and constructed a non-weighing gravity type lysimeter system with eighteen boxes at the experimental farm. Each lysimeter box is equipped with percolate collector. The percolation collector (bottom runoff outlet pipe) was placed at the bottom of the lysimeter box maintaining a slope of 5% towards the outlet. The percolation amount (subsurface runoff) can be collected and measured. Evapotranspiration was determined from water balance equation by accounting effective rainfall, run-off, irrigation, storage and deep percolation.

Madhavi (2017) conducted an experiment for comparing the evapotranspiration of okra in polyhouse and open field by using mini lysimeters in KCAET, Tavanur, Kerala. To obtain ET_0, *Kango signal* grass was selected as reference crop for this study. ETo estimated using climatological methods viz reduced pan, FAO -56 Penman-Monteith, FAO Blaney- Criddle and Thornthwaite were compared with measured lysimetric data using simple error analysis and linear regression. Out of all methods FAO-56 Penman-Monteith provides quite good agreement with evapotranspiration obtained by lysimetric data with a high correlation coefficient of 0.88 and 0.87 for polyhouse and open field conditions respectively.

2.9 DEVELOPMENT OF CROP COEFFICIENT CURVES

Haman *et al*. (1997) used drainage lysimeters to compute ET and develop K_c for two varieties of young blueberries at Florida. They used cylindrical tanks as lysimeters (1.6 m diameter and 1.8 m deep) equipped with permeable plates to remove drainage water. The ET_c in their study integrated transpiration and evaporation as that from the surface wetted by the irrigation system, but did not contain water loss from the grassed alleys. They noted that the computed K_c was different from the standard K_c but it provides the actual crop water use. Although K_c for both the varieties followed the same common trend, K_c values for the two varieties were dissimilar from each other. Differences in K_c values of the two varieties were attributed to the differences in plant development.

The K_c values represent the crop specific water use and is required for accurate estimation of irrigation requirements of different crops in a specific area. Development of K_c curves `involves determination of total growing period of the crop, identifying the length of different growth stages, and determination of K_c values for each growth stage. However, K_c cannot be measured directly, but is estimated as a ratio. While ET_o can be estimated using one of several available methods, ET_c can be estimated by a lysimeter study (Gratten *et al*., 1998).

Simon *et al*. (1998) conducted a study to develop crop K_c values for maize in Trinidad. They used 2 m × 2 m × 1.2 m drainage lysimeter for three seasons to develop Kc. The effects of dry and wet season (temporal variability of climate) on K_c were also discussed. They found that K_c during a wet season (K_c =1.13 to 1.41) was superior than during a dry season. (K_c = 0.73 to 0.94). They reported that the differences between the wet and dry season K_c is due to the lower ET_o during the wet season. Mean K_c for maize was found to be greater than the reported values by Doorenboss and Pruitt. As a result, the authors pointed out on the importance of developing regional K_c values for proper irrigation scheduling.

Ko *et al*. (2009) conducted study to determine the growth-stage-specific Kc and crop water use for cotton (*Gossypiumhirsutum*) and wheat (*Triticumaestivum*). Lysimeters were used to measure crop water use and local weather data were used to compute the reference evapotranspiration (ET_o). Six lysimeters were located in the center of a 1ha field beneath a linear-move sprinkler system equipped with low energy precision application (LEPA). Seventh lysimeter was installed to measure reference grass ET_o. Determination of crop water requirements, K_c, and comparison to existing FAO K_c values were done over a 2-year period on cotton and a 3-year period on wheat. Seasonal total amounts of crop water use ranged from 689 to 830mm for cotton and 483 to 505 mm for wheat. The K_c values determined over the growing seasons varied from 0.2 to 1.5 for cotton and 0.1 to 1.7 for wheat. Some of the values corresponded and some did not correspond to those from FAO-56. Development of regionally based and growth-stage-specific K_c helps in irrigation management and provides precise water applications for Uvalde region.

Materials and Methods

CHAPTER 3

MATERIALS AND METHODS

One of the key factors for enhancing agricultural production is the precise and timely application of the available water. Estimation of evapotranspiration (ET) is an important part of agricultural water management, in local and regional water balance studies and in hydrological modelling. At the field scale ET is important in irrigation planning and scheduling and is an integral part of field management decision support tools. Availability of experimentally determined crop coefficient and crop water requirement data is important for proper irrigation scheduling, efficient water management, optimum yield and profit. Evapotranspiration rate is an important component of canopy energy and water balance. The values may vary for soil and soil less medium as influenced by the higher water holding capacity in soil less media.

Many studies have been conducted over the years to develop the Crop Coefficient ($K_{c)}$ for different agricultural crops. K_c for any crop may vary from one place to another, depending on factors such as climate, soil, crop type, crop variety and irrigation methods. For an accurate estimation of the crop water use, it is important to develop a regional K_c. In the present study, Non-Weighing Mini-Lysimeters were used to determine evapotranspiration parameters and to develop crop-coefficient curves for Okra. The materials utilized and the methodology adopted for achieving the objectives of the study are enumerated under the following sub headings in this chapter.

3.1 LOCATION OF THE STUDY AREA

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. The field experiment was conducted in a naturally ventilated polyhouse in the research plot of the Department of Irrigation and Drainage Engineering, in KCAET campus, Tavanur, Kerala.

3.2 CLIMATE

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

3.3 PHYSICAL PROPERTIES OF SOIL AND SOIL LESS MEDIUM

3.3.1 Bulk density

Bulk density of both the medium filled in the Lysimeters were measured using core cutter method by standard procedure.

Equipment used:

1. Cylindrical core cutter
2. Steel rammer
3. Steel dolly

Procedure:

Height and internal diameter of the core cutter were measured, and the volume of the core cutter was determined. Core cutter was pressed into the soil to its full depth with the help of steel rammer and the soil around the cutter was removed by spade. The cutter was removed and the top and bottom of the sample surface was trimmed carefully. The soil core was removed from the cutter and the weight of the core soil was measured. Representative sample was taken from the cutter in to the moisture container to determine the moisture content. The sample was dried in the oven at 105ºC and constant weight was recorded (Plate 3.1). The same procedure was followed for soil less media

.

Plate 3.1 Determination of Bulk density by Core cutter

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

Bulk density of the medium (g/cm^3) $\gamma = \frac{W}{V}$ where,

W - Weight of medium (g)

V - Volume of medium (cm^3)

Dry density of the medium (g/cm^3) $\gamma_d = \frac{\gamma}{1+\omega}$ where,

γ - Bulk density of the medium

ω - Moisture content of medium

3.3.2 Soil Texture

Soil Texture was determined by using sieve analysis.

Procedure:

The oven dried sample of soil was separated into two fractions by sieving it through a 4.75 mm IS sieve. The portion retained on it (+ 4.75 mm size) termed as the gravel fraction was kept for the coarse analysis, while the portion passing through it (-4.75 mm size) was subjected to fine sieve analysis. IS: 100, 63, 20, 10 sieves were used for coarse sieve analysis and 4.75 mm and 2 mm, 1 mm, 600, 425, 300, 212, 150 and 75 micron sieves were used for fine sieve analysis.

Sieving was performed by arranging the various sieves one over the other in the order of their mesh openings. A receiver was kept at the bottom and a cover was kept at the top of the whole assembly. The soil sample was put on the top sieve, and shaking was done by hand. The portion of the soil sample retained on each sieve was weighed. The percentage of soil retained on each sieve was calculated on the basis of the total mass of soil sample taken.

3.4 FIELD EXPERIMENT

The experiment was conducted inside the naturally ventilated poly house during October 8^{th} - January 8^{th} 2017-18 and the crop duration was three months. The poly house was oriented east–west with an overall area of 208 m^2 (26 m length and 8 m width). View of the poly house are shown in Plate 3.2.

3.4.1 Field Preparation

Land preparation was done inside the naturally ventilated polyhouse. Polyhouse was divided into two parts and one portion was used for cultivation of Okra crop. Four raised beds of 10 m length, 1.0 m width and 0.25 m height were made for cultivating Okra. A reduced pan was installed in the middle of the polyhouse leaving an area of 48 m^2 without crop (Plate3.3).

Plate 3.2 View of the experiment site

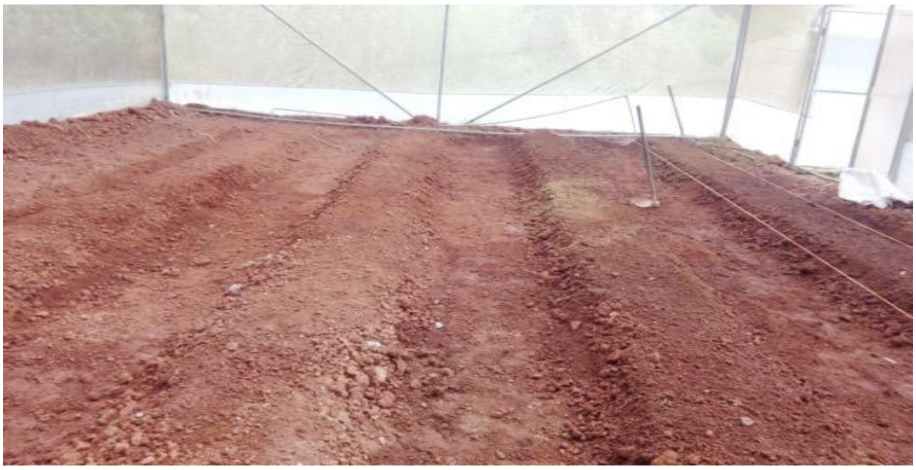

Plate 3.3 Poly house after land preparation

3.4.2 Preparation of Non weighing Mini Lysimeters

Six sets of mini non-weighing lysimeters were fabricated and used for this study. (Plate 3.4).

Plate 3.4 Non-weighing Mini lysimeter with drainage system

The drainage lysimeters were plastic containers of 42 cm diameter and 30 cm depth. Drainage provisions were provided at the sides at a height of 5 cm above the bottom. A hole was made in each lysimeter and drain pipe of ¾" was connected from the bottom of the tank to the drainage system to ensure free drainage of excess water. Drainage system consisted of a plastic bucket of 22 cm diameter and 20 cm depth with a lid provided to prevent evaporation.

3.4.3 Experiment setup

Six mini lysimeters were used inside the poly house of which, three were planted with Okra in soil and three in soil less media. Lysimeters were placed randomly on the raised beds in the naturally ventilated Polyhouse. Gravel was filled at the bottom of the lysimeter to a height of 5cm to ensure proper drainage. Three Okra plants were planted in each lysimeter. Lysimeters were surrounded by the same crop in grow bags (40×24 cm) in the same density in order to avoid the border effect. The grow bags were made of UV stabilized polyethylene. Drainage holes were provided on both sides of the grow bag, towards the bottom to allow drainage. Fig. 3.1 shows layout of the experiment setup and Plate 3.5 shows the experimental setup of lysimeters and grow bags before sowing inside the poly house.

Plate 3.5 Experimental setup

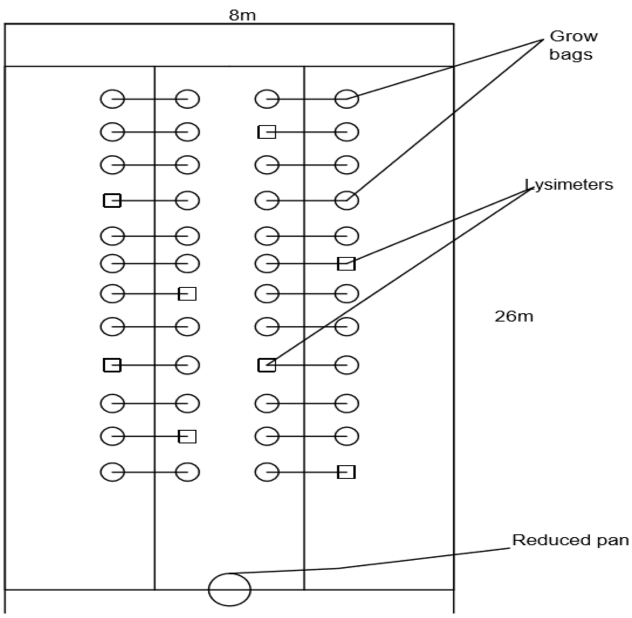

Figure 3.1 Layout of the Experiment

3.4.4 Preparation of growth medium

3.4.4.1 Preparation of soil media

Three lysimeters were filled with sandy soil collected from the field. It was mixed with equal amount of dried cow dung as potting mixture in order to ensure efficient nutrient availability(plate 3.6).

Plate 3.6 Soil media in Lysimeter

3.4.4.2 Preparation of soil less media

Three lysimeters were filled with soil less media. The media consisted of a mixture of coir pith, river sand and vermicompost, mixed in a proportion of 60:20:20. River sand was mixed to ensure proper drainage and vermicompost provided nutrients to the inert media (plate 3.7).

Plate 3.7 Soil less media in Lysimeter

3.4.5 Sowing of Okra

Okra variety *Varsha Upahar* was chosen for this study to estimate crop evapotranspiration. Sowing was done on 15th October. Seeds were directly sown in the Lysimeters and grow bags. In each Lysimeter or grow bag, three seeds were sown. Plate 3.8 shows the view of the field in the initial stage of Okra.

Plate 3.8 Initial stage of okra

3.4.6 Irrigation system

Water source is a filter point well from which water is pumped to an over head tank and conveyed through the main line of 63 mm diameter PVC pipes. 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 cutoff valve for controlling irrigation. Along the laterals, microtube of 6 mm diameter and length of 75 cm were connected using thin connectors and online drippers of 4 l/hr were fixed at the other end of the microtubes. Plate 3.9 depicts the irrigation system layout in the poly house.

Plate 3.9 Drip irrigation system layout

The irrigation applied to the plant was in a higher rate than the actual requirement in order to ensure drainage and to allow maximum evapotranspiration. At the initial stage the crop was irrigated daily with an application rate of 0.65 l/day/plant against the standard value of 0.6l\day\plant. During the mid season stage the plant requires more water than initial stage. So the water applied was increased from 0.65 to 1 l/day/plant. In the late season stage water application rate was reduced to 0.8 l/day/plant.

3.4.7 Fertigation

Macro nutrients were applied as water soluble fertilizer at a ratio of 19:19:19 through fertigation system with dosmatic pump (plate 3.10). Same quantities of fertilizers were applied with an equal interval of three days during crop period. Micro nutrients were also applied as foliage spray. It was applied at a rate of 5 g/l in 30, 45 and 60 days after germination of seed.

Plate 3.10 Dosmatic pump

3.4.8 Pest and disease management

Okra yield is usually reduced due to sucking insects and pests. Common problem for polyhouse okra are aphids mealy bugs, scale, stem borer, thrips, and white flies. Tatamida was sprayed twice during the crop period at a rate of 1ml/ 3 liters of water on the leaves for controlling sucking insects. Neem soap was also sprayed at a rate of 5g/l twice during the crop period.

3.5 DETERMINATION OF ET_c

Field studies using lysimetric data acts as an accurate tool in the determination of water balance variables, representing the existing field conditions. Non weighing lysimeters are also known as Drainage lysimeters or Percolation lysimeters. The soil column is isolated from the surroundings using lysimeter to prevent seepage of the adjoining fields and also to study the water inflow and outflow in the system. Drainage lysimeters work on the principle that evapotranspiration is equal to the amount of rainfall and irrigation added to the system, minus percolation, runoff and soil moisture change, assuming that the water flow is mainly vertical and occurrence of lateral flow components are negligible (Zupanc *et al*., 2005)

Water balance is defined by the general hydrologic equation, which is basically a statement of the law of conservation of mass as applied to the hydrologic cycle (Ridder and Boonstra, 1994).

The Lysimeter water balance equation used in the study was

$$\mathbf{ET = I + R - D - \Delta S}$$

Where,

I and D are respectively, the total volumes of applied irrigation water and collected drainage water, measured weekly.

R is effective rainfall measured with rain gauge near the site

ΔS is the change in volumetric soil moisture content measured weekly at two depths.

3.5.1 Water balance data collection

Applied irrigation water (l) was measured daily. Drainage from the lysimeters (D) was collected manually on daily basis and measured. Volume of water was converted to depth in mm of water using the following formula. Data are presented in Appendix II

$$\text{Depth in mm of water} = \frac{\text{Volume of water (l)}}{\text{Cross sectional area of the lysimeter } (m^2)}$$

The volumetric moisture content data of both the medium used in water balance calculations was derived from the gravimetric moisture content data. Medium sampling was done in each lysimeter at two sampling points 0-10 and 10-20 cm depth on a weekly basis. Moisture content was determined gravimetrically using oven drying method (Plate 3.11). Change in moisture storage was calculated layer wise using the following formula.

$$\Delta S = \sum_{i=1}^{n} \frac{M_{1st} - M_{2nd}}{100} \times (A \times D_i)$$

Where,

ΔS - change in moisture storage in mm

M_{1st} - moisture content at the time of 1_{st} sampling in the i^{th} layer

M_{2n} - moisture content at the time of 2_{nd} sampling in the i^{th} layer

A - apparent specific gravity of the medium

D_i - depth of the i^{th} layer of the medium in mm

n - no. of layers in the root zone

ETc from Okra was measured on weekly basis throughout the crop period inside polyhouse using water balance approach. Results are given in section 4.2

Plate 3.11 Moisture content estimation by oven drying method

3.6 INDIRECT METHODS OF ET ESTIMATION

3.6.1 ET_o from reduced pan data

The class A pan method has been one of the most accepted method due to its simplicity, relatively low cost, and computes daily evapotranspiration estimates. Because of the large area occupied by a class A pan, alternative methods have been sought to estimate ET_o inside Polyhouse. Reduced pan method was effectively used inside the Polyhouse to compute ET_o (Amiri *et al.,* 2011).

3.6.1.1 ***Fabrication of Reduced Pan***

Two reduced pans of dimensions, 60 cm diameter and 25 cm depth were fabricated with 22 mm galvanized iron sheet, and painted white. A stilling well was provided in the center of the Pan to prevent wave effects and a stainless steel scale was placed inside of the stilling well to monitor the water levels in the Pan. It was placed on a level wooden platform of height 15cm on the soil surface in order to avoid the crop shading effect. Plate 3.12 shows the view of the reduced pan.

Plate 3.12 View of reduced pan

3.6.1.2 *ET_o from reduced Pan data*

One reduced pan was installed in the naturally ventilated Poly house at the center position. Daily Pan Evaporation (E_p) was obtained by monitoring the water level in the stilling well. Depth of water level maintained in the stilling well was 15cm. Water level in the pan was measured daily and the amount of evaporation was calculated as the difference between observed water levels. A pan coefficient of 0.4564 was taken for conversion of reduced pan evaporation data to data from free water surface (Modaberi *et al*., 2014). Pan based ET_o was estimated by using following equation.

$$\mathbf{ET_o = K_p \times E_p}$$

Where,

ET_o - Reference evapotranspiration in mm

K_p - Pan coefficient

E_p - Pan Evaporation in mm

3.6.2 ET_o computation using CROPWAT

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 ET_O (FAO 1992). Computer model simulation is an emerging trend in the field of water management.

3.6.2.1 Data Requirements for CROPWAT

In this study climate data is given as input to the CROPWAT. The climatic data include maximum and minimum temperatures (ºC), mean daily relative humidity (%), daily sunshine (hours) and wind speed (km/day).

3.6.2.2 Climate data

Climate module window is presented in Fig. 3.2. The daily data of minimum temperature, maximum temperature, humidity, sunshine hours, and wind speed for twelve months were used to calculate radiation and ET_o. Minimum temperature, maximum temperature and relative humidity were measured inside the polyhouse from October 2017 to December 2017 using the Equinox Digital Temperature and Humidity meter at 8.30 am, 1.30 pm and 4.00pm everyday at crop canopy level based on IMD recommendations. Light intensity was recorded using Equinox Digital Light Meter at 8.30am , 1.30pm and 4.00pm everyday. Climate variations in the crop growth period at various time interval of the day were plotted and the results are presented in the section 4.4. Mean climatic data are given in the Appendix V

(a) (b)

(a) Equinox digital temperature and humidity meter (b) Equinox digital light meter

Plate 3.13. Instruments for direct measurement of climatic data

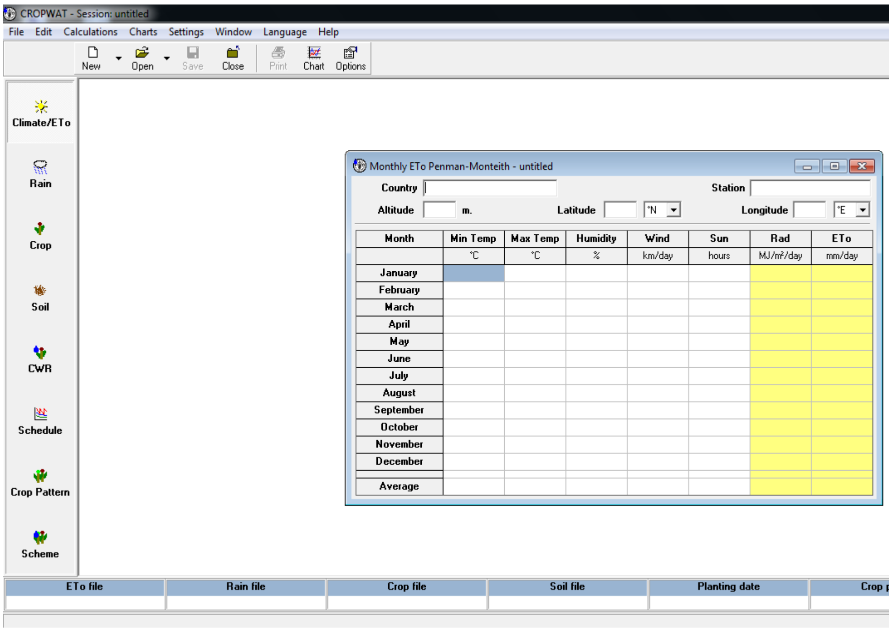

Fig. 3.2 Climate module window of CROPWAT model

For open field conditions, sunshine hours and wind speed were taken from the Meteorological observatory at RARS, Pattambi for the period 2017 January to 2017 December. For sunshine hours and wind speed data in poly house, suitable correction factors were applied to open field data based on literature due to lack of yearly measured 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 for Polyhouse by using CROPWAT model

3.6.2.3 *Penman-Monteith method*

To calculate 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 combination equation is,

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

Where,

ET_0 : The reference evapotranspiration [mm/day]

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

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

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}]

3.7 DEVELOPMENT OF CROP COEFFICIENT VALUES FOR OKRA

Evapotranspiration rates of various crops are related to ET rate from the reference crop by means of crop coefficients (Allen *et al*., 1998). The K_c value relates to evapotranspiration of a disease free crop grown in large fields under optimum soil water and fertility conditions and achieving full production potential under the given growing environment

Factors affecting K_c include crop type, crop growth stage, climate, soil moisture. K_c is normally expressed as a function of time. Steps for computing of K_c include determination of total growing period of the crop, identifying the length of different growth stages, and determination of K_c values for each growth stage. The growing period was divided into three distinct growth stages: initial, midseason and late-season. Weekly values of ET_c were estimated using lysimeters by the soil water balance approach for polyhouse in soil and soil less media. ET_0 was estimated by FAO Penman Montieth Equation using CROPWAT. The Crop coefficient values at each crop stages were calculated for weekly periods by using the equation:

$$\mathbf{K_c = ET_c / ET_o}$$

Crop coefficient curves were plotted for soil and soil less media. Results are presented in section 4.6

3.8 COMPARISON OF EVAPOTRANSPIRATION IN SOIL AND SOIL LESS MEDIUM

ETc measured by using lysimeters in soil and soil less medium and were compared and results are presented in section 4.3.

3.9 CROP GROWTH AND YIELD PARAMETERS

One plant from each lysimeter was selected and tagged for observations on growth and yield parameters.

3.9.1 Plant height

Plant height from base level of shoot to the tip was measured at initial, mid and late season and expressed in centimeters.

3.9.2 Number of leaves and branches

Number of leaves and branches per plant was noted at initial, mid and late season stage in selected plants.

3.9.3 Yield parameters

Harvesting was started 40 days after sowing and continued at an interval of two days. The number of fruits and weight of fruits harvested were noted from tagged plants for each harvest. Results are presented in section 4.7

Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

Results obtained from the field study on the comparative evaluation of evapotranspiration parameters in a naturally ventilated polyhouse in soil and soil less media were analyzed and details are discussed under various headings in this chapter.

4.1 PHYSICAL PROPERTIES OF MEDIUM

4.1.1 Bulk density

Bulk density of the soil and soil less media filled in the Lysimeters were measured using core cutter method. The value of bulk density of soil and soil less media was observed as 1.52 g/cc and 0.77g/cc respectively.

4.1.2 Soil Texture

Soil Texture was determined by using sieve analysis. From the analysis, it was found that 99.4 per cent of the soil was sandy and the remaining 0.6 per cent comprised of fines. Out of this 99.4 per cent sand, the percentage of coarse, medium and fine sand were 66, 30.4 and 2.9 per cent respectively. From the results, it could be concluded that the soil was predominantly sandy.

4.2 DETERMINATION OF ET_c

The amount of irrigation water applied, drainage from Non weighing mini lysimeters and change in soil moisture storage were observed to measure ETc in poly house in soil and soil less media using water balance approach. The total volumes of applied irrigation water and collected drainage water were measured daily and converted to weekly values. The change in volumetric soil moisture content was observed for two layers of soil in the root zone on a weekly basis.

4.2.1 Determination of ETc of Okra in soil media

ETc was measured for Okra crop inside the poly house using water balance approach by Non Weighing Mini Lysimeters. Table 4.1 gives water balance sample calculations for one lysimeter to determine ETc and the data and calculations for the remaining two lysimeters are presented in Appendix III. Table 4.2 and Fig. 4.1 shows seasonal mean values of ETc for three lysimeters inside the polyhouse. Minimum and maximum ETc values of Okra crop were 2.2 and 6.16 mm/day during the 1st and 7th week of crop period with a seasonal average of 4.23mm/day. The average daily ETc values of the Okra crop were 3.4, 5.16 and 2.7 mm/day during the initial stage, mid season stage and late season stage respectively. It implied that lowest seasonal ETc was observed in the late stage and highest ETc was observed in mid season stage. ETc increased from initial stage to mid season stage and then decreased in late season.

Table 4.1 Water balance computation for lysimeter A1 –soil media

Growing period	Applied water (I) mm	Drainage (D) mm	Soil moisture Storage change (Δs) mm	ETc=I-D±Δs (mm)
1st week	101.08	89.05	-4.5	16.54
2nd week	101.08	84.59	-10.39	26.88
3rd week	101.08	81.27	-8.03	27.84
4th week	115.52	76.28	8.3	30.94
5th week	126.35	69.96	15.3	41.09
6th week	126.35	67.16	18.6	40.59
7th week	129.96	56.64	32.6	40.72
8th week	151.62	54.92	66.3	30.41
9th week	151.62	49.86	75.2	26.57
10th week	151.62	39.35	89.2	23.07
11th week	126.35	37.55	70.2	18.61

Table 4.2 ETc of Okra for different growth stages – soil media

Growing period	Growth stages	Weekly ETc mm	Total ETc-stage wise Mm	Average daily ETc mm	Average daily stage wise ETc mm/day
1st week	Initial stage	15.43	71.56	2.2	3.4
2nd week		26.84		3.83	
3rd week		29.29		4.18	
4th week	Mid season stage	32.77	216.76	4.68	5.16
5th week		40.29		5.76	
6th week		41.72		5.96	
7th week		43.09		6.16	
8th week		32.49		4.64	
9th week		26.40		3.77	
10th week	Late season stage	20.74	37.68	2.96	2.67
11th week		16.94		2.42	

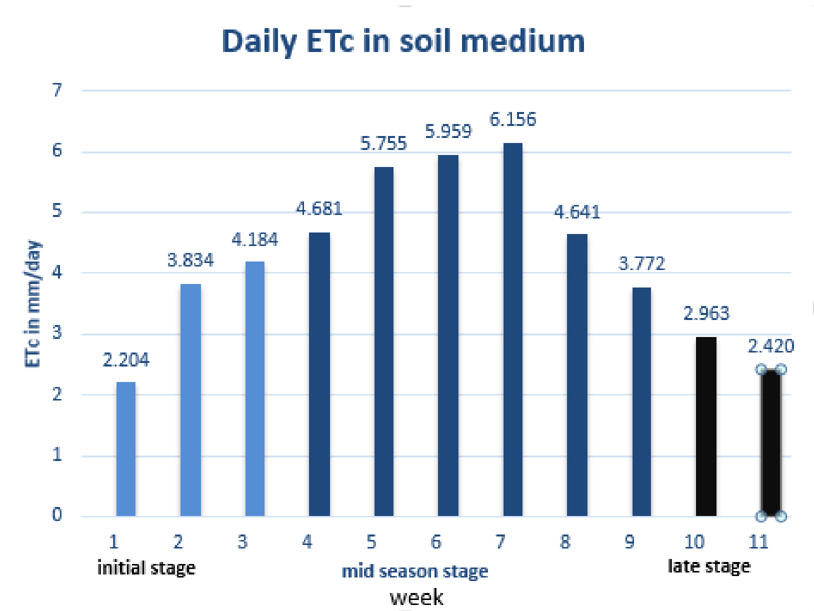

Fig.4.1.Average daily stage wise ETc of Okra in soil medium

4.2.2 Determination of ETc of Okra in soil less medium

Applied irrigation water, drainage and change in soil moisture storage were observed in soil less medium to compute ETc of Okra. ETc was computed using water balance approach by Non Weighing Mini Lysimeters. Table 4.3 gives sample water balance calculations for one lysimeter in soil less medium and remaining two lysimeter data and calculations are presented in Appendix IV.

Table 4.4 and fig.4.2 shows seasonal mean values of ETc for three lysimeters in soil less media. Minimum and maximum ETc values of Okra crop were 1.9 and 4.6 mm/day during the 1st and 6th week of crop period with a seasonal average of 3.1 mm/day for soil less medium. The average daily ETc values of the Okra crop were 2.5, 3.8 and 1.8 mm/day during the initial stage, mid season stage and late season stage respectively. The results imply that lowest ETc was observed in the late season stage and highest ETc was observed in the mid season stage respectively. ETc increased from initial stage to mid season stage and then decreased in the late season stage.

Table 4.3 Water balance computation for Lysimeter B1- soil less medium

Growing period	Applied water (I) mm	Drainage (D) mm	Soil moisture Storage change (Δs) mm	ETc=I+R-D±Δs (mm)
1st week	101.08	53.81	32.60	14.68
2nd week	101.08	78.11	5.60	17.37
3rd week	101.08	93.29	-11.41	19.21
4th week	115.52	103.00	-9.60	22.12
5th week	126.35	97.98	1.20	27.18
6th week	126.35	108.11	-12.50	30.75
7th week	129.96	93.65	4.50	31.82
8th week	151.62	97.87	25.60	28.15
9th week	151.62	61.00	70.20	20.43
10th week	151.62	41.66	96.30	13.66
11th week	126.35	32.56	81.90	11.89

Table 4.4 ETc of Okra for different growth stages- soil less medium

Growing period	Growth Stages	Weekly ETc mm	Total ETc- stage wise mm	Average daily ETc mm	Average Daily stage wise ETc mm/day
1st week	Initial stage	13.94	52.94	1.9	2.5
2nd week		17.29		2.470	
3rd week		21.71		3.101	
4th week	Mid season stage	23.24	161.3	3.320	3.8
5th week		29.37		4.196	
6th week		32.33		4.6	
7th week		31.98		4.569	
8th week		24.69		3.527	
9th week		19.69		2.813	
10th week	Late season stage	13.52	25.4	1.931	1.8
11th week		11.88		1.697	

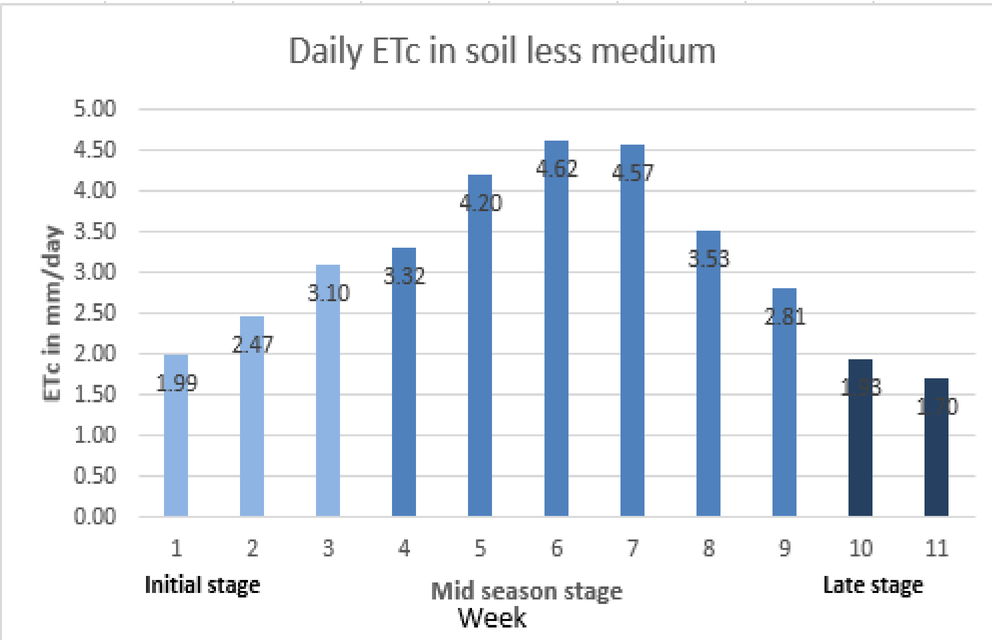

Fig.4.2 Average daily stage wise ETc of okra in soil less medium

4.3 COMPARISON OF DIRECT MEASURED ET_c FOR SOIL AND SOIL LESS MEDIUM.

4.3.1 Comparison of measured ETc for soil and soil less medium

ETc measured from the mini lysimeter inside the polyhouse for soil and soil less medium for Okra crop was compared. Fig.4.3 and Table 4.5 shows comparison of ETc between soil and soil less medium.

From the figure 4.3 it is understood that the ETc increases from initial stage to mid season stage and then decreases in late season stage for soil and soil less medium. Seasonal ETc values of Okra for soil and soil less medium were 4.23 and 3.11 mm/day. It is evident that, ETc was lower for soil less than soil medium, even though, applied irrigation water, fertilizer dosage and crop duration period were similar for both conditions. This may be due to the high water holding capacity of soil less media which might have contributed to lesser water requirement.

Table 4.5 Weekly mean values of measured ETc in soil and soil less medium

Growing period	Measured ETc (mm/day)	
	Soil medium	**Soil less medium**
1st week	2.204	1.992
2nd week	3.834	2.470
3rd week	4.184	3.101
4th week	4.681	3.320
5th week	5.755	4.196
6th week	5.959	4.618
7th week	6.156	4.569
8th week	4.641	3.527
9th week	3.772	2.813
10th week	2.963	1.931
11th week	2.420	1.697
Average	**4.23**	**3.11**

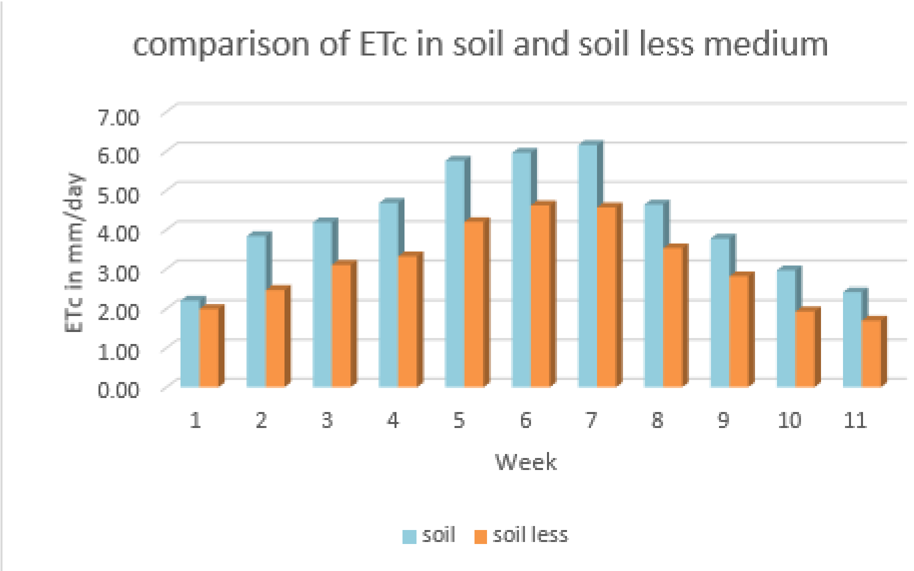

Fig.4.3 Comparison of ETc in soil and soil less medium

4.4 CLIMATIC PARAMETERS FOR POLYHOUSE

During crop growth period, microclimate inside the polyhouse was recorded. Temperature and relative humidity were observed as per the procedure detailed in section 3.6.2.2.

Fig. 4.4 shows weekly mean values of temperature inside polyhouse during the crop growing season. Maximum and minimum temperature recorded values were 33.49 ^{o}C and 30.34^{o}C during 7th and 2nd week of crop period respectively.

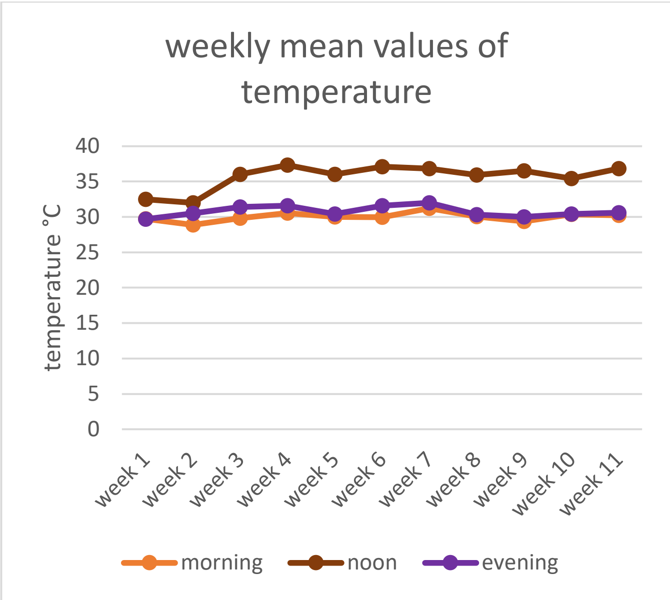

Figure 4.4 Weekly mean values of temperature

Fig. 4.5 shows variation of weekly mean relative humidity inside polyhouse during crop growing season. For polyhouse conditions, maximum and minimum relative humidity values were 79.63 and 45.86 per cent during 2nd and 6th week of crop period respectively.

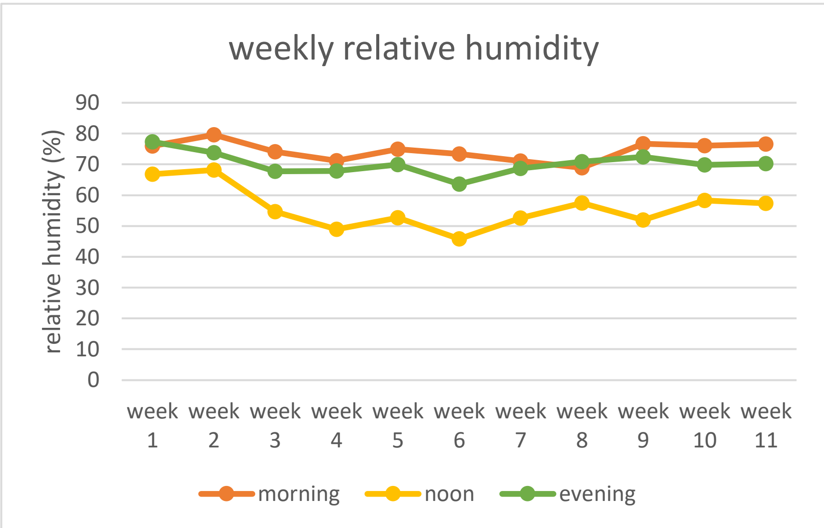

Fig. 4.5 Weekly relative humidity during crop period

Fig. 4.6 shows variation of weekly mean light intensity in polyhouse during crop growing season. For polyhouse conditions, maximum and minimum light intensity values were 21065 and 2341 lux during 4th and 8th week of crop period respectively.

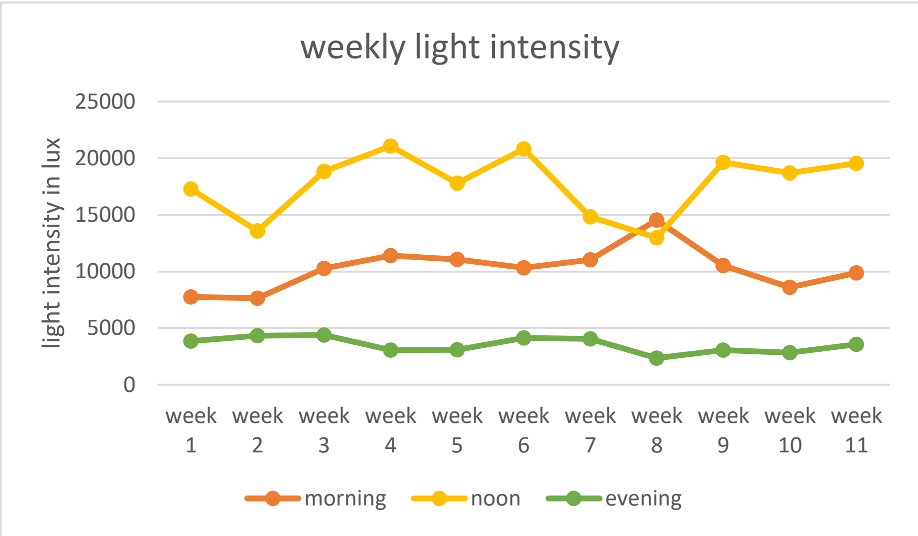

Fig. 4.6 Weekly light intensity (lux) during crop period

From figure 4.4, 4.5, 4.6 shows that highest average temperature, lowest relative humidity and light intensity was observed in 7th week after sowing. Higher values of ETc was also observed in this week. This shows that the micro climatic conditions inside the polyhouse may have resulted in highest ETc.

4.5 INDIRECT METHODS OF ET ESTIMATION

ETo was estimated using Pan evaporation method and FAO Penman-Monteith model.

4.5.1 Estimation of ETo by Pan evaporation method

Daily pan evaporation and pan coefficient were used to estimate the ETo from reduced pan inside polyhouse.Daily Pan Evaporation (E_p) was obtained by monitoring the water level in the stilling well. A pan coefficient of 0.4564 was taken for conversion of reduced pan evaporation data to data from free water surface (Modaberi *et al*., 2014).

Table 4.6 shows ETo from reduced pan inside polyhouse . Minimum and maximum daily ETo values were recorded during 1st and 10th week of the crop growing period as 0.44 to 1.17 mm/day with a seasonal average of 0.76 mm/day inside the polyhouse

Table 4.6 ETo from reduced pan data – polyhouse

Period	E_p in mm	ETo = E_p * K_p (mm)	ETo mm/day
1st week	6.80	3.10	0.44
2nd week	11.50	5.25	0.75
3rd week	13.00	5.93	0.85
4th week	12.00	5.48	0.78
5th week	11.00	5.02	0.72
6th week	13.50	6.16	0.88
7th week	11.50	5.25	0.75
8th week	10.00	4.56	0.65
9th week	12.00	5.48	0.78
10th week	18.00	8.22	1.17
11th week	10.50	4.79	0.68
Average	**11.68**	**5.33**	**0.76**

4.5.2 ETo estimated using climatological model

ETo was estimated by FAO-56 Penman-Monteith for polyhouse using daily values of minimum temperature, maximum temperature, humidity, sunshine hours, and wind speed data for twelve months as input.

Table 4.7 shows calculated ETo for polyhouse . Maximum and minimum daily average ETo recorded in the 1st and 7th week of crop period were 3.48 and 3.31 mm/day respectively.

In recent years, FAO-56 Penman-Monteith method gained more importance to estimate reference evapotranspiration. It provides better results in both arid and humid regions because it takes into account all climatological parameters. Hence, this model has been recommended as a standard method for estimating reference evapotranspiration (Gotardo *et al.*, 2016).

Comparing all other indirect models for calculation of reference crop evapotranspiration FAO-56 Penman-Monteith method provides quite good agreement with evapotranspiration obtained by lysimetric data with a high correlation coefficient of 0.88 and 0.87 for polyhouse and open field conditions respectively (Madhavi , 2017).

Table 4.7 Average daily ETo from Climatological method

Week	Penman montieth model	
	Weekly ET_0	ET_0 in mm/day
1	24.36	3.48
2	24.36	3.48
3	24.36	3.48
4	23.17	3.31
5	23.17	3.31
6	23.17	3.31
7	23.17	3.31
8	23.17	3.31
9	23.17	3.31
10	25.41	3.63
11	25.41	3.63
Average	**23.9**	**3.41**

4.6 CROP COEFFICIENT VALUES OF OKRA

Crop coefficient values of Okra were calculated as the ratio of ETc and ETo. Weekly values of ET_c and ET_o were estimated by the soil water balance approach using lysimeters and by Penman montieth equation respectively.

Tables 4.8 and 4.9 shows crop coefficient values of Okra in soil and soil less media for each crop growth stage calculated from weekly data. For soil Kc was around 0.98 during the crop establishment stage or initial stage and then Kc increased gradually, reaching a maximum value of 1.56 in the mid season stage and finally, Kc declined to 0.74 in the late season stage. For soil less Kc values were 0.72, 1.16 and 0.50 during initial, mid and late season stages respectively. During initial stage Kc values were lower compared to mid season stage in both conditions since the leaf area and transpiration was low during the initial stage. Kc values were higher until early harvesting time and slightly declined towards the end of the crop growth period.

Table 4.8 Crop coefficient values of Okra- soil medium

Growing period	**Growth stages**	**Weekly ETc (mm)**	**Weekly ETo (mm)**	**KC = ETc/ETo**	**Growth stage wise Kc**
1st week	Initial Stage	15.43	24.36	0.63	0.98
2nd week		26.84	24.36	1.10	
3rd week		29.29	24.36	1.20	
4th week	Mid season stage	32.77	23.17	1.41	1.56
5th week		40.29	23.17	1.74	
6th week		41.72	23.17	1.80	
7th week		43.09	23.17	1.86	
8th week		32.49	23.17	1.40	
9th week		26.40	23.17	1.14	
10th week	Late season stage	20.74	25.41	0.82	0.74
11th week		16.94	25.41	0.67	

Table 4.9 Crop coefficient values of Okra- soil less medium

Growing period	Growth stages	Weekly ETc (mm)	Weekly ETo (mm)	KC = ETc/ETo	Growth stage wise Kc
1st week	Initial season stage	13.94	24.36	0.57	0.72
2nd week		17.29	24.36	0.71	
3rd week		21.71	24.36	0.89	
4th week	Mid season stage	23.24	23.17	1.00	1.16
5th week		29.37	23.17	1.27	
6th week		32.33	23.17	1.40	
7th week		31.98	23.17	1.38	
8th week		24.69	23.17	1.07	
9th week		19.69	23.17	0.85	
10th week	Late season stage	13.52	25.41	0.53	0.5
11th week		11.88	25.41	0.47	

4.6.1 Crop Coefficient curves for Okra – soil vs. soil less medium

Fig.4.8 shows Kc curves of Okra for soil and soil less medium with respect to crop growth period. Kc values were not constant through the crop period and increased from initial stage to mid season stage and then decreased in the late season stage in both conditions, which implies that during mid season water requirement is more than the initial stage. From the figure it is understood that Kc for soil was higher than that in soil less medium, which results in lesser water requirement for soil less medium than soil medium mainly in the crop maturitystage.

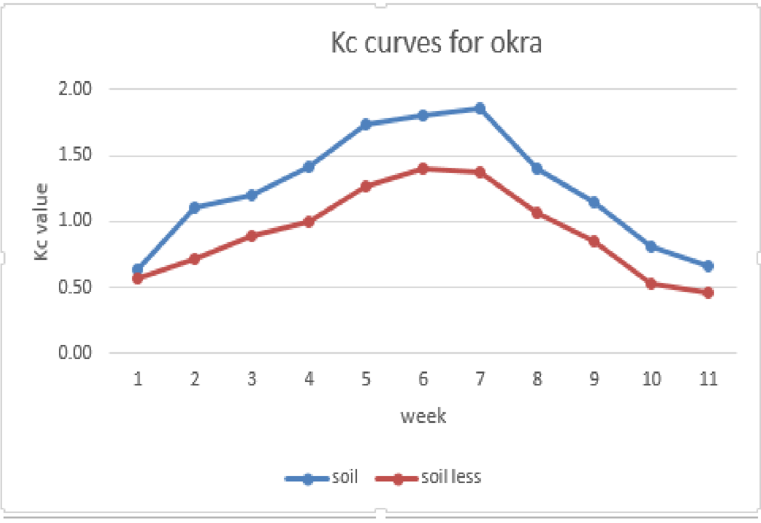

Fig. 4.7 Variation of Kc of Okra in the growth period

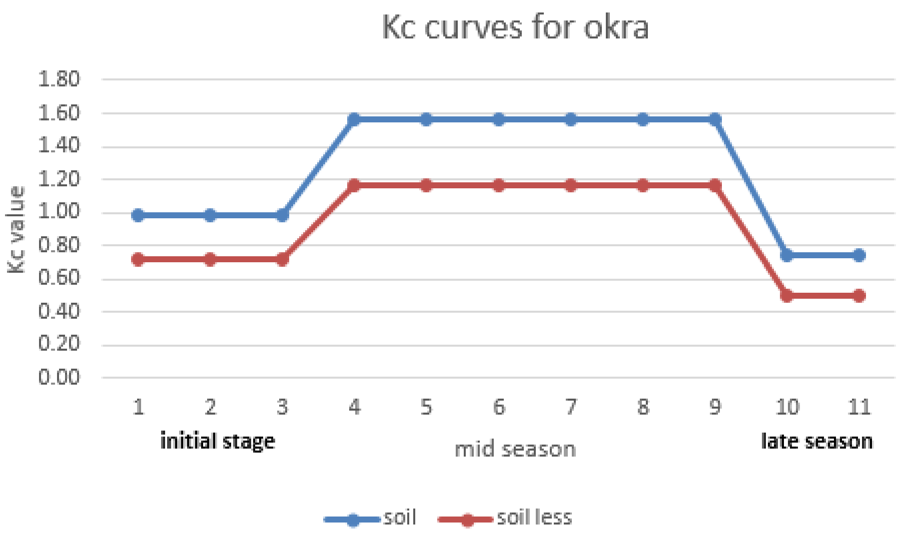

Fig. 4.8 Kc curves of Okra in soil and soil less medium

4.7 CROP GROWTH AND YIELD PARAMETERS

4.7.1 Plant height

The data on plant height at different stages of Okra was recorded for selected plants growing in soil and soil less medium and the data are given in Table 4.10 and

Fig.4.5. Plant height increased with respect to crop stage in both conditions. At the late season stage of the crop period, plant height was 175.6 cm in soil media, which was found higher than the soil less media (101.3 cm). This may be attributed to the less nutrient availability as soil less media is an inert medium. The fertigation with water soluble macro nutrients was provided uniformly to both systems along with drip irrigation.

Table 4.10 Mean values of Okra plant height in different crop stages

Plant height in cm			
Treatment	**Initial Stage**	**Mid season stage**	**Late season stage**
Soil media	25.5	123.9	175.6
Soil less media	20	83	101.3

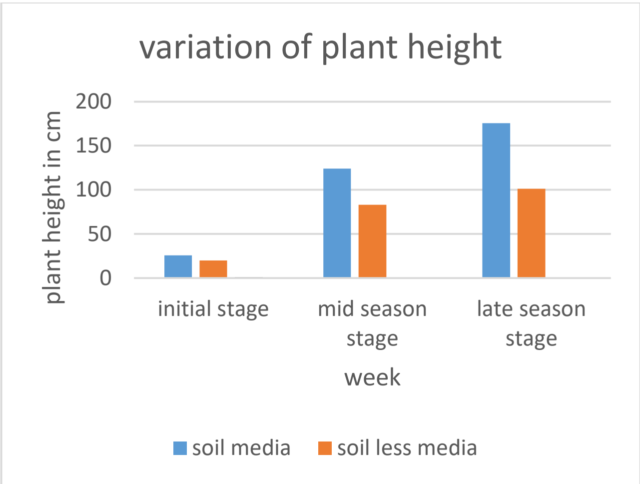

Fig.4. 9 Variation of plant height between soil and soil less media

4.7.2 Number of branches

The data on number of branches at different stages of Okra was recorded for selected plants growing in soil and soil less medium as shown in Table 4.11 and Fig.4.6. Number of branches increased with respect to crop stage in both conditions.

At the late season stage of the crop period, the number of branches in soil media slightly increased than soil less media.

Table 4.11 Mean of the number of branches in different crop stages

Number of branches			
Treatments	**Initial Stage**	**Mid stage**	**Late stage**
Soil media	1	3	5
Soil less media	0	2	3

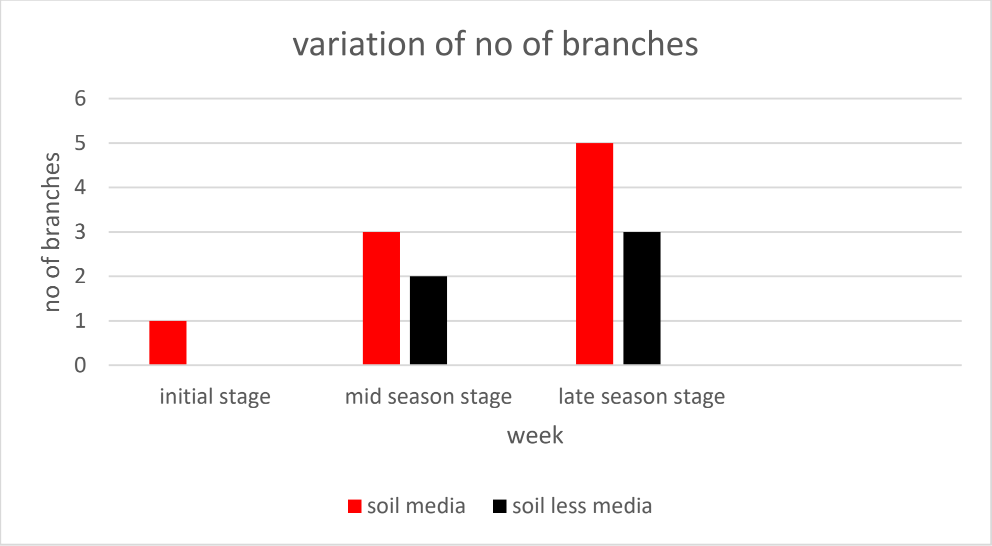

Fig. 4.10 Variation of no of branches between soil and soil less media

4.7.3 Number of leaves

The data on number of leaves at different stages of Okra were recorded for selected plants growing in soil and soil less media as shown in Table 4.12 and Fig.4.7. Number of leaves increased with respect to crop stage in both conditions. At the late season stage of the crop period, number of leaves was 36 in soil media, which was found to be higher than plants growing in soil less media (29). Plate 4.11 shows Okra crop during initial stage. Plate 4.2 shows Okra crop during maturity stage.

Table 4.12 Number of leaves in different crop stages

Number of leaves			
Treatments	**Initial Stage**	**Mid stage**	**Late stage**
Soil media	9	30	36
Soil less media	6	25	29

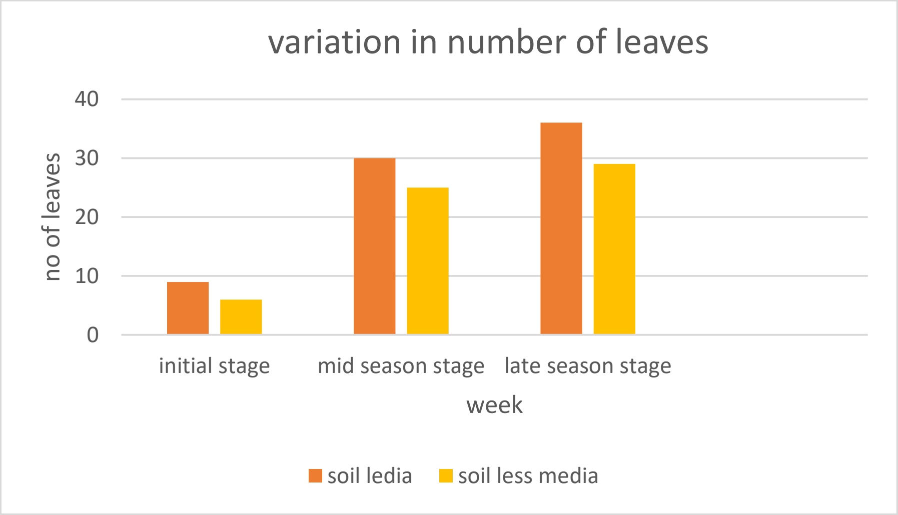

Fig. 4.11 Variation of no of leaves between soil and soil less media

(a) (b)

a) Okra crop in lysimeter during initial stage b) Overall view of Okra during initial stage

Plate .4.1 Okra crop during initial stage

Plate .4.2 Okra crop during mid season stage

4.7.4 Crop yield per plant

Plate 4.3 shows crop yield in soil and soil less media. The data on crop yield of Okra was recorded for selected plants growing in soil and soil less media as shown in Table 4.13 and Fig.4.8. The total crop yield per plant was recorded as 0.36 and 0.30 kg respectively for soil and soil less media. We had estimated the yield only for 75 DAS, the yield is still continuing, so there will be variation in total yield per plant Significant variation in yield was noted in soil and soil less media for the same quantity of applied irrigation, evapotranspiration loss was lesser for soil less compared to soil. The yield in soil less media was less due to lesser nutrient availability as soil less media is an inert medium. It need more nutrient requirement than soil. The results show that amount of fertigation should be higher in soil less media than soil. Due to this, less vegetative growth is seen in soil less medium which in turn results in lesser photosynthesis.

Table 4.13 Okra crop yield in soil and soil less media

Crop Yield in (Kg) per plant				
Treatments	**45 days**	**60 days**	**75 days**	**Total**
Soil media	0	0.2	0.25	0.45
Soil less media	0	0.1	0.2	0.3

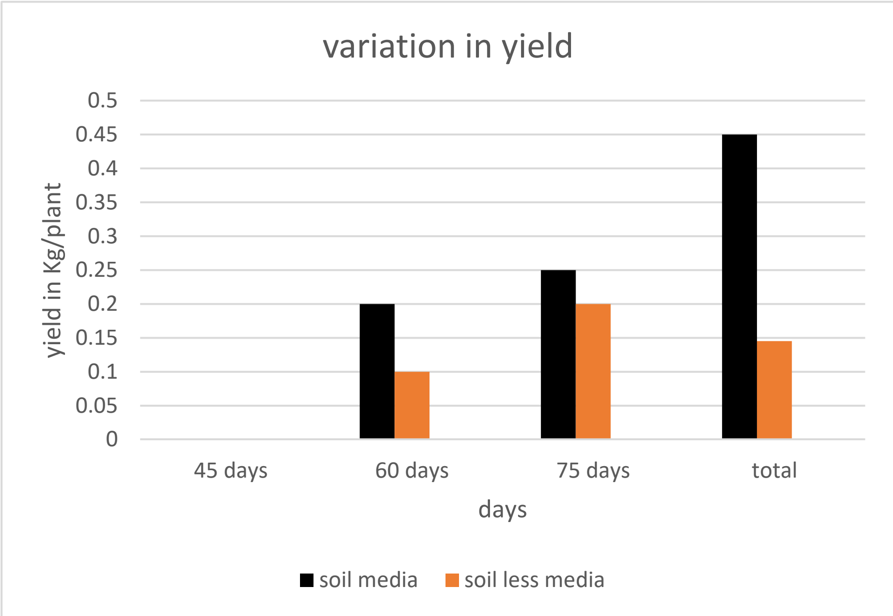

Fig.4.12 Variation of crop yield between soil and soil less medium

Plate 4.3 Harvested Okra

Table 4.13 shows consolidated data of evapotranspiration in soil and soil less media. The study revealed that seasonal average daily ETc and Kc of Okra were lower for soil less media than that of soil medium even though, applied irrigation water and crop duration period were similar for both conditions. This implies less water requirement for soil less cultivation compared to soil. High water holding capacity of soil less media may have contributed to lesser ET. Earlier studies have also reported similar results in other regions.

If the poly house irrigation is scheduled in such a way as to apply the right quantity of water enough to meet the evapotranspiration requirements of crops, water saving can be achieved but the study has also shown that the yield may be reduced if the nutrients supplied is same for both the media,as soil less medium requires higher nutrient concentrations.

Table.4.14 Consolidated data – soil vs. soil less

Measured data	**Soil medium**			**Soil less medium**		
Seasonal average daily ET_0(mm)	3.41			3.41		
Average daily stage wise ET_c(mm)	3.4	5.16	2.67	2.5	3.8	1.8
K_C value	0.98	1.56	0.74	0.72	1.16	0.5

Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

Field experiment on the comparative evaluation of evapotranspiration parameters in a naturally ventilated polyhouse in soil and soil less medium was conducted in the research plot of the Department of Irrigation and Drainage Engineering, in KCAET campus, Tavanur, Kerala during October 8th - January 8th 2017-18.In the study, Non-Weighing Mini-Lysimeters were used for direct determination of evapotranspiration parameter, ET_c and to develop crop-coefficient curves for Okra. The study also compares the data for soil and soil less media in order to quantify the effect of physical properties of soil less media on evapotranspiration.

The poly house was oriented east–west with an overall area of 208 m^2 (26 m length and 8 m width). Land preparation was done inside the naturally ventilated polyhouse. Polyhouse was divided into two parts and one portion was used for cultivating Okra crop (*Varsha Upahar*) Four raised beds of 10 m length, 1.0 m width and 0.25 m height were made and plastic troughs and grow bags were placed on the beds for cultivating Okra. A reduced pan was installed in the middle of the polyhouse leaving an area of 48 m^2 without crop. Six mini Non weighing lysimeters were used inside the poly house , of which, three were planted with Okra in soil media and three with soil less media. Lysimeters were placed randomly on the raised beds in the naturally ventilated polyhouse. Three Okra plants were planted in each lysimeter. Lysimeters were surrounded by the same crop in grow bags (40×24 cm) in the same density in order to avoid the border effect.

The value of bulk density was 1.52 g/cc and 0.77 g/cc for soil and soil less media respectively. Soil texture was analyzed by sieve analysis and it was found that 99.4 per cent of the soil was sandy and the remaining 0.6 per cent comprised of fines. It could be concluded that the soil was predominantly sandy.

The amount of irrigation water applied, drainage from Non weighing mini lysimeters and change in soil moisture storage were observed to measure the ETc in soil and soil less media by using water balance approach.

For soil, average daily ETc values of the Okra crop were 3.4, 5.16 and 2.67 mm/day during the initial stage, mid season stage and late season stage respectively. For soil less media the average daily ETc values of the Okra crop were 2.5, 3.8 and 1.8 mm/day during the initial stage, mid season stage and late season stage respectively. This implied that lowest seasonal ETc was observed in the initial stage and highest ETc was observed in mid season stage in both conditions. ETc increased from initial stage to mid season stage and then decreased in late season stage.

ETc measured from Non weighing mini- lysimeters inside polyhouse for soil and soil less media were compared. Seasonal ETc values of Okra for soil and soil less media were 3.74 and 2.7mm/day respectively. ETc values were low for soil less media than soil ,even though, applied irrigation water, fertilizer dosage and crop duration period were similar for both conditions. This may be due to the high water holding capacity of soil less media which might have contributed to lesser water requirement.

ETo was estimated from two methods namely reduced pan and FAO -56 Penman-Monteith equation. ETo estimated by FAO -56 Penman-Monteith model was taken as the standard as it provides quite good agreement with evapotranspiration obtained by lysimetric data (Madhavi, 2017)

Crop coefficient values of Okra were calculated as the ratio of ETc and ETo. Weekly values of ET_c were estimated by the water balance approach using lysimeters for polyhouse in soil and soil less media. For soil, Kc was around 0.98 during the crop establishment stage or initial stage and then Kc increased gradually, reaching a maximum value of 1.56 in the mid season stage and finally, Kc declined to 0.74 in the late season stage. For soil less media, values were 0.72, 1.16 and 0.5 during initial, mid and late season stages respectively. During initial stage, Kc values were lower compared to mid season stage in both conditions. Kc values were higher until early harvesting time and slightly declined towards the end of the crop growth period and it was observed that Kc for soil less media was lesser than that for soil.

During crop growth period, microclimate inside the polyhouse was recorded. Maximum and minimum temperature recorded values were 33.49 ^{o}C and 30.34^{o}C during 7th and 2nd week of crop period respectively. For polyhouse conditions, maximum and minimum relative humidity values were 79.63 and 45.86 per cent during 2nd and 6th week of crop period respectively.

Crop growth and yield parameters were observed during crop growth period at each stage. For soil, plant height was 175.6 cm, which was found higher than the soil less media (101.3 cm). The number of branches for soil and soil less were 5 and 3 respectively. For soil , number of leaves was 36, which was found higher than the soil less media (29). The total crop yield per plant was recorded as 0.29 and 0.15 kg respectively.

The yield in soil less media was less due to lesser nutrient availability as soil less media is an inert medium. It need more nutrient requirement than soil. The results show that amount of fertigation should be higher in soil less media than soil.. More detailed studies on ET parameters in soil less media under ideal irrigation and fertigation condition are required in different season to establish the results obtained in the study

Study results show that less ETc and Kc was obtained for soil less culture media than soil in naturally ventilated polyhouse. Hence, soil less culture is suitable for vegetable cultivation in water scarce areas.

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APPENDIX I

Physical properties by Core cutter method

Calculations- soil

Weight of core soil (W)	: 474.1 g
Volume of core soil (V)	: 311.02 cm^3
Weight of moisture container (W_1)	: 21.76g
Weight of moist soil + Moisture container weight (W_2)	: 28.12 g
Weight of dry soil + Moisture container weight (W_3)	: 26.43 g
Moisture content of soil (ω)	: 26.6%

Bulk density of soil were determined by using the following formula:

Bulk density of the soil (g/cm^3) $\gamma = \frac{W}{V}$

$= 474.1/311.02$

$= 1.52$ g/cc

Calculations- soil less media

Weight of core soil less media (W)	: 239.6 g
Volume of core soil less media(V)	: 311.02 cm^3
Weight of moisture container (W_1)	: 19.18g
Weight of moist soil less media + Moisture container weight (W_2)	: 27.6 g
Weight of dry soil less + Moisture container weight (W_3)	: 23.4 g
Moisture content of soil (ω)	: 49.9%

Bulk density of soil less media were determined by using the following formula:

Bulk density of the soil less media (g/cm^3) $\gamma = \frac{W}{V}$

$= 239.6/311.02$

$= 0.77$ g/cc

APPENDIX II

Applied irrigation water and drainage collected from lysimeters – soil.

Crop period in weeks	Applied irrigation in mm	Drainage in mm		
		Lysimeter-A1	Lysimeter-A2	Lysimeter-A3
1	101.08	89.05	91.23	90.20
2	101.08	84.59	86.27	86.62
3	101.08	81.27	80.10	82.56
4	115.52	76.28	76.94	54.15
5	126.35	69.96	64.87	50.37
6	126.35	67.16	78.19	38.47
7	129.96	56.64	64.87	29.53
8	151.62	54.92	54.15	17.25
9	151.62	49.86	44.01	16.10
10	151.62	39.35	37.04	18.56
11	126.35	37.55	37.26	10.65

Applied irrigation water and drainage collected from lysimeters – soil less

Crop period in weeks	Applied irrigation in mm	Drainage in mm		
		Lysimeter-B1	Lysimeter-B2	Lysimeter-B3
1	101.08	53.81	75.55	68.07
2	101.08	78.11	95.26	87.91
3	101.08	93.29	90.30	93.55
4	115.52	103.00	89.07	81.62
5	126.35	97.98	105.85	90.61
6	126.35	108.11	103.45	73.98
7	129.96	93.65	68.27	60.83
8	151.62	97.87	80.51	40.43
9	151.62	61.00	59.31	53.88
10	151.62	41.66	42.81	40.14
11	126.35	32.56	35.38	31.19

APPENDIX III

Water balance computation for lysimeter A2- Soil

Growing period	Applied water (I) in mm	Drainage (D) in mm	Soil moisture Storage change (Δs)	ET=I-D±Δs
1st week	101.08	91.23	-4.50	14.36
2nd week	101.08	86.27	-12.68	27.50
3rd week	101.08	80.10	-9.76	30.74
4th week	115.52	76.94	6.30	32.28
5th week	126.35	64.87	20.80	40.68
6th week	126.35	78.19	5.60	42.56
7th week	129.96	64.87	21.30	43.79
8th week	151.62	54.15	65.20	32.27
9th week	151.62	44.01	80.20	27.42
10th week	151.62	37.04	93.20	21.38
11th week	126.35	37.26	72.30	16.80

Water balance computation for lysimeter A3- Soil

Growing period	Applied water (I) in mm	Drainage (D) in mm	Soil moisture Storage change (Δs)	ET=I-D±Δs
1st week	101.08	90.20	-4.50	15.39
2nd week	101.08	86.62	-11.67	26.13
3rd week	101.08	82.56	-10.75	29.28
4th week	115.52	54.15	26.30	35.07
5th week	126.35	50.37	36.90	39.09
6th week	126.35	38.47	45.89	41.99
7th week	129.96	29.53	55.67	44.76
8th week	151.62	17.25	99.60	34.78
9th week	151.62	16.10	110.30	25.22
10th week	151.62	18.56	115.30	17.77
11th week	126.35	10.65	100.30	15.40

APPENDIX IV

Water balance computation for lysimeter B2- Soil less

Growing period	Applied water (I) in mm	Drainage (D) in mm	Soil moisture Storage change (Δs)	ET=I-D±Δs
1st week	101.08	75.55	11.20	14.33
2nd week	101.08	95.26	-10.20	16.02
3rd week	101.08	90.30	-12.30	23.08
4th week	115.52	89.07	2.53	23.92
5th week	126.35	105.85	-10.30	30.80
6th week	126.35	103.45	-9.80	32.70
7th week	129.96	68.27	30.20	31.50
8th week	151.62	80.51	48.20	22.92
9th week	151.62	59.31	73.20	19.11
10th week	151.62	42.81	95.20	13.62
11th week	126.35	35.38	79.20	11.77

Water balance computation for lysimeter B3- Soil less

Growing period	Applied water (I) in mm	Drainage (D) in mm	Soil moisture Storage change (Δs)	ET=I-D±Δs
1st week	101.08	68.07	20.20	12.81
2nd week	101.08	87.91	-5.30	18.47
3rd week	101.08	93.55	-15.30	22.84
4th week	115.52	81.62	10.23	23.68
5th week	126.35	90.61	5.60	30.14
6th week	126.35	73.98	18.84	33.54
7th week	129.96	60.83	36.50	32.63
8th week	151.62	40.43	88.20	22.99
9th week	151.62	53.88	78.20	19.54
10th week	151.62	40.14	98.20	13.28
11th week	126.35	31.19	83.20	11.96

APPENDIX V

Direct measured climatic parameters- morning

week	Minimum temperature(^{0}C)	Maximum temperature(^{0}C)	Relative humidity(%)	Light intensity(lux)
1	29.61	29.87	74.98	7757
2	28.81	29.95	79.63	7633
3	29.69	29.92	74.05	10277
4	30.44	30.66	71.14	11394
5	29.83	30.14	74.14	11055
6	29.81	30.12	73.36	10318
7	31.08	31.37	71.09	11048
8	29.89	30.22	69.89	14549
9	29.21	29.54	76.74	10158
10	30.07	30.09	76.1	8660
11	29.63	30.56	76.58	98474

Direct measured climatic parameters- afternoon

week	Minimum temperature(^{0}C)	Maximum temperature(^{0}C)	Relative humidity(%)	Light intensity(lux)
1	32.3	32.7	66.8	17290
2	31.9	32.1	68.17	13573
3	35.7	36.2	54.64	18836
4	37.1	37.6	48.97	21065

5	35.8	36.2	52.63	17803
6	36.8	37.4	45.86	20817
7	36.7	37	52.52	14820
8	35.5	36.3	57.44	12978
9	36.3	36.8	51.95	19628
10	35.1	35.7	58.25	18695
11	34.2	35.1	56.4	19541

Direct measured climatic parameters- evening

week	Minimum temperature(^{0}C)	Maximum temperature(^{0}C)	Relative humidity(%)	Light intensity(lux)
1	29.6	29.8	77.32	3854
2	30.3	30.6	73.74	4336
3	31.3	31.6	67.75	4396
4	31.5	31.6	67.85	3063
5	30.3	30.5	69.94	3087
6	31.5	31.7	63.6	4150
7	31.9	32.1	68.68	4046
8	30.3	30.4	70.9	2341
9	29.9	30.1	72.43	3050
10	30.3	30.4	69.6	2836
11	29.5	30.5	70.2	3569

COMPARATIVE EVALUATION OF EVAPOTRANSPIRATION PARAMETERS OF OKRA IN POLYHOUSE FOR ALTERNATE GROWING MEDIA

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PROJECT REPORT

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ABSTRACT

Water is considered as a critical resource for agriculture and supplying the right amount in the right time is essential for healthy plants and optimum productivity. This objective can be met only through scientific water management and judicious water application, which in turn requires proper scheduling of irrigation events. For most of the agricultural crops a relationship can be found between evapotranspiration and climate by introducing a crop coefficient (K_c), which is the ratio of crop evapotranspiration (ET_c) to reference crop evapotranspiration (ET_o). Hi-tech horticultural systems use protected cultivation with soil and soil less media as substrates. Evapotranspiration in open field and inside of polyhouse will differ due to the micro climatic variation. Water balance components in the mini lysimeter will be influenced by the atmospheric condition and the media used in the mini lysimeter. At present water requirement for open field vegetable cultivation is adopted as such as in polyhouse cultivation. Hence there is a need to study the consumptive use of crops in soil and soilless media inside the polyhouse.

Field experiment on the comparative evaluation of evapotranspiration parameters in a naturally ventilated polyhouse for alternate growing media was done in a Naturally ventilated polyhouse in the research plot of the Department of Irrigation and Drainage Engineering, in KCAET campus, Tavanur. In the study, Non-Weighing Mini-Lysimeters were used to determine evapotranspiration parameters and to develop crop-coefficient curves for Okra for soil and soil less media. The study compares the data for soil and soil less media in order to quantify the properties of these medias on evapotranspiration. ET_0 was estimated by Penman montieth equation using CROPWAT model. Studies on crop morphological parameters indicated that plant growth and yield parameters were higher for soil media than soil less.

Seasonal average ETc values of Okra for soil and soil less media were 4.23 and 3.1mm/day. The calculated values of Kc for the initial, mid and late season

stages were 0.98, 1.5and 0.74 in soil. Soil less media values were 0.72, 1.16 and 0.5 for different stages respectively. It was observed that soil less Kc values were lower than the soil. This may be due to the higher water holding capacity of the soil less media, which resulted in lesser evapotranspiration. The results implied that water requirement is lower for soil less media compared to soil.

The results of this study can be used as a guideline in the computation of water requirement of soil and soil less in polyhouse for Tavanur region. If the poly house irrigation is scheduled in such a way as to apply the right quantity of water enough to meet the evapotranspiration requirements of crops, considerable water saving can be achieved.