STANDARDIZATION OF IRRIGATION AND FERTIGATION REQUIREMENT FOR AMARANTHUS UNDER POLYHOUSE

By

MALAVIKA V K (2016-02-022)

MONCY S AKKARA (2016-02-025)

NAZILA C (2016-02-027)

VISHNU K M (2016-02-046)

DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

TAVANUR-679573, MALAPPURAM, KERALA, INDIA

2020

STANDARDIZATION OF IRRIGATION AND FERTIGATION REQUIREMENT FOR AMARANTHUS UNDER POLYHOUSE

By

MALAVIKA V K (2016-02-022)

MONCY S AKKARA (2016-02-025)

NAZILA C (2016-02-027)

VISHNU K M (2016-02-046)

PROJECT REPORT

Submitted in partial fulfillment of the requirement for the degree of

Bachelor of Technology

In

Agricultural Engineering

Faculty of Agricultural Engineering and Technology

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF SOIL AND WATER CONSERVATION ENGINEERING

KELAPPAJI COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY, TAVANUR-679573, MALAPPURAM, KERALA, INDIA

2020

DECLARATION

We hereby declare that this project entitled **"STANDARDIZATION OF IRRIGATION AND FERTIGATION REQUIREMENT FOR AMARANTHUS UNDER POLYHOUSE"** is a bonafide record of project work done by us during the course of study and that the report has not previously formed the basis for the award to us of any degree, diploma, associate ship, fellowship or other similar title of another university or society.

Malavika V K (2016-02-022)

Moncy S Akkara (2016-02-025)

Nazila C (2016-02-027)

Vishnu K M (2016-02-046)

Place: Tavanur

Date: 29/06/2020

CERTIFICATE

Certified that the project entitled **"STANDARDIZATION OF IRRIGATION AND FERTIGATION REQUIREMENT FOR AMARANTHUS UNDER POLYHOUSE"** is a record of project work done jointly by **Ms. Malavika V K, Ms. Moncy S Akkara, Ms. Nazila C and Mr. Vishnu K M** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title of any other university or society.

Dr. Jinu A

Asst.Professor

Dept. of SWCE

KCAET

Tavanur

Place: Tavanur

Date:29.06.2020

ACKNOWLEDGEMENT

First of all, with an open heart, we thank the "**God Almighty**" for his invisible helping hand that guided us through the right way to pursue our journey to the completion of this project.It is our prerogative to express profound gratitude and respect to our guide, **Dr. Jinu A**, Asst.Professor, Department of Soil and Water Conservation Engineering, KCAET, Tavanur for his valuable suggestions, abiding, encouragement and acumen which served as a blessing throughout our work.We are thankful to **Dr. Sathian K K**, Dean, KCAET, Faculty of Agricultural Engineering and Technology, for the unfailing guidance and support that he offered while carrying out the project work.We engrave our deep sense of gratitude to **Er. Ardra Wilson, Er. Sreeja K**, **Er. Ajay Gokul,** Department of Soil and Water Conservation Engineering, KCAET, Tavanur, **Dr. Prashanth**, KVK Malappuram, for their interest and kind advice given to us at all stages of our study.We also thank **Er. Mohammed Favazil, Er. Arun P.S** (technical staff) **Mr. Paramesvaran P.V (**PFDC employee) and all staff and workers of PFDC, Tavanur for their valuable support and help during our project work.

Words do fail to acknowledge our dear **friends** for their support, encouragement and help which have gone a long way in making this attempt a successful one.We also wish to remember and gratify **our Parents**, who always bless us for our betterment and pray for our success.

Finally, we thank **all those**, who directly or indirectly helped us.

Malavika V K (2016-02-022)

Moncy S Akkara (2016-02-025)

Nazila C (2016-02-027)

Vishnu K M (2016-02-046)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

SYMBOLS AND ABBREVIATIONS

SYMBOL	ABBREVIATION
%	Percentage
Asst.	Assistant
&	And
/	Per
º	Degree
ºC	Degree Celsius
Dept.	Department
E.g.	Example
Etc.	Etcetera
et al	And others
GM	Genetically Modified
Kg	Kilogram
kPa	Kilopascal
t/ha	Tonne per hectare
Viz	Namely
Ie	that is
KCAET	Kelappaji College of Agricultural Engineering And Technology
Sq.m	Square metre

M	Metre
‘	Minutes
N	North
E	East
RH	Relative humidity
PFDC	Precision farming development centre
mm	Millimetre
G	Gram
CO_2	Carbon dioxide
pH	Pouvoir hydrogen
WSN	Wireless sensor network
IDE	Integrated development environment
W	Watt
CU	Consumptive use
CWR	Crop Water Requirement
ER	Effective rainfall
ET_o	Reference Crop Evapotranspiration
NIR	Net Irrigation Requirement
RAW	Readily available water
Kc	Crop coefficient
RH	Relative humidity

T	Air temperature

CHAPTER I

INTRODUCTION

Water is an essential natural resource for all living things including plants. Although water is available in all three forms, viz. solid, liquid and gas, fresh water that is being available is only 3%. The major contribution to this 3% fresh water is from polar ice caps. Currently, world is facing an acute water scarcity due to aridity and drought. On one side man made desertification and water shortage is aggravating the situation while on the other side the population blast is demanding more fresh water. Therefore, improved management and planning is required for the efficient utilization of quality water from fresh water bodies.

Water is an essential input influencing the scale and pattern of agricultural growth and agriculture is the largest user of water among all human activities where irrigation water contributes almost 70% of the total anthropogenic use of renewable water. The major source through which plants get water is rainfall. If the rainfall could not meet the requirements of crops, water is applied externally and this external application of water is known as irrigation. Irrigation can be defined as the quantity and depth of water that need to be supplied in addition to the precipitation, to produce the desired crop yield and quality and to maintain acceptable salt balance in the root zone. With an ever increasing demand for water in municipal and industrial sectors, its allocation for agriculture is decreasing steadily. Therefore, many more interpretations and innovations are required to increase the efficiency of use of water that is available.

The required timing and amount of water that need to be applied is determined by prevailing climatic conditions, crop growth stages, root development and type of soil. Water within the root zone is available to plants for evapotranspiration. Therefore, it is necessary to conduct field water balance to find the irrigation requirements. All crops will be having a critical growth period during which a slight variation in the moisture content could affect its growth. This critical growth period varies from crop to crop. Sufficient care must be taken to ensure that crops do not undergo a stressed condition due to soil moisture deficit. Irrigation scheduling involves determining the irrigation method, quantity of water to be provided and the frequency at which water need to be applied.

Many researches have undergone so far to investigate the impacts of socio-economic development, climatic change and variability on crop production but less on irrigation water use; both globally and regionally. Changes in precipitation combined with the changes in evapotranspiration demands are likely to increase the irrigation demands by 8% by 2070. Only the scientific management of irrigation water could combat the weather induced uncertainties and thereby enhance the agricultural production.

A higher yield is likely to obtain when water is maintained between two limits such that it is not that much higher to cause leaching and should not be much lesser to induce stress in crops. For the irrigation purpose the water that is being available to the plants is defined as the difference between the field capacity and permanent wilting point. Irrigation needs to be provided when a certain percentage (normally 30%-60%) of the total available water is being depleted. In order to determine the irrigation requirements and irrigation scheduling, a thorough knowledge on the crop water use is necessary. Daily and weekly crop water use data is used for the irrigation scheduling while annual water use estimates are required to specify the storage and conveyance system capabilities. Here comes the need to establish a procedure to estimate the water use in the present scenario of climatic change.

Proper irrigation practices could enhance the productivity in any country. But it is being estimated that around 50% of the agricultural water withdrawals reach the crops and the remainder is lost in irrigation infrastructure. The primary goal of irrigation is to apply water to maintain crop evapotranspiration if the precipitation is insufficient.Hess (2005) defined crop water requirements as the total water needed for evapotranspiration, from planting to harvest for a given crop in a specific climate regime, when adequate soil water is maintained by rainfall and/or irrigation so that it does not limit plant growth and crop yield. It is necessary to know the crop water requirement that has to be met by irrigation, for sustainable development of agriculture. Good irrigation scheduling will apply water at the right time and in the right quantity in order to optimize production and minimize adverse environmental impact. Under or over watering can lead to reduced yields, lower quality and inefficient use of nutrients.

Many methods are being available to estimate the evapotranspiration rates. They are broadly classified into direct and indirect methods. The indirect methods that are being used for determining ET_O include empirical formulae like Blaney Criddle, Hargreaves method, radiation method, Penman method, Penman Moneith method, modified Penman method etc. while the direct methods include lysimeter, field experimental plots, water balance method, soil depletion method etc. Of this Penman Monteith method is the most accurate one. But still the use of numerous tables and calculations increase the complexity and errors are likely to occur. The unscientific estimation of ET_O could result in faulty irrigation practices leading to irrigation losses, deficit irrigation and decreased irrigation efficiency.

Hence in order to increase the productivity, accurate and scientific estimation of crop water requirement is necessary. One of the major practices done by researchers to estimate the crop water requirement is software modelling. For determining the crop water requirements, crop evapotranspiration and irrigation scheduling CROPWAT 8.0 developed by FAO (Food and Agricultural Organization) Land and water Development Division seems to be accurate and reliable. It includes a simple water balance model that allows the simulation of crop water stress conditions and estimation of yield reductions on the basis of well-established methodologies.

Temporal and spatial variations could be observed in rainfall. Agriculture in a region mainly depends upon the total rainfall availability, its intensity, distribution and frequency. But the recent trends in rainfall showing abnormalities have put agriculture under a risk. India which is basically an agrarian economy will be affected by this badly. Even though Kerala receives a fairly good amount of rainfall, the productivity of the state is far below the national average. The uneven rainfall distribution, decreased water holding capacity and increased stress conditions during summer season are the major limiting factors (Surendran *et.al* 2015).

Although Kerala is blessed with timely and adequate rainfall with an annual rate of 3107 mm in recent times the rate of rainfall has weakened, causing serious concern for both power generation and drinking water. Normally, the South-West Monsoon (June- September) and North-East (October-December) contribute 66 percent each; the North-East (October-December) 16 percent, the winter rains (January-February) 3 percent and the summer rains (March-May) 15 percent to the water availability of the state. Nonetheless, large deviations occur in monthly rainfall and rainfall across the regions, which make irrigation a necessity for the stabilization of the water requirement of the crops. Hence soil moisture deficit throughout summer season is one of the foremost limiting factors for higher yield in the state.

Adequate data on irrigation water requirement for crops are not available in developing countries like India. This is the reason for the failure of irrigation projects in such countries. The present irrigation practices in the state of Kerala have a general nature and does not account for all types of soil, crop and climate in various zones. Lacunae of site specific information on irrigation requirement for various crops are one of the main reasons for the low irrigation efficiency in the state. Hence there is a need for regional scale information with respect to crop water needs to improve or sustain productivity. On the whole, it can be said that irrigation in the state has the status of protective irrigation, the focus being on the efficient management of water to improve or sustain productivity. Fertilizer management is the most important agro-technique, which controls development, yield and quality of a crop. Appropriate fertigation schedule offers an opportunity to correct the nutrient status of plant regularly and thus protecting plant from nutrient deficiencies.

In view of all the above facts an attempt was made to compute crop water requirement and irrigation schedules for Amaranthus. The specific objectives of the study are:

1. To find the ETo value.
2. To estimate the crop water requirement of Amaranthus and develop irrigation schedule for the crop.
3. To develop fertigation schedule for the crop.
4. To find out which treatment gives maximum yield.

CHAPTER II

REVIEW OF LITERATURE

A computer based software model will be able to estimate accurate crop water requirement scientifically based on soil, crop and climate. The FAO developed the CROPWAT 8.0 seems to be sufficiently good in this content. Hence this study estimated ETo, ETc, irrigation requirement, irrigation scheduling, fertigation requirement and fertigation scheduling of Amaranthus grown in Tavanur using FAO CROPWAT 8.0 model.

The review has been organized objective wise under the following subheads.

1. Estimation of evapotranspiration.

2. Determination of crop water requirement and irrigation requirement.

3. Effect of fertigation on crop growth.

4. Effect of mulching and drip irrigation.

5. Performance of crop under Polyhouse.

6. Crop water requirement and irrigation scheduling by FAO CROPWAT.

2.1 ESTIMATION OF EVAPOTRANSPIRATION

Sakellariou and Vagenas (2006) conducted a study using FAO Penman-Monteith method to map the reference crop evapotranspiration and rainfall. They estimated the total irrigation crop water requirement in central Greece with the aid of these maps which was irrigated by both private and public boreholes and by surface waters during the irrigation period of the year 2001 by using FAO penman-Monteith method. Crop evapotranspiration and net water requirements were computed for each crop in the municipalities on the prefectures for the whole irrigation period.

Ghazala and Ghulam (2007) conducted a study to analyze the subsequent effects of increasing temperatures on the ETo and on the agricultural water demand in the Pakistan. This study helped in crop monitoring and in the assessment of how much water is available in future for crops and which type of crops would suit the climate. They found that better management and building of new water reservoirs may help to cope the situation for an improved agricultural growth.

Junzeng *et al.* (2008) conducted a lysimeter experiment to investigate tomato and cow pea crop evapotranspiration inside the green house in eastern China. The result showed remarkable decline in crop evapotranspiration inside the green house as compared to outside and ET increased with the growth stage of the crop and varied in accordance with the temperature inside the green house.

Choudhary and Shrivastava (2010) estimated the monthly reference evapotranspiration by FAO Penman-Monteith method and irrigation requirements for the system based on the methodology suggested in FAO 24. Artificial Neutral Network approach was found to be appropriate for the modelling of reference evapotranspiration for MRP command area. The study explored the potential of feed forward neutral (FFNN) for estimation and forecasting of monthly ETo values in MRP command area.

Shekar (2012) explained evapotranspiration more broadly as a need of hour because in context of climate change as the average temperature is rising and certainly evaporative demand is shooting up. The different model for estimating ET differs in the effect of specific meteorological parameters on ET demand. The variations in temperature also caused variations in other parameters such as humidity, wind speed and vapour pressure which directly changed ET. In this study 10 years (2002-2011) weather data taken from ozone unit, Indian Meteorological Department, Banaras Hindu University (BHU), Varanasi had been analyzed for the change in temperature, wind speed and solar radiation.

Hashim *et al.* (2012) conducted experiments for determining water requirement and crop water productivity of crops grown in Makkah region of Saudi Arabia. Using neutron probe and mini lysimeter ET data was acquired at different crop growth stages. The data thus obtained were used for assessing the total water requirements of different crops. 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.

Toyin *et al.* (2014) determined actual evapotranspiration and crop coefficient (Kc) of Amaranthus cruentus grown in weighing lysimeter under a screen house. Climatic variables such as solar radiation, relative humidity, air temperature and wind speed were collected for the estimation of reference evapotranspiration (ETo) using the FAO-Penman Monteith model. Actual crop evapotranspiration (ETc) was measured directly from the daily drop in the level of water in the burette that was connected to the lysimeter. Results obtained showed that the ETc increases rapidly during the vegetative and flowering stages, indicating that crop water requirement was highest during this crop growth stages. The ETc values varied from 0.6 mm day^{-1} in the emergence stage to peak values of 2.0 mm day^{-1} during the vegetative and flowering stages.

Silva *et al.* (2018) conducted a study aimed to evaluate the performance of the FAO Penman-Monteith method with limited meteorological data and other methods as alternatives to the FAO Penman-Monteith method with all required data for the municipality of Jaíba-MG, Brazil. And they made these conclusions, in the absence of only solar radiation, relative humidity or wind speed data, or even simultaneous absence of relative humidity and wind speed data, the FAO Penman-Monteith method showed the best performances. And the FAO Penman-Monteith method in the absence of measured solar radiation data and more one meteorological variable showed intermediate performance in ETo estimation. The methods that used only measured air temperature data are not recommended for Jaíba-MG, Brazil, even after calibration of ETo values.

2.2 DETERMINATION OF CROP WATER REQUIREMENT AND IRRIGATION REQUIREMENT

Pakhale *et al.* (2010) focused on analyzing the irrigation water requirement of wheat crop for rabi season from 1999 to 2003 in Karnal district of Haryana state, India. Area under wheat cultivation was determined using Landsat ETM+ image by applying Artificial Neural Network (ANN) classification technique. Potential Evapotranspiration and crop coefficient for wheat was used for estimating crop water requirement. They found that the water requirement for wheat was higher in the vegetative and mid-season stage where as a decreasing trend was shown towards the maturity stage. They also found that the irrigation water requirement was highly correlated with crop water requirement.

Chowdhury *et al.* (2013) carried out a study on implications of climate change on crop water requirements in arid region. This study sheds a light on the possible implications of climate change on crop water requirements and its direct and indirect effects on water resources management.

Aguilar *et al*. (2015) conducted a study on irrigation scheduling based on soil moisture sensors and evapotranspiration. The moisture sensors helped to schedule irrigation. The study validated the importance of moisture sensors to be installed in representative locations with good soil - sensor contact.

Zhe Gu *et al*. (2017) carried out a study on irrigation scheduling using RZZWQM2 model (Roots Zone Water Quality Model). This software predicted the development of crop water stress and its evaluation. They found that in semi-arid region the water stress-based irrigation scheme saved water use and maintained the crop yield.

2.3 EFFECT OF FERTIGATION ON CROP GROWTH

Singadhupe *et al*. (2003) carried out a study to analyze the response to urea fertilizer with drip irrigation was tested and compared with conventional furrow irrigation for 2 year (1995 and 1996) at the research farm of water management project, Mahatma Phule Agricultural University, Rahuri (Maharashtra), India. The apparent N recovery was 82.5% at 48 kg N/ha in comparison with 47.9% at 120 kg N/ha during 1996. Stomatal resistance was higher in furrow irrigation than that of drip system at various plant heights. Lower leaf had less resistance than upper leaf irrespective of irrigation methods.

Singadhupe *et al*. (2005) conducted a field experiment during the winter season of 2003-2004 in a field grown tomato. Application of 31% and 69% N from 58 kg N/ha during initial crop growth and flowering to reproductive stages, respectively, resulted 41 tonnes/ha total fruit yield and saved 27.5% N. Agronomic efficiency and physiologic efficiency were maximum in reduced amount of N applied.

Solanki *et al.* (2016) conducted a field experiment during winter (rabi) season of 2011-2012 at instruction farm, Department of Agronomy, Junagadh Agricultural University, Junagadh to evaluate the effect of scheduling irrigation and organic manure on yield attributes, nutrient content and uptake of rabi under Saurashtra condition. The result revealed that application of irrigation at 0.1 IW/CPE ratio recorded higher yield attributes yield (1711 kg ha^{-1}), stover yield (3411 kg ha^{-1}), nutrient content and uptake over 0.4, 0.6, 0.8 IW/CPE ratio. Application of FYM @6 t ha^{-1} was found efficient to achieve significant increased grain yield (1701 kg ha^{-1}), stover yield (3303 kg ha^{-1}), Nitrogen, Phosphorus and potassium status in grain and stover and uptake by grain amaranthus over the control.

2.4 EFFECT OF MULCHING AND DRIP IRRIGATION

Filipovic *et al.* (2016) conducted field experiment to compare the effects of different mulching types (color) on soil temperature and crop growth, estimate the effect of plastic mulch cover (MULCH) on water and nitrate dynamics using HYDRUS-2D. Results showed that plastic mulch had a significant effect on soil temperature regime and crop yield. The dark color mulch (black, brown) caused higher soil temperature, which consequently enabled earlier plant development and higher yields.

Paul *et al.* (2013) field experiments were conducted on the loamy sand soil at Bhubaneswar in eastern coastal of India for two years (2007-08 and 2008-09) to evaluate the yield, water-use-efficiency and economic feasibility of capsicum grown under drip and surface irrigation with non-mulch and black Linear Low Density Poly Ethylene (LLDPE) plastic mulch. The study indicated better plant growth, more number of fruits per plant and enhancement in the yield under drip irrigation system with LLDPE mulch. The highest yield (28.7 t/ha) was recorded under 100% net irrigation volume with drip irrigation (VD) and plastic mulching as compared to other treatments.

Reddy *et al*. (2018) conducted a study to review the Plastic mulch and drip irrigation method to grow Tomato for Madanapalle area in Chittoor district of Andhra Pradesh. The study also aims to review the effectiveness of combination of Plastic mulch and drip irrigation for water management and suggest these techniques amongst the farmer community to enhance the yield and also to battle against water scarcity.

Laulina and Hasan (2018) carried out field experiment study the response of different colored plastic mulches on surface and root zone temperature of drip fertigated capsicum under greenhouse. The experiment was conducted under naturally ventilated greenhouse condition at Centre for Protected Cultivation Technology (CPCT) farm at Indian Agricultural Research Institute (IARI), New Delhi. It was found that the mulch practice in the naturally ventilated greenhouse optimize the microclimatic conditions necessary for capsicum growth which enhance the irrigation water use and yield.

Devi *et al.* (2020) carried out an investigation to evaluate the performance of tomato in polyhouse with drip and mulch at AICRP on Plasticulture Engineering and Technologies experimental field of College of Agricultural Engineering and Post-

Harvest Technology (CAEPHT), Ranipool, Sikkim. The study thus reveals that drip irrigation with mulch give better water use efficiency, increased yield and thereby achieving the prime objective of ‘more crop per drop’.

2.5 PERFORMANCE OF CROP UNDER POLYHOUSE

Sheeba (2015) conducted a field experiment on the performance evaluation of five leafy vegetables in naturally ventilated polyhouse in randomized block design during the rainy season (June- August 2014) revealed coriander, palak and green Amaranthus to establish and grow well with higher biomass production compared to lettuce and red Amaranthus. The results of the study reveal the feasibility of growing leafy vegetables under protected environments during the rainy season which is not possible under open conditions as experienced in the experiment during this cropping season. Among the five crops tried, green Amaranthus, Palak and coriander prove to be ideal, red Amaranthus is susceptible to disease and all the vegetable crops under protected conditions require a higher dose of nutrients compared to the recommended package for open cultivation.

Santosh *et al.* (2017) conducted a field experiment to investigate the effect of irrigation levels using drip irrigation system for Lettuce crop grown under polyhouse and in open field condition during winter season (November-February) for two consecutive years. Reference evapotranspiration was estimated using FAO-56 Penman Monteith approach. The total water requirement of Lettuce crop was estimated to be 219 mm and 339 mm for polyhouse and open field condition respectively. The research trials showed that 100% of water requirement met with drip irrigation under polyhouse (T2) resulted in maximum plant height, head diameter, number of leaves, fresh and dry weight of leaves and crop yield. Open field cultivation produces lowest yield compares to all irrigation level treatments under polyhouse.

Thenmozhi and Kottiswaran (2017) conducted experiments in naturally ventilated polyhouse and open field conditions at PFDC farm, TNAU, Coimbatore to study the effect of drip fertigation with different polyethylene mulches in Capsicum crop under polyhouse and open field conditions. The result concluded that maximum yield obtained in polyhouse when compare to open field. Mulches increase the soil temperature, retard the loss of soil moisture and check the weed growth. The experiment concluded that 25 micron plastic mulch increased the soil temperature that prevent soil water evaporation and retains soil moisture, which leads to maximize the crop yield.

Kothari *et al.* (2019) carried out a study to determine the crop water requirement of capsicum (*Capsicum annum L.*) cultivated under polyhouse conditions. Precise estimation of reference evapotranspiration (ETo) and crop evapotranspiration (ETc) on a daily basis is important for scheduling irrigation to apply water through drip system for crops grown in the greenhouse. Reference evapotranspiration (ETo) was estimated using the method suggested by FAO-56. The crop ET was determined using soil moisture depletion method. Weekly reference evapotranspiration inside polyhouse was maximum in 16th week (after transplant) 6.25 mm/day. Total water requirement inside NVPH (Naturally ventilated Polyhouse) under the different treatments over the growing period of capsicum were 411.11 (T1), 370 (T2), 328.88 (T3), 287.77 (T4), 246.66 (T5) and 525.11 mm (T6).

2.6 CROP WATER REQUIREMENT AND IRRIGATION SCHEDULING BY FAO CROPWAT

Sudip *et al*. (2012) carried out a study to find the impact of climate change on crop water requirement. In this study, potato was taken as the reference crop due to its growing period and high response to irrigation. The ET values from the potato field were measured using field water balance method and this data was used to validate the CROPWAT 8.0 model. After proper validation of CROPWAT 8.0 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 – 15% during 2050.

Karim *et al.* (2012) used FAO CROPWAT 8.0 model along with remote sensing for estimating CWR for paddy crop located in the main branch canal of Bhadra command area in Karnataka. The results found that water requirements for Rabi crops were higher than those of the Kharif crops. The water requirement of paddy was found to be 1180.4mm for the entire growth period.

Gowda *et al.* (2013) carried out a study on water requirement of maize using CROPWAT 8.0 model in northern transitional zone of Karnataka. They did this study under rainfed condition at Dharwad during Kharif season. The field experimental data with the two dates of sowing of maize i.e June 16, 2010 and July 30, 2010 were collected and analyzed. They found that the total water requirement of maize sown at an early date was 116.0 mm and that of sown at late date was 183.8 mm.

Ma'an (2013) used the software CROPWAT 8.0 to study effect of deficit irrigation on wheat crop production in Sumel area. The climate data included temperature, humidity, wind and sunshine hours. Crop and soil data were obtained from the manual of FAO 56. By the application of this software, crop water requirements were found out along with irrigation scheduling for this area.

Banik *et al.* (2014) investigated the potential of CROPWAT model 8.0 to schedule the crop water assessment using filed data. They cultivated paddy and wheat in Karnal (Haryana) and Dehradun (Uttarakhand) for plain and hilly region. The results showed that reference evapotranspiration of rice and wheat crop were more for plain region as compared to hilly region. While crop evapotranspiration of rice was more for hilly region and it was more for wheat in plain region.

Manikandan *et al.* (2014) used the CROPWAT 8.0 model to estimate stage-wise information of irrigation water requirement for mustard crop in Raipur to help judicious utilization of available water which may reduce the over utilization of ground water source.

Surendran *et al.* (2015) carried out a study on modelling the crop water requirement using FAO-CROPWAT and assessment of water resources for sustainable water resource management. They computed the crop water requirements of major crops in different agroecological zones of Palakkad using CROPWAT 8.0 model of FAO and compared the same with the available water resources of the district. The major cultivated crops are rice, coconut, banana, areca nut, vegetables, pulses, rubber, tea, coffee, cotton etc. The total water requirement for these crops in various agro-ecological zones was computed. The deficit results indicated that if the total area is brought under irrigation there will be deficit years and during such periods deficit irrigation or reduction in command area may have to be adopted.

Nithya and Shivapur (2016) carried out a study to determine the crop water requirement of few selected crops for the command area in Tarikere taluk in Karnataka state, India. The crops include areca nut, coconut, and cotton, banana for two seasons, sweet pepper, onion, potato, rice, pulses, mango, and cotton, sugarcane and millet (ragi). Crop water requirement for each crop was determined by using 30-year climatic data in CROPWAT 8.0. The study showed that reference evapotranspiration (ETo) varies from 2.5 to 3.36 mm/day for the area under study. The gross water requirement was 342.42 mm/year with an application efficiency of 70. Thus, the dam can conveniently supply the water required for irrigation in the area.

Kumari (2017) conducted a study on irrigation scheduling using CROPWAT 8.0. They determined the crop water requirement and irrigation scheduling of major crops namely sugarcane, rice, tobacco, etc. using different approaches by CROPWAT 8.0 model of Waghodia region of Vadodara.

Hossain *et al.* (2017) conducted a study to estimate irrigation requirement and made irrigation scheduling of T. Aman (wet season) and Boro (dry season irrigated) rice in the western region of Bangladesh using CROPWAT 8.0 model. The model estimated1408 mm annual ETo in the study area, of which the highest amounts of 175 mm was in April and the lowest (70 mm) in December. The average annual rainfall was 1592 mm of which 986 mm was effective for plant growth and development.

Surendran *et al.* (2017) calculated the water needs for various crops in different agroecological units (AEUs) of Kollam district (a humid tropical region of Kerala) using FAO CROPWAT 8.0. The major cultivated crops are rice, coconut, rubber, pepper, banana, brinjal, tomato, tapioca, cardamom, tea, etc. Using evapotranspiration and effective rainfall in each unit, a water balance has been worked out.

Bhat *et al.* (2017) conducted a study on water requirement and irrigation scheduling of maize using CROPWAT 8.0 model. This study focused on developing an optimal irrigation scheduling, to increase crop yield under water scarcity conditions. The crop water requirement and irrigation requirement were found to be 304 mm and 288.2 mm respectively. The model calculated evapotranspiration and crop water requirements, allowed the development of recommendations for improved irrigation practices and planning of irrigation schedules under varying water supply conditions.

Shah (2018) carried out a study to determine the crop water requirements and irrigation scheduling for rabi and hot weather crops for the Waghodia region at Vadodara. Crop water requirement of each crop was determined using 7 year climatic data with the help of FAO CROPWAT 8.0 model. Irrigating at critical depletion and irrigating at fixed interval per stage were the two approaches used in this study. The results showed that irrigation requirement for the crops like wheat, maize, potato and castor bean were 264.8 mm, 236.9 mm, 365.5 mm and 465.6 mm respectively.

Trivedi *et al.* (2018) conducted a study on estimation of evapotranspiration using CROPWAT 8.0 model for Shipra river basin in Madhya Pradesh, India. In this study they determined the potential evapotranspiration and actual evapotranspiration using crop coefficient in the Shipra river basin for the time series

1990 to 2010. From the study it was found out that the maximum average actual ET was in the month of May i.e., 288mm due to highest temperature in this month and the minimum average actual ET was in the month of November i.e., 34mm due to minimum temperature in this month. Thus the study concluded that PET and AET increased when temperature increased and vice –versa.

Memon and Jamsa (2018) conducted a study to determine Crop Water Requirement and irrigation scheduling of Soybean and Tomato crop using FAO- CROPWAT 8.0 software. They concluded that Reference Crop Evapotranspiration, Effective Rainfall, Crop water requirement and Irrigation water requirement can be estimated using CROPWAT 8.0 Software with the input of climatic data like maximum and minimum temperature, relative humidity, wind speed and sunshine hours and rainfall. The use of modern scientific tools like CROPWAT 8.0 can assess the water requirement of crops with large accuracy and suggest the crop pattern and crop rotation which can be readily acceptable to farmers.

CHAPTER III

MATERIALS AND METHODS

This chapter explains the various methods used in the study, description of the study area and collection of data. The methods pertaining to the analysis of variability in ET, water requirement, fertilizer requirement and scheduling of irrigation were explained in detail. Each of these parts are discussed in detail under the following sub-heads.

3.1 STUDY AREA

The field experiment was conducted inside the saw tooth type polyyhouse in the research plot of Precision Farming Development Centre (PFDC) situated near the farm, KCAET, Tavanur. The area lies in the cross point of 10.85^0 N latitude and 75.98^0 E longitude. The area was selected due to the availability of all parameters needed for this study.

3.2 CLIMATE

The average minimum and maximum temperature of Tavanur region is 22.8 ℃ and 27.6 ℃ respectively. The region falls under humid tropical climate. The average annual rainfall of the region is about 2749 mm. The rainy season in the area begins in late May and ends in the months of September. Summer season is hot with a maximum temperature of 36 ℃ during April and May. The relative humidity is low in summer with 35% and it goes up to 85% during the monsoon season. The wind speed in the region is about 3-6 km/hr.

3.3 ESTIMATION OF CROP WATER REQUIREMENT

The crop water requirement of a crop is defined as the amount of water that is required to meet its evapotranspiration demands. Consumptive use (CU) is used to designate the losses due to ET and water that is used for its metabolic activities of plants. Thus CU exceed ET by the amount of water used for digestion, photosynthesis, transport of minerals and photosynthates, structural support and growth. Since this difference is usually less than 1%, ET and CU are normally assumed to be equal. The crop water need mainly depend on the climate, crop type and stage of growth of crop. The crop evapotranspiration can be directly estimated by the mass balance or energy transfer methods. It can also be determined by from lysimeters or from the studies of soil water balance. Sometimes Penman – Monteith equation is also applied for the estimation of crop water requirement directly but the lack of consolidate information on the aerodynamic and canopy features of the cropped area restricts its use.

Nowadays, the crop water requirement is usually calculated from the crop coefficient approach. The formula used is as follows:

ETc = Kc × ETo

Where,

Kc = crop coefficient

ETo = reference crop evapotranspiration (mm)

ETc = crop evapotranspiration (mm)

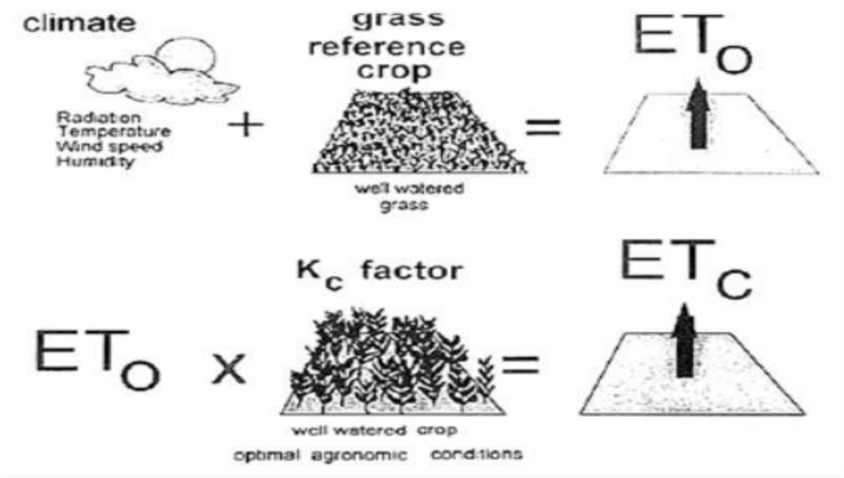

Fig. 3.1 Estimation of evapotranspiration (Source: Allen *et al.* 1998)

Crop evapotranspiration (ETo) refers to the amount of water that is lost through evapotranspiration, while crop water requirement (ETc) refers to the amount of water need to be supplied.

3.3.1 Crop coefficient (kc)

The crop coefficient is generally the ratio of crop evapotranspiration to the reference crop evapotranspiration. Kc values mainly depend upon type of crop, climate and growth stage of crop. The crop coefficient predicts ETc under standard conditions, i.e, conditions where there are no limitations on crop growth due to water shortage, crop density, disease, weed, insect or salinity pressures. This represents the upper envelope of evapotranspiration.

In order to determine Kc it is necessary to determine the total growing period of each crop, various growth stages of each crop and the value of Kc in different growth stages.

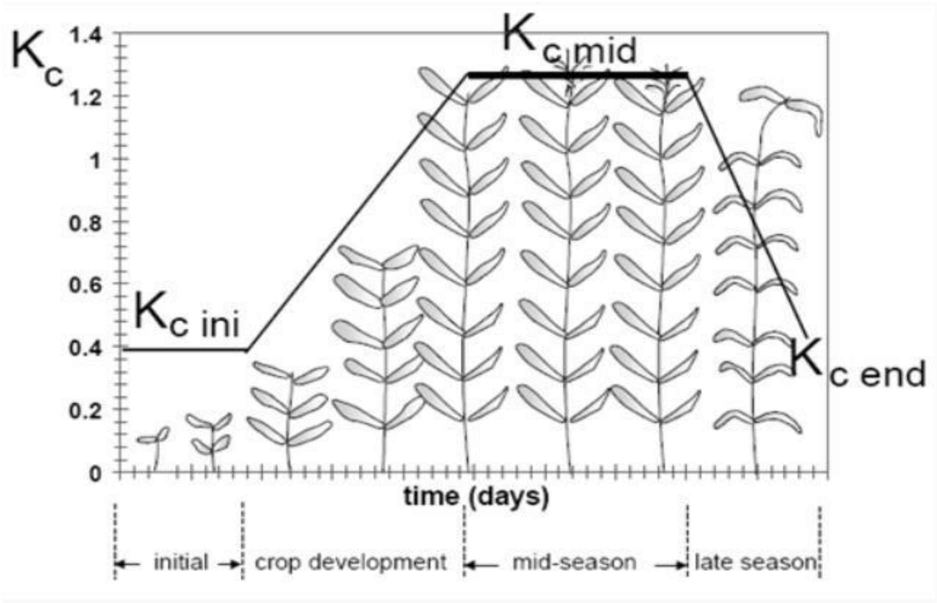

Fig. 3.2 Variation of crop coefficient with crop growth stages (Source: Allen *et al.* 1998)

3.3.2 Estimation of reference crop evapotranspiration (ETo)

Evapotranspiration is a combination of two processes- evaporation and transpiration. Crop evapotranspiration from an extensive surface of green grass of uniform height(0.12m), actively growing, completely shading the ground with an albedo of 0.23 and having ample water supply is called reference crop evapotranspiration and is denoted by ETo. Various methods are in use for the determination of ETo.

FAO-56 Penman – Monteith method

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

Where,

ETo = Reference crop evapotranspiration (mm/day)

Rn = Net radiation at the crop surface (MJ/m2/day)

G = Soil heat flux density (MJ/m^2/day)

T = Air temperature at 2 m height (°C)

U_2 = Wind speed at 2 m height (m/s)

e_s = Saturation vapour pressure (kPa)

The Penman-Monteith equation is used widely nowadays for the estimation of ETo.

3.4 DESCRIPTION OF CROPWAT 8.0 MODEL

The estimation of crop water requirements manually using these equations is a tedious job. Computerized programs could easily access the wide range of data and could give the desired results on crop water requirements and irrigation scheduling. The land and water development division under the Food and Agricultural organisation has developed a software CROPWAT 8.0 for the determination of crop water requirement and irrigation scheduling. It is meant as a standard tool for carrying out calculations for reference crop evapotranspiration, crop water requirement and crop irrigation requirement. The CROPWAT model offers the possibility to:

1. Design an indicative irrigation schedules and its impact over yield

2. Evaluate field irrigation program in terms of efficiency of water use and yield reduction.

3. Simulate field irrigation program under water deficiency conditions, rain-fed conditions, supplementary irrigation, etc.

This computer program utilizes FAO Penman-Monteith equation for the calculation of ETo. The program allows development of irrigation schedules under various management and water supply conditions. The major features of CROPWAT 8.0 include:

1) Monthly, decade and daily input of climate data.

2) Possibility to estimate climate data in the absence of measured value.

3) Decade and daily calculation of crop water requirements based on update calculation algorithms including adjustment of crop-coefficient value.

4) Calculation for dry crops and for paddy and upland rice

5) Daily soil water balance output tables.

6) Easy saving and retrieval of session and of user defined irrigation scheduling.

7) Graphical presentation of input data and calculation results.

8) Easy import/export of data and graphics through clipboard or ASCII text file.

9) Extensive printing routines.

10) Context-sensitive help system

3.5 INPUT REQUIREMENTS FOR CROPWAT 8.0 MODEL

The input data required for CROPWAT 8.0 include:

3.5.1 Meteorological data

The meteorological data were collected for the past four months (March to June) from KCAET, Tavanur. These data include daily maximum and minimum temperatures, relative humidity, daily wind speed and daily sunshine hours. The average values of these data are calculated using the model.

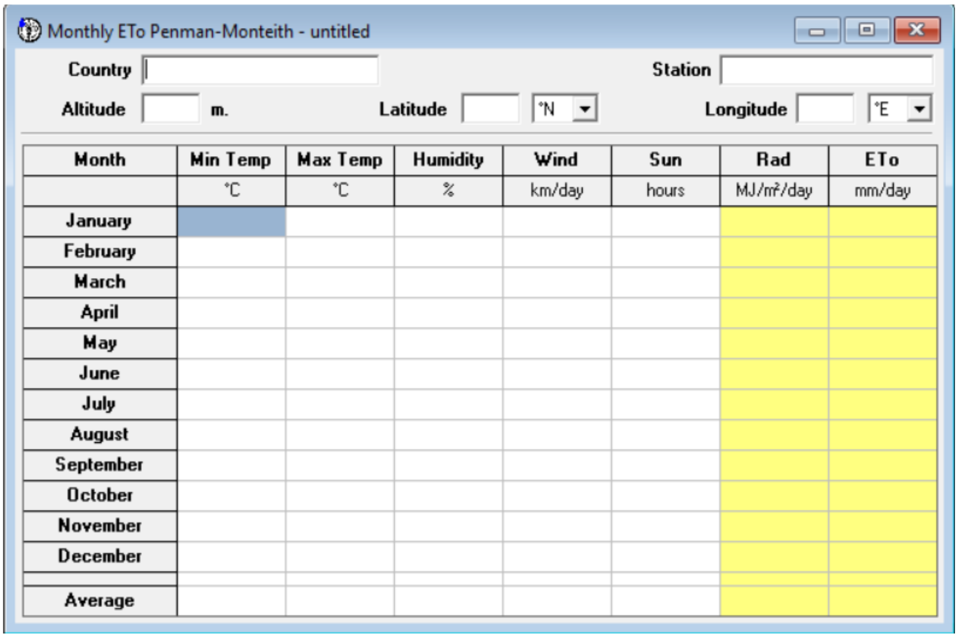

Fig. 3.3 Input window for climate data CROPWAT

These parameters are used by CROPWAT 8.0 in order to calculate the radiation and ETo.

Table 3.1 Mean monthly values of weather parameters of Tavanur (1983-2017)

Sl no	Month	Max. Temp, °C	Min. Temp, °C	RH, %	Wind speed, km/hr	Sunshine (hr)
1	January	33.3	20.48	58.5	5.81	8.61
2	February	35.28	21.05	61	4.81	8.86
3	March	36.11	23.36	62.5	4	8.5
4	April	35.28	24.53	71.85	3.222	7.9
5	May	33.75	24.71	76.75	3.08	7.25
6	June	30.2	23.43	84.75	2.64	4.47
7	July	29.44	22.88	83.5	3.13	3.35
8	August	29.61	23.09	83	3.49	4.44
9	September	30.47	23.61	80.25	3.13	5.76

10	October	31.2	23.26	79	2.08	5.62
11	November	32.2	22.22	73.5	2.83	6.65
12	December	32.12	21.04	69.25	5.17	7.85

3.5.2 Soil data

The soil in Tavanur region is of sandy loam nature. The major data requirements for soil include total available soil water content, maximum infiltration rate, maximum rooting depth and initial soil water content.

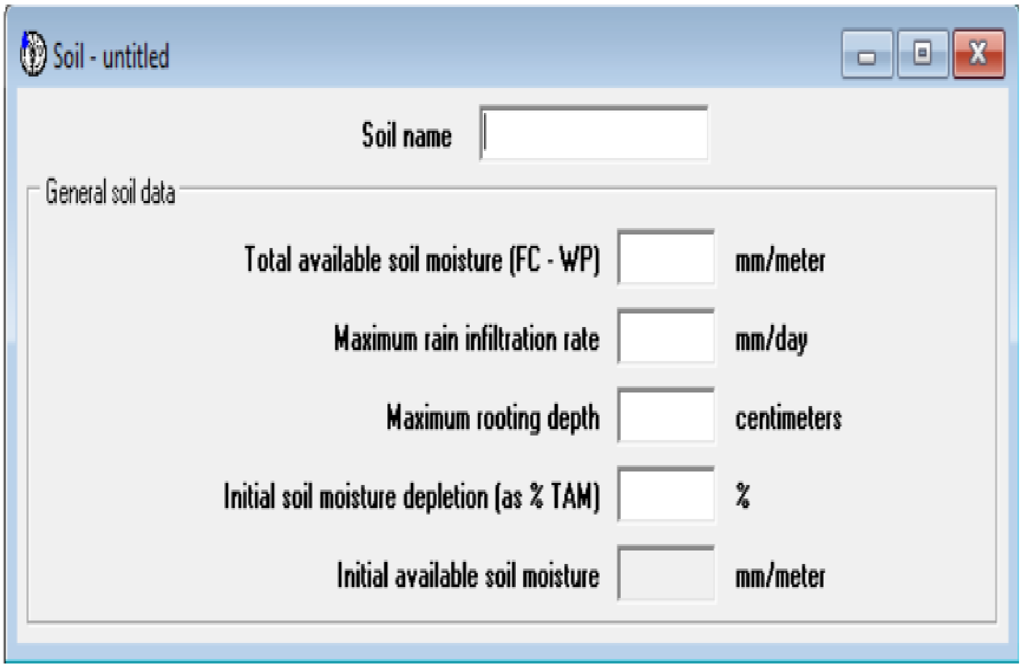

Fig. 3.4 Input window of soil data (dry crop) CROPWAT 8.0

Table 3.2 Soil data

Type of soil	Sandy loam soil
Total available soil water content	100 mm/m
Maximum infiltration rate	30 mm/day
Maximum rooting depth	40 cm
Initial soil water content	83 mm/m

3.5.3 Crop data

The crop selected for the study is Amaranthus (*Amaranthus retroflexus)*. The data collected include crop coefficient, critical depletion and length of growing season. The data is being collected from FAO 56 paper for each crop.

Table 3.3 Crop data for Amaranthus

Date of sowing		08/03	**Harvesting Date**		06/05
Crop parameter	**Initial**	**Development**	**Mid-season**	**Late**	**Total**
Kc	0.7		0.9		0.8
Length, days	20	20	15	5	60
Rooting depth	0.04		0.13		
Critical depletion fraction	0.2		0.2	0.2	
Yield response factor	1.0	1.0	1.0	1.0	1.0
Crop height, m			0.3		

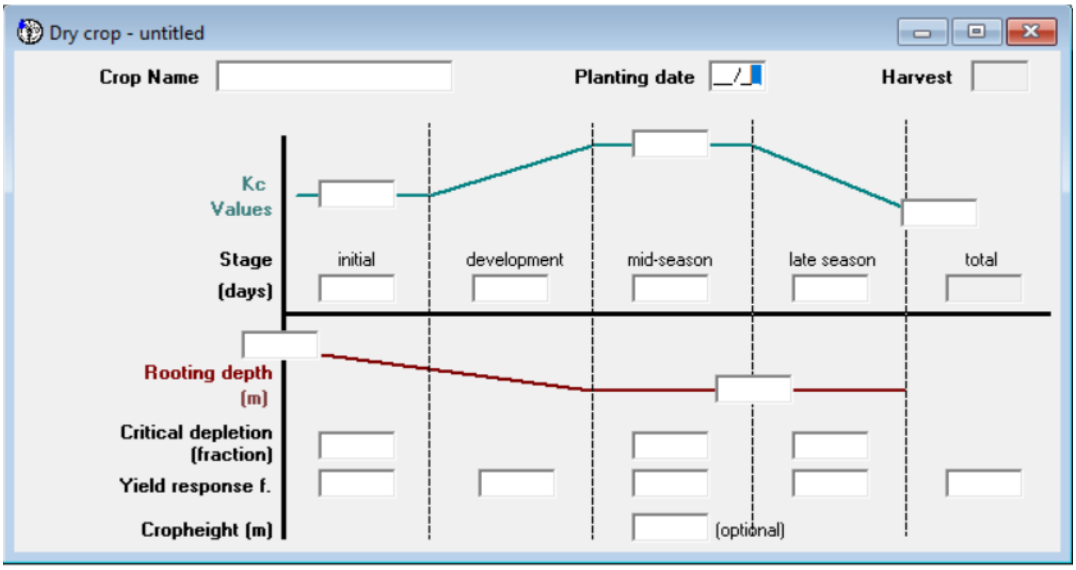

Fig. 3.5 Input window for Amaranthus

3.6 NET IRRIGATION REQUIREMENT (NIR)

Irrigation is necessary when rainfall could not meet the evapotranspiration demands of the crops. Irrigation should apply the right quantity of water at the right time. The timing and depth of future irrigations can be planned by calculating soil water balance in the root zone on a daily basis. The irrigation requirement, expressed in mm is calculated for the specified interval. Net irrigation requirement is the variation between concerned crop evapotranspiration growing under standard conditions with the effective rainfall for the specified time interval. It indicatively represents the fraction of crop water requirements that needs to be satisfied through irrigation contribution in order to ensure optimum crop growing conditions.

NIR = WR – ER – Ge

Where,

WR = Water Requirement (ETc)

ER = Effective Rainfall

Ge = Groundwater contribution from the water table (not considered in the study as this is negligible).

3.7 IRRIGATION SCHEDULING

Irrigation scheduling primarily aims at determining how to irrigate, when to irrigate and how much to irrigate. The primary aim of scheduling is to maintain optimum water supply to improve productivity so that the water level in the root zone is maintained between the confines of readily available water (RAW). CROPWAT model handles irrigation scheduling of each crop individually. The schedule not only enables the efficient management of water but also develop effective water delivery schedules under restricted supply conditions.

The irrigation scheduling option in CROPWAT provides a number of options depending on user's objectives, available water sources the conditions of the irrigation system. Here in this study, irrigation is done at critical depletion. Current one year data (Jan–Dec, 2017) is used for scheduling the irrigation. In this approach, the soil moisture content is refilled to field capacity and the irrigation is supposed to have an efficiency of 100%.

3.8 FIELD EXPERIMENT

Growth and yield parameters of Amaranthus with different irrigation and fertigation schedules were studied. The experiment was conducted inside the naturally ventilated polyhouse during 2020 (March 8th) – 2020 (May 6th) and the crop duration was two months (60 days). The polyhouse was oriented east–west with an area of 292 m^2 (36.5 m length and 8 m width). A view of the polyhouse is shown in Fig. 3.6.

3.8.1 Field preparation

Polyhouse was cleaned inside out. Land preparation was done inside the naturally ventilated polyhouse using an alligator. Nursery was prepared and CO-1 variety of Amaranthus was sawn. Seed beds were formed and cow dung was applied. Main, submain and laterals were laid. Mulching is done and holes were drilled. Emitters were connected to the lateral. Poly house was divided into beds and each bed was applied with a different irrigation and fertigation schedule. Beds were of the dimensions 17.3 m length, 0.4 m width and 0.25m height. Layout of the field experiment is shown in figure 3.9.

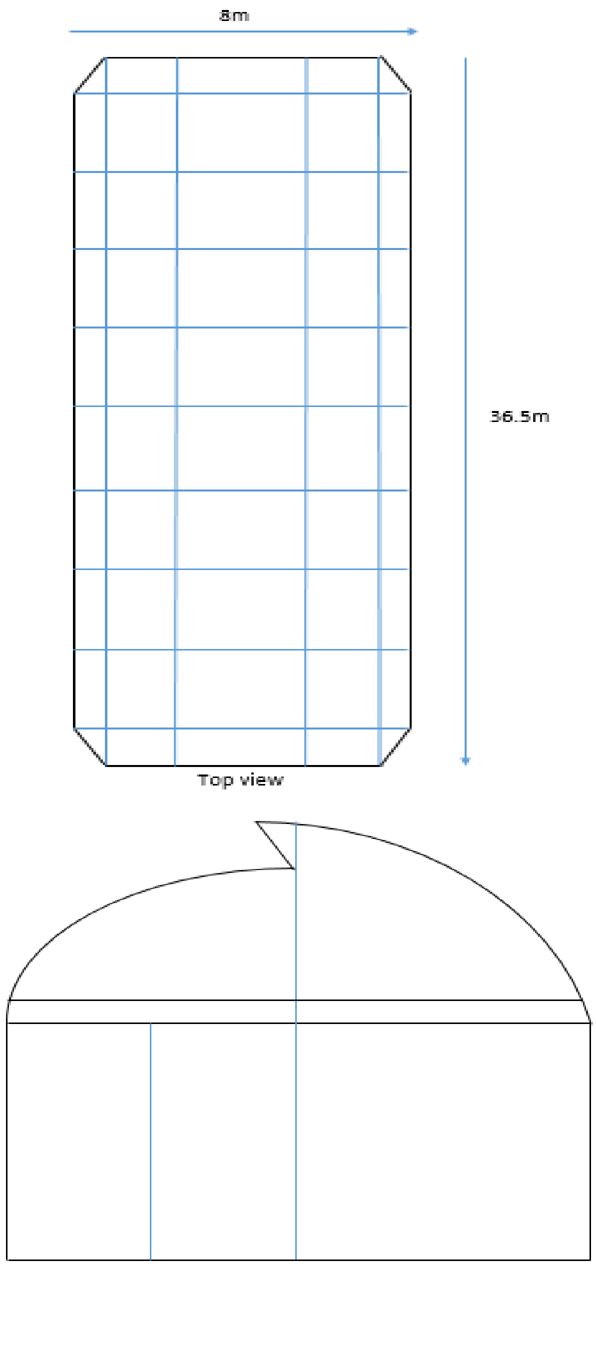

Fig. 3.6 Top view and Front View of Polyhouse

Plate 3.1 View of the poly house

Plate 3.2 Cleaning of the poly house

Plate 3.3 Cleaning inside poly house using an alligator

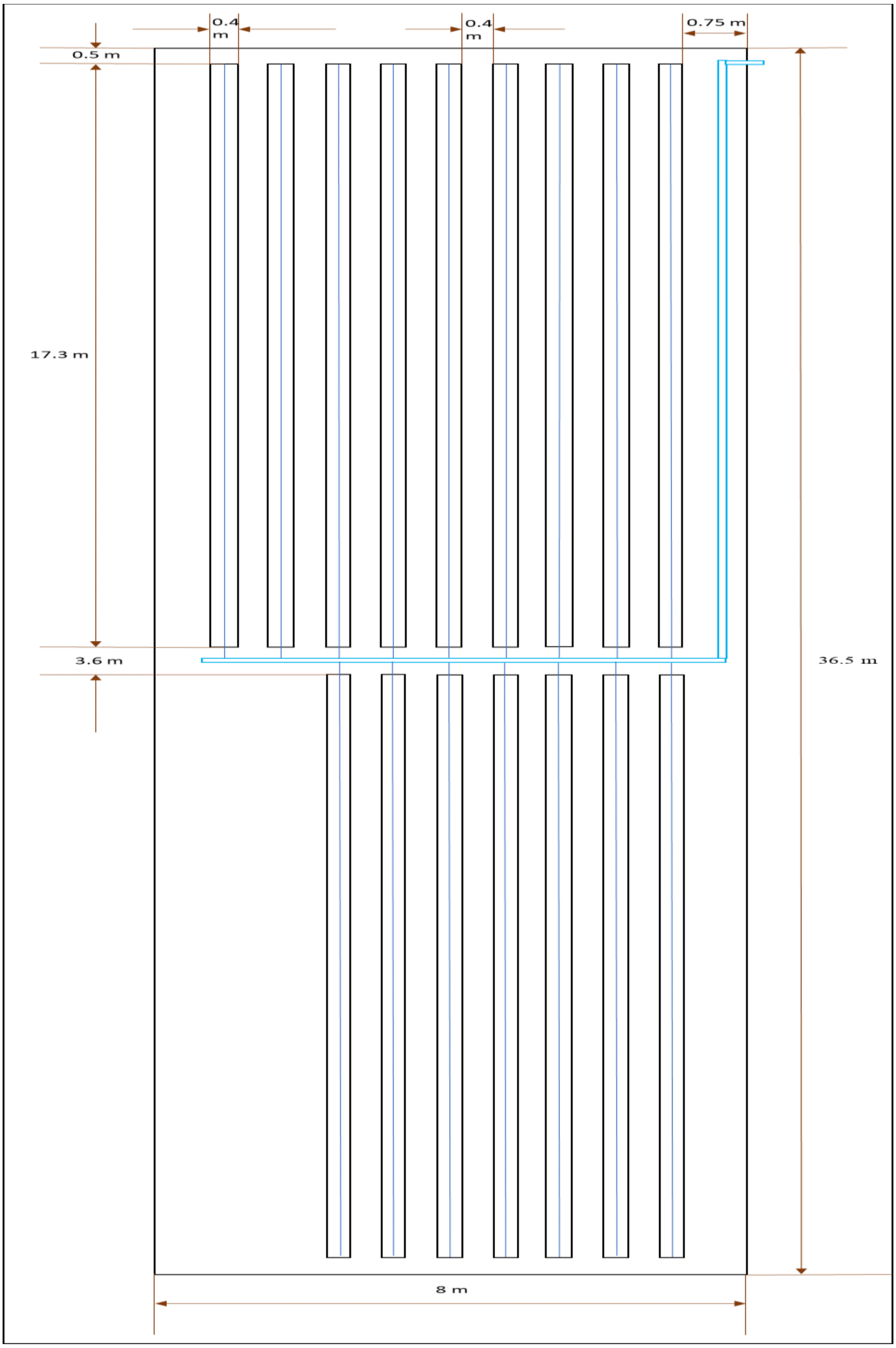

Fig. 3.7 Layout of the experimental field

3.8.2 Nursery

Amaranthus variety CO-1 was chosen for cultivation. Seeds were sown in a nursery bed of dimensions 3.5 m length and 0.7 m width and ten days old seedlings were transplanted to the main field.

3.8.3 Transplanting

Transplanting was done on 17th March 2020. There were 42 plants in each bed with a plant spacing of 42 cm. The total plant population was 672 numbers. Row to row distance is 80 cm. The view of the plot after transplanting is given in Fig 3.11.

Plate 3.4 Amaranthus seedling after transplant

Plate 3.5 Plot after transplanting

3.9 EXPERIMENT DESIGN

The experiment was designed under Factorial Completely Randomized Block Design. The design details are as furnished in the Table 3.4 and 3.5.

Table 3.4 Experiment Design Details

Crop variety	Amaranthus : *CO-1*
Experiment design	Factorial CRD
Factors	**F – Fertigation levels** F1- 75% fertigation F2- 100% fertigation F3- 125% fertigation F4-150% fertigation **T – Irrigation levels** T1- 60% irrigation

	T2- 80% irrigation T3- 100% irrigation T4- 120% irrigation
No. of replications	3
No of treatment combinations	16

Table 3.5 Treatment details

F1T1	Crop with 75% fertigation and 60% irrigation
F1T2	Crop with 75% fertigation and 80% irrigation
F1T3	Crop with 75% fertigation and 100% irrigation
F1T4	Crop with 75% fertigation and 120% irrigation
F2T1	Crop with 100% fertigation and 60% irrigation
F2T2	Crop with 100% fertigation and 80% irrigation
F2T3	Crop with 100% fertigation and 100% irrigation
F2T4	Crop with 100% fertigation and 120% irrigation
F3T1	Crop with 125% fertigation and 60% irrigation
F3T2	Crop with 125% fertigation and 80% irrigation
F3T3	Crop with 125% fertigation and 100% irrigation
F3T4	Crop with 125% fertigation and 120% irrigation
F4T1	Crop with 150% fertigation and 60% irrigation
F4T2	Crop with 150% fertigation and 80% irrigation
F4T3	Crop with 150% fertigation and 100% irrigation
F4T4	Crop with 150% fertigation and 120% irrigation

3.10 IRRIGATION SYSTEM

Irrigation water source was tube well from which water was pumped to a sand filter and conveyed through the main line of 1.5” diameter. One end of the venturi injector is connected to the main and the other end to disc filter . PVC sub main of 1.5” diameter was connected to the disc filter to which, Low density polyethylene laterals of 16 mm diameter were connected. End caps were provided at the end of laterals. Each lateral was provided with individual cut off valves for controlling irrigation. Along the laterals, online drippers of 8 lph were placed at fixed intervals.Venturimeter was also used. Fig 3.16 depicts the irrigation system layout in the poly house.

Plate 3.6 Pump

Plate 3.7 Bypass assembly

Plate 3.8 Laterals drawn from submain

Plate 3.9 Cut off valve

Plate 3.10 Drip irrigation system layout in the poly house

3.11 FERTIGATION

In all modern systems, fertilization and irrigation are integrated into one system which enables supply of fertilizers and water at the same time (fertigation). Once it became evident that all nutrients essential for crops (macro- and micronutrients) could be supplied through hydro soluble fertilizer salts, systems were developed with fertilizers dissolved at relatively high concentrations in special stock solutions. Stoke solution was prepared by dissolving the following minerals in 10 litres of water.

Table 3.6 Fertilizer schedule

Application stages	Fertilizers	75% fertigation	100% fertigation	125% fertigation	150% fertigation
Initial stage	19:19:19 13:0:45 Urea	7.5 g 7.5 g 10 g	10 g 10 g 13.33 g	12.5 g 12.5 g 16.66 g	15 g 15 g 20 g
Final stage	19:19:19 13:0:45 Urea	7 g 2.5 g 13.5 g	9.33 g 3.33 g 18 g	11.6 g 4.1 g 22.5 g	14 g 5 g 27 g

3.12 FIELD OBSERVATIONS

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

3.12.1 Plant growth parameters

3.12.1.1 Plant height

The height of the plant from base level of shoot to the tip was measured at one week interval and expressed in centimeters for each treatment.

3.12.1.2 Number of leaves

Number of leaves per plant was noted at one week interval in selected plants.

3.12.1.3 Stem girth

The width (diameter) of stem was recorded at one week interval.

3.12.1.4 Leaf length

The length of leaf at the middle was noted at one week interval.

3.12.1.5 Leaf width

The average width at the middle of leaf was noted at one week interval.

Plate 3.11 Amaranthus crop inside the poly house

3.12.2 Yield parameters

Harvesting was started twenty seven days after transplanting at an interval of four or five days. The weight of crop harvested was noted from the tagged plants for each harvest. The average value of crop weight per plant was accordingly computed from the data of all harvests. Total five harvests were done and total yield was taken. The crop period was not over and harvest was continuing when the experiment was stopped. The results reported are upto the first five harvest of the crop.

Plate 3.12 View of the poly house during the experiment

3.13 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.

$$WUE=Y/W.$$

Where,

WUE=Water use efficiency (kg/ha mm) of water used.

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

W.A = Total water applied (mm)

CHAPTER IV

RESULTS AND DISCUSSION

The evapotranspiration rate and thereby the water requirement of crops are dependent upon the various weather parameters. The variability of these parameters over years has greatly influenced the water demands of crops. The rainfall alone could not meet the ET demand of crop. The remaining water has to be applied externally via irrigation. A good irrigation practice applies right quantity of water at the right time. Here comes the need to establish a better scheduling for irrigation. This could result in the judicious use of water in the current scenario of water scarcity. An analysis of gap between the rainfall and water requirement of crop will help whether rainfall could meet the required demand. Results and discussion pertaining to all the above aspects were discussed in the following sub heads.

4.1 WATER REQUIREMENT OF AMARANTHUS

The water requirement of Amaranthus was found for the year 2020 using CROPWAT 8.0 model. The model calculated the IR for the entire growth period, in a decade wise pattern (10 days). The results obtained from the model are shown in Table 4.1.

Table 4.1 water requirement of Amaranthus

Month	Decade	Stage	Kc	Etc	Etc	Er	Ir
			Coefficient	mm/ day	mm/dec	mm/dec	mm/dec
March	1	Initial	0.70	2.86	2.9	0	2.9
March	2	Initial	0.70	3.02	30.2	0	30.2
March	3	Develo pment	0.7	2.51	27.6	0	27.6

April	1	Development	0.76	3.59	35.9	0	35.9
April	2	Mid	0.83	3.64	36.4	0	36.4
April	3	Mid	0.85	3.04	30.4	0	30.4
May	1	Late	0.82	3.85	30.8	0	30.8
					194.2		194.2

The average ET_O value is 3.62mm/day.

4.2 IRRIGATION SCHEDULING OF AMARANTHUS

4.2.1 Irrigation at 100% critical depletion.

The Fig. 4.8 represents the output window obtained from CROPWAT 8.0 model for irrigation scheduling of Amaranthus at critical depletion. It was found that the total gross irrigation was about 276.4 mm, NIR was 193.5 mm.

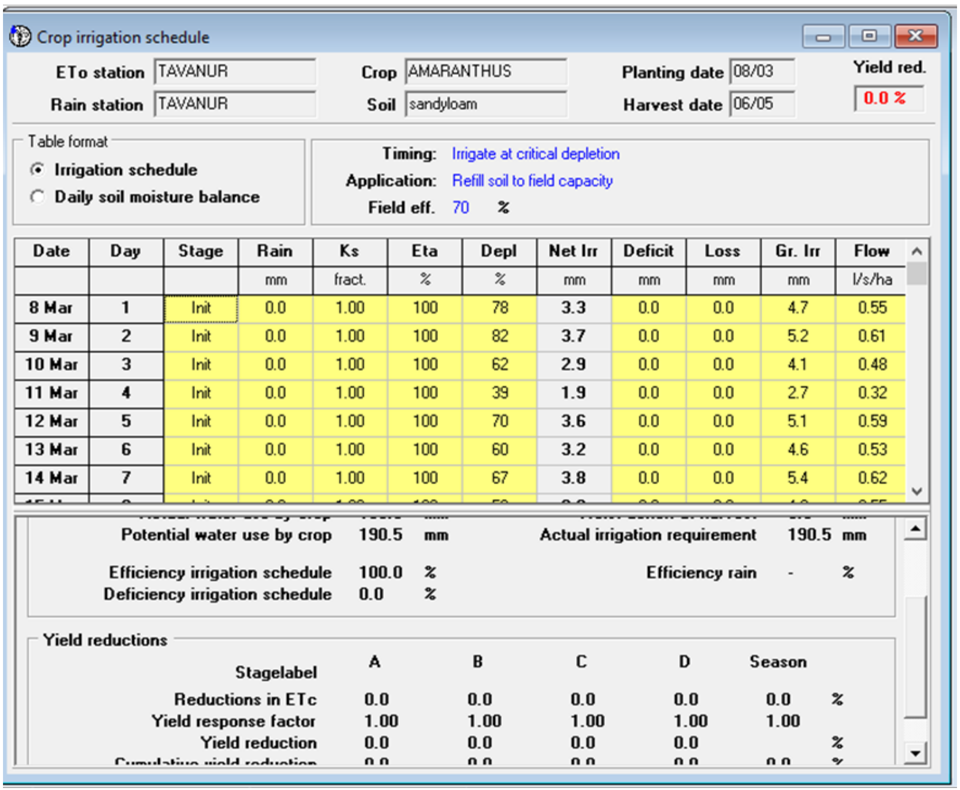

Fig. 4.1 Output window of irrigation scheduling of Amaranthus at 100 % critical depletion.

4.3 OBSERVATIONS ON CROP GROWTH PARAMETERS

Data on observations viz, number of leaves, plant height, stem girth, length of leaves, width of leaf at middle and yield per plant for each treatment were observed during different stages crop growth. The data were statistically analyzed and results are enumerated under various headings.

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

Table 4.2 shows effect of alternate growing systems and irrigation interval on plant height, stem girth, no of leaves, width of leaf at middle and length of leaves during first day of transplanding.

Table 4.2 Plant growth parameters after 1st day of transplanting

Treatment		Plant height	Stem girth	No of leaves	Width of leaf at middle	length of leaves
		cm	cm		cm	cm
T1F1	R1	10	1.5	4	1.9	4
	R2	10.5	1.3	5	1.8	3.9
	R3	11	1.3	5	1.7	3.6
T1F2	R1	10.5	1.4	4	1.8	3.5
	R2	12.5	1.5	6	1.9	3.9
	R3	13	1.4	5	2.1	4.1
T1F3	R1	12.5	1.3	4	1.9	4.1
	R2	11	1.4	5	1.8	3.9
	R3	12.5	1.5	5	2.1	3.7
T1F4	R1	11	1.3	4	2	3.7
	R2	10.5	1.5	6	1.9	3.8
	R3	12.5	1.3	5	1.8	4.2
T2F1	R1	11	1.4	6	1.9	4.1

	R2	12	1.3	4	2.1	3.9
	R3	11.5	1.4	6	1.9	3.8
T2F2	R1	12.5	1.3	6	1.8	3.9
	R2	10.5	1.4	4	1.9	3.7
	R3	10.5	1.5	5	1.7	3.8
T2F3	R1	12.5	1.4	5	1.8	4.1
	R2	11.5	1.3	6	1.9	3.6
	R3	10.5	1.3	6	2	4
T2F4	R1	11	1.4	4	2.1	3.8
	R2	11.5	1.3	5	1.8	3.6
	R3	11.5	1.3	4	1.4	4.8
T3F1	R1	10.5	1.5	6	1.9	4.8
	R2	12	1.4	4	1.8	4.7
	R3	12.5	1.4	5	1.9	4.5
T3F2	R1	11	1.4	5	1.8	4
	R2	10.5	1.5	6	2.1	4.1
	R3	10	1.3	5	1.9	4.2
T3F3	R1	12.5	1.4	4	1.7	3.9
	R2	12	1.5	6	1.8	4.2
	R3	11.5	1.3	5	2.1	4.1
T3F4	R1	10.5	1.4	4	2.2	4.3
	R2	11	1.5	5	1.8	3.9
	R3	10.5	1.4	6	2.4	4.1
T4F1	R1	12.5	1.5	4	2.1	4.2
	R2	10.5	1.3	5	2.2	4.1
	R3	12.5	1.4	5	1.7	3.8
T4F2	R1	11.5	1.5	6	1.9	4.2
	R2	10.5	1.3	6	1.8	3.9
	R3	11	1.4	5	1.9	3.9
T4F3	R1	12.5	1.4	5	2.1	4.3

	R2	11	1.5	6	1.8	4.1
	R3	11.5	1.3	6	2.3	4.5
T4F4	R1	13.5	1.4	4	2.1	4.3
	R2	12.5	1.5	5	2.2	4.6
	R3	12	1.3	5	1.9	3.9

Table 4.3 shows effect of alternate growing systems and irrigation interval on plant height, stem girth, no of leaves, width of leaf at middle and length of leaves during first week.

Table 4.3 plant growth parameters after 1st week of transplanting

Treatment		Plant height	Stem girth	No of leaves	Width of leaf at middle	length of leaves
		cm	cm		cm	cm
T1F1	R1	19	2.1	9	3.6	5.5
	R2	19.5	2	8	3.8	5.3
	R3	18	2	8	3.9	5.2
T1F2	R1	18.5	2.2	7	3.7	5.4
	R2	17.5	2.1	8	3.7	5
	R3	18	1.9	9	3.9	6
T1F3	R1	18.5	2.1	8	3.6	5.9
	R2	18	2	7	3.6	5.6
	R3	19	2.1	8	3.7	5.7
T1F4	R1	18	2.2	8	3.8	6
	R2	19.5	2.1	9	3.6	5.5
	R3	18.5	2	8	3.8	5.4
T2F1	R1	19.5	1.9	8	3.7	5.4
	R2	21	2.2	9	3.6	5.8
	R3	21.5	2.1	10	3.7	5.9
T2F2	R1	21	2.2	11	3.8	6

	R2	21	2	8	3.9	5.9
	R3	19.5	1.9	9	3.8	6
T2F3	R1	20.5	2.1	10	3.6	5
	R2	21	2	8	3.9	5.6
	R3	21.5	2.2	9	3.7	5.7
T2F4	R1	20	2.3	9	3.9	5.6
	R2	21	2.1	9	3.9	5.3
	R3	21.5	2	10	3.8	5.9
T3F1	R1	22.5	2.4	9	4.1	5.7
	R2	22.5	2.2	10	3.9	5.4
	R3	23	2.5	10	3.7	5.5
T3F2	R1	23	2.7	12	4.3	6.4
	R2	23.5	2.6	11	4.2	6.5
	R3	23.5	2.8	12	4.3	6.5
T3F3	R1	21	2.5	10	4.2	6.3
	R2	215	2.7	11	4.1	6.4
	R3	22	2.6	11	4	6
T3F4	R1	22.5	2.6	10	4.3	6.4
	R2	22	2.5	12	4.2	6.3
	R3	23	2.6	11	4.1	6.4
T4F1	R1	23	2.7	10	4.1	6
	R2	21	2.6	11	4	6.3
	R3	22	2.4	11	4	6.2
T4F2	R1	21.5	2.3	11	4.1	6.3
	R2	23	2.4	10	4	6.4
	R3	21.5	2.4	11	4.2	6.2
T4F3	R1	22	2.5	12	4.1	6.3
	R2	23	2.3	11	4	6.4
	R3	22.5	2.6	10	4.3	6.3
T4F4	R1	22	2.8	11	4.2	6.1

	R2	23	2.2	12	4	6.6
	R3	23	2.6	10	4.1	6.1

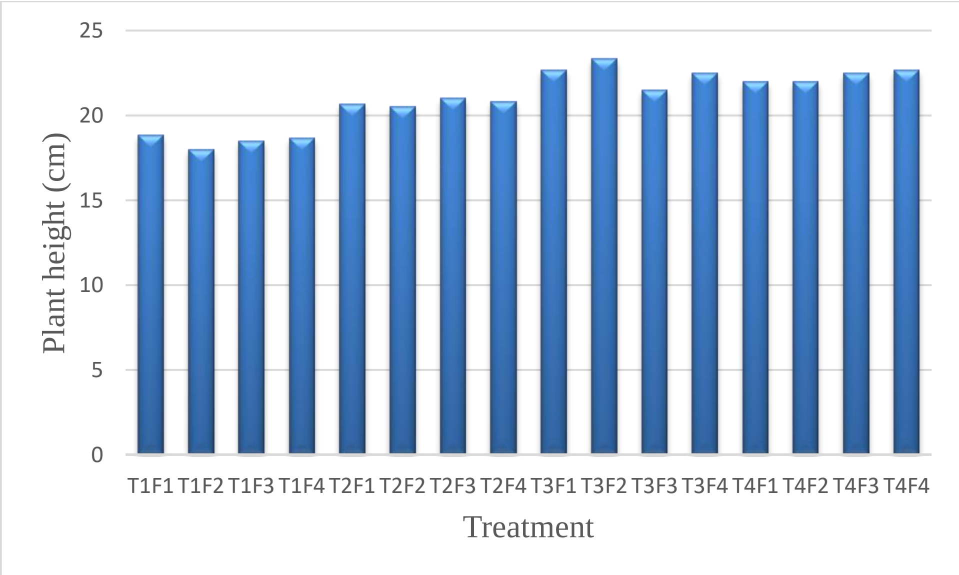

Fig. 4.2 Observation of plant height after 1st week of transplanting

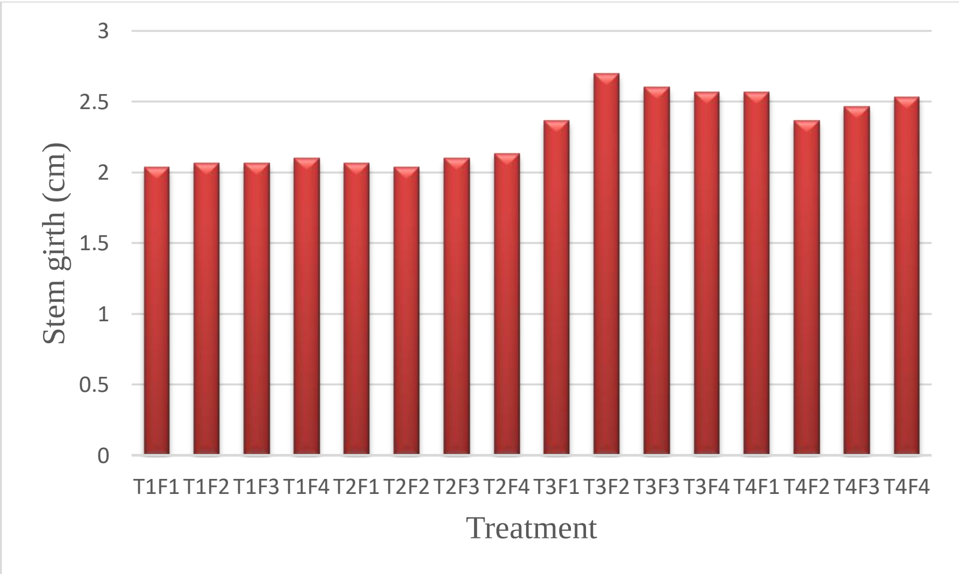

Fig. 4.3 Observation of stem girth after 1st week of transplaning

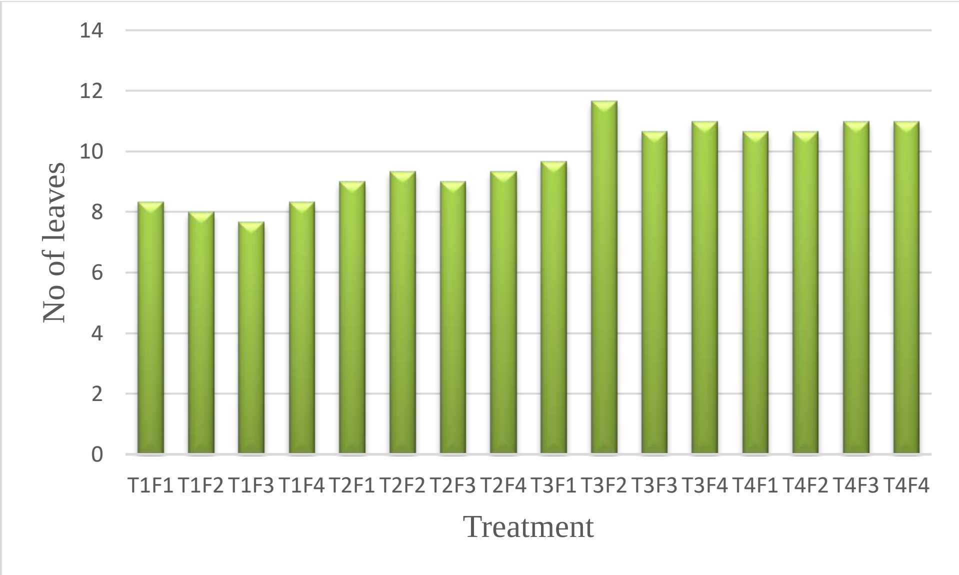

Fig. 4.4 Observation of no of leaves after 1St week of transplanting

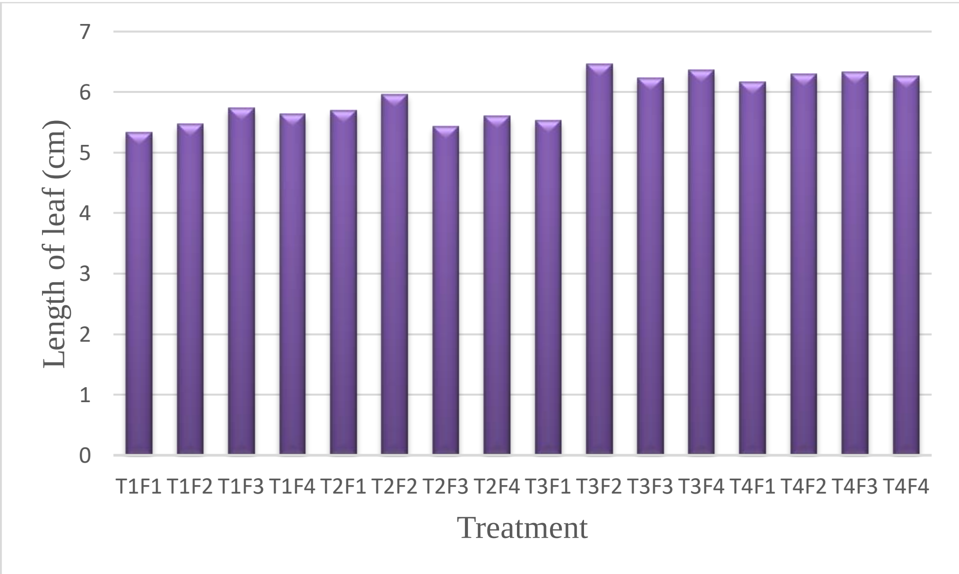

Fig. 4.5 Observation of length of leaf after 1St week of transplanting

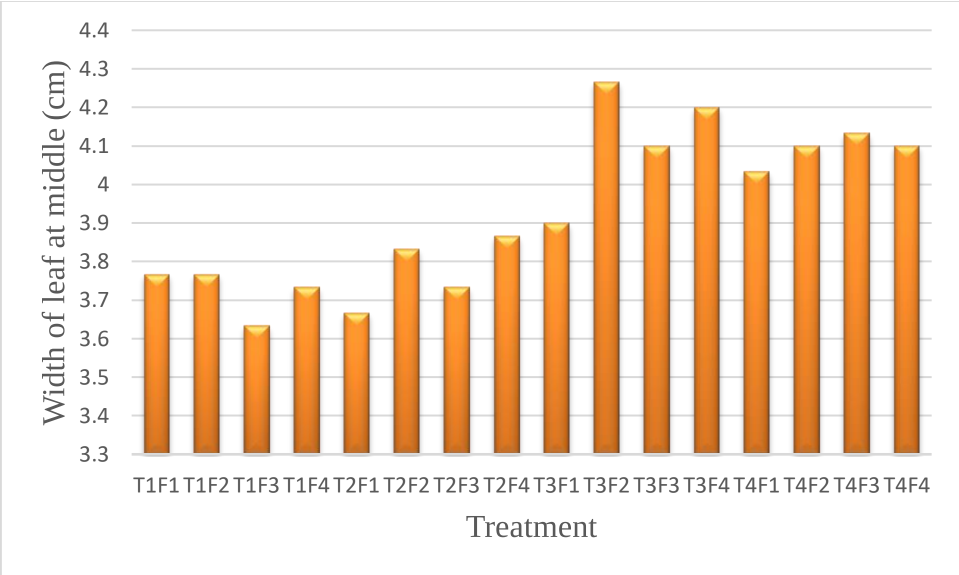

Fig. 4.6 Observation of width of leaves after 1st week of transplanting

Table 4.4 shows effect of alternate growing systems and irrigation interval on plant height, stem girth, no of leaves, width of leaf at middle and length of leaves during second week.

Table 4.4 Observation of growth parameters after 2nd week of transplanting

3/31/2020		Plant height	Stem girth	No of leaves	Width of leaf at middle	length of leaf
T1F1	R1	26	2.7	11	4.1	7.5
	R2	27	2.8	12	4.2	7.1
	R3	26.5	2.7	11	4.1	7.8
T1F2	R1	28	2.9	12	4.3	7.8
	R2	26	2.7	11	4.5	7.5
	R3	27.5	2.9	13	4.1	7.6
T1F3	R1	29	2.9	12	4.2	7.5
	R2	28	2.8	11	4.5	7.5
	R3	28.5	2.9	13	4.3	7.4
T1F4	R1	29	2.8	12	4.3	7.3

	R2	28.5	2.9	11	4.4	7.9
	R3	29	2.9	13	4.3	7.8
T2F1	R1	30	3	12	4.7	8.2
	R2	32	2.9	13	4.2	8.1
	R3	31.5	3	13	4.5	7.4
T2F2	R1	33	2.9	13	4.3	7.8
	R2	29	2.8	12	4.2	7.9
	R3	29.5	3	12	4.3	7.5
T2F3	R1	32	2.8	11	4.2	7.9
	R2	31	2.9	11	4.3	8.1
	R3	31.5	2.8	13	4.7	8
T2F4	R1	31.5	2.9	12	4.2	7.8
	R2	31	3	10	4.8	8.2
	R3	31.5	3.1	13	4.3	8.4
T3F1	R1	29.5	3.2	12	4.4	8.3
	R2	33	3	11	4.7	8
	R3	32	3.2	12	4.5	8.1
T3F2	R1	33.5	3.9	16	5.8	9.6
	R2	34	3.7	15	5.6	9.4
	R3	32.5	3.8	15	5.8	9.7
T3F3	R1	31.5	3.6	14	5.4	9.4
	R2	32	3.5	15	5.4	9
	R3	31.5	3.6	14	5.2	9.5
T3F4	R1	32	3.7	15	5.3	9.3
	R2	31	3.6	16	5.3	9.4
	R3	33	3.7	15	5.4	9.6
T4F1	R1	31	3.6	15	5.8	9.7
	R2	29.5	3.6	14	5.4	9.5
	R3	32	3.8	16	5.3	9.2
T4F2	R1	31.5	3.7	14	5.4	9.4

	R2	32	3.6	14	5.7	9.6
	R3	31.5	3.8	15	5.3	9.1
T4F3	R1	32	3.6	13	5.4	9.3
	R2	31	3.7	15	5.3	9.4
	R3	31.5	3.6	16	5.4	9
T4F4	R1	32	3.9	15	5.6	9.4
	R2	31	3.4	14	5.8	9.6
	R3	32	3.6	15	5.5	9

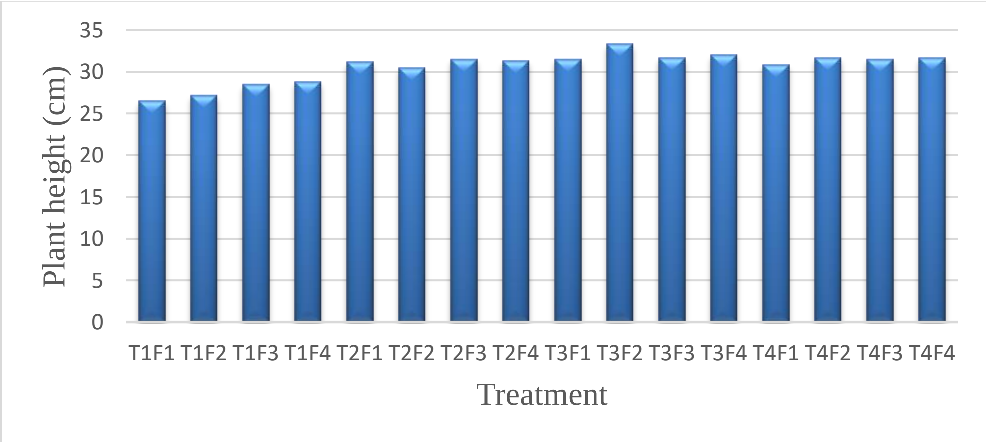

Fig. 4.7 Observation of plant height after 2nd week of transplanting

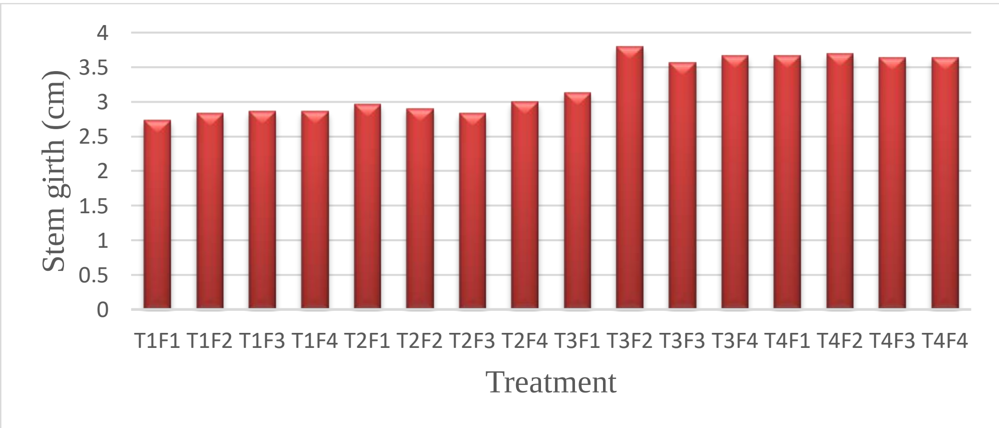

Fig. 4.8 Observation of stem girth after 2nd week of transplanting

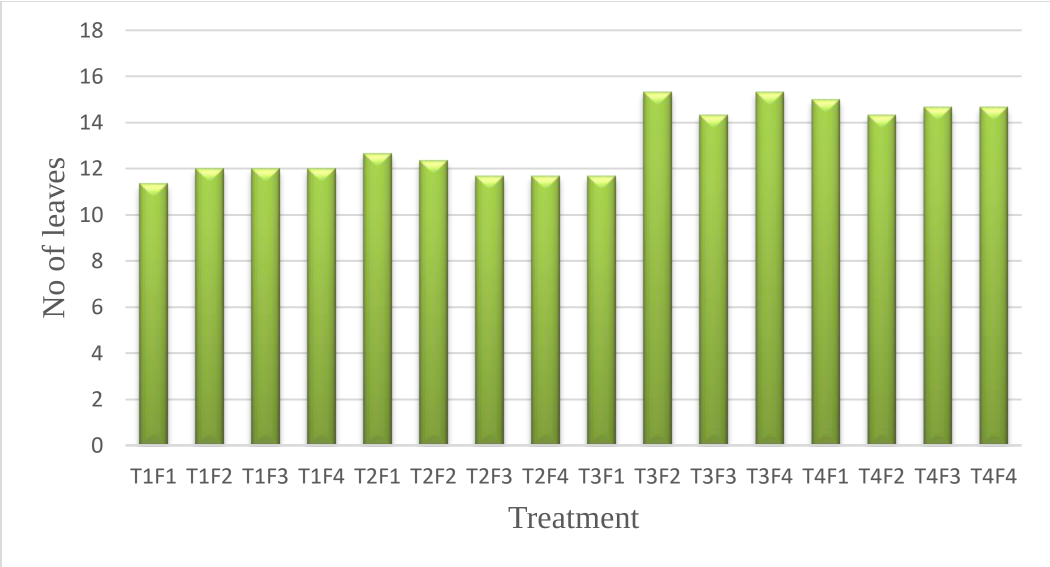

Fig. 4.9 Observation no of leaves after 2ndweek of transplanting

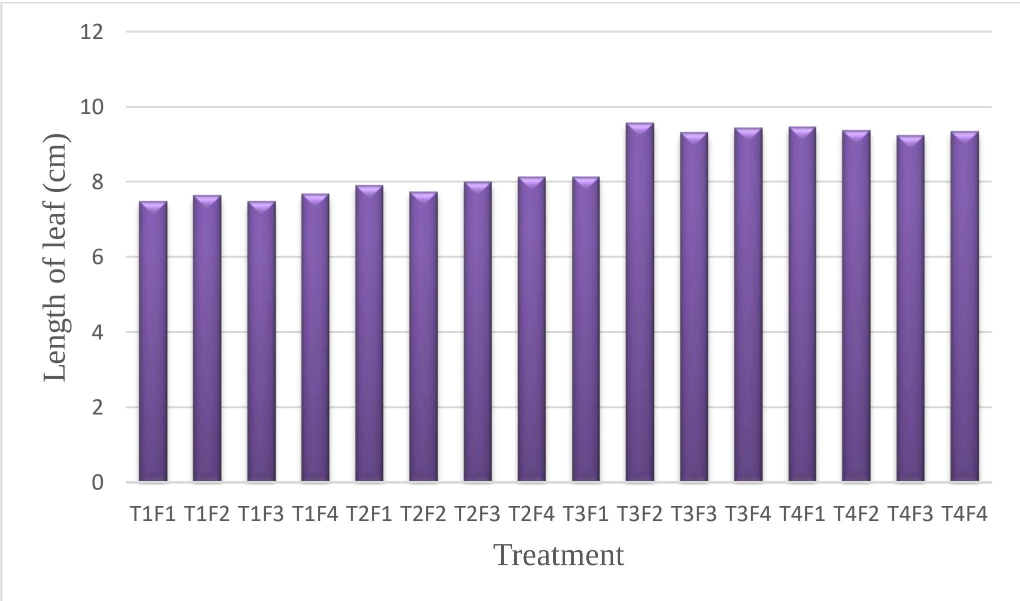

Fig. 4.10 Observation of leaf length after 2nd week of transplanting

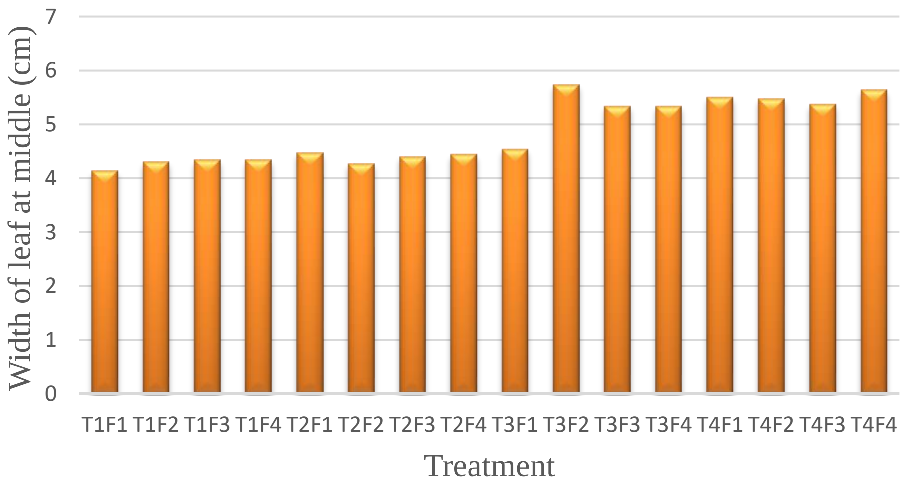

Fig. 4.11 Observation of width of leaves after 2nd week of transplanting

Table 4.5 shows effect of alternate growing systems and irrigation interval on plant height, stem girth, no of leaves, width of leaf at middle and length of leaves during third week.

Table 4.5: observation of plant growth parameters after 3rd week of transplanting

4/7/2020		Plant height	Stem girth	No of leaves	Width of leaf at middle	length of leaf
T1F1	R1	34	3.6	17	6.8	10.2
	R2	35	3.5	16	6.9	10.5
	R3	36	3.4	16	6.5	1.6
T1F2	R4	37	3.5	19	6.7	10.3
	R5	38	3.4	17	7	11
	R6	39	3.6	16	7.1	11.1
T1F3	R7	40	3.5	15	6.9	10.6
	R8	41	3.4	18	7.2	10.5
	R9	42	3.6	18	7.1	10.6

T1F4	R10	41	3.7	19	7.3	10.9
	R11	46	3.8	16	7.5	11
	R12	40	3.8	17	7.6	11.2
T2F1	R13	46	3.9	16	7.4	10.8
	R14	47	3.8	19	7.4	10.8
	R15	48	3.9	18	7.3	11.3
T2F2	R16	45	3.7	20	7.5	11.2
	R17	45	3.8	19	7.2	11.1
	R18	42	3.7	19	7.4	10.8
T2F3	R19	46	3.9	21	7.5	10.9
	R20	45	3.8	20	7.3	11
	R21	42	4.1	21	7.4	10.9
T2F4	R22	47	4	21	7.6	11.5
	R23	42	4.1	20	7.2	11
	R24	45	4.1	19	7.4	11.8
T3F1	R25	47	4.1	20	7.3	12
	R26	44	4.5	21	7.5	11.4
	R27	48	4.3	20	7.4	12
T3F2	R28	55	4.7	22	8.3	12.8
	R29	53	4.8	21	8.2	12.6
	R30	54	4.7	22	8.3	12.7
T3F3	R31	55	4.3	20	8.1	12.4
	R32	51	4.4	21	8	12.3
	R33	43	4.5	22	8.2	12.1
T3F4	R34	52	4.1	21	8.2	12.2
	R35	51	4.5	20	8.3	12
	R36	52	4.4	19	8.1	12.3
T4F1	R37	53	4.3	19	8.2	12.5
	R38	55	4.5	20	8.1	12.3
	R39	54	4.6	20	8	12.7

T4F2	R40	55	4.7	19	8.3	12.3
	R41	53	4.4	20	8.2	12.4
	R42	54	4.3	21	8.1	12
T4F3	R43	51	4.4	20	8.2	12.3
	R44	56	4.5	19	8.1	12.3
	R45	54	4.5	20	8.3	12.4
T4F4	R46	50	4.3	20	8.2	12.5
	R47	51	4.6	19	8.1	12.7
	R48	53	4.7	21	8	12.4

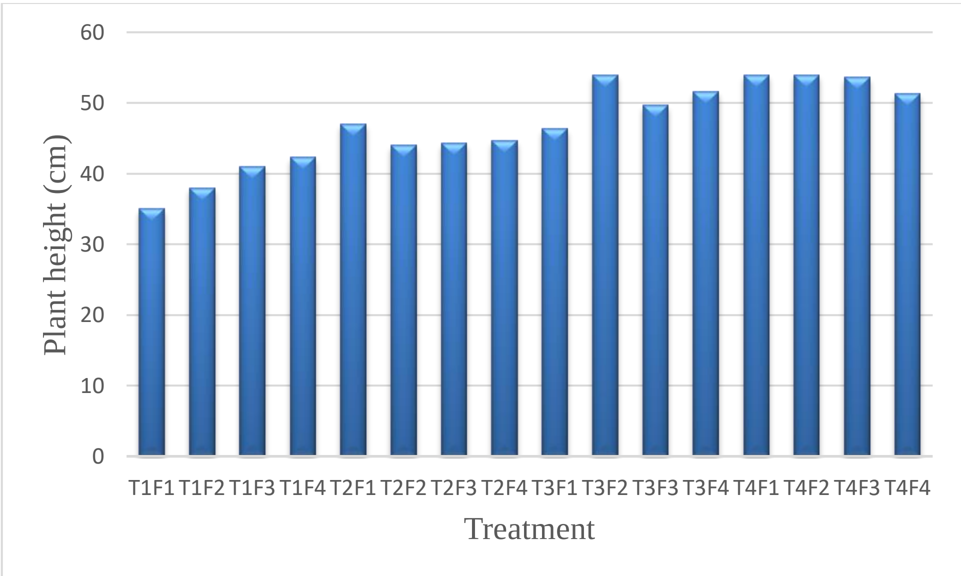

Fig. 4.12 Observation of plant height after 3rd week of transplanting

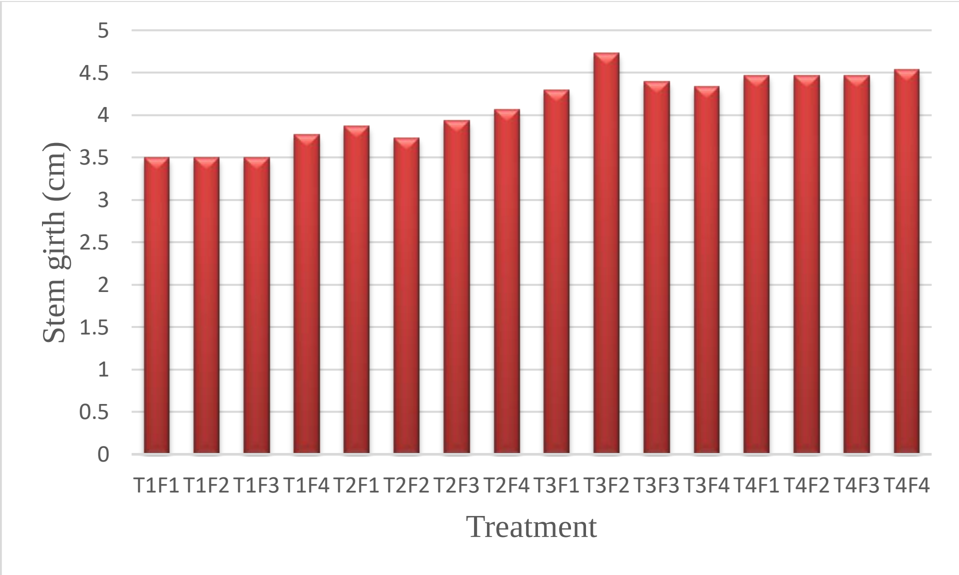

Fig. 4.13 Observation of stem girth after 3rd week of transplanting

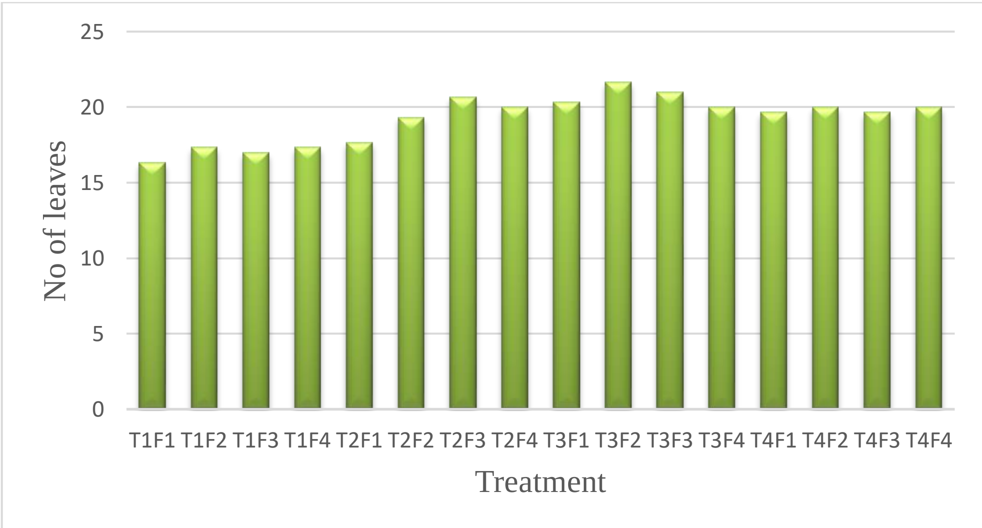

Fig. 4.14 Observation of no of leaves after 3rd week of transplanting

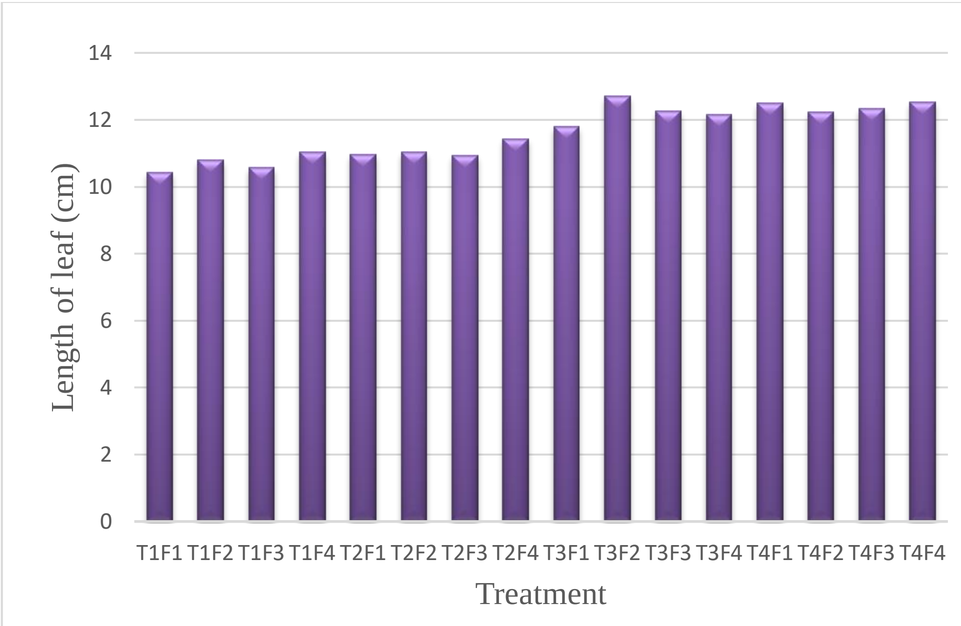

Fig. 4.15 Observation of length of leaves after 3rd week of transplanting

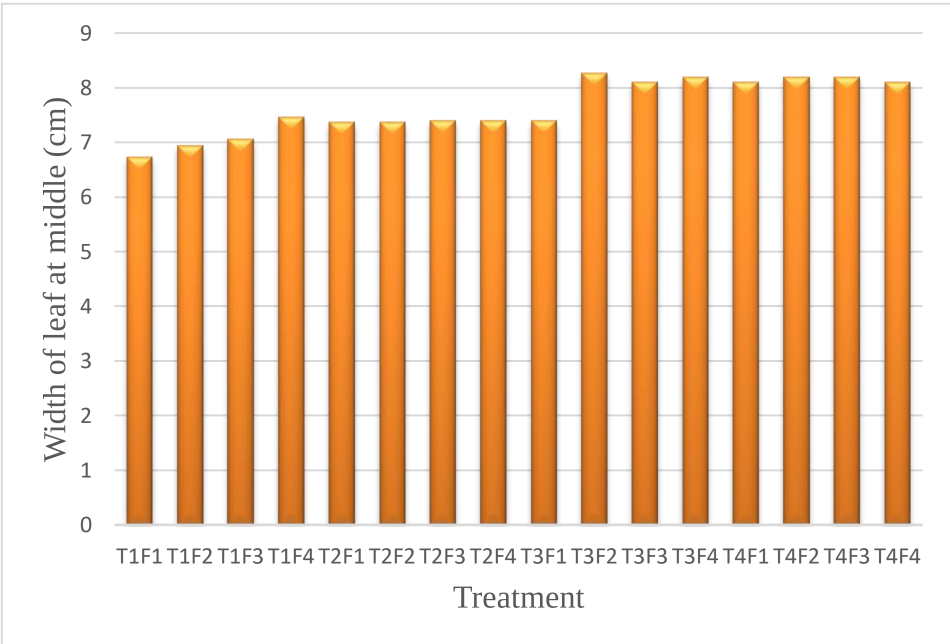

Fig. 4.16 Observation of width of leaf after 3rd week of transplanting

Table 4.6 shows effect of alternate growing systems and irrigation interval on plant height, stem girth, no of leaves, width of leaf at middle and length of leaves during forth week.

Table 4.6: Observation of growth parameters after 4th week of transplanting

4/13/2020		Plant height	Stem grith	No of leaves	Width of leaf at midle	length of leaf
T1F1	R1	48	4.3	17	9.5	15
	R2	49	4.2	18	9.6	16
	R3	44	4.3	19	10	15.5
T1F2	R1	46	4.5	18	9	16.2
	R2	48	4.3	19	9.5	16.3
	R3	49	4.6	21	11	16.7
T1F3	R1	46	4.2	17	10.2	15.6
	R2	50	4.3	18	10	16.1
	R3	48	4.5	17	9.5	15.5
T1F4	R1	48	4.2	18	9.5	15.8
	R2	48	4.3	19	10.5	15.8
	R3	49	4.2	17	10.6	16
T2F1	R1	51	4.6	19	10.3	16.2
	R2	52	4.7	20	10.5	17
	R3	49	4.6	21	9.5	17.2
T2F2	R1	51	4.8	19	9.5	16
	R2	54	4.9	20	10.5	16.4
	R3	49	4.8	25	10.2	16.3
T2F3	R1	55	4.6	19	10.5	16.5
	R2	53	4.9	22	11	17
	R3	51	5.1	21	10	16.5
T2F4	R1	54	4.9	19	10.3	16

	R2	51	5.1	21	9.6	16
	R3	54	4.6	20	10.3	15.9
T3F1	R1	61	4.8	25	10.2	15.8
	R2	58	5.1	23	10.8	15.4
	R3	62	5.2	24	9.5	15.9
T3F2	R1	69	5.5	26	11.6	18.5
	R2	67	5.6	25	11.3	17.9
	R3	68	5.4	28	11.5	18.2
T3F3	R1	65	5.1	25	11.2	17.5
	R2	62	5.3	24	10.9	17.5
	R3	61	5.2	23	11.6	17.6
T3F4	R1	62	5.1	25	11	17.3
	R2	64	5.2	24	10.8	17.5
	R3	61	5.1	23	11.5	18
T4F1	R1	62	4.8	23	10.5	17.9
	R2	63	4.9	22	10.6	16.8
	R3	65	5.1	24	11	17
T4F2	R1	62	5.2	25	10.9	17.5
	R2	64	5.1	24	11.2	17.9
	R3	65	5.2	25	11.4	18.2
T4F3	R1	61	5.6	24	11	18
	R2	62	5.1	26	10.9	18.1
	R3	64	5.2	25	11.5	18
T4F4	R1	6	5	25	11	17.7
	R2	63	5.2	24	11.4	17.9
	R3	65	4.9	25	11.3	18

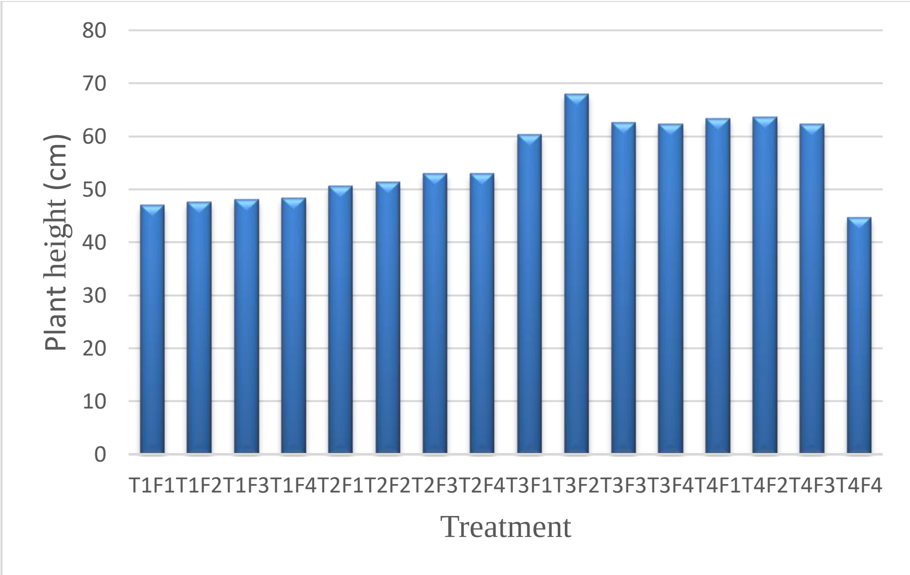

Fig. 4.17 Observation of plant height after 4 th week of transplanting

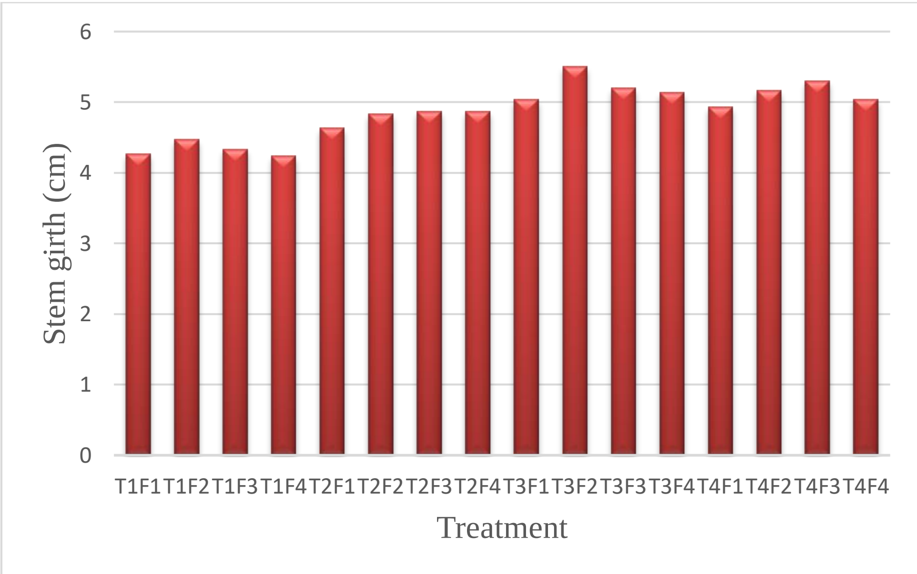

Fig. 4.18 Observation of stem girth after 4th week of transplanting

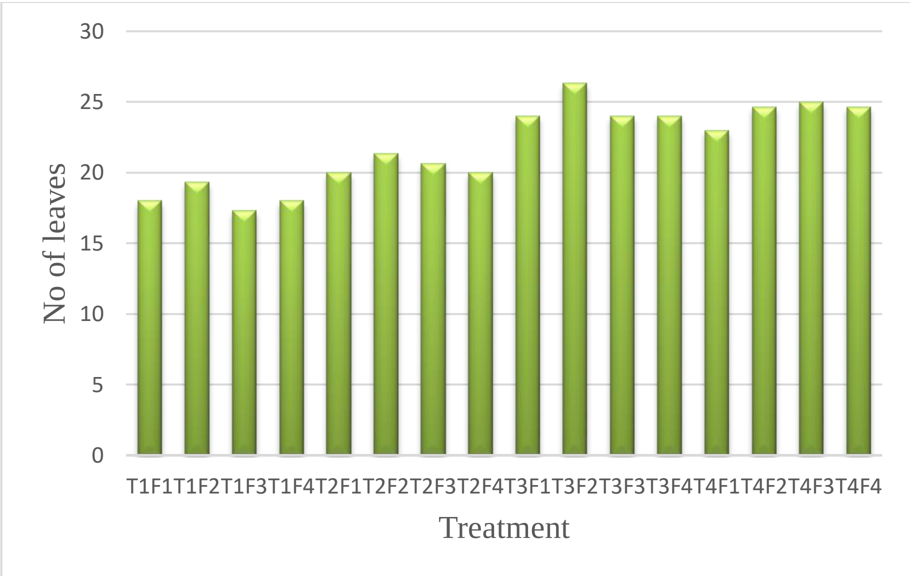

Fig. 4.19 Observation of no of leaves after 4th week of transplanting

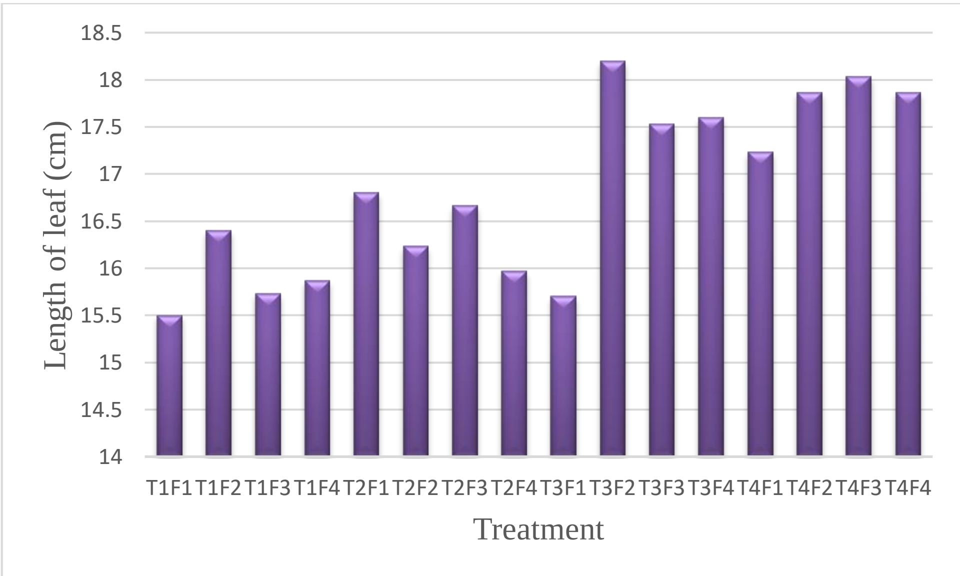

Fig. 4.20 Observation of length of leaf after 4th week of transplanting

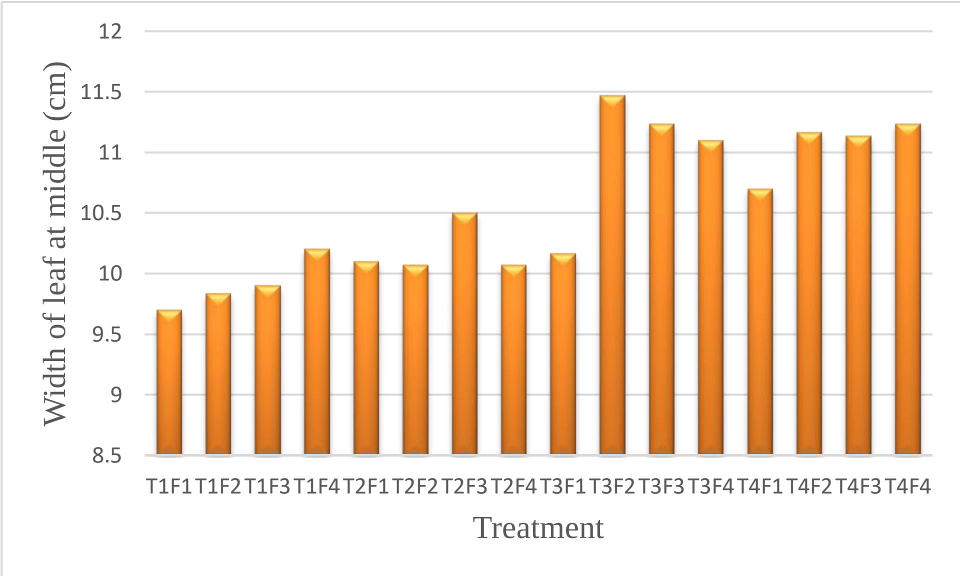

Fig. 4.21 Observation of width of leaf after 4th week of transplanting

4.4 OBSERVATION OF YIELD FROM VARIOUS TREATMENTS IN THE FIELD

Observations of yield from various treatments in the field at different harvest were taken. The data were statistically analyzed and results are enumerated under various headings.

Table shows yield from various treatment in the field during respective harvest.

Table 4.7 Yield from various treatment in the field during respective harvest.

Treatments	Replication	Yield from 1st harvest (g)	Yield from 2nd harvest (g)	Yield from 3 rd harvest (g)	Yield from 4 th harvest (g)	Yield from 5 th harvest (g)	Total yield (g)
T1F1	R1	81	95	103	99	121	499

	R2	78	96	99	96	125	494
	R3	83	93	101	108	127	512
T1F2	R1	91	92	109	96	130	518
	R2	86	96	105	94	134	515
	R3	81	91	104	105	129	510
T1F3	R1	79	98	103	103	120	503
	R2	88	96	109	114	131	538
	R3	89	94	108	102	138	531
T1F4	R1	531	98	103	108	126	531
	R2	531	93	106	104	132	531
	R3	80	92	101	102	128	503
T2F1	R1	81	98	109	110	134	532
	R2	83	95	96	105	138	517
	R3	84	93	104	112	127	520
T2F2	R1	86	94	113	104	132	520
	R2	81	96	102	103	124	506
	R3	83	97	96	108	137	521
T2F3	R1	82	97	107	116	124	526
	R2	80	96	110	101	121	508
	R3	83	95	101	103	120	502
T2F4	R1	86	94	117	119	128	544
	R2	84	96	101	104	127	512
	R3	83	95	106	101	126	511
T3F1	R1	83	97	108	106	129	523
	R2	81	96	103	115	131	526
	R3	88	97	110	106	134	535
T3F2	R1	94	105	119	116	143	577
	R2	96	108	121	124	149	598
	R3	102	103	111	119	145	580
T3F3	R1	93	101	112	121	143	570

	R2	92	108	109	111	136	556
	R3	91	102	108	106	129	536
T3F4	R1	91	104	111	109	134	549
	R2	92	106	109	118	137	562
	R3	96	105	101	104	141	547
T4F1	R1	91	101	109	106	143	550
	R2	92	103	114	103	139	551
	R3	88	103	109	115	137	552
T4F2	R1	94	101	109	111	134	549
	R2	91	104	103	103	139	540
	R3	93	106	116	109	147	571
T4F3	R1	92	101	118	119	141	571
	R2	94	102	101	110	137	544
	R3	96	103	108	113	142	562
T4F4	R1	91	108	106	101	147	553
	R2	93	101	109	119	138	560
	R3	91	105	115	115	148	574

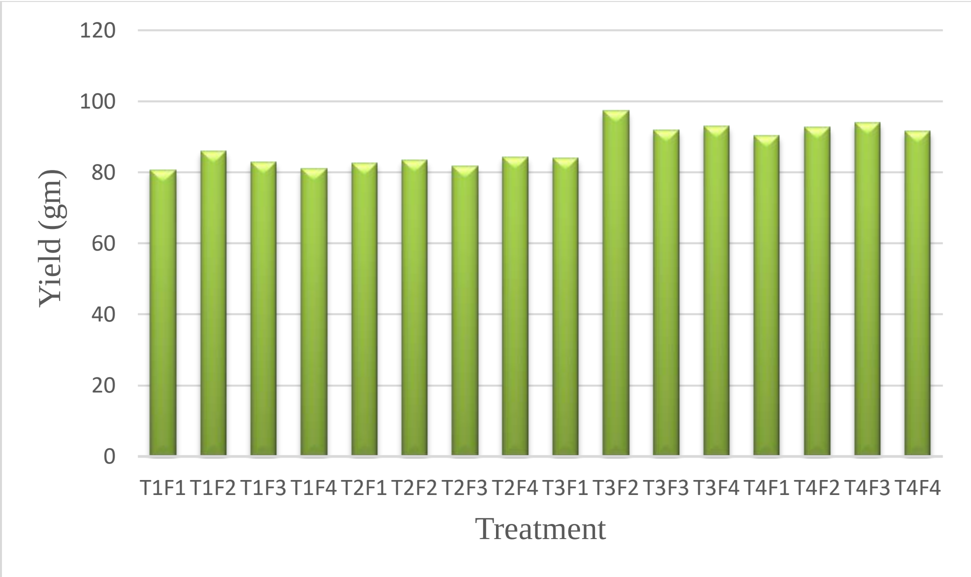

Fig. 4.22 Yield from the 1st harvest in grams

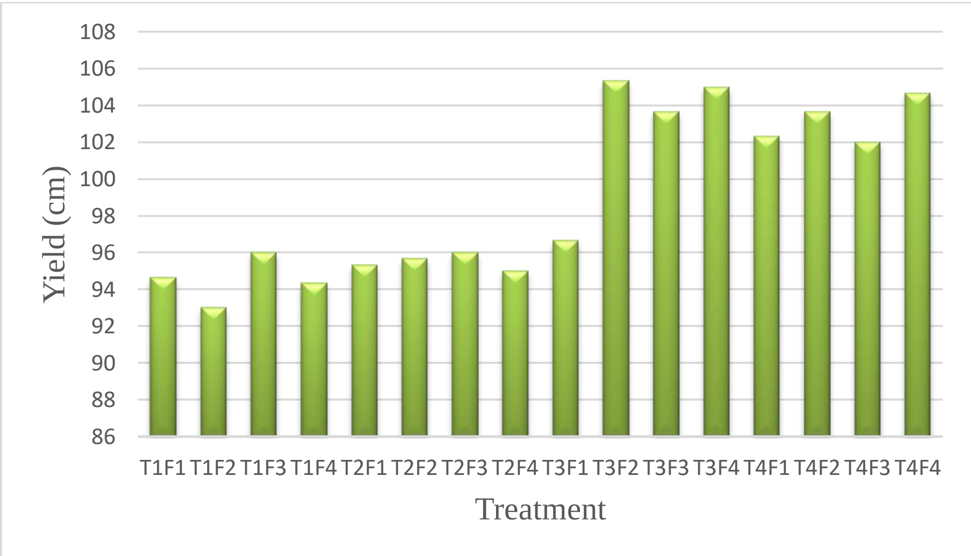

Fig. 4.23 Yield from the 2nd harvest in grams

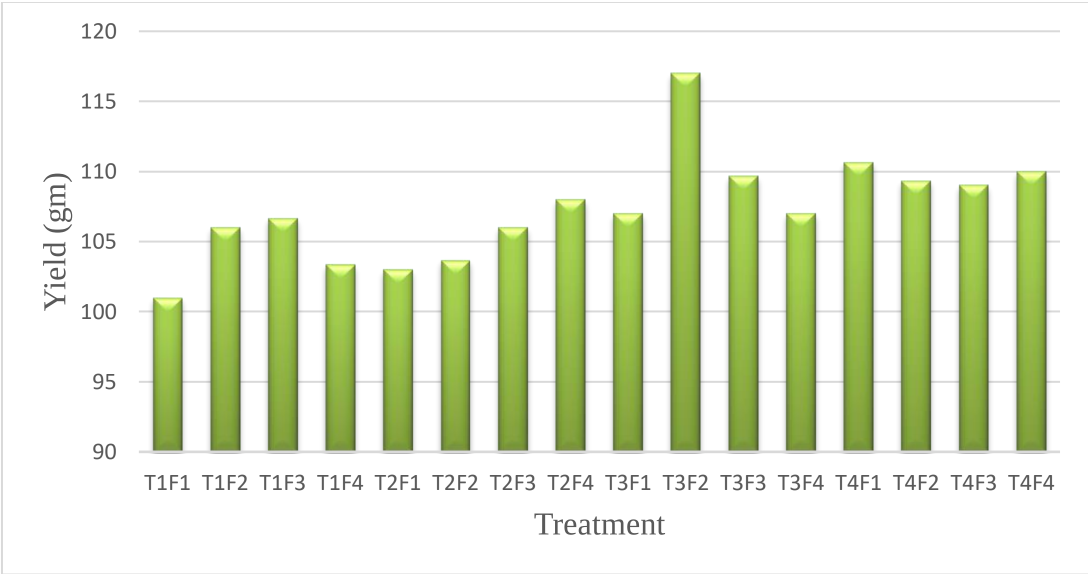

Fig. 2.4 Yield from the 3rd harvest in grams

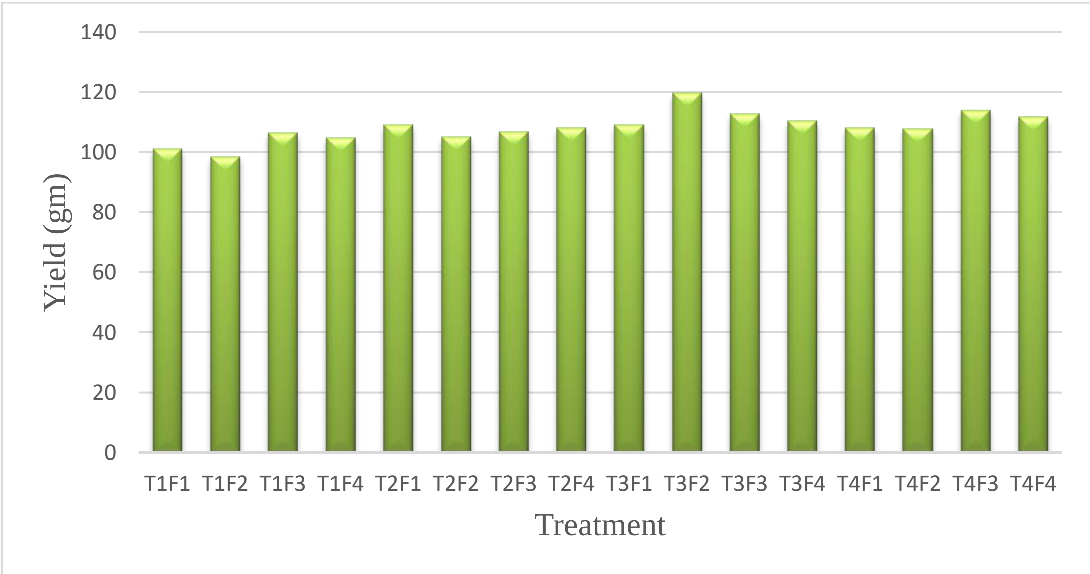

Fig. 4.25 Yield from the 4 the harvest in grams

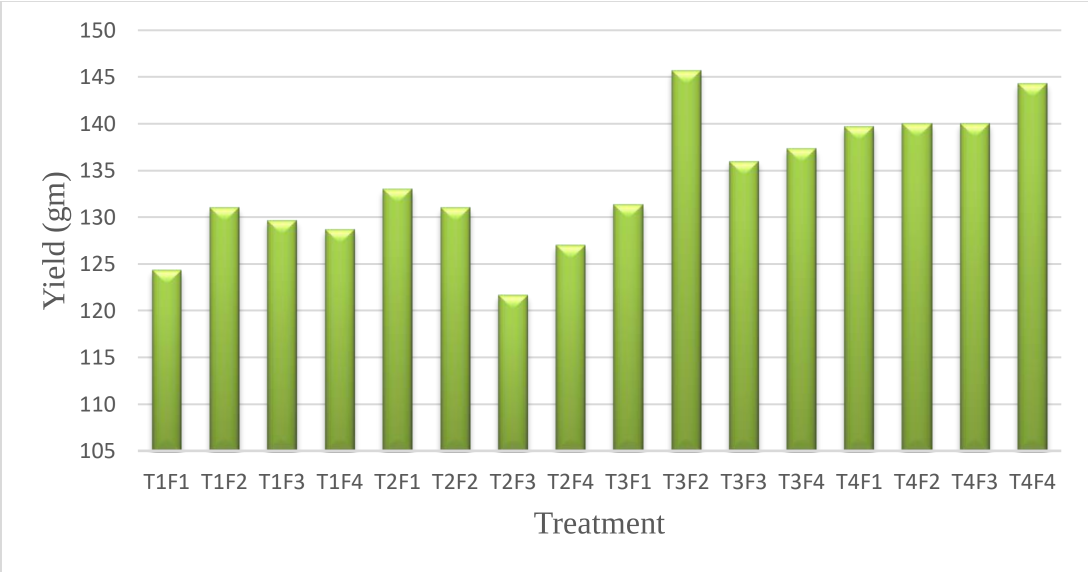

Fig. 4.26 Yield from the 5th harvest in grams

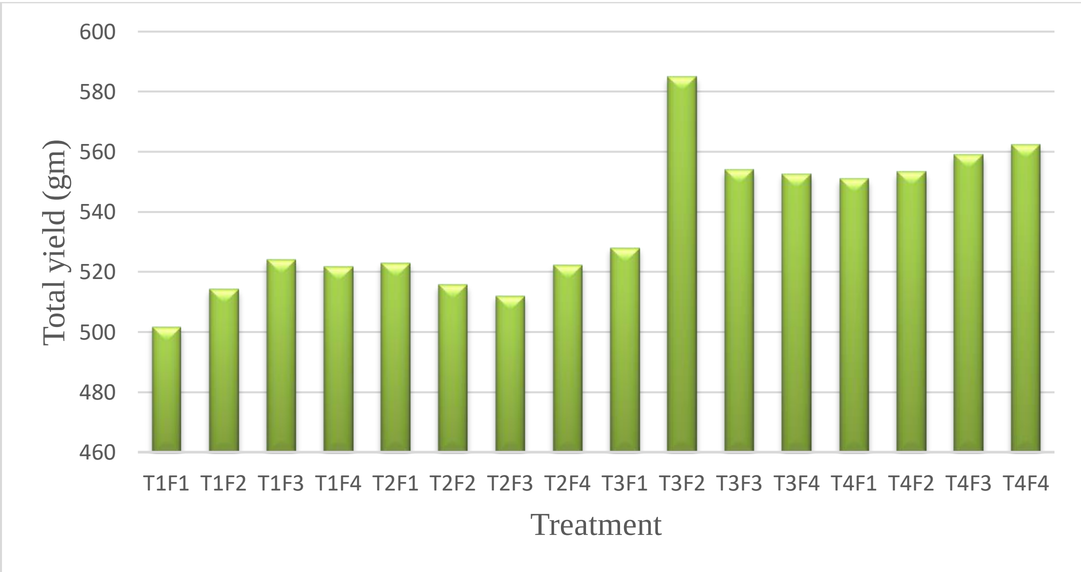

Fig. 4.27 Yield from total 5 harvests in grams

4.5 ECONOMIC ANALYSIS

The economic aspects of project preparation and analysis require a determination of the likelihood that a proposed project will contribute significantly to the development of the total economy and that its contribution will be great enough to justify using the scarce resources it will need. Economic analysis is done in order to find the feasibility of the project

- Life expectancy of greenhouse structure assumed as 10 years.
- Life expectancy of irrigation system components assumed as 10 years.
- Life expectancy of plastic mulching sheet assumed as 2 years.
- Benefit cost ratio= (total returns/total expenditure).
- Duration of 1 season Amaranthus crop taken as 3 months.

Sl. No.	Item Description	Quantity	Unit	Rate	Total	no of useful seasons	cost/season
1	structure and irrigation components(fixed cost)						
1.1	polyhouse structure				150000	60	2500
1.2	Drip Lateral Od 16 mm CL II X 100 mtr	284	m	15	4620	40	115.5
1.3	Drip Poly Grommet take off 16 X 13 mm	16	no	6.5	104	40	2.6
1.4	Drip Lateral End Stop 8 Shape 16 mm	16	no	3.5	56	40	1.4
1.5	Disc Filter Armas 50 mm	1	no	2650	2650	40	66.5
1.6	Mulching Sheet 400 meter 30 Micron 1.2 m Siver/Black	1	284m	3350	2378.5	8	297.5
1.7	Mini Valve	16	no	40	640	40	16
1.8	Drip J-Loc Dripper 8 lph	630	no	3.6	2268	40	56.7
1.9	extra fitting bend,tee and solvent				500	40	12.5
1.10.	1.5" pvc pipe	25.5	6m	200	850	40	21.25
1.11	ventury injector system				500	40	12.5
1.12	cladding material	400	m²	50	20000	20	1000
2	cultivation (variable cost)						
2.1	workers wage for bed preparation,planting etc	4	men days	700	2800	1	2800
2.2	fertilizers	0.5	kg	100	100	1	100
2.3	FYM	300	kg	1	300	1	300
2.4	seed	4	packet	10	40	1	40
2.5	petrol for alligator	2	litre	77	154	1	154
3	Total expenditure						7496.45

Fig. 4.28 Calculation of cost

11:00 PM

item no	season duration	rate	unit	total yeild/season in kg	amount
Total revenue by the sale of amaranthus	3 months	25	kg	400	10000
Total expenditure					7496.45
Benefit cost ratio					1.334

Fig. 4.29 Calculation of benefit cost ratio

- Amaranthus was sold to sales counter in our collage and also to our collage faculties.
- Benefit cost ratio=1.334
- Benefit cost ratio was found to be above 1 hence cultivation of Amaranthus under polyhouse is found to be economically feasible.

4.6 WATER USE EFFICIENCY

Table 4.7 Irrigation and water use efficiency

Treatment combinations	Yield (g/plant)	WUE (kg/ha mm)	Gross depth of irrigation water appliesld in mm
T1F1	502	89.5	166.86
T1F2	512	91.3	166.86
T1F3	523	93.3	166.86
T1F4	518	92.4	166.86
T2F1	510	68	222.48
T2F2	518	69.3	222.48
T2F3	516	69.05	222.48
T2F4	522	69.8	222.48
T3F1	524	56.1	278.1
T3F2	582	58.1	278.1
T3F3	558	55.7	278.1
T3F4	548	54.7	278.1
T4F1	546	46.7	333.72

T4F2	550	49.06	333.72
T4F3	560	49.9	333.72
T4F4	563	50.2	333.72

Irrigation water use efficiency was found higher for the treatment T1F3.

- The treatment T3F2 (Irrigation 100% of ETc and Fertigation 100% of RDF) showed comparatively better performance in yield as compared to the other treatments.
- T1F1 resulted in significantly lowest yield among other treatments.
- T3F2 resulted in higher yield in all levels of treatments. The highest plant height (69 cm), highest number of leaves (27nos), highest stem girth (5.5), width of leaves (11.5) and length of leaves was noticed in the irrigation 100 % of irrigation and 100% dose of nutrients in the form of water soluble fertilizers led to higher yield.
- The 100 % dose of nutrients and 100 % of irrigation has resulted in higher yield per plant (0.145kg).100% of irrigation and 100% dose of nutrients might have served as optimum doses among these treatments.
- The results obtained could be attributed better growth and yield associated with optimum treatment.
- Hence drip fertigation with 100% of ETc and Fertigation of 100% of RDF has been standardized for cultivation of amaranthus under polyhouse of PFDC, KCAET, Tavanur, Kerala
- Study on lettuce by Santhosh *et al*., (2017) reported that biometric and yield parameters are significantly superior in the treatment t_2 (100% crop water requirement through drip irrigation in poly house).
- Similar study on capsicum by Thenmozhi and Kottiswaran, (2017) revealed that the maximum yields were obtained in the treatment of 25 micron thickness with 100% RDF (fertigation).

CHAPTER-V

SUMMARY AND CONCLUSION

Growth and yield parameters of Amaranthus with different irrigation and fertigation schedules were studied. The experiment was conducted inside the saw tooth type polyhouse in the research plot of precision farming center situated near the farm, Thavanur.th area lies in the cross point of 10.85°N latitude and 75.98° longitude. During 2020 (March 8th) – 2020 (May 6th) and the crop duration was two months (60 days). The polyhouse was oriented east–west with an area of 292 m^2 (36.5 m length and 8 m width). In present study, data on climate, plant growth yield, parameters were recorded. The summary of results obtained from the experiments and the conclusions drawn out of the field experimentation are presented in this chapter.

Amaranthus variety CO-1 was chosen for cultivation. Seeds were sown in a nursery bed of dimensions 3.5 m length and 0.7 m width and ten days old seedlings were transplanted to the main field. There were 42 plants in each bed with a plant spacing of 42 cm. The total plant population was 672 numbers. Row to row distance is 80 cm.

The experiment was designed under Factorial completely randomized block design. To factors was considered.

1. F – Fertigation: F1- 75% fertigation, F2- 100% fertigation, F3- 125% fertigation, F4-150% fertigation
2. T - Irrigation schedules: T1- 60% irrigation, T2- 80% irrigation, T3- 100% irrigation, T4- 120% irrigation

No of treatment combinations are 16: F1T1, F1T2, F1T3, F1T4, F2T1, F2T2, F2T3, F2T4, F3T1, F3T2, F3T3, F3T4, F4T1, F4T2, F4T3.

The experiment revealed that the irrigation and fertilizer management is an important factor in crop production. Higher water application and inefficient fertilizer application is the current farming scenario. We should standardize the water and fertilizer application according to our area and mode of cultivation. Water use efficiency of the crops has to be increased in order to reduce the water loss from the field. Drip irrigation system is considered as the most effective micro irrigation method, as water is applied directly to the crop root zone. Hence it can be concluded that drip fertigation with 100% of ETc and Fertigation of 100% of RDF is best suited for cultivation of Amaranthus under polyhouse. The total yield obtained from all beds under study was 400kg.

REFERENCES

Adeniran, K. A., Amodu, M. F., Amodu, M. O., and Adeniji, F. A. 2010. Water Requirements of Some Selected Crops in Kampe Dam Irrigation Project.1(4): 119-125.

Aguilar, J., Rogers, D., and Kisekka, I., 2015. Irrigation Scheduling Based on Soil Moisture Sensors and Evapotranspiration. Kansas Agricultural Experiment Station Research Reports. 1(5).

Ajay Gokul, A. J., K. K. Shaheemath Suhara and Sheeja, P. S. 2020. Standardization of Irrigation and Fertigation Requirement for Amaranthus under Polyhouse. *Int.J.Curr.Microbiol.App.Sci.* 9(04): 490-493.

Allen, R. G., Pereira, L. A., Raes, D. and Smith, M., 1998. Crop Evapotranspiration – FAO Irrigation and Drainage Paper 56, Rome, p. 293. 13.

Banavath, R. N., Latha, T. H and Babu, C. M. 2015. Command area development by using FAO Cropwat 8.0 model and impact of climate change on crop water requirement- a case study on Araniar reservoir basin. *International Journal of applied Research.* 1(13): 142-155.

Bhat, S. A., Pandit, B. A., Khan, J. N., Kumar, R., and Jan, R., 2017. Water Requirements and Irrigation Scheduling of Maize Crop using CROPWAT Model. *Int.J.Curr.Microbial.App.Sci.* 6 (11): 1662-1670.

Bouraima. A., Weihua. Z., Chaofu. W., (2015). Irrigation Water Requirement of Rice using CROPWAT model in Northern Benin. *Int. J. Agric. & Biol. Eng.* 8(2):58-64.

Chowdhary, A., and Shrivastava, R. K., 2010. Reference Crop Evapotranspiration Estimation using Artificial Neural Networks. *Int. J. Eng. Sci. Technol.* 2(9): 4205-4212.

Chowdhary, A., Shrivastava, R. K., 2010. Reference Crop Evapotranspiration Estimation using Artificial Neural Networks. *Int. J. Eng. Sci. Technol.* 2(9): 4205-4212.

Chowdhury, S., Al- Zahrani, M., Abbas, A., 2013. Implications of Climate Change on Crop Water Requirements in Arid Region: An example of Al- Jouf, Saudi Arabia. *J. King. Saud. Univ. Eng. Sci.* 8: 21-31.

Diro, S. B., and Ketema, T., (2009). Evaluation of the FAO CROPWAT model for deficit irrigation scheduling for onion crop in a semiarid region of Ethiopia. *J. Appl Hortic.* 11 (2): 103-106.

Filipovic, v., Romic, D., Romic, M., Borosic, J., Filipovic, L., Mallman, F.J.K., and Robinson, D.A., 2016. Plstic mulch and nitrogen fertigation in growing vegetables modify soil temperature, water and nitrate dynamics: experimental design and a modeling study. *Agric. Water. Manage.*176:100-110.

Ghazla, N., and Raheem, R., 2007. Projections of Crop Water Requirement in Pakistan under Global Warming. *Pak. J. Meteorol.* 7(13):45-51.

Gouranga, K., Verma, H.N., 2005. Climatic water balance, probable rainfall, rice crop water requirements and cold periods in AER 12.0 in India. *Agric. Water. Manag.* 72(1): 15-32.

Gowda, T. P., Manjunaththa, S. B., Yogesh, T. C., and Satyareddi, S. A., 2013. Study on Water Requirement of Maize (*Zea mays l.*) using CROPWAT model in Northern Transitional Zone of Karnataka. *J. Environ. Sci. Comput. Sci. Eng. Technol*. 3(1): 105-113.

Gupta, V. P., and Goyal, R. K., 2001. Interrelationship of Methods for Estimation of Reference Evapotranspiration: A Case Study of Arid Region of Rajasthan. (India). *J. Ind. Water. Resour. Soc.* 21(3): l20-126.

Halim, O., Sener, M., 2001. A Study on Irrigation Scheduling of Onion (Allium cepa L.) in Turkey. *J. Biol. Sci.* 1(8): 735-736.

Hashim, M.A. A., Siam. N., Dosari, A., Asl-Gaadi. K.A., Patil. V. C., Tola, E. H. M., Rangaswamy, M., and Samdani, M. S., 2012. Determination of Water Requirement and Crop water productivity of Crops Grown in the Makkah Region of Saudi Arabia. *Aust. J. Basic Appl. Sci.* 6(9): 196-206.

Hossain, B., Maniruzzaman., and Biswas, J. C., 2017. Irrigation Scheduling of Rice (Oryza sativa L.) Using CROPWAT model in the Western Region of Bangladesh. The Agriculturists. 15(1): 19-27.

Junzeng, X., Shizhang, P., Yufeng, L., and Xiyun, J., 2008. Tomato and Cowpea Crop Evapotranspiration in an Unheated Greenhouse. *Water. Sci. Eng.* 1 (2): 112–120.

Kashyap,P.S., and Panda, R.K. 2001. Evaluation of Evapotranspiration Estimation Methods and Development of Crop coefficients for Potato crop in a sub humid region. *Agric. Water Manag*. 50: 9-11.

Kore. J. R., Nimbalkar. P. T. and Hirave. P. 2017. Crop Water Requirements and Irrigation Scheduling of Some Selected Crops Using Cropwat 8.0: A Case Study of Khadakwasla Dam Irrigation Project. *Int. J. Civil Eng. Technol*. 8(5): 342-349.

Pakhale, G., Gupta, P., Nale, J., 2010. Crop and Irrigation Water Requirement Estimation by Remote Sensing and GIS: A Case Study of Karnal district, Haryana, India. *Int. J. Eng. Technol*. 2(4): 207-211.

Paul, J.C., Mishra, J.N., Pradhan, P.L., and Panigrahi, B., 2013. Effect of drip and surface irrigation on yield water-use-efficiency and economics of capsicum grown under mulch and non-mulch condition in eastern costal India. *Eur. J. Sustain. Dev. t*2(1):99-108.

Putthividhya. A., Sukgerd. P., 2015. Water Requirements and Irrigation Scheduling of Ban Khai Irrigation Project Using GIS And Cropwat Model In Rayong Province Thailand. *Int. Commn. Irrig. Drain*.

Reddy, M.S., Reddy, Y.R., and Rajashekhar, S.L., 2018. A review on performance evaluation of plastic mulch and drip irrigation in tomato plant cultivation in Mulakalacheruvu, Mandal, Chittor district, Andhra Pradesh. *Int. J. Appl.Eng. Res.* 13(7):224-228.

Sakellariou, M., and Vagenas, I.N., 2006. Mapping Crop Evapotranspiration and Total Crop Water Requirements Estimation in Central Greece. *Eur. J. water.* 13(14): 3-13.

Santosh, D.T., Raja Gopala Reddy and Tiwari, K.N. 2017. Effect of Drip Irrigation Levels on Yield of Lettuce under Polyhouse and Open Field Condition. *Int. J. Curr. Microbiol. App. Sci.* 6 (7): 1210-1220.

Saravanam, K., and Saravanam, R., 2014. Determination of Water Requirement of Main crops in the Tank Irrigation Command area using CROPWAT 8.0. *Int. J. Interdisciplinary. Multidisciplinary. Stud.* (IJIMS), 1(5): 266-272.

Shah, V., 2018. Determination of Crop Water Requirements and Irrigation Scheduling Using CROPWAT: A Case Study of Waghodia Region. *Int. J. Innovative. Res. Sci. Eng. Technol.* 7(2): 1137-1144.

Shekhar, S., 2012. Study of Evapotranspiration in Context of Changing Climate. *J. Mech. Civ. Eng*. 2(6): 2278-1684.

Silva, G.H., Dias, S.H.B., Ferreira, L.B., Santos, J.E.O., and Cunha, F.F., 2018. Performance of different methods for reference evapotranspiration estimation in Jaiba Brazil. *Rev. bras. eng. Agric. Ambient.* 22(2):83-89.

Singadhupe, R.B., Antony, E., Mohanty, S., and Srivastava, R., 2005. Effect of fertigation on field grown tomato (*Lycopersicon esculentum*). *Ind. J. Agri. Sci.* 75(6):329-332.

Solanki, R.P., Solanki, R.M., Patel, H.A., Odedra, R.K., Prajapati, V.S., and Dodia, V.D., 2016. Effect of scheduling irrigation and organic manure on yield attributes, nutrient content and uptake of rabi amaranthus (amaranthus paniculatus l.) In saurashtra region. *Int. J. sci. environ. technol.* 5(4):2076-2083.

Sreya, U. P., 2018. Customized Fertilizer Formulation. *Int. J. Chem. Stud.* 6(6): 2144-2153.

Sudip, K. C., Saon. B., and Mridul, B., 2012. Climate Change Impact on Crop Water Requirement in Ganga River Basin, West Bengal, India. International Conference on Biology, Environment and Chemistry. 46(4).

Surendran, U., Sushanth, C. M., George M. and Joseph, E. J., 2014 Modelling the impacts of increase in temperature on irrigation water requirements in Palakkad district – a case study in humid tropical Kerala. J. Water Clim. Change. 5(3): 471–487.

Surendran, U., Sushanth, C. M., Mammen, G., and Joseph, E. J., 2015. Modelling the crop water requirement using FAO-CROPWAT and assessment of water resources for sustainable water resource management: a case study in Kollam district of humid tropical Kerala, India. Aquat. Proc., 23 (4), 1211–1219.

Toyin, F.J., Miguel, .J., Gbenro, O.P., and Ebenezer, A.A., 2014. Greenhouse evapotranspiration and crop factor of Amaranthus cruentus grown in weighing lysimeters. *Afri. J. Agric. Res.* 10(34):3453-3461.

Trivedi, A., Pyasi, S. K., and Galkate, R.V., 2018. Estimation of Evapotranspiration using CROPWAT 8.0 Model for Shipra River Basin in Madhya Pradesh, India. *Int. J. Curr. Microbiol. App. Sci.* 7(5): 1248-1259.

Vashisht, A., and Satpute, S. T., 2015. Water Requirement and Irrigation Scheduling of Direct Seeded Rice- Wheat using CROPWAT model. *Ind. J. Hill . Farming.* 28(2): 144-153.

Zhe, G. B., Zhiming, Q., Liwang, M., Dongwei, G., Junzeng, X., Quanxiao, F., and Shouqi, Y., 2017. Development of an Irrigation Scheduling Software Based on model Predictedcrop Water Stress. *Comput. Electron. Agric.* 1(3): 208-221.

Zhiming. F., Dengwei. L., and Yuehong. Z., (2007). Water Requirements and Irrigation Scheduling of Spring Maize Using GIS and CROPWAT model in Beijing-TianjinHebei Region. 17(1): 56-63.

ABSTRACT

The study entitled "Standardization of irrigation and fertigation requirement for Amaranthus under polyhouse" was taken up to compute the crop water requirement, irrigation schedule and fertigation schedule of amaranthus (*Amaranthus retroflexus*) crop and to find out the best treatment which gives maximum yield under polyhouse conditions in Tavanur region. The CROPWAT 8.0 model developed by FAO was used for the determination of crop water requirement and irrigation scheduling. Climatological data including temperature, sunshine hours, wind speed and relative humidity were collected from KCAET, for the last four months (March to June 2019). The required soil, crop and climate data inputs were given to the model and the cropwater demand and irrigation schedule for amaranthus was obtained. Average ET_o was found to be 3.62 mm/day. Water requirement for amaranthus was found as 194.2 mm and the gross irrigation requirement as 276.4 mm at a 100% irrigation eficiency.

Field experiment was conducted inside the naturally ventilated polyhouse in the research plot of Precision Farming Development Center situated at KCAET, Tavanur, during the period March 2020 to May 2020. In the present study, 60%, 80%, 100% and 120% of ETc were selected as irrigation treatments and 75%, 100%, 125% and 150% of RDF were selected as fertigation treatment.

In this experiment, the land was leveled and beds were raised. Amaranthus variety CO-1 was chosen for cultivation. The experiment was laid out in factorial completely randomized design. The plot was divided into 16 beds having 16 treatments with three replications and two factors. Fertigation include both macro and micro nutrients applied as water soluble fertilizers through fertigation system with venturimeter. Vegetative parameters and yield parameters for each treatment were observed during different stages of crop growth. Analyzing the effect of different treatments, it was found that in amaranthus crop, better performance was found in the treatment T3F2 (irrigation 100% of ETc and fertigation 100% of RDF).The highest plant height (69 cm), number of leaves (27 nos), stem girth (5.5 cm), width of leaf (11.5 cm), length of leaf (18.2 cm) and yield from plant (0.145 kg) was noticed in T3F2. The lowest yield was for T1F1 (irrigation 60% of ETc

and fertigation 75% of RDF). The highest IWUE (Irrigation water use efficiency) was for T1F3 (93.3 kg/ha.mm) and lowest was for T4F1 (46.7 kg/ha.m). On economic analysis, Benefit Cost Ratio was found to be 1.334.

The results of this experiment showed that it is possible to obtain better performance in terms of both growth and yied for amaranthus variety grown under polyhouse conditions under 100% of irrigation and 100% dose of nutrients as they might have served as optimum doses among the treatments. Hence drip fertigation with 100% of ETc and fertigation of 100% of RDF has been standardized for cultivation of amaranthus under poly house of PFDC, KCAET, Tavanur, Kerala.

The results of the study can be used as a guide for the farmers to plan their irrigation and cropping pattern. Also the results can be extrapolated to the future to analyze the trends in future crop water demands.