

**EFFECT OF MODELING OF CLIMATIC PARAMETERS ON
GROWTH AND YIELD OF TOMATO CROP DURING SECOND
HALF OF THE YEAR GROWN UNDER NATURALLY
VENTILATED POLYHOUSE**

**प्राकृतिक रूप से हवादार पॉलीहाउस के तहत उगाई गई वर्ष की दूसरी
छमाही में टमाटर की फसल की वृद्धि और उपज पर जलवायु मापदंडों के
प्रभाव का प्रतिरूपण**

Jagtap Priyanka Pandurang

Thesis

**Master of Technology in Agricultural Engineering
(Soil and Water Conservation Engineering)**



2019

**Department of Soil and Water Engineering
College of Technology and Engineering
Maharana Pratap University of Agriculture & Technology, Udaipur**

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Thesis

Submitted to the

Maharana Pratap University of Agriculture and Technology Udaipur

**In Partial Fulfillment of the Requirement For
the Degree of**

**Master of Technology in Agricultural Engineering
(Soil and Water Conservation Engineering)**



By

Jagtap Priyanka Pandurang

2019

**COLLEGE OF TECHNOLOGY AND ENGINEERING
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND
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Date: /08/2019

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CERTIFICATE-II

Date: /08/2019

This is to certify that this thesis entitled “**Effect of modeling of climatic parameters on growth and yield of tomato crop during second half of the year grown under naturally ventilated polyhouse**” submitted for the degree of **Master of Technology** in Agricultural Engineering in the subject of **Soil and Water Conservation Engineering** embodies bonafide research work carried out by **Miss Jagtap Priyanka Pandurang** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on 01/06/2019.

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UDAIPUR**

CERTIFICATE – III

Date: /08/2019

This is to certify that this thesis entitled “**Effect of modeling of climatic parameters on growth and yield of tomato crop during second half of the year grown under naturally ventilated polyhouse**” submitted by **Miss Jagtap Priyanka Pandurang** to Maharana Pratap University of Agriculture & Technology, Udaipur in partial fulfillment of the requirement for the degree of **Master of Technology** in the subject of **Soil and Water Conservation Engineering** after recommendation by the external examiner was defended by the candidate before the following members of the examination committee. The performance of the candidate in the oral examination held on 09/08/2019 was found satisfactory; we therefore, recommend that the thesis be approved.

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Date: /08/2019

This is to certify that **Miss Jagtap Priyanka Pandurang** student of **Master of Technology** in Agricultural Engineering in the subject of **Soil and Water Conservation Engineering**, Department of Soil and Water Engineering has made all corrections/modifications in the thesis entitled “**Effect of modeling of climatic parameters on growth and yield of tomato crop during second half of the year grown under naturally ventilated polyhouse**” which were suggested by the external examiner and the advisory committee in the oral examination held on 09/08/2019. The final copies of the thesis duly bound and corrected were submitted on 12/08/2019.

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LIST OF ABBREVIATIONS

Agril.	:	Agricultural
ACRIP	:	All India Coordinated Research Project
Agric.	:	Agriculture
ANOVA	:	Analysis of Variance
ARPN	:	Asian Research Publishing Network
ARS	:	Agricultural Research Services
ASAE	:	American Society of Agricultural Engineers
ASM	:	Available Soil Moisture
Avg.	:	Average
B:C	:	Benefit cost ratio
BD	:	Bulk density
CD	:	Critical difference
Cm	:	Centimetre
cm ²	:	Square Centimetre
cm ³	:	Cubic Centimetre
CPE	:	Cumulative pan evaporation
CRD	:	Completely Randomized Design
CROPWAT	:	Crop water requirement software developed by FAO
CTAE	;	College of Technology and Engineering
cv	:	Crop variety
D	:	Day
DAP	:	Days after planting
DAT	:	Days after transplanting
Dept.	:	Department
Dia.	:	Diameter
DI	:	Deficit irrigation
Dr.	:	Doctor
DS	:	Double span
dS/m	:	Deci – Siemens per metre
Epan	:	Pan evaporation
EC	:	Electrical Conductivity
Eds.	:	Editions
e.g.	:	For example
Eq.	:	Equation
Engg.	:	Engineering
Er.	:	Engineer
ET	:	Evapotranspiration
ET _o	:	Reference Evapotranspiration
ET _{o out}	:	Reference Evapotranspiration outside the polyhouse
ET _a	:	Actual Evapotranspiration
ET _c	:	Crop Evapotranspiration
Et _{c in}	:	Crop evapotranspiration inside the polyhouse

Et _{c out}	:	Crop evapotranspiration outside the polyhouse
etc.	:	Etcetera
<i>et al.</i>	:	(et-alai) and other
EU	:	Emission Uniformity
FAO	:	Food and Agriculture Organization
FC	:	Field capacity
FYM	:	Farm yard manure
FI	:	Full irrigation
Fig.	:	Figure
FWUE	:	Field water use efficiency
G	:	Gram
g/cc	:	Gram per cubic metre
GOI	:	Government of India
Ha	:	Hectare
HP	:	Himachal Pradesh
H	:	Hour
I	:	Irrigation
ICAR	:	Indian Council of Agricultural Research
i.e.	:	That is
IIVR	:	Indian Institute of Vegetable Research
ISAE	:	Indian Society of Agricultural Engineers
IW	:	Irrigation Water
IWME	:	Irrigation Water Management Engineering
IWUE	:	Irrigation water use efficiency
Jr.	:	Journal
K	:	Potassium
K _c	:	Crop coefficient
K _{cp}	:	Pan coefficient
Kg	:	Kilogram
Kg/ sq m	:	Kilogram per square meter
Kg/ha	:	Kilo gram per hectare
Km/h	:	Kilo meter per hour
K Pa	:	Kilo Pascal
lit.	:	Litre
lph.	:	Litre per hour
l/h	:	Litre per hour
LDPE	:	Low Density Polyethylene
Lit.	:	Limited
LUP	:	Land Use Planning
m	:	Metre
m ²	:	Square Metre
max.	:	Maximum
m/s	:	Metre per second
mm	:	Millimetre
mm/day	:	Millimetre per day
MC	:	Moisture Content
MCM	:	Million Cubic Metre

Min	:	Minute
Min.	:	Minimum
MJ m ⁻² day ⁻¹	:	Mega joule per square metre per day
MPa	:	Mega Pascal
MPUAT	:	Maharana Pratap University of Agriculture and Technology
M.Tech.	:	Master of Technology
N	:	North
NBSS	:	National Bureau of Soil Survey
No.	:	Number
NPK	:	Nitrogen Phosphorus Potassium
NS	:	Non significant
NVPH	:	Naturally ventilated polyhouse
P	:	Phosphorous
pp.	:	Page
PE	:	Pan evaporation
PET	:	Potential evapotranspiration
P. I.	:	Project Incharge
P-M	:	Penman- Monteith
PM	:	Peat moss
Ph	:	Negative logarithm of hydrogen ion
PhD	:	Doctor of philosophy
Pvt.	:	Private
PVC	:	Poly Vinyl Chloride
POP	:	Package of practices
PRD _v	:	Partial root zone drying vertical
PRD _c	:	Partial root zone drying compartment
PWP	:	Permanent Wilting point
Q	:	Quintal (100 kg)
q/ha	:	Quintal per hectare
R	:	Replication
Rs.	:	Rupees
RBD	:	Random Block Design
RCBD	:	randomized complete block design
RDI	:	Regulated Deficit Irrigation
RH	:	Relative humidity
RH _{max}	:	Maximum relative Humidity
RH _{min}	:	Minimum relative Humidity
RH _{mean}	:	Mean relative humidity
RZD	:	Root zone depth
S. No.	:	Serial number
S	:	Second
Sci.	:	Science
SCS	:	Soil conservation services
Sq. km	:	Square kilometre
SMD	:	Soil Moisture Depletion
SEm	:	Standard error of mean
SMS	:	Sensor irrigation controllers

SMW	:	Standard Meteorological Week
SWCE	:	Soil and Water Conservation Engineering
SWE	:	Soil and Water Engineering
T	:	Temperature
T _{max}	:	Maximum Temperature
T _{min}	:	Minimum temperature
T _{mean}	:	Mean Temperature
T	:	Tonne (1000 kg)
t/ha	:	Tonne per hectare
TDR	:	Time domain Reflect meter
Tech.	:	Technology
TSDI	:	Time space deficit irrigation
TSS	:	Total soluble solids
USDA	:	U. S. Department of Agriculture
UV	:	Ultraviolet
var.	:	Variety
VC	:	Vermicompost
viz.	:	Namely (videlicet)
Vol.	:	Volume
vs	:	Verses
VWC	:	Volumetric water content
W _a	:	Wetted area
W _r	:	Water requirement
WT NVPH	:	Walking tunnel type naturally ventilated polyhouse
WUE	:	Water use efficiency
Y	:	Yield
YMCA	:	Young Men's Christian Association

LIST OF SYMBOLS

%	:	Per cent
@	:	At the rate of
&	:	And
=		Equal
/	:	Per
°C	:	Degree Celsius
>	:	Greater than
<	:	Less than
Δ	:	Slope of saturation vapour pressure curve at given air temperature
γ	:	Psychometric constant
μ	:	Micron
e_a	:	Actual vapour pressure at air temperature
E	:	East
e_s	:	Saturated vapour pressure at mean air temperature
G	:	Soil heat flux
H	:	Sensible heat flux
N	:	North
Q	:	Discharge
q_n	:	Average of the lowest $\frac{1}{4}$ of the emission point discharge for field data.
q_a	:	Average emission point discharge of test sample operated at the reference Pressure head.
R_n	:	Net radiation
u_2	:	Average daily wind speed at 2 m height

CHAPTER - I

INTRODUCTION

1.1 GENERAL

Agriculture continues to play a dominant role in the growth of Indian economy. Agriculture is the backbone of India's economic activity as it contributes about 17 per cent to the total GDP and provides employment to over 60 per cent of the population. Today, India ranks second worldwide in farm output. Agriculture is the basic source of food supply of all the countries of the world whether underdeveloped, developing or even developed. Raising supply of food by agricultural sector has therefore, great importance for economic growth of our country.

If India has to emerge as an economic power in the world, our agricultural productivity should be equal to those countries, which are currently rated as the economic power of the world. We need a new and effective technology which can improve continuously the productivity, profitability, sustainability of the farming systems. Protected cultivation is one among the different available technologies in the present era. (Bose, 2015).

Our country is self-dependent on food grain production but to fulfill the nutritional security, the gap between increasing demand of horticultural produce has to be filled. Both these demands can be met when the environment for the plant growth is suitably controlled. Vegetable production in our country is significantly influenced by the seasonality and weather conditions. Extends of abundance and deficiency in production and availability cause considerable fluctuations in the prices and quality of vegetables. Striking a balance between all-season availability of high quality vegetables with minimum environment impact, and still to remain economically competitive in this time of globalization, is a major challenge for the modern technology of crop production.

There is need to protect the crops against unfavorable environmental conditions led to the development of protected agriculture. Polyhouse is the most practical method of achieving the objectives of protected agriculture, where natural environment is modified by using sound engineering principles to achieve optimum plant growth and yield. Besides modifying microclimate, these protective structures provide protection against wind, rain and insects.

Protected cultivation offers several advantages to produce vegetables of high quality and yields-particularly during the off-season when prices are higher, thus using the land and other resources more efficiently. This becomes relevant to vegetable growers in India who have land holding smaller than one hectare. They would be interested in a technology which helps them to produce more crops each year from their land, particularly during off-season when prices are higher. Along with productivity, the better quality of produce is also obtained under polyhouse cultivation. Other advantages of greenhouse cultivation include timely harvest as per market demand; higher yield due to better management, optimum use of land and increase in harvesting period and raising quality seedlings and plant propagation (Kundu, 2014).

The polyhouses are constructed with the help of ultraviolet resistant plastic sheets, so that they may last for more than 5 years. The structure is covered with 200 μm thick plastic sheet. The direction of polyhouse is East to West or sometimes North to South, so that the maximum sunshine is available. The house should not be constructed in shade. The size of polyhouses may differ depending on the necessity. The polyhouses are kept cold or hot depending upon the season. From the point of view of earning more profit only such off-season crops should be grown, which are being sold at higher prices in the market. In such areas like hill areas and remote regions where fresh vegetables are required regularly for meeting out the requirements of security forces, the construction of polyhouses are more lucrative and is a must.

The main objectives of cultivation of vegetables in a polyhouse condition are, to protect the crop against biotic (pests, diseases and weeds) and abiotic (temperature, humidity and light,) stresses and to ensure round the year production of high-value quality vegetables like tomato especially, during the off-season. (Murthy, 2016).

Tomato (*Lycopersicon esculentum* Mill) belongs to the *Solanaceae* family. Tomato is an important vegetable crop grown worldwide for both fresh and processing markets. Tomato can play an important role in human diet. It is a valuable source of vitamins A and C as well as several minerals including calcium, iron, manganese and particularly potassium (Cheena *et al.*, 2018). In 2017, the worldwide production of tomatoes totaled 170.8 million tons. China, the leading producer of

tomatoes, accounted for 31% of the total production. India and the United States followed with the second and third highest production of tomatoes in the world. The main tomato producers were China, the USA, India, Turkey, Egypt, Italy, Iran, Spain, Brazil and Mexico (75% of the world production) (FAO, 2011). In India, area under tomato cultivation is 7.73 lakh ha with a total production of 187.32 lakh MT and productivity of 24.2 MT/ha in year 2015-16 (Anonymous, 2017). Major tomato growing states in India are Bihar, Karnataka, Orissa, Maharashtra and Andhra Pradesh.

Climate change is a major threat for crop production all over the world. Tomato production is commonly affected due to adverse environmental conditions. In some areas of our country particularly in the northwestern part, the night temperature falls even sometimes go below 5-6°C in late December to January, which results remarkable yield loss in tomato (Islam *et al.*, 2017). Transplanting time has tremendous effect on the tomato fruit quality and seed yield because of widely varying agro climatic conditions and intricate crop-weather relationships. Optimum time of planting is one of the non-monetary inputs for increasing the productivity of the crop (Madhumathi and Sadarunnisa 2013).

Water is an important input for polyhouse vegetable cultivation, because irrigation is the only source for application of water to plants inside. The sustainable use of water in agriculture has become a major concern. The adoption of strategies for saving irrigation water and maintaining acceptable yields may contribute to the preservation of this ever more restricted resource (Mahmoud and Abduroul, 2012). In areas of water shortage and long summer droughts, maximizing water productivity may be more beneficial to the farmer than maximizing crop yield.

Extensive efforts have been made by the researchers to use drip irrigation as an efficient input under protected cultivation. The use of drip irrigation method in the polyhouse, not only saves water but also gives better yield and quality with reduced humidity build up due to precise application of water to the root zone and improving irrigation efficiency (Ramanjaneya, 2015). Drip irrigation is one of the method of on-farm water application optimizing the water for crop production. The system generally produces higher ratio of yield per unit volume of water than typical surface or sprinkler systems.

WUE is one of the key water use indicators derived in the study of sustainable irrigated agriculture. The definition focuses farmer's attention on both water use and production and provides an indication of whether the resource has been used effectively.

According to the Inter-Governmental Panel on Climate Change (IPCC, 2014) there is a general reduction of potential crop yields and a decrease in water availability for agriculture and population in many parts of the developing world. The polyhouse environment has a profound effect on crop productivity and profitability. Climate decides crop selection while weather decides crop production and productivity. Polyhouse structures have distinct effect on several environmental parameters particularly temperature, light, carbon dioxide and humidity. The plant response to specific environmental parameter is related to the physiological processes and to yield and quality.

Potentially changing climates will have considerable impact upon horticultural processes and productivity across the globe. In fact, the increase of temperature limits crop yield by accelerating the plant development, affecting the floral organs and fruit formation and the functioning of photosynthetic apparatus (Safia, 2015). Since the microclimate components inside the structures influences the functional aspects of plant, the emphasis is normally given to the maintenance of the optimal level of the factors for the successful and better productivity in the protective cultivation. The maintenance of crop photosynthesis is essential under the protective structure as it is responsible for 90% dry matter accumulation and plant productivity. Hence for checking the impact of weather parameters on yield of tomato crop is done by regression analysis method.

Regression Analysis has been defined as a structured approach which stresses on the analysis of data for the research purpose on decision making and problem solving. There are problems/situations that require simultaneous analysis of multiple variables or objects for efficient decision making. We consider two factors like average air temperature and average relative humidity that contributes to the yield of crop. In this work, regression analysis is used to establish the relationship among these two factors and to identify their influence on crop yield. In this study we made a regression analysis of the fruit yield and tried to make a simulation model for

predicting the yield based on averaged air temperature and averaged relative humidity.

1.2 JUSTIFICATION

Tomato (*Lycopersicon esculentum* Mill) is one of the most popular, cash earning and versatile vegetable crops for small farmers of India. It is also most important and remunerative vegetable crop in India and able to fetch very good rates from market due to its high demand in hotels and restaurants.

Main constraint of its cultivation round the year in plains of North-West India including Rajasthan where weather condition during winter and summer season is extremes. The tomato fruits are thus available for a short period (Seasonally availability). It is a challenge to the vegetable production technology and utilization of natural resources to produce vegetables several times more to meet the needs of the expected vegetable requirement of 150 million tons by 2020. In these circumstances greenhouse production offers great scope (Kundu, 2014).

Through protected cultivation the farmers can increase the production. In open cultivation a farmer can cultivate only 3-4 months but in protective cultivation a farmers can cultivate 7-8 months. In open cultivation the crop loss is more due to insect pest attack where as in protected cultivation the wastage is very less. As the farmer can produce vegetables in off season, so the farmer can sell the product in higher price to the retail stores, restaurants and big hotels. To avoid wastage of the produce, the farmers can produce product according to the demand of these retail stores.

Being an important vegetable crop, research on every aspect of its cultivation to improve its productivity becomes essential. Tomato has a great demand throughout the year, but its production is concentrated during the few months in our country. Although production of summer tomatoes has just started, there is still a long way to go for successful year-round commercial production. Thus it is important to identify an appropriate planting time for successful production of tomato.

Water scarcity and continuous decreases in water resources coupled with an increasing demand for water in agriculture and other sectors. With the increase of population availability of water decreasing so it is very essential to efficient by use of available water. Drip irrigation is one of the best and latest methods for efficient

utilization of irrigation water. Drip irrigation provides high water use efficiency, higher crop yield, less labor requirement and relatively low operating cost, less weed growth, less insect and pest attacks, shorter growing season and earlier harvest of the crop. Use of poor quality of water is also possible through drip up to certain limit, more automation, easy adjustment and control and more irrigated crops cultivation is possible in problem soils are the some advantages of drip irrigation as compared to conventional methods.

There is a wide gap between potential and actual yield of tomato and the growth and yield largely depends on the various weather factors like temperature, rainfall, solar radiation and relative humidity that prevail during the growing season. In order to study the impact of various weather parameters in the actual field conditions the use of a suitable model becomes mandatory. Various models are used in farm decision making, analyzing for strategic planning, making production management decisions, analyzing policies and defining research needs. Regression analysis for tomato was used to validate the growth, development and yield of tomato as well as predict the future yield under the different scenarios (Safia, 2015).

Keeping all these points in view, the present study entitled “Effect of modeling of climatic parameters on growth and yield of tomato crop during second half of the year grown under naturally ventilated polyhouse” was undertaken with the following specific objectives:

- 1) To determine crop water requirement for tomato crop under different transplanting dates.
- 2) To study the effect of climate on different dates of transplanting on growth and yield of tomato crop.
- 3) Modeling of effect of variation of temperature and relative humidity on growth parameters and yield of tomato crop.
- 4) To estimate the water use efficiency under drip irrigated system in tomato.

CHAPTER - II

REVIEW OF LITERATURE

2.1 GENERAL

This section briefly deals with the review of the research work carried out in India and abroad in relation to the objectives of the proposed study. An extensive review of research has been made on the line of objective contemplated to facilitate devising and appropriate methodology towards accomplishing the entire research topic. The proposed study consists of the development of the methodology and planning a tomato production under polyhouse in Udaipur region Rajasthan.

2.2 DETERMINATION OF CROP WATER REQUIREMENT

The determination of crop coefficients (species factor) and evaporation are important for estimating irrigation water requirements in order to have better irrigation scheduling and water management.

Bhakar and Singh (2003) developed improved crop coefficients for precise estimates of wheat evapotranspiration. The crop coefficient curve was developed by plotting the ratio of crop evapotranspiration and reference evapotranspiration with respect to time. The evapotranspiration values of wheat crop were measured with the help of electronic weighing lysimeter at Udaipur. The crop coefficient curves were developed for wheat by FAO-56 curve method and modified FAO-56 method. The FAO-56 method underestimates wheat evapotranspiration by 28.17 per cent. Therefore, FAO-56 curve method does not appear to predict wheat evapotranspiration accurately. The modified FAO-56 curve method underestimates wheat evapotranspiration only by 5.55 per cent. Therefore, the performance of modified FAO-56 curve method was found better than FAO-56 curve method for estimation of wheat evapotranspiration.

Harmanto *et al.* (2005) conducted a study on water requirement of drip irrigated tomatoes grown in greenhouse in tropical environment. Four different levels of drip fertigated irrigation equivalent to 100, 75, 50, and 25% of crop evapotranspiration (ET_c), based on Penman-Monteith (PM) method, were tested for their effect on crop growth, crop yield, and water productivity. Based on this, the actual irrigation water for tomato crop in tropical greenhouse could be recommended between 4.1 and 5.6 mm/day or equivalent to 0.3-0.4 l/plant day. For growing

tomatoes, greenhouse farming system performed better than the open farming system in terms of crop yield, irrigation water productivity and fruit quality. Drip irrigation applied with 75% of crop evapotranspiration (ET_c) was found to be the optimum irrigation amount for humid tropic environment in order to obtain the maximum tomato yield of 0.44 kg/m².

Hector *et al.* (2009) conducted study on evaluation of water requirements for a greenhouse tomato crop using the Priestley-Taylor (PT) model and was evaluated for estimating the real evapotranspiration (ET_{real}) of a drip-irrigated greenhouse tomato (*Lycopersicon esculentum* Mill.) crop. For this experiment, an automatic weather station (AWS) installed inside the greenhouse to measure solar radiation (R_{gi}), net radiation (R_n), air temperature (T_a) and relative humidity (RH). Another AWS was installed over a grass cover to measure atmospheric conditions outside the greenhouse. The PT model was evaluated using the ET_{real} obtained from the water balance (WB) method. Thus, the PT model evaluated in this study could be used for scheduling irrigation for a greenhouse tomato crop, using internal measurements of air temperature and relative humidity, and external measurements of solar radiation.

Adeniran *et al.* (2010) carried out study to determine the crop water requirement of some selected crops for the area around Kampe (Omi) Dam Irrigation Project. These crops include rice, maize, tomato, vegetable amaranth, pepper, onion and cabbage. Crop water requirement for each of the crops was determined by using 25-year climatic data in CROPWAT. Reference crop evapotranspiration (ET_0) was determined using the FAO Penman Monteith method. The study shows that for the area under study, reference evapotranspiration (ET_0) varied from 3.4 to 4.8 mm/day. Crop evapotranspiration (ET_c) and crop water requirement for paddy rice varied from 0.28 to 4.18 mm/day and 2.0 to 102.4 mm/day, for maize from 1.82 to 4.88 and 1.3 to 45.6 mm/day, for tomato from 8.7 to 52.8 and 0.0 to 45.2 mm/day, for vegetable from 3.07 to 4.74 and from 7.4 to 45.6 mm/day, for pepper 3.13 to 4.8 and from 15.1 to 40.7 mm/day, for onion from 1.80 to 38.4 mm/day, and for cabbage from 28.2 to 40.9 mm/day respectively. The peak water requirement was 0.63 l/s/ha or 5.4 mm/day with an application efficiency of 65%.

Gadge (2010) studied the daily crop water requirement using daily reference crop Evapotranspiration (ET_0) and crop coefficient (K_c) values. The crop coefficient curves were developed from the locally developed crop coefficient values. In absence

of locally developed stage wise crop coefficient values, the data from FAO were adopted. The developed crop coefficient curves estimates the daily crop coefficient values. For more reliable estimation of the reference crop Evapotranspiration (ET_0), the average of 30 years climatological data were used. Crop water requirement thus developed serve as a guideline for optimal utilization of available water under surface and micro irrigation methods in the canal command area.

Owusu-Sekyere *et al.* (2012) determined the crop coefficient, water requirement and the effect of deficit irrigation on the development and yield of tomato in the coastal savannah zone of Ghana. There were four (4) different water treatments, namely: 100% of water requirement (T_1), 90% of water requirement (T_2), 80% water requirement (T_3) and 70% water requirement (T_4). The seasonal water requirement of tomato was found to be 302.98 mm, while the K_c was also between 0.62-1.61. They suggest that 10-15% reduction of ET_c of tomato will have no significant difference in growth and development while reduction of above 20% will have a negative effect on growth of tomato.

Shukla (2013) research under scheduling of irrigation for capsicum crop under protected cultivation. In this study the capsicum has been grown under four small size, naturally ventilated protected structures that is shed net house, insect net house, poly house with shade net vents, poly house with insect net vents at plasticulture farm CTAE Udaipur. The irrigation water requirement under each structure was found 527.04 mm, 638.81 mm, 606.96 mm, and 545.65 mm. The crop water requirement for outside condition was calculated by FAO 56 method, it was 791.73 mm for entire crop duration. It was observed that the water saving under Structure-1, Structure-2, Structure-3, and Structure-4 were 33.43 %, 19.32%, 23.34% and 31.08% respectively, compare to outside condition

Harel *et al.* (2014) studied about the growth stage specific crop coefficient for greenhouse tomatoes grown in the semi arid Mediterranean was evaluated. The evaluation consisted of two simultaneous field trails: 1) Data accumulation of the water consumption of round and cherry tomato plants with the use of drainage lysimeters. 2) Irrigation of tomatoes planted in local sandy soil with either reduced or excess irrigation water doses using the lysimeter water consumption data as the reference criteria. Crop coefficients of between 0.3-1 for the time period from seedling establishment until first fruit harvest and 0.8 for the fruit harvest period were

recorded for the winter season round tomato crop. During the summer season, coefficients of between 0.2-0.9 for the time period from seedling establishment until first fruit harvest and 0.8 for the fruit harvest period were measured for the round tomato crop.

Owusu-Sekyere *et al.* (2015) studied about water requirement, deficit irrigation and crop coefficient of hot pepper (*Capsicum frutescens*) using irrigation interval of four days. The treatments imposed were T1, application of 100% crop water requirement, T2, was 80%, T3 60% and T4 40 % of crop water requirement. It was determined that pepper requires about 587.48 mm of water over the growth season. The crop coefficient under full water supply was found to be: 0.47, 0.86, 1.42 and 0.91 for initial, development, mid-season and the late season stages, respectively. The study also revealed that reduction in 20% water need of hot pepper has no significant effect on growth, development and fruiting of the crop.

Sharma *et al.*, (2015) conducted study on the effect of deficit irrigation on growth and production of drip irrigated tomato under shade net house. Four different levels of drip irrigation equivalent to 100%, 80%, 60% and 40% of crop evapotranspiration with five replications were considered for their effect on crop growth and crop yield inside the shade net house. Plant height, number of leaves and individual fruit weight were found to be highest with 80 % irrigation, giving highest yield of 108.30 t ha⁻¹. Actual irrigation water application between 1.62 and 4.58 mm/day was thus recommended for tomato crop in a shade net house.

Surendran *et al.* (2015) computed crop water requirements of crops in agro-ecological units (AEUs) of Palakkad district of humid tropical Kerala with CROPWAT 8.0 using the meteorological parameters. The major cultivated crops were rice, coconut, banana, arecanut, vegetables, pulses, rubber, tea, coffee, cotton, tomato etc. The gross irrigation demand for the district was 1146 mm³, in which 981 mm³ was from surface water and 165 mm³ from groundwater sources. Water balance analysis was done for the current scenario and future demand for agriculture, domestic and industrial demand. The projected future total water demands for irrigation, drinking and industrial purpose was estimated to be 3841 mm³. However, the secondary data showed that an utilizable water resource of Palakkad district was less and will create a deficit scenario. This deficit indicates 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.

Janani *et al.* (2016) studied review on off season crops that can be grown successfully even in the adverse climatic condition is possible under polyhouse. Naturally ventilated polyhouse is the one in which the temperature can be maintained and creates the favorable condition for crop growth. Greenhouse, the latest world in Indian agriculture is one such means, where the plants are grown under controlled or partially controlled environment resulting in higher yields than that possible under open conditions (Navale *et al.*, 2003) in capsicum. Among the hybrids, the Indra (capsicum) recorded maximum (number of flowers and fruits 13.41 and 12.11 respectively) at 120 DAP. The mineral fertilizer and FYM also have a bigger share in total energy input used in polyhouse pepper production (Ozkan *et al.* 2004). Naturally ventilated polyhouse recorded highest total marketable yield in capsicum with more number of excellent quality export grade fruits.

Arya *et al.* (2017) studied Irrigation water requirement of Capsicum (*Capsicum annum* L.var. Grossum) for Jhalawar region of Rajasthan. The daily reference evapo-transpiration (ET_0) was estimated by using the 'CROPWAT 8.0' Model based on FAO-56 Penman-Monteith (1998) method. The maximum and minimum ET_0 of 4.59 and 1.72 mm/day were observed on 22nd September and 25th December respectively. Crop coefficient was considered as suggested by Allen *et al.* (1998) for different growth stages of Capsicum. The total water requirement of 380 mm for capsicum was estimated during crop growing period (6th September-5th March)

Dirirsa *et al.* (2017) developed a crop coefficient and water requirement of Tomato (Melka Shola Variety) at Melkassa, Central Rift Valley of Ethiopia. In this study, non-weighing type lysimeters were used to determine water requirement (ET_c) and crop coefficient (K_c) of Tomato (Melka Shola cultivar). Reference crop evapotranspiration (ET_0) was determined using weather data of the site computing with modified Penman Monteith method. The measured average stage-wise ET_c values were 43.53 mm, 112.50 mm, 270.63 mm, and 124.98 mm during the initial, development, mid-season and late season growth stages, respectively. The average crop coefficient (K_c) values, calculated as ratio of ET_c to ET_0 , were 0.57, 0.86, 1.13 and 0.88 for the initial stage, developmental stage, mid-season stage and of late

season stages, respectively. The crop coefficient value at the end of the late season stages was found to be 0.63. The length of each of the growth stages of initial, development, mid-season and late-season were 14, 25, 36 and 29 days, respectively. The water requirement and crop coefficient values determined in this study will help to accurately plan and manage the water resources in production of tomato.

2.3. EFFECT OF DATE OF PLANTING ON GROWTH AND PRODUCTION OF TOMATO UNDER POLYHOUSE

Hossain *et al.* (2013) studied the effect of different sowing dates on yield of tomato genotypes. The experiment was conducted at Agricultural Research Station, Thakurgaon, Bangladesh during October 2009 to March 2010. Three sowing dates viz. October 1, October 15 and October 30 were considered as factor A and tomato variety viz., BARI Tomato-2, BARI Tomato-3, BARI Tomato-4, BARI Tomato-9 and BARI Hybrid Tomato-4 considered as factor B. They found results that the early flowering (52.40 days) as well as early fruit harvesting (119.13 days) was occurred in October 1 sowing, whereas sowing on October 30 resulted in delayed flowering (71.73 days) and fruit harvesting (140.67 days), respectively. Number of fruits per plant was also the highest (27.40) in October 1 sowing and the lowest (13.73) was in October 30 sowing. Seed sowing of October 1 was found better in respect of yield (74.75 t ha⁻¹) compared to October 15 (58.55 t ha⁻¹) and October 30 (24.60 t ha⁻¹) sowing.

Madhumathi and Sadarunnisa (2013) studied the effect of different transplanting dates and varieties on fruit quality and seed yield of tomato. Transplanting of tomato during 15th of October recorded significantly higher number of fruits per plant (33.31), yield per plant (1.25 kg), fruit size (length, diameter and volume), fruit weight (42.63 g), pulp content (54.01%), ascorbic acid (20.81 mg/100 g pulp) and number of seeds per fruit (192.21) over other dates of planting. Among the treatment combinations Pusa Ruby planted on October 15th emerged as the best combination with regard to fruit quality and seed characters.

Emami (2014) conducted study on effect of transplanting dates on fruit yield and related quality traits of tomato genotypes. In order to determine the effects of transplanting dates on morpho physiological traits of tomato genotypes, an experiment conducted in Kahriz station during 2010-11 at two years. The experiment

was split plot based on randomized complete blocks design with three replications. Five genotypes including Early Urbana-Y, Primo Early, Chef, Early Urbana-VF and L-144 arranged at main plots, three transplanting dates including 20 May, 5 June and 20 June were as subplots. The most fruit yield with 91 and 78t ha⁻¹ were achieved in L-144 and Early Urbana-Y at 20 May transplanting date, respectively. Simple correlation coefficient between traits showed that fruit yield was positive significant correlation with number of fruits at per plant ($r=0.66^{**}$). At 20 June Chef with 73t ha⁻¹ fruit yield and 5.46% soluble solids had the highest values. It was conclude that chef cultivar is recommended for second cropping systems in cold regions.

Singh *et al.* (2015) studied the effect of planting date and integrated nutrient management on the production potential of tomato (*Solanum lycopersicon* Mill.) under polyhouse condition. An experiment was performed to assess the different date of planting viz; September 15 (D₁), September 30 (D₂) and October 15 (D₃) and different sources of organic and inorganic fertilizers. The result revealed that the growth parameters and yield attributing traits were significantly influenced by different planting dates and sources of nutrients. Planting on September 15 (D₁) recorded the highest plant height (254.95 cm), number of leaves per plant (33.47), fruits per plant (80.39), fruit length (6.75 cm), fruit girth (5.53 cm), mean fruit weight (124.26 g), yield per plant (10.39 kg) and yield per plot (42.44 kg) over later date of planting.

Islam *et al.* (2017) the present study was carried out to examine the variation in growth and yield of tomato at different transplanting dates. Three transplanting were done at an interval of 10 days. The different transplanting dates were; December 10, December 20 and December 30. The experimental results revealed that different planting dates showed significant influence on growth and reproductive characters of tomato including fruit yield. The first transplanting date, December 10 resulted in improvement of all the attributes including increased plant height (63.54 cm), leaf number (33.3), flower number (71.15 days), fruit number (41.98 days), number of flowers per plant (150), number of fruit per plant (86.08) and yield per hectare (85 t) compared to 2nd transplanting date, December 20 and 3rd transplanting date, December 30. Therefore, it is suggesting that earlier transplanting produced higher fruit yield of tomato.

Cheena *et al.* (2018) a study was carried out to determine the effect of sowing dates on yield and growth of indeterminate tomato varieties under poly house conditions. In their research three sowing dates i.e. July 15, August, 15 and September, 15 were considered as factor A and tomato variety viz., Heemsona, Ranganga and Shikar were considered as factor B. The experiment was laid out in FRBD with three replications. The number of fruits per plant was highest (308.87) with 15th September planting in heemsona variety and lowest with 15th July planting in Shikar variety. The planting with 15th September with Heemsona was founded better in respect of yield (77.74 t ha⁻¹) compared to 15th July planting with Ranganga variety (16.66 t ha⁻¹).

2.4. TOMATO PRODUCTION IN OFF-SEASON UNDER POLYHOUSE

Ganesan (2002) studied four different poly-greenhouse models were compared with open field condition at the Ecohorticulture farm, M.S. Swaminathan Research Foundation, Livestock Research Station, Kattupakkam, Kancheepuram district, Tamil Nadu in 1999. The effects of temperature on plant growth and yield of tomato in poly-greenhouses and open field condition were investigated. The air temperature in the open field condition was lower than in the poly-greenhouse treatments throughout the growth period. Poly-greenhouse with ventilation gaps in the triangular roof and four sidewalls was found more suitable for better plant growth and yield of tomato than those with the other ventilation gaps in poly-greenhouses and open field condition.

Murthy *et al.* (2009) examined the economic viability of production of capsicum and tomato in a naturally ventilated polyhouse of medium cost category with drip irrigation system. Data were generated by cost accounting method for estimating the feasibility of production and was analyzed by using project evaluation methods, like Pay Back Period (PBP), Benefit Cost Ratio (BCR), Net Present Value (NPV) and Internal Rate of Return (IRR). Cultivation of capsicum in a polyhouse was found to be highly feasible as reflected in higher values of NPV (Rs.3,23,145/500 m²), BCR (1.80) and IRR (53.7%) with payback period of less than two years. Breakeven price for capsicum production in a polyhouse (Rs.11.80 /kg) was lesser than average wholesale price. Production of tomato in a polyhouse was found not feasible, as the breakeven price was more than the average market price and all the project appraisal parameters indicated that it was not feasible. Only at about 48%

premium price over the prevailing market price or reduction of cost of polyhouse structure by 60% from Rs.400 to Rs.160 /m², could make the tomato production viable in a poly house.

Singh *et al.* (2009) examined economics of Naturally Ventilated Greenhouse (SVBPU Model) for Tomato Production in Northern Plain of India. For that they took four hybrids of tomato crop were grown successfully under naturally ventilated greenhouse. Best quality fruit yield of 12.6 kg/m² was harvested from Naveen 2000 hybrid of tomato and the crop was 98% virus free. The greenhouse performed well for off season vegetable cultivation. The higher and early yield of vegetables inside green house was mainly because of higher temperature upto 6°C-11°C observed during winter season and reduction in temperature upto 3°C-9°C observed during summer season. The B: C ratio, pay back period, cost of cultivation/m², and net return/m² were worked out as 1.92, 3 yrs, Rs. 79/-and Rs. 721/- respectively. It is clear from all the financial criteria, the greenhouse vegetable cultivation projects worth making the investment.

Parvej *et al.* (2010) studied about phenological development and production potentials of tomato under polyhouse climate. They compare the phenological development and production potentials of two tomato varieties viz. BARI Tomato-3 and Ratan under polyhouse and open field conditions. It was found that from December to February the mid day air temperature under polyhouse and open field varied from 31.8 to 39.1°C and 23.3 to 31.1°C, respectively indicating about 8°C higher air temperature inside polyhouse and during that time the average air temperature inside polyhouse was about 28°C which was optimum for the growth and development of tomato plants. Relative humidity had opposite trends with that of air temperature i.e. it was lower inside the polyhouse as compared to open field. Flowering, fruit setting and fruit maturity in polyhouse plants were advanced by about 3, 4 and 5 days, respectively compared to the crop raised in open field condition. Polyhoused plants had higher number of flower clusters/plant, flowers/cluster, flowers/plant, fruit clusters/plant, fruits/cluster and fruits/plant, and fruit length, fruit diameter, individual fruit weight, fruit weight/plant and fruit yield over open field condition. The fruit yield obtained from the polyhouse was 81 t ha⁻¹ against 57 t ha⁻¹ from the open field.

Rajasekar *et al.* (2013) did research on influence of weather and growing environment on vegetable growth and yield. Tomato, eggplant, chilli, cucumber, cluster bean, radish, amaranthus, coriander, bhendi and capsicum were grown in the summer and winter. The influence of environmental variables temperature, relative humidity and light intensity were studied. All vegetables registered better performance for growth and yield during both seasons. Relative humidity & mean weekly temperature were always higher and light intensity was lower under shadenet house than in open field during both seasons. Lower temperature caused plant height, number of branches, internodal length, average fruit weight and yield per plant to be higher in the shadenet house than in the open field. Hence, the growing of vegetables under shade house conditions will be more profitable irrespective of the seasons.

2.5. MODELING OF GROWTH AND YIELD OF TOMATO USING CLIMATIC PARAMETERS

Willits *et al.* (1998) studied about the effect of night temperature on greenhouse grown tomato yields in warm climates and which contain data from six seasons. Each season contained at least one treatment where night temperatures in one greenhouse were kept below 20⁰C, using air conditioning, and one treatment where night temperatures in a separate greenhouse were essentially the same as those outside. Regression analysis indicated a strong dependence of yield on the night temperature during fruitset when the warm treatment temperature exceeded 21⁰C. Total fruit numbers were as much as 39% higher, and total weights as much as 53% higher, than that observed in the warmer treatment. The effect on fruit quality was even greater, with No. 1 number and No. 1 weight increases as high as 85% and 106%, respectively, as the warm treatment approached 24⁰C.

Wada *et al.* (2012) studied the simulation model for predicting fruit yield of tomatoes grown on a single-truss system under shade in summer. This study was carried out to make a simulation model for predicting the fruit yield of tomatoes in summer. Tomato seeds were sown monthly from February to September. Plants were grown hydroponically on a single-truss system in 0, 30, 55, and 83% shade. Total fruit yield per plant increased linearly with increasing integrated solar radiation from the first flower anthesis to the first fruit harvest. From these results, the simulation model for predicting fruit yield from both integrated solar radiation and averaged air temperature was constructed. The model could be applied at 19 to 27°C of averaged

air temperature. Standard error of cross-validation (SECV) of the data excluding the June crop was lower (92.1) in the model modified with air temperature, compared with the model with only integrated solar radiation (111.4).

Umesha (2012) studied the effect of weather parameters on growth and yield parameters of tomato under natural poly house. The experiment was conducted to study the effect of changes in microclimate produced by poly house conditions on plant growth characteristics and fruit yield of tomato was studied during 2009-2010 at TNAU campus. Daily climatic parameter fluctuations of temperature, relative humidity and light intensity were measured at various stages of crop growth. Temperature (39.88 °C) was high in poly house during afternoon time. The relative humidity (91.06 %) was higher during morning time, and in afternoon (38.48 %) it was lower under polyhouse. The light intensity inside the poly house was higher at afternoon (58865, lux) and it was also observed that during morning and evening hours there was low light intensity. The changes in microclimates are positively influenced on growth and yield parameters of tomato under poly house condition.

Sellam and Poovammal (2016) the present study on prediction of crop yield using regression analysis. The objective of this work is to analyze the environmental parameters like Area under Cultivation (AUC), Annual Rainfall (AR) and Food Price Index (FPI) that influences the yield of crop and to establish a relationship among these parameters. In this research, Regression Analysis (RA) is used to analyze the environmental factors and their infliction on crop yield. RA is a multivariate analysis technique which analyzes the factors groups them into explanatory and response variables and helps to obtain a decision. A sample of environmental factors like AR, AUC, FPI are considered for a period of 10 years from 1990-2000. Linear Regression (LR) is used to establish relationship between explanatory variables (AR, AUC, FPI) and the crop yield as response variable. R^2 value clearly shows that yield is mainly dependent on AR. AUC and FPI are the other two factors influencing the crop yield. This research can be extended by considering other factors like Minimum Support Price (MSP), Cost Price Index (CPI), Wholesale Price Index (WPI) etc. and their relationship with crop yield.

2.6. WATER USE EFFICIENCY UNDER DRIP IRRIGATED SYSTEM

Dunage *et al.* (2008) conducted a field experiment at the Regional Agricultural Research Station, Raichur (Karnataka) during summer 2005 revealed that, the total water requirements for tomato under net-house conditions using 60, 80, 100 and 120% evapotranspiration (ET) levels of drip irrigation were 52.720, 61.451, 69.607 and 79.524 liter per plant respectively. The mean application efficiency of the system sources, the farmyard manure (FYM) treatment gave the maximum water use efficiency (WUE) of 10.40 t ha/cm and the lowest was obtained in case of chemical fertilizers (9.12 t ha/cm). Within the drip irrigation treatments, the highest WUE of 11.90 t ha/cm was obtained under the treatment of irrigation at 60% and the least in 120% ET (7.45 t ha/cm). The payback period of the investment in nethouse cultivation of tomato using drip irrigation was found out to be one and a half years (three seasons) by which time the system became beneficial.

Biswas *et al.* (2014) this study investigated the combined effects of drip irrigation and mulches on yield, water-use efficiency and economic return of tomato. The treatments of the study comprised different combinations of three drip irrigation levels (100, 75 and 50% of crop water requirement, ET_c) and two mulches (black polyethylene sheet and paddy straw). The highest yield for each mulch (81.12 t ha⁻¹ for polyethylene and 79.49 t ha⁻¹ for straw) was obtained when 50% of water requirement was applied. With 100% water application, polyethylene-mulched treatment produced lower yield than the straw-mulched treatment. The highest water use efficiency of 592 kg/ha/mm was obtained with 50% water application under polyethylene mulch. The study thus reveals that drip irrigation with mulch has an explicit role in increasing the land and water productivity of tomato.

Mazher *et al.* (2014) have grown three vegetables (tomato, cucumber and bell pepper) were grown in plastic tunnels as off season crops for three years from 2009-10 to 2011-12 to evaluate comparative water use efficiency. A permanent tunnel of 80 x 27 x 10 ft. was erected. Irrigation was applied through drip and furrow irrigation systems. Each crop was planted on 20 x 27 ft. under drip irrigation and on 20 x 9 ft. under furrow irrigation system. Average water use efficiency increased by 2.50% for tomato, 2.74% for cucumber and 2.45% for bell pepper under drip irrigation system as compared to furrow system. On the contrary, the average fruit yield increased only by 2.05% for tomato, 3.32% for cucumber and 2.35% for bell

pepper from furrow irrigated plots over those of drip irrigated plots. This suggested that drip irrigation has a greater scope for production of off-season vegetables especially in water scarce areas of Pakistan.

Haidula (2016) studied irrigation water use and vegetable production efficiency assessment between sprinkler and drip irrigation systems at North Central Namibia (NCN) on three vegetable crops: tomato, cabbage, and pepper. Data were analyzed in R software, whereby three statistical linear regression model such as; backward selection model, Akaike information criterion and interactions were used to measure the objectives. The relationship between water use and irrigation systems was not significant; neither crop yield difference was not observed between drip and sprinkler irrigation systems. However, the statistical findings contradict the findings based on opinions and observations of farmers on crop yield and water use; which concluded that drip is more efficient relative to sprinkler irrigation. Together these results highlighted no clear difference between drip and sprinkler on water use and irrigation production efficiency on North-central Namibia.

2.7. CONCLUDING REMARK OF REVIEW

The above cited reviews indicate the importance of weather parameters and different planting dates on yield of crop under NVPH. The research review presented clearly indicates the importance of crop water requirement and water use efficiency and which is region specific. No such studies have been undertaken for this region. Studies on “Effect of modeling of climatic parameters on growth and yield of tomato crop during second half of the year grown under naturally ventilated polyhouse” have been under taken for Udaipur region.

CHAPTER III

MATERIAL AND METHODS

The quality of any research work is judged on the basis of its methodological approach. It is a way to systematically solve the research problem. The study involves collection of data and undertakings observations. In this section, the description of location of the study area, the methods that will be used for collecting data and undertaking observations and the procedure used for study to effect of protected climate over the water requirement and production of tomato under natural ventilated polyhouse. The materials and methodology adopted are furnished here under. The details of the materials used and the methodology adopted for the present study has been demonstrated in this chapter.

3.1 DETAILS OF EXPERIMENTAL MATERIALS

3.1.1 Location of the Study Area

The field experiment was conducted at the Plasticulture Farm of College of Technology and Engineering, MPUAT Udaipur, transplanting of tomato crop were made from 5th July 2018 to 5th December 2018. However, final harvesting was done on 20th May 2019.

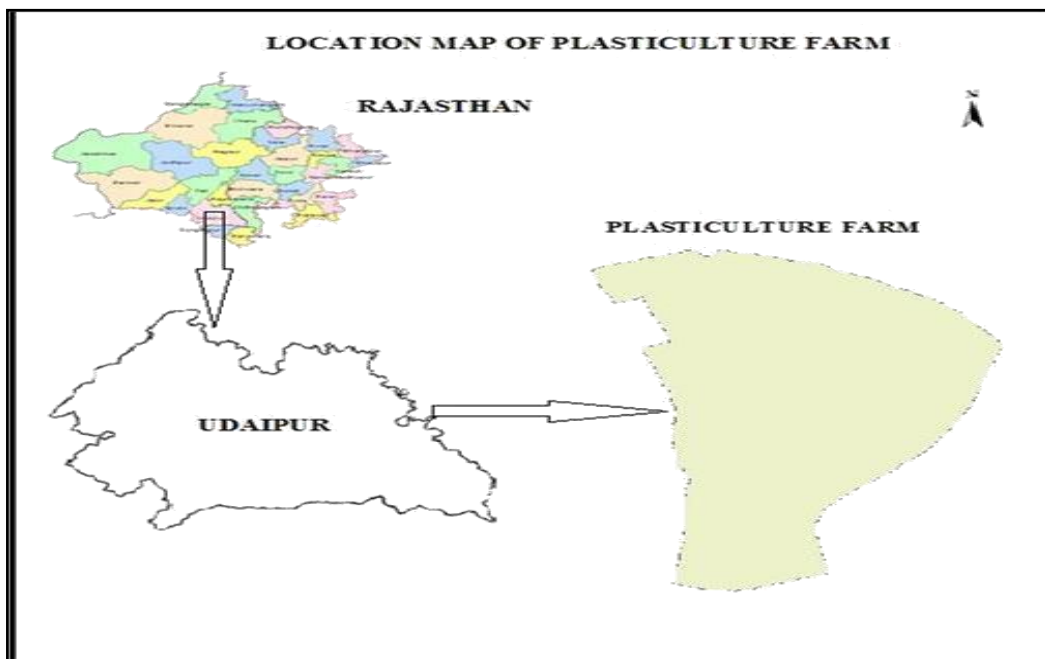


Fig. 3.1 Location map of the study area plasticulture farm, CTAE, Udaipur

3.1.2 Geographical Location

Udaipur is situated in the southern region of Rajasthan at 24° 35'31.5" to 24° 35'38.5" N-latitude, 73° 44'18.2" to 73° 44'21.1" E-longitude and at an Altitude of 582.17 meter above the mean sea level.

3.1.3 Climatic Conditions of Study Area

3.1.3.1 General climatic conditions

Udaipur comes under sub-humid agro-climatic region. It receives an average annual rainfall of 654.3 mm, most of the received during the period of July to September. May is the hottest and December is the coolest month of the year. The maximum temperature goes as high as 46 °C during summer and minimum as low as 5 °C during winter months. The atmospheric humidity is high from June to October.

3.1.3.2 Climatological data

The meteorological data of significant weather parameters were collected on a daily basis from the meteorological observatory of Department of Soil and Water Engineering, CTAE, Udaipur. The meteorological data for a period of 5 years (2013-2017) were collected in this study. The meteorological data include daily parameters (i.e. maximum temperature (Tmax) and minimum temperature (Tmin), maximum relative humidity (RHmax), minimum relative humidity (RHmin), wind speed at the height of 3 m, pan evaporation, and sunshine hours).

Dry and wet bulb thermometers located inside the polyhouse was used to determine relative humidity values inside the polyhouse.

3.1.4 Soil Analysis

The Physio-chemical properties of the soil in the study area were analyzed by adopting the standard methods given in Table 3.1 and 3.2. The representative samples of soil were collected from the field. The samples were mixed thoroughly and air dried in the shade. The stones, roots and other debris were separated out from the soil samples. A composite sample weighing 1 kg was obtained and powdered in a wooden mortar and pestle, sieved through a 2 mm sieve and analyzed for its physical and chemical properties by using standard methods.

Table 3.1 Methods to determine physical properties of soil

S. No.	Details	Method used	Reference
1.	Soil texture a) Sand (%) b) Silt (%) c) Clay (%)	Buoyoucos hydrometer method (1927)	Buoyoucos (1927)
2.	Textural class	Triangular diagram of Pursuit, Tylor and Marshall	Piper (1956)
3	Bulk Density (g/cm ³)	Core sampler method	Black (1965)
4.	Field capacity (%)	Pressure plate apparatus	Richards (1947)
5.	Permanent wilting point (%)	Pressure plate apparatus	Richards (1947)

Table 3.2 Methods to determine chemical properties of soil

S. No.	Details	Instrument used	Reference
1.	pH	pH meter	Jackson (1973)
2.	EC (dS/m)	EC meter	Jackson (1973)
3.	Available N (kg/ha)	KEL PLUS semi auto Analyzer	Subbiah and Arija (1956)
4.	Available P (kg/ha)	Olsen Olsen's method	Olsen (1954)
5.	Available K (kg/ha)	Flame photometer	Hanway and Heidal (1952)
6.	Organic carbon	Wet Digestion and Titration	Walkey and Black (1934)

3.1.5 Structural Details

In this research work a well established naturally ventilated polyhouse fully covered with 50 % shading net with manually operated mechanism for expanding and retracting at Plasticulture Farm, CTAE, Udaipur has been used. The size of structure is 32 m × 24 m i.e. 768 m² and it have south side face opening gate. Curtains are having roll up provision and insect net firm. 200 micron transparent plastic film is used as curtain provided up to 3 m height on all sides and provision for manual opening and closing of curtain provided 40 mesh nylon insect proof nets of equivalent

size fixed inside the curtains. This structure is constructed away from buildings, trees and also away from industrial or vehicular pollutants. The site is free from drainage problems. There is good provision of electricity and good quality irrigation water.

3.1.6 Drip Irrigation System

The irrigation is operated by a suitable capacity of water pump and which is used to supply water through the components of the drip irrigation system at a specific level of pressure. There are twenty- four laterals in each at a distance from 1 m and length of 16 m. Each lateral is fitted with micro valve to operate the particular lateral. The drippers are fitted at the interval of 30 cm on one raised bed two rows of tomato were planted and single lateral has been used for irrigation.

3.1.6.1 Details of drip irrigation system

The details of drip irrigation system installed for application of water in the experimental field is as follows:

Main and submain pipe	: PVC
Size of main pipe	: 63 mm (Outer Diameter)
Size of sub main/manifold pipe	: 53 mm (Outer Diameter)
Lateral pipe	: 16-2-30 (16 mm- Diameter, 2 lph- Discharge,30 cm-Emitter distance)
Size of lateral	: 8 mm
Type of dripper	: inbuilt
Discharge of emitter	: 2 lph
Spacing between lateral	: 1 m
Number of laterals per treatment	: One
Number of drippers per lateral	: 53

3.1.7 Treatment Details

3.1.7.1 Transplanting dates and irrigation treatments

The irrigation will be based on crop evapotranspiration (ET_c) for tomato crop and will be determined by using climatological parameters. The drip irrigation with 100% ET_c is common for all treatments and other details of treatments are given as follow.

- T1: Transplanting of crop in 1st week of July
- T2: Transplanting of crop in 1st week of August
- T3: Transplanting of crop in 1st week of September
- T4: Transplanting of crop in 1st week of October
- T5: Transplanting of crop in 1st week of November
- T6: Transplanting of crop in 1st week of December

All treatments will be arranged randomly with four replication R1, R2, R3, R4 for each treatment.

3.1.7.2 Experimental design and layout

The experiment will be conducted in randomized block design with four replications R1, R2, R3, and R4 under polyhouse. Thereafter, six treatments will also be randomly arranged in the equally sized beds of 16 m × 0.8 m area. Each treatment will be comprised of 64 plants of tomato, out of which 5 plants will be selected randomly for observation of plant parameters. The layout of polyhouse is depicted in Fig. 1 and other details of experiment are as under.

Design	:	Randomized Block Design (RBD)
No. of replication	:	4
Treatment	:	6
Bed size	:	0.8 m × 16 m
Experimental field size	:	32 m × 16 m (512 m)
Gross field size	:	32 m × 24 m (768)
Plant Spacing	:	0.5 m × 0.5 m
Crop and Variety	:	Tomato, cv 'Dev'
No. of plants per row	:	32
No. of rows in each bed	:	2
Total no. of plants in each bed	:	64

The layout of the poly house is depicted in Fig. 3.2 and other details of the experiment are given below:

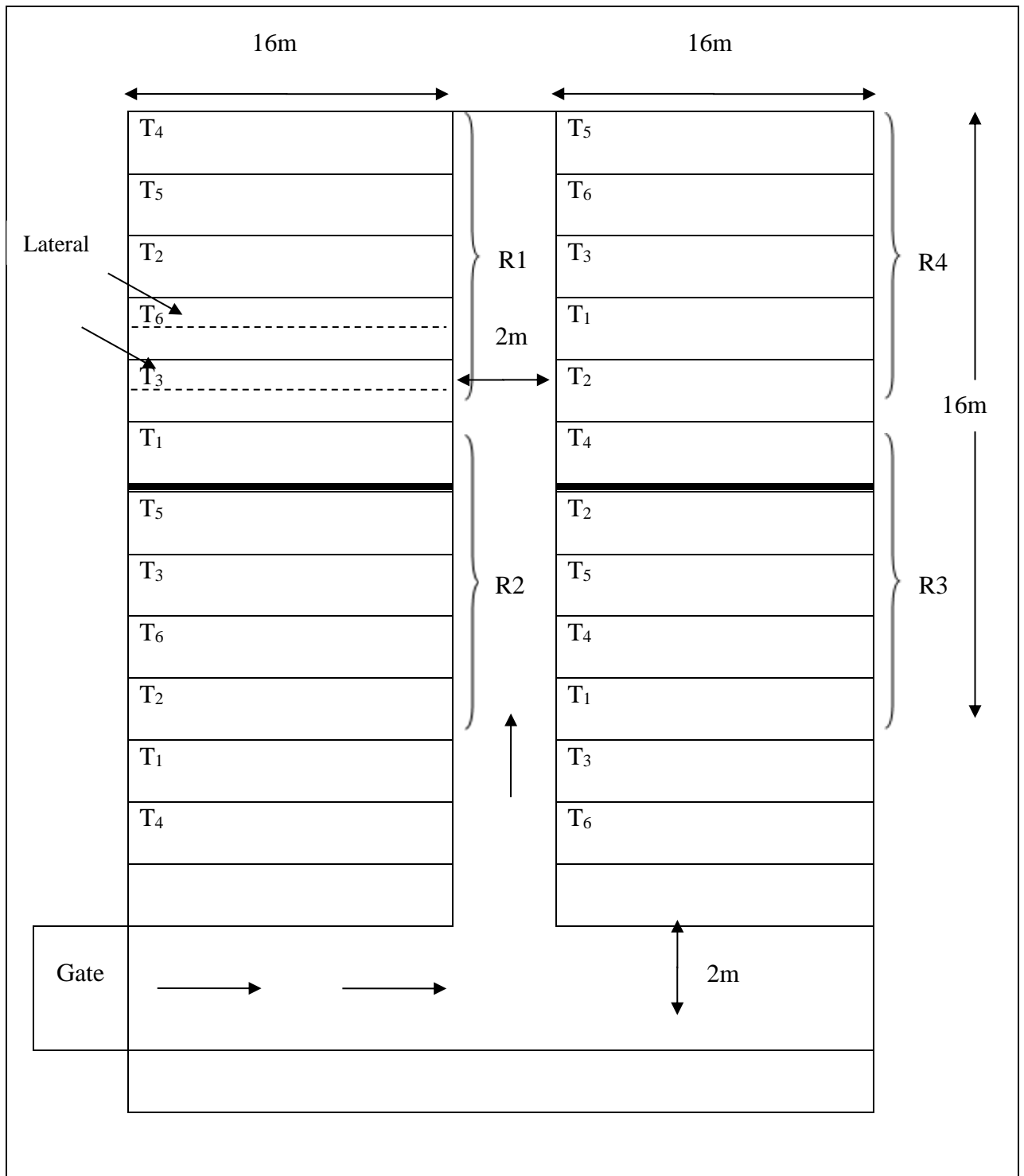


Fig. 3.2 Experimental layout inside polyhouse

Bed Width = 80cm, Gallery between beds = 20 cm, Path = 2 m



Plate 3.1 Prepared beds inside polyhouse



Plate 3.2 Gap filling of tomato crop inside polyhouse



Plate 3.3 Experimental view of tomato crop inside polyhouse

3.2 DETERMINATION OF WATER REQUIREMENT FOR TOMATO CROP

3.2.1 Determination of Water Requirement Before Growing of Crop From Last Five Year Metrological Data

Meteorological data: daily parameters (i.e., maximum temperature (Tmax) and minimum temperature (Tmin), maximum relative humidity (RHmax) and minimum relative humidity (RHmin), wind speed at height of 3 m, sun shine hours and pan evaporation.) have been collected from meteorological observatory of Department of Soil and Water Engineering, CTAE, Udaipur. Meteorological data for a period of 5 year were used in the study. The water requirement of plants varies with time and depends on the season and growth of plants. It is essential to irrigate optimally during the stage of flowering to fruit maturity. Water requirement of the plant will be evaluated to design the system and for that the following method will be used.

3.2.1.1 Estimation of reference crop evapotranspiration (ET₀)

The evapotranspiration rate from a reference surface, not short of water, is called the reference evapotranspiration and is denoted as ET₀. The factors affecting ET₀ are the climatic parameters which can be computed from weather data. ET₀ represents the evaporating power of atmosphere at a specific location and time of the year; it does not consider the crop characteristics and soil factor.

For pre scheduling of crop water requirement the daily reference evapotranspiration outside the polyhouse form last 5 year data have been determined by using the standard method i.e. Penman-Monteinth (Allen et al., 1998) for the present study and is given by

$$ET_0 = \frac{0.408 \Delta (R_n - G) + \gamma \left(\frac{900}{T + 273} \right) u_2 (e_s - e_a)}{\Delta + \gamma (1 + 0.34 u_2) * E_0} \quad \dots (3.1)$$

Where,

- ET₀ = Reference evapotranspiration, (mm/day)
- G = Soil heat flux density, (MJ/m²/day)
- R_n = Net radiation, (MJ/m²/day)
- T = Mean daily air temperature, (°C)

Γ	=	Psychometric constant, (kPa/ ⁰ C)
Δ	=	Slope of saturation vapour pressure function, (kPa/ ⁰ C)
e_s	=	Saturated vapour pressure at air temperature T, (kPa)
e_a	=	Actual vapour pressure at dew point temperature, (kPa)
u_2	=	Average daily wind speed at 2 m height, (m/sec)

3.2.1.2 Crop Evapotranspiration:

Crop evapotranspiration obtained as:

$$ET_C = K_C \times ET_0 \quad \dots (3.2)$$

Where,

ET_C	=	Crop evapotranspiration, (mm/day)
K_c	=	Crop coefficient
ET_0	=	Reference Crop Evapotranspiration, (mm/day)

3.2.1.3 Water requirement

The water requirement of plants varies with time and depends on the season and growth of plants. It is essential to irrigate optimally during the stage of flowering to fruit maturity. Water requirement of the plant will be evaluated to design the system and for that the following equation will be used.

$$W_r = \frac{\text{Crop area} \times ET_0 \times K_c \times W_a}{E_u} \quad \dots (3.3)$$

Where,

W_r	=	Peak water requirement, (lit/day/plant)
Crop area	=	Row to row spacing (m) \times Plant to plant spacing (m) of the crop
ET_c	=	Crop evaporation rate, (mm/day)
K_c	=	Crop Coefficient
W_a	=	Wetted area, (%)
E_u	=	Emission Uniformity of drip system, decimal

3.2.1.4 Determination of emission uniformity (Eu)

This term has generally been used to describe the emitter flow variation for a drip irrigation unit. The discharges collected at each emitting device as per procedure for developing pressure-discharge relationship was used for determining the emission uniformity of the system. The following equation as suggested by (Keller and Karmeli, 1975) was used.

$$Eu = (q_n / q_a) \times 100 \quad \dots(3.4)$$

Where,

- Eu = Emission uniformity of drip system, decimal
- qn = Average of the lowest ¼ of the emission point discharges for field data, lph.
- Qa = Average emission point discharge of test sample operated at the reference pressure head, lph.

3.3 PHYSIOLOGICAL PARAMETER AND YIELD OF CROP

3.3.1 Experimental Procedure

The crop was grown in polyhouse by adopting the recommended package of practices.

3.3.2 Planting

About 1 month old seedling of tomato (Variety- Dev) was transplanted according to the crop spacing of 50 × 50 cm.

3.3.3 Fertilizer Application

The nutrient requirement for tomato is 200:250:250 kg of NPK per ha. 75 % of P (187.5 kg P which comes to 1172 kg of superphosphate) is applied as basal. The remaining quantity of 200:62.5:250 kg of NPK per ha is applied through fertigation. The total quantity of the requirement of 19:19:19 is 132 kg, 12:61:0 is 62 kg, 13:0:45 is 500 kg and Urea is 223 kg per ha. Micro nutrients are also use and it may depend on the edaphic factors of soil. Fertilizer has been applied as per recommended dose.

3.3.4 Irrigation

The plants are irrigated as per recommended schedule with drip irrigation system. Plants are watered before 12 noon or late evening.

3.3.5 Gap Filling

The practice of gap filling was completed 20 days after planting the tomato to maintain total plant population.

3.3.6 Weeding

Weeding was done by scrapping weeds out of the soil with a hoe as per the standard agronomic practices.

3.3.7 Plant Protection Measures (Disease and Pest Control)

Any insect or disease that damage leaves can reduce the amount of light intercepted by the canopy and limit the growth. In order to protect the crop from the attack of insect and pests, Shikari (Insecticides) solution with deltamethrin and triazophos an emulsifiable concentrate were sprayed at 30 days interval as a precautionary measure against mites and other insects. To protect the crop from powdery mildew disease, Karatane @ 1 ml/l water has been sprayed at 15 days intervals. Several tomato disease and disorder causes leaf spot and fruit rots. So for that purpose a standered management practice has been followed as per the guide line of plant protection measures.

3.4 OBSERVATIONS

3.4.1 Biometric Observations

For recording various biometric observations five sample plants were selected from each treatment and tagged for their identification. The various biometric observations such as plant height, time required for first harvest, were recorded.

3.4.1.1 Plant height

Five plants were tagged at random in each treatment for recording the plant height at an interval of 30 days starting from the days of transplanting (DAT). The plant height was measured from the ground level to the growing tip of the main stem at 30, 60, 90, 120, 150 and 180 days after transplanting (DAT). The average height was calculated and expressed in centimetres.

3.4.1.2 Time required for first harvest

The individual flowers have been tagged and the same fruits have been harvested at maturity by recording the date of harvest and number of days were counted and recorded.

3.4.2 Reproductive Parameters

The reproductive parameters such as number of flowers per plant, number of fruits per plant, percent fruit set were evaluated for the study.

3.4.2.1 Number of flowers per plant

The fully opened flowers were counted, summed and mean was calculated at 60, 90, 120, 150 and 180 days for each tagged plant and recorded.

3.4.2.2 Number of fruits per plant

The number of mature fruits that were harvested from the tagged plants in each picking was recorded till the final harvest.

3.4.3 Yield Parameters

The yield parameters such as individual fruit weight (gm), fruit yield per plant (kg), fruit yield (ton/ha) was evaluated for the study.

3.4.3.1 Individual fruit weight

The numbers of fresh tomato fruits harvested from the labelled plants from each treatment were counted; weighed and average individual fruit weight was calculated and recorded in grams.

3.4.3.2 Fruit yield per plant

The weight of mature fruits harvested from each picking was recorded till final harvest and total yield of fruits per plant was recorded in kilograms.

3.4.3.3 Fruit yield

The weight of mature fruits harvested from each picking in tagged plants in each replication was recorded till final harvest and the total yield of fruits per hectare was computed and expressed in tons per hectare.

3.5 STATISTICAL ANALYSIS

The statistical analysis of data was carried out by statistical method known as “Analysis of variance” (ANOVA) appropriate for the “Randomized Block Design”. The standard error (SE) for each factor and their interaction was worked out. Wherever, the results vary significantly, critical difference (CD) at five percent level of significance was worked out.

3.6 MODELLING OF CLIMATIC PARAMETERS WITH YIELD

PARAMETER OF TOMATO CROP

In this study, we will use regression analysis modelling which investigates the relationship between a dependent and independent variable. Crop yield will be considered as a dependent variable and average air temperature and average relative humidity will be considered as independent variables. Regression Analysis will be used to find the relative strength between a dependent variable and an independent variable i.e. impact of average air temperature on yield and average relative humidity on yield with respect to crop stages.

3.6.1 Regression Analysis

Regression analysis is used to analyze and determine the relationship between response variable and explanatory variable. Regression Analysis is a commonly used technique in the research where relationship among the two considered variables (average air temperature and average relative humidity) has to be established and to identify their effects on crop yield. Crop yield is considered as a dependent variable and average air temperature and average relative humidity are considered as independent variables. Regression Analysis is used to find the relative strength between a dependent variable and an independent variable i.e. impact of average air temperature on yield and average relative humidity on yield with respect to crop stages.

3.6.2 Simple Linear Regression Analysis

The crop yield will be predicted using different climatic parameters (humidity and air temperature). In which, taking crop yield as dependent variable and climatic parameter as independent variable linear regression analysis will be carried out (Nageshwara Rao, 2008).

$$Y = a + \beta X \quad \dots (3.5)$$

Where,

A	=	Intercept
β	=	Slope of regression line or Regression coefficient
Y	=	Predicted yield
X	=	Climatic parameters (Humidity and Air temperature)

3.7 WATER USE EFFICIENCY

The water use efficiency will be determined by the ratio of yield and water applied

$$WUE = \frac{Y}{WR} \quad \dots (3.6)$$

Where,

WUE	=	Water use efficiency, (kg/m ³)
Y	=	Crop yield, (kg/m ²)
WR	=	Water requirement, (m)

3.8 ECONOMIC ANALYSIS

3.8.1 Cost of Cultivation

The cost of production was worked out for each treatment. The cost includes paid out cost on hired human labour, seeds, water charges, interest on working capital, interest on fixed capital, depreciation, repair and maintenance charges for drip irrigation system and polyhouse.

3.8.2 Net Income

The net income was worked out by subtracting the cost of production from the gross momentary returns in each treatment. The net income was calculated using Eq. 3.11 as shown:

$$\text{Net returns (Rs/ha)} = \text{Gross returns (Rs/ha)} - \text{Cost of cultivation (Rs/ha)} \quad \dots (3.7)$$

3.8.3 Output - Input Ratio

The Output- input ratio was worked out by dividing the cost of income from produce to the cost of production in each treatment under study. Generally, if the output- input ratio is greater than one, then the investment of that project can be considered as economically viable. The output- input ratio was calculated using Eq.3.12 as shown:

$$\text{Output - input ratio} = \frac{\text{Income from Produce (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}} \quad \dots (3.8)$$

CHAPTER - IV

RESULTS AND DISCUSSION

4.1 GENERAL

This chapter deals with the examination of results obtained through the analysis of the data collection using techniques described in the chapter materials and methods. In this study, six different transplanting dates as treatments were considered under the effect of modeling of climatic parameters on growth and yield of tomato crop during second half of the year grown under naturally ventilated polyhouse.

The field experiment was carried out to estimate crop water requirement for tomato crop under different transplanting dates, to study the effect of climate on different dates of transplanting on growth and yield of tomato crop, modeling of effect of variation of temperature and relative humidity on growth parameters and yield of tomato crop and to estimate the water use efficiency under drip irrigated system in tomato. In order to check the economic viability of the polyhouse cultivation, the economic analysis of tomato production is also demonstrated in this chapter. The achieved results of the field experiment supported with the suitable discussion are presented in this chapter.

4.2 SOIL SAMPLING AND ANALYSIS

The soil samples were collected under polyhouse with the help of screw auger hole. The soil of the experiment site was analyzed at Department of Agriculture Chemistry and Soil Science, Rajasthan College of Agriculture (RCA), Udaipur. A composite soil sample was collected from 0-20 cm depth prior to planting during the study and analyzed for particle size distribution, bulk density, field capacity, wilting point, Hydraulic conductivity, EC, OC, CC, N, P, K, and pH. Details of soil physical and chemical properties of the experiment site are shown in Table 4.1.

Study of infiltration characteristics of soil has been done on the experimental field. The value of basic infiltration rate of soil was depicted in Table 4.1. The physiological character of crop observed under the structure with an interval and the climatic data were taken regularly under structure.

Table 4.1 Physical and chemical properties of soil

S. No.	Soil property	Soil depth (0-20 cm)
A.	Physical properties of soil	
1.	Soil texture	
	a) Sand (%)	69.37
	b) Silt (%)	18.26
	c) Clay (%)	12.37
2.	Texture	Sandy loam
3.	Bulk Density (g/cm ³)	1.46
4.	Basic infiltration rate (cm/hr)	2.8
5.	Field capacity (%)	20.95
6.	Permanent wilting point (%)	6.8
B.	Chemical properties of soil	
1.	pH	7.78
2.	EC (dS/m)	1.19
3.	Available N (kg/ha)	130.50
4.	Available P (kg/ha)	29.12
5.	Available K (kg/ha)	160.50
6.	Organic carbon (%)	0.434

4.3 DETAIL INFORMATION OF TOMATO CROP

The detail information about the tomato crop *i.e.* date of planting and harvesting, crop duration, growth stages, is depicted in Table 4.2

Table 4.2 Detail of crop duration and growth stages of tomato crop

Crop	Dates of Transplanting	Date of Harvesting	Duration (Days)	Growth Stages			
				1.	2.	3.	4.
Tomato	5.07.2018	11.01.2019	186	35	45	74	30
	5.08.2018	5.03.2019	210	35	45	100	30
	5.09.2018	1.04.2019	207	35	45	97	30
	5.10.2018	3.05.2019	209	35	45	99	30
	5.11.2018	10.05.2018	185	35	45	75	30
	5.12.2018	25.05.2018	160	35	45	60	30

4.4 DETERMINATION OF CROP WATER REQUIREMENT FOR TOMATO CROP UNDER DIFFERENT TRANSPLANTING DATES

4.4.1 Determination of Weekly Reference Evapotranspiration (ET₀) Outside the Naturally Ventilated Polyhouse on the Basis of 5 Year Data for All Treatments

The daily climatic data of last 5 year for the crop period were used to determine daily reference evapotranspiration outside the NVPH for entire crop period and converted into weekly reference evapotranspiration. The daily reference evapotranspiration (ET₀) was computed using FAO-56 Penman-Monteith Method for Udaipur.

4.4.1.1 Weekly reference evapotranspiration (ET₀) for treatment 1 (T1)

The daily climatic data for the period July 2013- Dec 2013 to July 2017- Dec 2017 to i.e., (5 years) were used to determine the weekly reference evapotranspiration outside the NVPH (ET_{0 out}) and is presented in Table 4.3.

Table 4.3 Estimated weekly reference evapotranspiration (ET₀) outside the NVPH for T1

Year Std. Met. Week	Reference Evapotranspiration, mm/day					
	July-13 to Dec-13	July-14 to Dec-14	July-15 to Dec-15	July-16 to Dec-16	July-17 to Dec-17	Mean
27	3.22	4.58	3.47	3.28	4.76	3.86
28	3.41	4.11	3.19	2.79	4.50	3.60
29	3.17	3.33	2.62	3.81	3.90	3.36
30	3.11	3.10	2.34	3.50	2.59	2.93
31	2.65	3.53	4.61	2.49	4.57	3.57
32	2.59	3.05	4.39	2.45	4.86	3.47
33	3.12	4.39	4.45	4.15	4.85	4.19
34	3.02	4.34	4.57	2.73	3.97	3.73
35	3.89	3.63	4.82	3.62	3.25	3.84
36	2.78	2.44	4.38	4.28	4.64	3.70
37	3.62	3.44	4.42	4.23	4.51	4.04
38	3.61	4.18	3.22	4.27	4.24	3.90
39	3.19	3.96	4.20	3.85	3.84	3.81
40	3.81	3.87	3.98	2.95	3.95	3.71
41	3.32	3.74	3.69	3.67	3.68	3.62
42	2.93	3.63	3.53	3.14	3.33	3.31
43	3.13	3.23	3.34	2.88	3.09	3.14
44	2.70	2.91	2.98	2.57	2.85	2.80
45	2.31	2.81	2.82	2.47	2.66	2.61
46	2.18	2.45	2.71	2.34	2.37	2.41
47	2.09	2.42	2.21	2.18	2.29	2.24
48	2.18	2.27	2.37	2.20	2.20	2.24
49	1.88	2.18	2.12	2.04	2.03	2.05
50	2.01	1.99	2.04	1.98	1.93	1.99
51	1.90	1.74	1.79	2.01	1.89	1.87
52	1.65	1.81	1.90	1.90	1.87	1.83
ET₀ (mm)	506.25	570.08	594.63	536.48	607.88	563.07

It has been found that the total reference evapotranspiration outside NVPH was recorded 563.07 mm during the crop period of 180 days from last 5 year data.

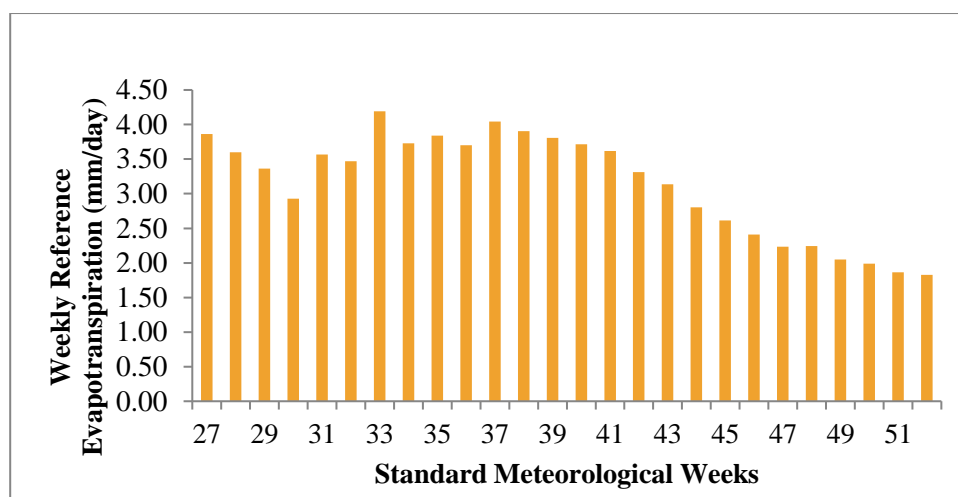


Fig. 4.1 Weekly average reference evapotranspiration for T1

From Fig. 4.1 it is observed that the maximum and minimum mean reference evapotranspiration outside the NVPH over the crop growth period are 4.19 mm/day (33rd week) and 1.83 mm/day (52th week) respectively.

4.4.1.2 Weekly reference evapotranspiration (ET₀) for treatment 2 (T2)

The daily climatic data for the period Aug 2013- Jan 2014 to Aug 2017- Jan 2018 to i.e., (5 years) were used to determine the weekly reference evapotranspiration outside the NVPH (ET_{0 out}) and is presented in Table 4.4.

Table 4.4 Estimated weekly reference evapotranspiration ET₀ outside the NVPH for T2

Year Std. Met. Week	Reference Evapotranspiration, mm/day					Mean
	Aug-13 to Jan-14	Aug-14 to Jan-15	Aug-15 to Jan-15	Aug-16 to Jan-17	Aug-17 to Jan-18	
32	2.59	3.05	4.39	2.45	4.86	3.47
33	3.12	4.39	4.45	4.15	4.85	4.19
34	3.02	4.34	4.57	2.73	3.97	3.73
35	3.89	3.63	4.82	3.62	3.25	3.84
36	2.78	2.44	4.38	4.28	4.64	3.70
37	3.62	3.44	4.42	4.23	4.51	4.04
38	3.61	4.18	3.22	4.27	4.24	3.90
39	3.19	3.96	4.20	3.85	3.84	3.81
40	3.81	3.87	3.98	2.95	3.95	3.71
41	3.32	3.74	3.69	3.67	3.68	3.62
42	2.93	3.63	3.53	3.14	3.33	3.31
43	3.13	3.23	3.34	2.88	3.09	3.14

44	2.70	2.91	2.98	2.57	2.85	2.80
45	2.31	2.81	2.82	2.47	2.66	2.61
46	2.18	2.45	2.71	2.34	2.37	2.41
47	2.09	2.42	2.21	2.18	2.29	2.24
48	2.18	2.27	2.37	2.20	2.20	2.24
49	1.88	2.18	2.12	2.04	2.03	2.05
50	2.01	1.99	2.04	1.98	1.93	1.99
51	1.90	1.74	1.79	2.01	1.89	1.87
52	1.65	1.81	1.90	1.90	1.87	1.83
1	1.63	1.86	2.28	1.94	1.81	1.90
2	1.64	2.01	2.36	1.72	1.90	1.93
3	1.92	2.04	2.01	1.95	2.24	2.03
4	1.77	2.15	2.02	2.09	2.29	2.06
5	2.20	2.09	2.48	2.53	2.45	2.35
ET₀ (mm)	464.535	518.594	565.157	499.673	550.086	519.609

It has been found that the total reference evapotranspiration outside NVPH was recorded 519.60 mm during the crop period of 180 days from last 5 year data.

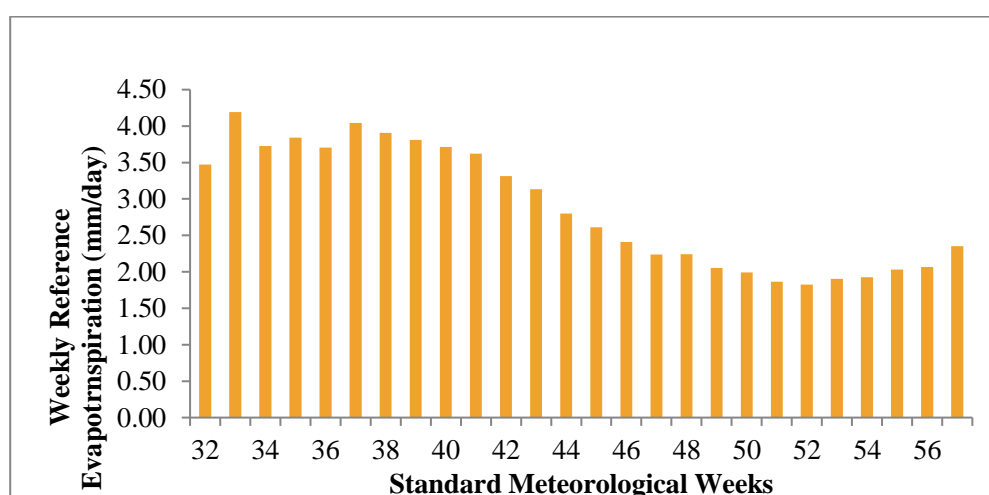


Fig. 4.2 Weekly average reference evapotranspiration for T2

From Fig. 4.2 it is observed that the maximum and minimum mean reference evapotranspiration outside the NVPH over the crop growth period are 4.19 mm/day (33rd week) and 1.83 mm/day (52th week) respectively.

4.4.1.3 Weekly reference evapotranspiration (ET₀) for treatment 3 (T3)

The daily climatic data for the period Sept 2013- Feb 2014 to Sept 2017- Feb 2018 to i.e., (5 years) were used to determine the weekly reference evapotranspiration outside the NVPH (ET_{0 out}) and is presented in Table 4.5.

Table 4.5 Estimated weekly reference evapotranspiration ET₀ outside the NVPH for T3

Year Std. Met. Week	Reference Evapotranspiration, mm/day					
	Sept-13 to Feb- 14	Sept-14 to Feb-15	Sept-13 to Feb-14	Sept-13 to Feb-14	Sept-13 to Feb-14	Mean
36	2.77	2.49	4.30	4.17	4.66	3.68
37	3.62	3.44	4.42	4.23	4.51	4.04
38	3.61	4.18	3.22	4.27	4.24	3.90
39	3.19	3.96	4.20	3.85	3.84	3.81
40	3.81	3.87	3.98	2.95	3.95	3.71
41	3.32	3.74	3.69	3.67	3.68	3.62
42	2.93	3.63	5.35	3.14	3.33	3.68
43	3.13	3.23	3.34	2.88	3.09	3.14
44	2.72	2.91	2.98	2.59	2.85	2.81
45	2.31	2.81	2.82	2.47	2.66	2.61
46	2.13	2.45	2.71	2.34	2.37	2.40
47	2.08	2.42	2.21	2.18	2.29	2.23
48	2.18	2.27	2.37	2.20	2.20	2.24
49	1.82	2.18	2.12	2.04	2.03	2.04
50	2.00	1.99	2.04	1.98	1.93	1.99
51	1.85	1.74	1.79	2.01	1.89	1.86
52	1.57	1.81	1.90	1.90	1.87	1.81
1	1.63	1.86	2.28	1.94	1.81	1.90
2	1.64	2.01	2.36	1.72	1.90	1.93
3	1.92	2.04	2.01	1.95	2.24	2.03
4	1.77	2.15	2.02	2.09	2.29	2.06
5	2.27	2.34	2.51	2.57	2.45	2.43
6	2.77	2.66	2.56	2.90	2.38	2.66
7	2.41	3.01	3.01	3.02	2.90	2.87
8	2.80	3.45	2.95	3.31	3.23	3.15
9	2.48	2.32	3.37	2.60	3.10	2.77
ET₀ (mm)	446.464	491.276	525.554	487.787	505.255	491.267

It has been found that the total reference evapotranspiration outside NVPH was recorded 419.26 mm during the crop period of 180 days from last 5 year data.

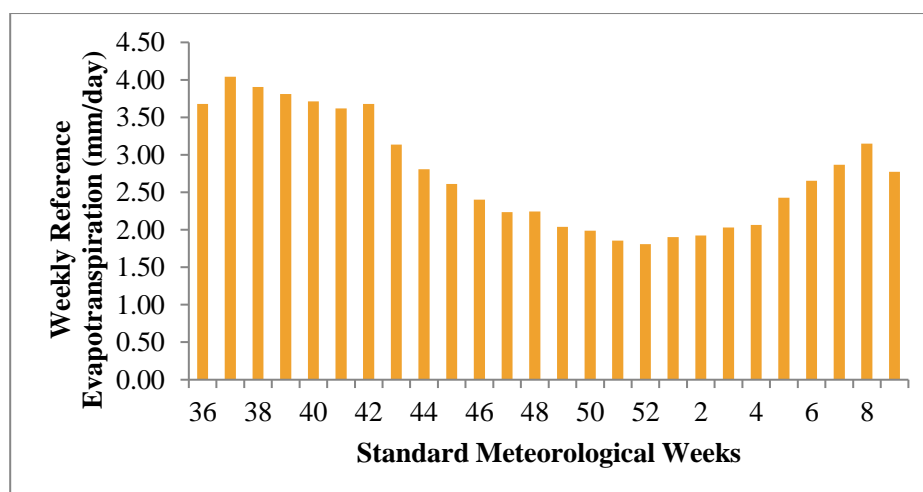


Fig. 4.3 Weekly average reference evapotranspiration for T3

From Fig. 4.3 it is observed that the maximum and minimum mean reference evapotranspiration outside the NVPH over the crop growth period is 4.04 mm/day (37th week) and 1.81 mm/day (52th week) respectively.

4.4.1.4 Weekly reference evapotranspiration (ET₀) for treatment 4 (T4)

The daily climatic data for the period Oct 2013- March 2014 to Oct 2017- March 2018 to i.e., (5 years) were used to determine the weekly reference evapotranspiration outside the NVPH (ET_{0 out}) and is presented in Table 4.6.

Table 4.6 Estimated weekly reference evapotranspiration ET₀ outside the NVPH for T4

Year Std. Met. Week	Reference Evapotranspiration, mm/day					
	Oct-13 to March-14	Oct-14 to March-15	Oct-15 to March-16	Oct-16 to March-17	Oct-17 to March-18	Mean
40	3.81	3.83	3.81	2.76	3.88	3.62
41	3.32	3.74	3.69	3.67	3.68	3.62
42	2.93	3.63	3.54	3.14	3.33	3.32
43	3.13	3.23	3.34	2.88	3.09	3.14
44	2.72	2.91	2.98	2.59	2.85	2.81
45	2.31	2.81	2.82	2.47	2.66	2.61
46	2.13	2.45	2.71	2.34	2.37	2.40
47	2.08	2.42	2.21	2.18	2.29	2.23
48	2.18	2.27	2.37	2.20	2.20	2.24
49	1.82	2.18	2.12	2.04	2.03	2.04
50	2.00	1.99	2.04	1.98	1.93	1.99
51	1.85	1.74	1.79	2.01	1.89	1.86

52	1.57	1.81	1.90	1.90	1.87	1.81
1	1.63	1.86	2.28	1.94	1.81	1.90
2	1.64	2.01	2.36	1.72	1.90	1.93
3	1.92	2.04	2.01	1.95	2.24	2.03
4	1.77	2.15	2.02	2.09	2.29	2.06
5	2.27	2.34	2.51	2.57	2.45	2.43
6	2.77	2.66	2.56	2.90	2.38	2.66
7	2.41	3.01	3.01	3.02	2.90	2.87
8	2.80	3.45	2.95	3.31	3.23	3.15
9	2.62	2.51	3.45	2.45	3.28	2.86
10	3.28	3.49	4.11	1.79	3.88	3.31
11	3.85	3.57	4.06	1.92	4.16	3.51
12	4.09	3.98	4.73	1.99	4.26	3.81
13	4.42	4.60	4.41	2.24	4.62	4.06
ET₀ (mm)	460.013	497.705	520.544	427.717	503.882	481.007

It has been found that the total reference evapotranspiration outside NVPH was recorded 481.07 mm during the crop period of 180 days from last 5 year data.

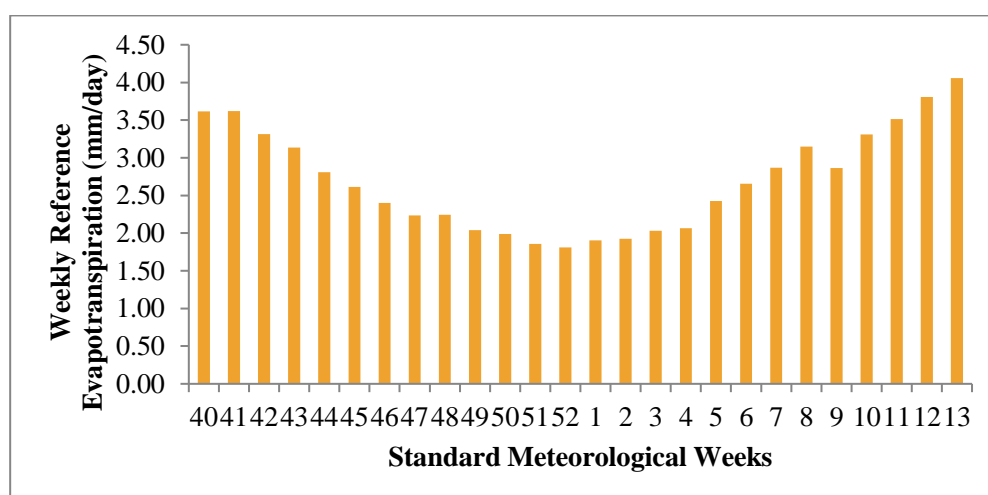


Fig. 4.4 Weekly average reference evapotranspiration for T4

From Fig. 4.4 it is observed that the maximum and minimum mean reference evapotranspiration outside the NVPH over the crop growth period are 4.06 mm/day (13th week) and 1.82 mm/day (52th week) respectively.

4.4.1.5 Weekly reference evapotranspiration (ET₀) for treatment 5 (T5)

The daily climatic data for the period Nov 2013- April 2014 to Nov 2017- April 2018 to i.e., (5 years) were used to determine the weekly reference evapotranspiration outside the NVPH (ET_{0 out}) and is presented in Table 4.7.

Table 4.7 Estimated weekly reference evapotranspiration ET₀ outside the NVPH for T5

Year Std. Met. Week	Reference Evapotranspiration, mm/day					
	Nov-13 to April-14	Nov-14 to April-15	Nov-15 to April-16	Nov-16 to April-17	Nov-17 to April-18	Mean
45	2.31	2.81	2.82	2.47	2.66	2.61
46	2.13	2.45	2.71	2.34	2.37	2.40
47	2.08	2.42	2.21	2.18	2.29	2.23
48	2.18	2.27	2.37	2.20	2.20	2.24
49	1.82	2.18	2.12	2.04	2.03	2.04
50	2.00	1.99	2.04	1.98	1.93	1.99
51	1.85	1.74	1.79	2.01	1.89	1.86
52	1.57	1.81	1.90	1.90	1.87	1.81
1	1.63	1.86	2.28	1.94	1.81	1.90
2	1.64	2.01	2.36	1.72	1.90	1.93
3	1.92	2.04	2.01	1.95	2.24	2.03
4	1.77	2.15	2.02	2.09	2.29	2.06
5	2.27	2.34	2.51	2.57	2.45	2.43
6	2.77	2.66	2.56	2.90	2.38	2.66
7	2.41	3.01	3.01	3.02	2.90	2.87
8	2.80	3.45	2.95	3.31	3.23	3.15
9	2.62	2.51	3.45	2.80	3.28	2.93
10	3.28	3.49	4.11	1.79	3.88	3.31
11	3.85	3.57	4.06	1.92	4.16	3.51
12	4.09	3.98	4.73	1.99	4.26	3.81
13	4.42	4.60	4.41	2.24	4.62	4.06
14	4.70	5.04	5.03	2.71	4.99	4.49
15	4.58	4.86	5.21	2.94	5.42	4.60
16	4.95	5.38	5.49	3.20	5.64	4.93
17	5.40	5.71	5.38	3.33	5.09	4.98
18	6.18	5.69	5.47	4.67	5.06	5.41
ET₀ (mm)	526.034	561.404	583.87	437.336	569.757	537.327

It has been found that the total reference evapotranspiration outside NVPH was recorded 537.32 mm during the crop period of 180 days from last 5 year data.

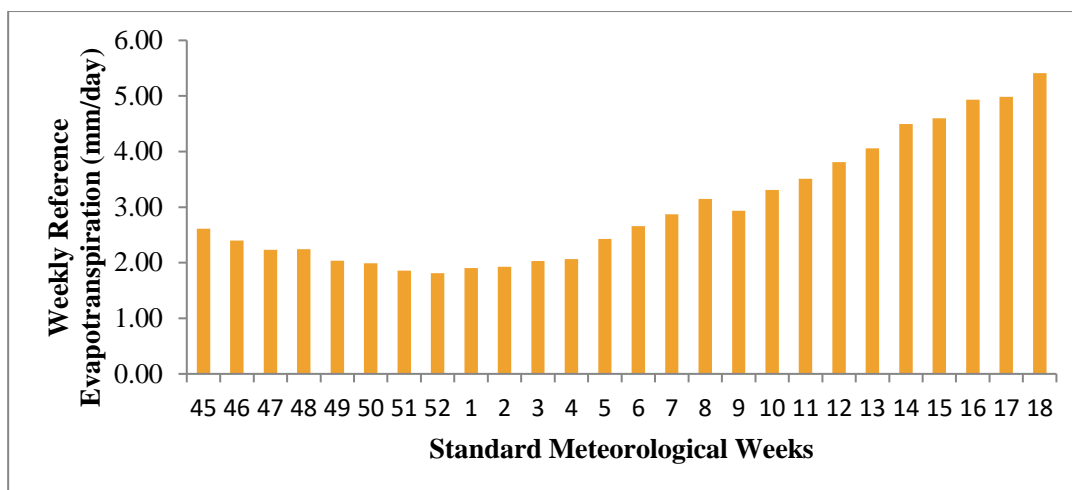


Fig. 4.5 Weekly average reference evapotranspiration for T5

From Fig. 4.4 it is observed that the maximum and minimum mean reference evapotranspiration outside the NVPH over the crop growth period are 5.41 mm/day (18th week) and 1.81 mm/day (52th week) respectively.

4.4.1.6 Weekly reference evapotranspiration (ET₀) for treatment 6 (T6)

The daily climatic data for the period Dec 2013- May 2014 to Dec 2017- May 2018 to i.e., (5 years) were used to determine the weekly reference evapotranspiration outside the NVPH (ET_{0 out}) and is presented in Table 4.8.

Table 4.8 Estimated weekly reference evapotranspiration ET₀ outside the NVPH for T6

Year Std. Met. Week	Reference Evapotranspiration, mm/day					
	Dec-13 to May-14	Dec -14 to May -15	Dec -15 to May -16	Dec -16 to May - 17	Dec -17 to May -18	Mean
45	49	1.85	2.18	2.03	1.97	1.97
46	50	2.00	1.99	2.04	1.98	1.93
47	51	1.85	1.74	1.79	2.01	1.89
48	52	1.57	1.81	1.90	1.90	1.87
49	1	1.63	1.86	2.28	1.94	1.81
50	2	1.64	2.01	2.36	1.72	1.90
51	3	1.92	2.04	2.01	1.95	2.24
52	4	1.77	2.15	2.02	2.09	2.29
1	5	2.27	2.34	2.51	2.57	2.45
2	6	2.77	2.66	2.56	2.90	2.38
3	7	2.41	3.01	3.01	3.02	2.90

4	8	2.80	3.45	2.95	3.31	3.23
5	9	2.62	2.51	3.45	2.45	3.28
6	10	3.28	3.49	4.11	1.79	3.88
7	11	3.85	3.57	4.06	1.92	4.16
8	12	4.09	3.98	4.73	1.99	4.26
9	13	4.42	4.60	4.41	2.24	4.62
10	14	4.70	5.04	5.03	2.71	4.99
11	15	4.58	4.86	5.21	2.94	5.42
12	16	4.95	5.38	5.49	3.20	5.64
13	17	5.40	5.71	5.38	3.33	5.09
14	18	6.01	5.63	5.89	4.77	5.07
15	19	6.00	6.26	5.80	5.43	5.01
16	20	6.16	6.13	5.82	5.84	5.40
17	21	6.11	6.65	6.75	5.74	6.15
18	22	6.56	6.84	5.95	5.67	5.70
ET₀ (mm)	646.285	678.356	692.101	536.441	664.237	643.484

It has been found that the total reference evapotranspiration outside NVPH was recorded 643.48 mm during the crop period of 180 days from last 5 year data.

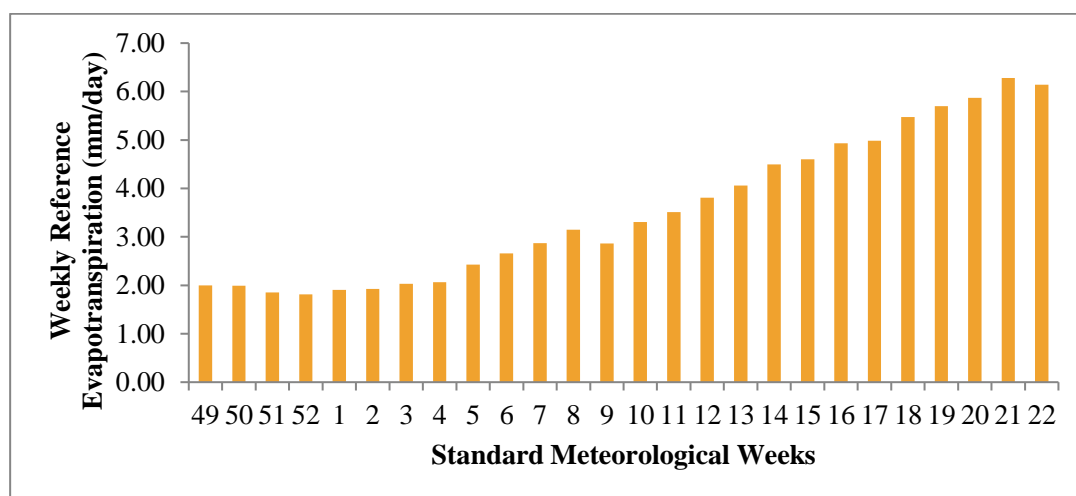


Fig. 4.6 Weekly average reference evapotranspiration for T6

From Fig. 4.4 it is observed that the maximum and minimum mean reference evapotranspiration outside the NVPH over the crop growth period are 6.15 mm/day (17th week) and 1.81 mm/day (49th week) respectively.

Rate of evapotranspiration is depending on the several factors like temperature, humidity, wind speed and also other factors. The rate of evapotranspiration increases when temperature increases and it is decrease with decrease in temperature. The relationship is vice versa for relative humidity.

4.4.2 Drip Irrigation System

The water is supplied by gravity fed drip irrigation system, in the experimental field. The details are as under:

Lateral spacing	:	1 m
Distance between two consecutive emitters	:	30 cm
Emitters discharge	:	2 lph
Lateral length	:	16 m
Total no. of plants per lateral	:	64
Sub main size	:	50 mm in diameter

4.4.2.1 Performance evaluation of drip irrigation system

The performance evaluation of drip irrigation system on the basis of data recorded were determination of emission uniformity. Three laterals position were selected head, middle and end of the lateral with dripper discharge was 2 lph for the recorded data from drip irrigation system.

4.4.2.2 Determination of emission uniformity (EU)

A major aspect of drip irrigation system performance is uniformity of water application at each emitting device. Emission Uniformity (EU) is one single most important criterion for evaluating the performance of the system i.e. to see whether the emitter are applying the water uniformity or otherwise.

The average emission uniformity of emitters of drip system observed 89.50% shown in Appendix C. The average discharge in emitters of drip was 1.79 lph as against the standard recommended emitter discharges of 2 lph. The reduction in the discharge of emitter was due to the head losses occurred in the systems.

This shows the micro irrigation system is operating good as the value of EU was higher than the design criteria. (Keller and Karmali, 1975).

4.4.3 Estimation of Crop Evapotranspiration (ET_C)

The relationship between crop evapotranspiration (ET_C) and reference evapotranspiration (ET₀) was determined by using equation (3.2). It was referred from FAO-56. The growing season of tomato crop divided into four stages viz., (i) initial stage, (ii) crop development stage, (iii) mid-season stage, and (iv) late season

stage. The crop coefficient (K_c) for initial stage, mid-season stage and late season stage was taken 0.6, 1.15, and 0.75 respectively (Allen *et al.*, 1998).

Irrigation scheduling has been decided before growing of the crop by using the last five year data for all crop periods. The crop evapotranspiration outside the NVPH calculated from climatic data shown in the following tables.

4.4.3.1 Estimated weekly crop evapotranspiration (ET_C) outside the NVPH for treatment 1 (T1)

Table 4.9 Estimated weekly crop evapotranspiration (ET_C) outside the NVPH

Year Std. Met. Week	Crop Evapotranspiration, mm/day					
	July-13 to Dec-13	July-14 to Dec-14	July-15 to Dec-15	July-16 to Dec-16	July-17 to Dec-17	Mean
27	1.93	2.75	2.08	1.97	2.86	2.32
28	2.05	2.47	1.91	1.67	2.70	2.16
29	3.17	3.33	2.62	3.81	3.90	3.36
30	1.86	1.86	1.40	2.10	1.56	1.76
31	1.59	2.12	2.77	1.49	2.74	2.14
32	1.60	1.90	2.71	1.52	3.00	2.15
33	2.19	3.07	3.10	2.88	3.38	2.92
34	2.35	3.41	3.58	2.15	3.08	2.91
35	3.39	3.14	4.18	3.16	2.84	3.34
36	2.65	2.33	4.17	4.08	4.43	3.53
37	3.75	3.60	4.59	4.40	4.68	4.20
38	4.05	4.70	3.63	4.80	4.75	4.38
39	3.67	4.56	4.84	4.43	4.41	4.38
40	4.38	4.45	4.58	3.39	4.55	4.27
41	3.81	4.30	4.25	4.22	4.23	4.16
42	3.37	4.17	4.06	3.61	3.83	3.81
43	3.60	3.72	3.85	3.32	3.55	3.61
44	3.11	3.35	3.42	2.96	3.27	3.22
45	2.65	3.23	3.24	2.84	3.06	3.00
46	2.51	2.82	3.12	2.69	2.73	2.77
47	2.40	2.78	2.54	2.51	2.63	2.57
48	2.50	2.61	2.72	2.52	2.53	2.58
49	2.06	2.39	2.32	2.23	2.22	2.24
50	2.01	1.99	2.04	1.99	1.94	1.99
51	1.73	1.58	1.62	1.83	1.71	1.69
52	1.33	1.47	1.53	1.53	1.51	1.47
ET_0 (mm)	474.59	530.28	554.15	503.64	556.69	523.87

The mean value of water requirement for the year 2013 to 2017 for July transplanting has been taken to decide the schedule for irrigation of the tomato crop. It has been found 523.87 mm for the whole growing period i.e. 195 days. Variation in weekly crop evapotranspiration values outside NVPH over the growth period of tomato is describe in Fig. 4.7.

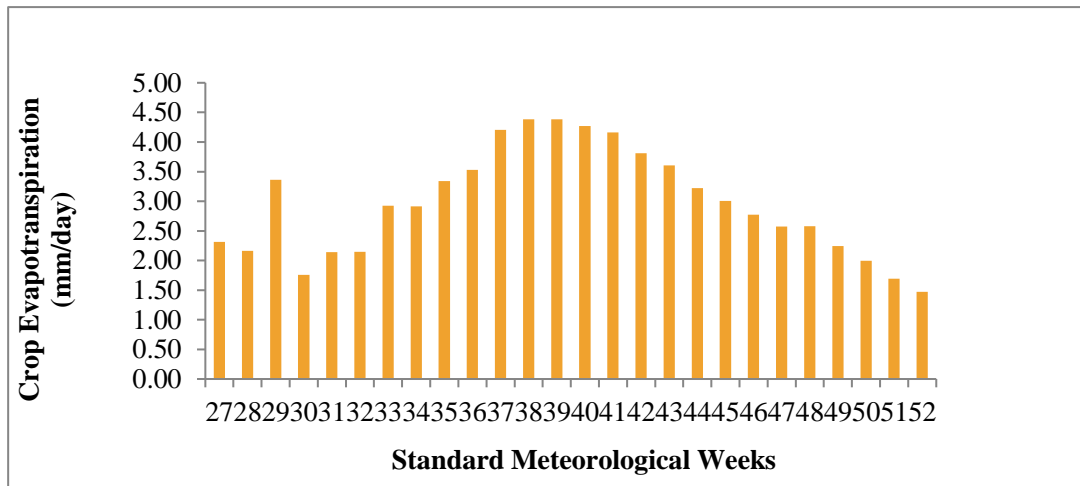


Fig. 4.7 Variation in average values of (ET_C) outside the NVPH for T1

From Fig.4.7 it is observed that the maximum and minimum mean crop evapotranspiration over the crop growth period are 4.38 mm/day during 39th week and 1.47 mm/day during 52th week respectively

4.4.3.2 Estimated weekly crop evapotranspiration (ET_c) outside the NVPH for treatment 2 (T2)

Table 4.10 Estimated weekly crop evapotranspiration (ET_c) outside the NVPH

Year Std. Met. Week	Crop Evapotranspiration, mm/day					
	Aug-13 to Jan-14	Aug-14 to Jan-15	Aug-15 to Jan-15	Aug-16 to Jan-17	Aug-17 to Jan-18	Mean
32	1.55	1.83	2.64	1.47	2.92	2.08
33	1.87	2.64	2.67	2.49	2.91	2.51
34	1.81	2.61	2.74	1.64	2.38	2.24
35	2.34	2.18	2.89	2.17	1.95	2.31
36	1.67	1.47	2.63	2.58	2.79	2.23
37	2.38	2.29	2.92	2.80	2.98	2.67
38	2.68	3.12	2.41	3.19	3.16	2.91
39	2.64	3.29	3.49	3.20	3.20	3.17
40	3.49	3.55	3.65	2.70	3.62	3.40
41	3.33	3.75	3.70	3.68	3.69	3.63
42	3.20	3.95	3.84	3.42	3.62	3.61
43	3.59	3.71	3.84	3.31	3.55	3.60
44	3.11	3.35	3.42	2.96	3.27	3.22
45	2.65	3.23	3.24	2.84	3.06	3.00
46	2.18	2.45	2.71	2.34	2.37	2.41
47	2.40	2.78	2.54	2.51	2.63	2.57
48	2.51	2.61	2.72	2.53	2.53	2.58
49	2.16	2.51	2.44	2.34	2.34	2.36
50	2.31	2.29	2.34	2.28	2.22	2.29
51	2.19	2.00	2.06	2.31	2.17	2.15
52	1.89	2.09	2.18	2.19	2.15	2.10
53	1.82	2.08	2.54	2.17	2.02	2.13
54	1.68	2.06	2.43	1.76	1.95	1.98
55	1.79	1.91	1.88	1.82	2.09	1.90
56	1.48	1.81	1.70	1.76	1.93	1.73
57	1.71	1.62	1.92	1.96	1.90	1.82
ET₀ (mm)	421.91	469.86	501.60	449.37	485.89	465.73

The mean value of water requirement for the year 2013 to 2017 for August transplanting has been taken to decide the schedule for irrigation of the tomato crop. It has been found as 465.73 mm for the whole growing period i.e. 210 days. Variation in weekly crop evapotranspiration values outside NVPH over the growth period of tomato is described in Fig. 4.8.

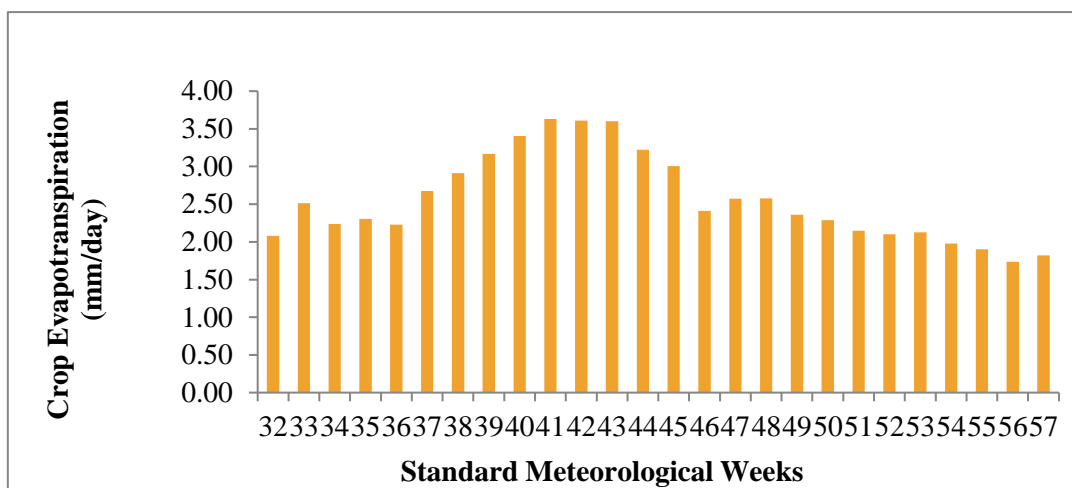


Fig. 4.8 Variation in average values of (ET_C) outside the NVPH for T2

From Fig. 4.8 it is observed that the maximum and minimum mean crop evapotranspiration over the crop growth period are 3.63 mm/day during 41th week and 1.73 mm/day during 56th week respectively.

4.4.3.3 Estimated weekly crop evapotranspiration (ET_C) outside the NVPH for treatment 3 (T3)

Table 4.11 Estimated weekly crop evapotranspiration (ET_C) outside the NVPH

Year Std. Met. Week	Crop Evapotranspiration, mm/day					Mean
	Sept-13 to Feb-14	Sept-14 to Feb-15	Sept-13 to Feb-14	Sept-13 to Feb-14	Sept-13 to Feb-14	
36	1.66	1.49	2.58	2.50	2.80	2.21
37	2.17	2.07	2.65	2.54	2.71	2.43
38	2.17	2.51	1.93	2.56	2.54	2.34
39	1.91	2.38	2.52	2.31	2.30	2.29
40	2.29	2.32	2.39	1.77	2.37	2.23
41	2.08	2.34	2.31	2.30	2.30	2.27
42	2.09	2.58	3.78	2.23	2.36	2.61
43	2.48	2.57	2.66	2.29	2.46	2.49
44	2.40	2.56	2.62	2.27	2.50	2.47
45	2.23	2.71	2.72	2.39	2.57	2.52
46	2.24	2.58	2.85	2.46	2.49	2.52
47	2.35	2.74	2.50	2.47	2.59	2.53
48	2.51	2.61	2.72	2.53	2.53	2.58
49	2.09	2.51	2.44	2.34	2.34	2.34
50	2.30	2.29	2.34	2.28	2.22	2.29

51	2.13	2.00	2.06	2.31	2.17	2.13
52	1.80	2.09	2.18	2.19	2.15	2.08
1	1.87	2.14	2.62	2.23	2.08	2.19
2	1.88	2.31	2.72	1.97	2.18	2.21
3	2.21	2.35	2.31	2.24	2.58	2.34
4	2.03	2.47	2.32	2.41	2.63	2.37
5	2.59	2.67	2.86	2.94	2.80	2.77
6	2.96	2.84	2.73	3.09	2.53	2.83
7	2.35	2.92	2.94	2.94	2.82	2.79
8	2.46	3.03	2.60	2.92	2.84	2.77
9	1.97	1.85	2.68	2.08	2.46	2.21
ET₀ (mm)	397.11	437.65	463.59	432.98	444.42	435.15

The mean value of water requirement for the year 2013 to 2017 for September transplanting has been taken to decide the schedule for irrigation of the tomato crop. It has been found 435.15 mm for the whole growing period i.e. 180 days. Variation in weekly crop evapotranspiration values outside NVPH over the growth period of tomato is described in Fig. 4.9.

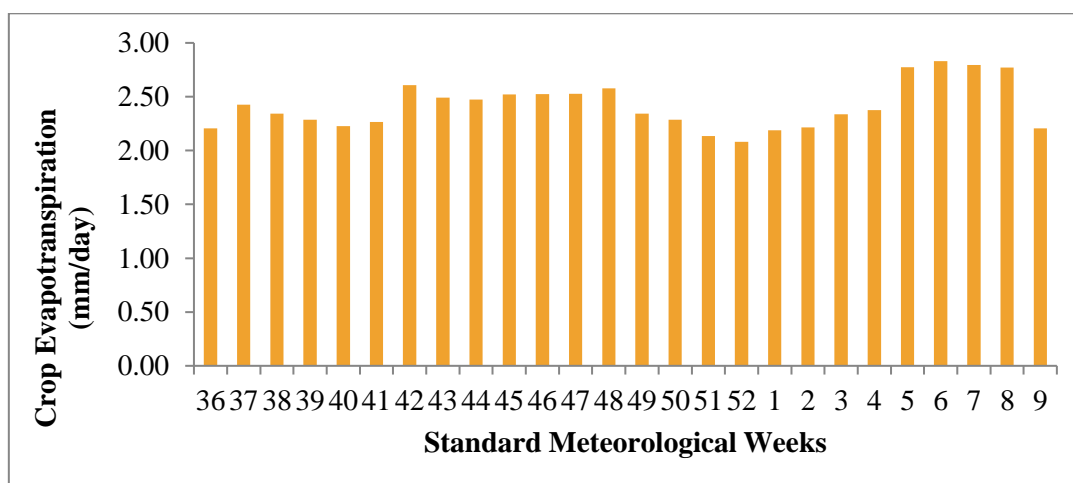


Fig. 4.9 Variation in average values of (ET_C) outside the NVPH for T3

From Fig. 4.9 it is observed that the maximum and minimum mean crop evapotranspiration over the crop growth period are 2.83 mm/day during 6th week and 2.13 mm/day during 51th week respectively.

4.4.3.4 Estimated weekly crop evapotranspiration (ET_c) outside the NVPH for treatment 4 (T4)

Table 4.12 Estimated weekly crop evapotranspiration (ET_c) outside the NVPH

Year Std. Met. Week	Reference Evapotranspiration, mm/day					
	Oct-13 to March-14	Oct-14 to March-15	Oct-15 to March-16	Oct-16 to March-17	Oct-17 to March-18	Mean
40	2.29	2.30	2.29	1.66	2.33	2.17
41	1.99	2.24	2.22	2.20	2.21	2.17
42	1.76	2.18	2.12	1.89	2.00	1.99
43	1.88	1.94	2.01	1.73	1.85	1.88
44	1.63	1.75	1.79	1.55	1.71	1.68
45	1.41	1.71	1.72	1.51	1.62	1.59
46	1.46	1.68	1.86	1.60	1.62	1.65
47	1.60	1.87	1.70	1.68	1.76	1.72
48	1.86	1.94	2.03	1.88	1.88	1.92
49	1.71	2.05	2.00	1.92	1.91	1.92
50	2.05	2.04	2.09	2.04	1.98	2.04
51	2.06	1.93	1.99	2.24	2.10	2.06
52	1.80	2.09	2.18	2.19	2.15	2.08
1	1.87	2.14	2.62	2.23	2.08	2.19
2	1.88	2.31	2.72	1.97	2.18	2.21
3	2.21	2.35	2.31	2.24	2.58	2.34
4	2.03	2.47	2.32	2.41	2.63	2.37
5	2.61	2.69	2.88	2.96	2.82	2.79
6	3.19	3.06	2.95	3.33	2.74	3.05
7	2.77	3.46	3.46	3.47	3.34	3.30
8	3.22	3.97	3.39	3.81	3.72	3.62
9	3.00	2.88	3.96	2.81	3.77	3.28
10	3.54	3.77	4.44	1.94	4.19	3.58
11	3.80	3.52	4.01	1.89	4.10	3.47
12	3.65	3.55	4.23	1.78	3.81	3.40
13	3.53	3.68	3.53	1.79	3.70	3.25
ET₀ (mm)	421.26	454.68	478.69	395.36	464.06	442.81

The mean value of water requirement for the year 2013 to 2017 for October transplanting has been taken to decide the schedule for irrigation of the tomato crop. It has been found 442.81 mm for the whole growing period i.e. 207 days. Variation in weekly crop evapotranspiration values outside NVPH over the growth period of tomato is described in Fig. 4.10.

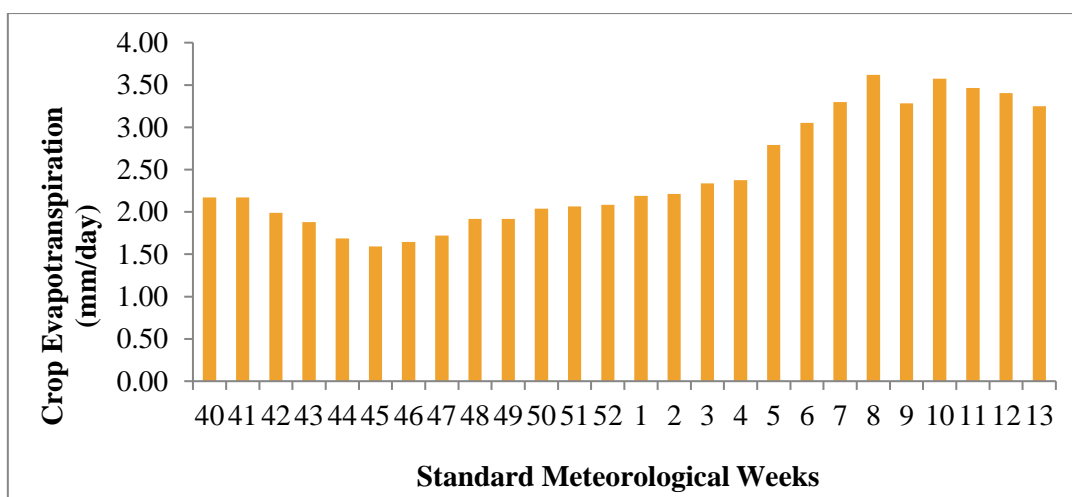


Fig. 4.10 Variation in average values of (ET_c) outside the NVPH for T4

From Fig. 4.10 it is observed that the maximum and minimum mean crop evapotranspiration over the crop growth period are 3.62 mm/day during 8th week and 1.59 mm/day during 45th week respectively.

4.4.3.5 Estimated weekly crop evapotranspiration (ET_c) outside the NVPH for treatment 5 (T5)

Table 4.13 Estimated weekly crop evapotranspiration (ET_c) outside the NVPH

Year Std. Met. Week	Reference Evapotranspiration, mm/day					Mean
	Nov-13 to April-14	Nov-14 to April-15	Nov-15 to April-16	Nov-16 to April-17	Nov-17 to April-18	
45	1.38	1.68	1.69	1.48	1.60	1.57
46	1.28	1.47	1.63	1.40	1.42	1.44
47	1.25	1.45	1.32	1.31	1.37	1.34
48	1.31	1.36	1.42	1.32	1.32	1.35
49	1.09	1.31	1.27	1.22	1.22	1.22
50	1.30	1.29	1.32	1.29	1.25	1.29
51	1.36	1.28	1.31	1.48	1.39	1.36
52	1.30	1.50	1.57	1.57	1.54	1.50
1	1.50	1.71	2.09	1.78	1.66	1.75
2	1.64	2.01	2.37	1.72	1.91	1.93
3	2.09	2.22	2.19	2.11	2.44	2.21
4	2.03	2.47	2.32	2.40	2.63	2.37
5	2.61	2.69	2.88	2.96	2.82	2.79
6	3.19	3.06	2.95	3.33	2.74	3.05
7	2.77	3.46	3.46	3.47	3.34	3.30
8	3.22	3.97	3.39	3.81	3.72	3.62

9	3.01	2.89	3.96	3.31	3.78	3.39
10	3.77	4.02	4.72	2.06	4.46	3.81
11	4.43	4.10	4.67	2.21	4.78	4.04
12	4.71	4.57	5.44	2.29	4.90	4.38
13	5.08	5.29	5.07	2.58	5.31	4.67
14	5.26	5.64	5.62	3.03	5.57	5.02
15	4.70	5.00	5.36	3.02	5.57	4.73
16	4.63	5.02	5.12	2.98	5.26	4.60
17	4.54	4.80	4.53	2.80	4.28	4.19
18	4.74	4.24	4.30	3.56	3.82	4.13
ET₀ (mm)	504.77	537.68	562.22	410.01	550.78	513.09

The mean value of water requirement for the year 2013 to 2017 for November transplanting has been taken to decide the schedule for irrigation of the tomato crop. It has been found 513.09 mm for the whole growing period i.e. 180 days. Variation in weekly crop evapotranspiration values outside NVPH over the growth period of tomato is described in Fig. 4.11.

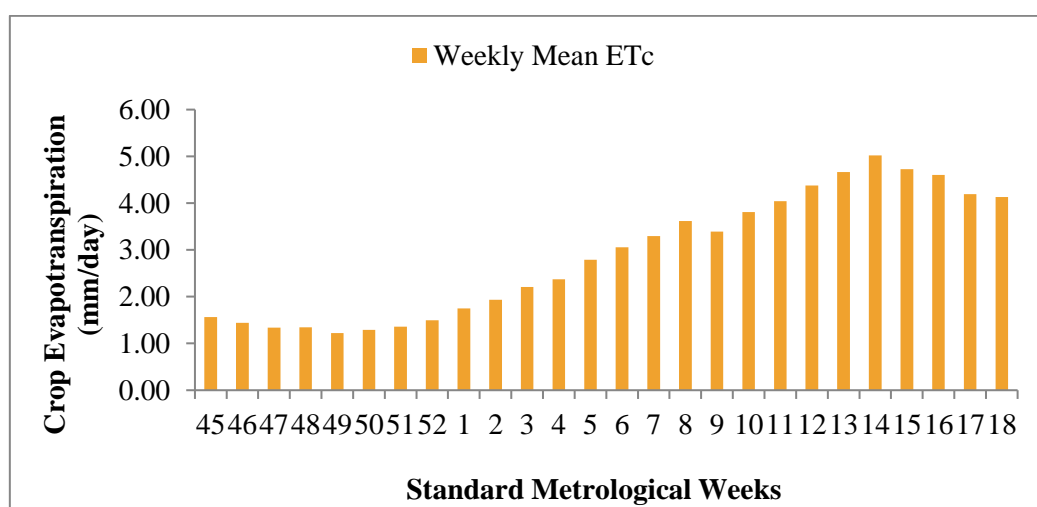


Fig. 4.11 Variation in average values of (ET_c) outside the NVPH for T5

From Fig. 4.11 it is observed that the maximum and minimum mean crop evapotranspiration over the crop growth period are 5.02 mm/day during 14th week and 1.22 mm/day during 49th week respectively.

4.4.3.6 Estimated weekly crop evapotranspiration (ET_c) outside the NVPH for treatment 6 (T6)

Table 4.14 Estimated weekly crop evapotranspiration (ET_c) outside the NVPH

Year Std. Met. Week	Reference Evapotranspiration, mm/day					
	Dec-13 to May-14	Dec -14 to May -15	Dec -15 to May -16	Dec -16 to May - 17	Dec -17 to May -18	Mean
45	1.11	1.31	1.22	1.18	1.18	1.20
46	1.20	1.19	1.22	1.19	1.16	1.19
47	1.11	1.04	1.07	1.21	1.13	1.11
48	0.94	1.09	1.14	1.14	1.12	1.09
49	0.98	1.12	1.37	1.16	1.09	1.14
50	1.04	1.28	1.51	1.10	1.21	1.23
51	1.39	1.47	1.45	1.40	1.62	1.47
52	1.44	1.74	1.63	1.69	1.85	1.67
1	2.03	2.09	2.24	2.30	2.19	2.17
2	2.71	2.61	2.51	2.84	2.33	2.60
3	2.55	3.20	3.20	3.21	3.09	3.05
4	3.19	3.93	3.36	3.77	3.68	3.59
5	3.01	2.89	3.96	2.82	3.78	3.29
6	3.77	4.02	4.72	2.06	4.46	3.81
7	4.43	4.10	4.67	2.21	4.78	4.04
8	4.71	4.57	5.44	2.29	4.90	4.38
9	5.08	5.29	5.07	2.58	5.31	4.67
10	5.41	5.80	5.78	3.12	5.73	5.17
11	5.27	5.59	5.99	3.38	6.23	5.29
12	5.69	6.19	6.32	3.68	6.48	5.67
13	6.22	6.57	6.19	3.83	5.85	5.73
14	6.84	6.40	6.69	5.42	5.77	6.22
15	6.32	6.59	6.11	5.71	5.28	6.00
16	5.91	5.87	5.58	5.61	5.18	5.63
17	5.29	5.77	5.87	4.98	5.33	5.45
18	5.24	5.20	4.61	4.43	4.45	4.79
ET₀ (mm)	641.20	670.11	686.26	513.12	660.80	634.30

The mean value of water requirement for the year 2013 to 2017 for December transplanting has been taken to decide the schedule for irrigation of the tomato crop. It has been found 634.30 mm for the whole growing period i.e. 180 days. Variation in

weekly crop evapotranspiration values outside NVPH over the growth period of tomato is described in Fig 4.12.

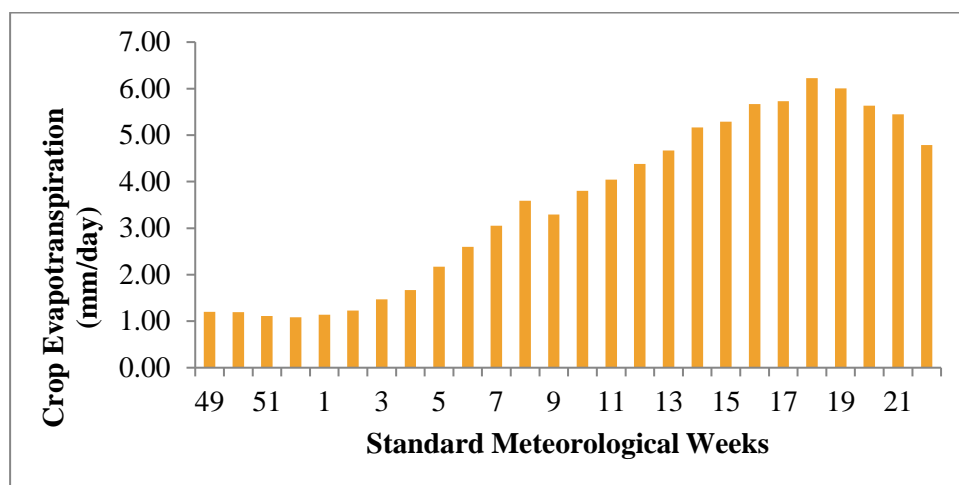


Fig. 4.12 Variation in average values of (ET_c) outside the NVPH for T6

From Fig. 4.12 it is observed that the maximum and minimum mean crop evapotranspiration over the crop growth period are 6.22 mm/day during 14th week and 1.09 mm/day during 48th week respectively.

The water requirement of *Tomato* crop was estimated on daily basis for all months considered under study. Daily time to operate drip irrigation system was worked out taking the application rate per plant has been given in Appendix E.

4.4.4 Determination of Crop Water Requirement Inside the NVPH

4.4.4.1 Determination of weekly ET₀ and (ET_c) determined from meteorological data recorded during the year 2018-2019

The meteorological data viz., temperature, relative humidity, sunshine hours, wind velocity etc. during the crop growing period were taken from meteorological observatory of department of Soil and Water Engineering, CTAE, Udaipur and the daily weather data inside the polyhouse recorded by hygrometer and pyranometer which are installed inside the polyhouse. The daily weather data recorded during the crop period is used for calculating the daily reference evapotranspiration and crop evapotranspiration after that it converted into weekly reference and crop evapotranspiration and which is given in Table 4.15 and 4.16.

Table 4.15 Estimated weekly ET₀ (mm/day) from climatologically data for the year 2018-2019 inside naturally ventilated polyhouse

Week No.	Treatment wise ET ₀ (mm/day)					
	T1	T2	T3	T4	T5	T6
27	4.37	-	-	-	-	-
28	3.33	-	-	-	-	-
29	2.65	-	-	-	-	-
30	3.22	-	-	-	-	-
31	4.18	-	-	-	-	-
32	4.61	4.61	-	-	-	-
33	4.20	4.20	-	-	-	-
34	2.96	2.96	-	-	-	-
35	3.76	3.76	-	-	-	-
36	4.11	4.11	4.11	-	-	-
37	3.97	3.97	3.97	-	-	-
38	3.48	3.48	3.48	-	-	-
39	3.40	3.40	3.40	-	-	-
40	3.11	3.11	3.11	3.11	-	-
41	2.72	2.72	2.72	2.72	-	-
42	2.00	2.00	2.00	2.00	-	-
43	2.21	2.21	2.21	2.21	-	-
44	2.05	2.05	2.05	2.05	2.05	-
45	1.77	1.77	1.77	1.77	1.77	-
46	1.73	1.73	1.73	1.73	1.73	-
47	1.65	1.65	1.65	1.65	1.65	-
48	1.45	1.45	1.45	1.45	1.45	-
49	1.45	1.45	1.45	1.45	1.45	1.45
50	1.31	1.31	1.31	1.31	1.31	1.31
51	1.19	1.19	1.19	1.19	1.19	1.19
52	1.27	1.27	1.27	1.27	1.27	1.27
1	1.24	1.24	1.24	1.24	1.24	1.24
2	-	1.30	1.30	1.30	1.30	1.30
3	-	1.38	1.38	1.38	1.38	1.38
4	-	1.47	1.47	1.47	1.47	1.47
5	-	1.80	1.80	1.80	1.80	1.80
6	-	1.87	1.87	1.87	1.87	1.87
7	-	2.04	2.04	2.04	2.04	2.04
8	-	2.49	2.49	2.49	2.49	2.49
9	-	2.71	2.71	2.71	2.71	2.71
10	-	-	3.05	3.05	3.05	3.05
11	-	-	3.05	3.05	3.05	3.05
12	-	-	3.52	3.52	3.52	3.52
13	-	-	3.78	3.78	3.78	3.78
14	-	-	-	3.94	3.94	3.94
15	-	-	-	4.04	4.04	4.04
16	-	-	-	4.09	4.09	4.09

17	-	-	-	4.28	4.28	4.28
18	-	-	-	-	4.56	4.56
19	-	-	-	-	4.43	4.43
20	-	-	-	-	-	4.48
21	-	-	-	-	-	4.40
ET₀ (mm)	512.16	495.17	465.07	487.09	467.01	470.78

Table 4.16 Estimated weekly ET_c (mm/day) from climatologically data for the year 2018-2019 inside naturally ventilated polyhouse

Week No.	Treatment wise ET _c (mm/day)					
	T1	T2	T3	T4	T5	T6
27	2.62	-	-	-	-	-
28	2.00	-	-	-	-	-
29	1.59	-	-	-	-	-
30	1.93	-	-	-	-	-
31	2.51	-	-	-	-	-
32	2.85	2.77	-	-	-	-
33	2.92	2.52	-	-	-	-
34	2.32	1.78	-	-	-	-
35	3.27	2.25	-	-	-	-
36	3.92	2.47	2.44	-	-	-
37	4.12	2.61	2.38	-	-	-
38	3.91	2.56	2.09	-	-	-
39	3.91	2.78	2.04	-	-	-
40	3.58	2.79	1.87	1.84	-	-
41	3.12	2.66	1.70	1.68	-	-
42	2.30	2.12	1.42	1.21	-	-
43	2.54	2.51	1.76	1.36	-	-
44	2.35	2.35	1.80	1.24	-	-
45	2.03	2.03	1.71	1.07	1.07	-
46	1.99	1.99	1.82	1.11	1.04	-
47	1.89	1.89	1.86	1.19	1.01	-
48	1.67	1.67	1.67	1.16	0.88	-
49	1.67	1.67	1.67	1.26	0.88	0.88
50	1.50	1.50	1.50	1.25	0.85	0.81
51	1.30	1.36	1.36	1.20	0.85	0.71
52	1.26	1.46	1.46	1.28	0.95	0.71
1	1.11	1.42	1.42	1.53	1.19	0.80
2	-	1.49	1.49	1.44	1.22	0.80
3	-	1.59	1.59	1.55	1.42	0.97
4	-	1.69	1.69	1.71	1.69	1.19
5	-	2.03	2.07	1.99	1.99	1.54
6	-	1.95	2.15	2.15	2.15	1.81
7	-	1.93	2.34	2.31	2.31	2.11
8	-	2.13	2.87	2.81	2.81	2.77

9	-	2.08	3.02	3.09	3.09	3.09
10	-	-	3.12	3.44	3.44	3.44
11	-	-	2.86	3.49	3.49	3.49
12	-	-	2.93	3.96	3.96	3.96
13	-	-	3.01	4.37	4.37	4.37
14	-	-	-	4.26	4.47	4.47
15	-	-	-	4.08	4.68	4.68
16	-	-	-	3.66	4.49	4.63
17	-	-	-	3.47	4.30	4.89
18	-	-	-	-	4.15	5.27
19	-	-	-	-	3.55	4.96
20	-	-	-	-	-	4.48
21	-	-	-	-	-	3.96
ET_c (mm)	465.01	434.57	418.40	464.68	465.08	486.64

From Table 4.17 it was found that the crop evapotranspiration under NVPH at different transplanting dates like July, August, September, October, November and December were observed as 465.01 mm, 434.57 mm, 418.40 mm, 464.68 mm, 465.08 mm and 486.64 mm, respectively. The results reveal that for September transplanting date the minimum water requirement and for December it is maximum.

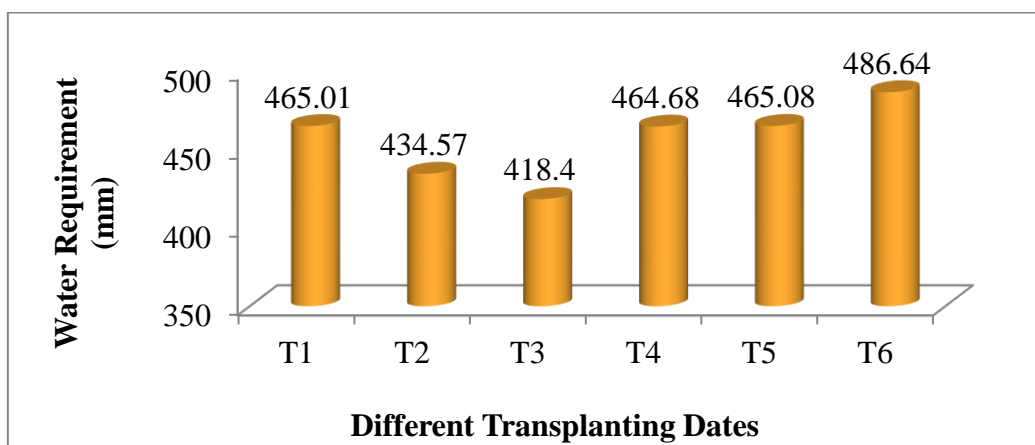


Fig 4.13 Total crop water requirement inside naturally ventilated polyhouse

The water requirement inside the NVPH under the different treatments over the growth period of tomato is shown in Fig 4.13. The water requirement of tomato crop was estimated on daily basis for all months consider under study and application of water to the tomato crop in alternate days only. Daily time to operate drip irrigation system was worked out taking the application rate per plant. The daily data of time of water application has been given in Appendix G. The calculated volume of water is

applied as per treatment through time bound monitoring the lateral valve according to discharge rate of dripper.

4.5 EFFECT OF CLIMATE ON DIFFERENT DATES OF TRANSPLANTING ON GROWTH AND YIELD OF TOMATO CROP

The climate is the aggregates of all external conditions which influences the growth and development of crop, which play dominant role in crop production. Each crop has its own set of environmental conditions under which it grows best for that purpose following study was done.

4.5.1 Biometric Observations

The biometric observation recorded for drip irrigated tomato crop under different dates of transplanting were statistically analyzed and the results are presented in this section.

4.5.1.1 Plant height (cm)

The plant height of the tagged tomato plants were measured at 30, 60, 90, 120, 150 and 180 days after transplanting (DAT). The data on plant height at different stages of crop growth was significantly influenced due to individual effect of different dates of transplanting are presented in Table 4.17 and graphically shown in Fig. 4.14.

Table 4.17 Effect of different dates of transplanting on plant height of tomato crop

Treatments	Mean Plant Height, (cm)					
	DAT					
	30	60	90	120	150	180
T1 (July Transplanting)	53.3	97.25	150.00	177.60	200.05	224.62
T2 (August Transplanting)	54.67	98.75	157.30	182.75	208.87	230.52
T3 (September Transplanting)	66.75	122.1	167.57	191.75	230.87	257.05
T4 (October Transplanting)	59.00	106.25	160.80	188.60	213.20	235.31
T5 (November Transplanting)	51.47	94.20	147.20	172.87	196.82	220.55
T6 (December Transplanting)	43.15	88.15	144.15	165.65	190.75	214.68
SE_m±	1.83	2.91	4.01	3.96	4.04	4.58
CD (p = 0.05)	5.51	8.78	12.08	11.94	12.17	13.79

At 30 DAT, among the different transplanting dates, plant height was observed maximum 66.75 cm in T3 (September Transplanting) treatment, which is significantly superior over the other five transplanting dates. The minimum plant

height 43.15 cm was recorded in T6 treatment. A similar trend was noticed at 60 DAT, 90 DAT, 120 DAT, 150 DAT and at the 180 DAT as that of 30 DATT. The result data clearly indicates that the effect of the irrigation treatments was found significant at 5% level of significance.

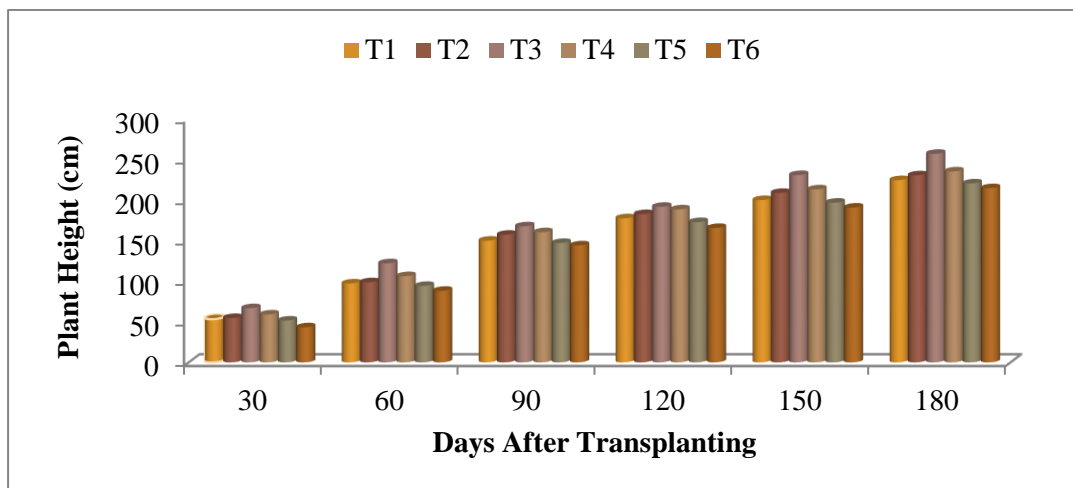


Fig. 4.14 Effect of different transplanting dates on plant height of tomato crop



Plate 4.1 Measurement of height of tomato plant

During the successive stages of crop growth viz., 30, 60, 90, 120, 150 and 180 DAT, the plant height of tomato crop was found to be increasing and it was 257.05 cm at 180 DAT in T3 treatment, followed by T4 treatment 235.51 cm and minimum in treatment T6 i.e. 214.68 cm.

This may be attributed to the enhanced plant metabolic activities like photosynthesis and respiration due to favorable micro-climate conditions that prevailed in the T3 treatment. As The tomato crop is more sensitive to the temperature, so that the difference in crop height for different transplanting dates occurs due to the variation in temperature and relative humidity. That's why the increase in plant height with September transplanting date, T3 as compared to other treatments. The similar results were also reported by Cheena *et al.*, (2018) for tomato crop.

4.5.1.2 Number of leaves per plant

The data on number of leaves at different stages of crop growth was significantly influenced due to individual effect of different dates of transplanting are presented in Table 4.17 and graphically shown in Fig. 4.15.

Table 4.18 Effect of different dates of transplanting on number of leaves of tomato crop

Treatments	Mean Number of Leaves per Plant DAT					
	30	60	90	120	150	180
T1 (July Transplanting)	8.95	16.25	20.00	23.23	26.68	30.65
T2 (August Transplanting)	9.86	18.41	22.19	25.27	28.28	32.54
T3 (September Transplanting)	11.30	20.04	26.81	32.74	35.30	39.95
T4 (October Transplanting)	10.08	19.20	24.21	28.68	31.27	36.59
T5 (November Transplanting)	7.65	14.15	18.02	21.22	23.89	26.00
T6 (December Transplanting)	7.13	12.20	16.31	17.53	21.35	23.49
SE_m±	0.23	0.31	0.71	0.82	0.55	0.55
CD (p = 0.05)	0.69	0.92	2.15	2.48	1.67	1.66

At 30 DAT, number of leaves was obtained maximum 11.30 in T3 treatment, which is significantly superior over the other five irrigation treatments. The minimum number of leaves per plant 7.13 was recorded in T6 treatment. A similar trend was noticed at 60 DAT, 90 DAT, 120 DAT, 150 DAT and 180 DAT as that of 30 DAT. It is evident from the observations that the different transplanting dates give the

significant effects on number of leaves per plant. It was found significant on 5 % level of significance through number of leaves per plant in treatment T₃.

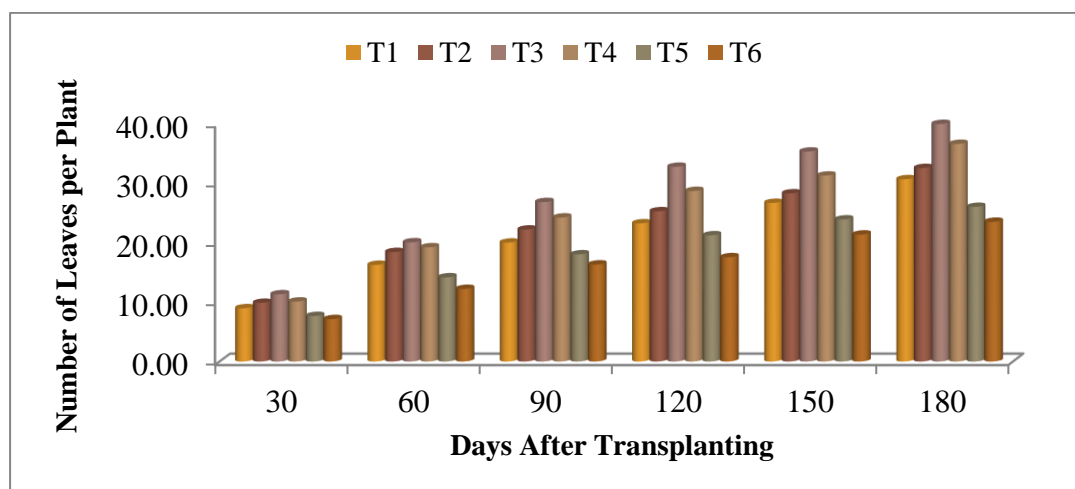


Fig. 4.15 Effect of different transplanting dates on number of leaves of tomato crop

The number of leaves per plant was maximum 39.95 in treatment T₃ at 180 DAT. This might be due to the taller plants, increased number of branches and the congenial microclimate that prevailed in T₃ treatment, favoring increased growth rate of plants; similar results were obtained by Cheena *et al.*, (2018) for tomato crop.

4.5.1.3 Time taken for flower initiation and first harvest

The data recorded on time taken for flower initiation and to first harvest were also significantly influenced by different transplanting dates as shown in Table 4.18 and depicted in Fig. 4.16.

Table 4.19 Effect of different transplanting dates on time taken for flower initiation and on first harvest of tomato crop

Treatments	Number of days to Flowering	Number of days to harvest
T1	43.25	74.75
T2	42.25	73.75
T3	40.25	68.25
T4	41.5	70.5
T5	44.25	75.5
T6	45.5	76.75
SEm		
±	0.53	1.01
CD (p=0.05)	1.60	3.04

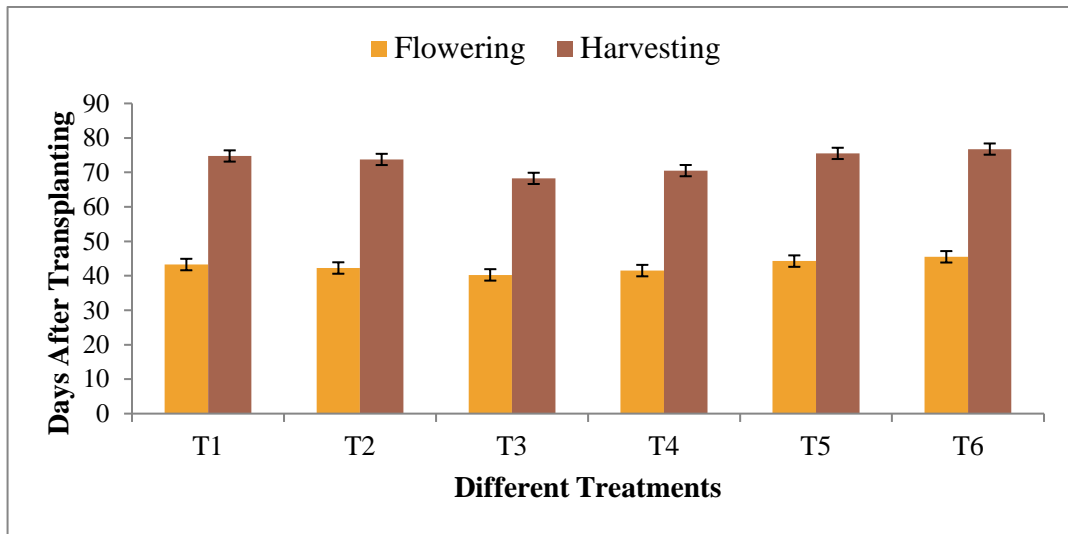


Fig. 4.16 Effect of different transplanting dates on time taken for flower initiation and on first harvest of tomato crop

Among the different transplanting dates, early flower initiation (40.25 DAT) was recorded in T₃ treatment, which was significantly superior over other five treatments, only where the late flower initiation (45.5 DAT) was noticed. It is exhibited from the data given in Table 4.18 that the effect of different transplanting dates was also found significant on first harvest of plant. The early first harvesting of plant i.e. 68.25 DAT was noticed in T₃ treatment.

From the Table 4.18 it is also clear that the effect of different transplanting dates on time taken to flower initiation and to first harvesting was found significant for the both characters. This may be due to accumulation of maximum photosynthesis favoring fast growth which triggered early initiation of flowers in T₃ treatment. Cheena *et al.*, (2018) reported same results for tomato crop which confirms the result of the present study.

4.5.2 Reproductive Parameters

4.5.2.1 Number of flowers per plant

The data pertaining to the average cumulative number of flowers per plant at different stages of crop growth was influenced by different transplanting dates as shown in Table 4.19 and depicted in Fig. 4.17.

Table 4.20 Effect of transplanting dates on number of flowers per plant of tomato crop

Treatments	Mean Number of Flowers per Plant DAT					
	30	60	90	120	150	180
T1 (July Transplanting)	0	13.79	20.95	31.99	41.29	45.84
T2 (August Transplanting)	0	15.15	22.00	33.50	42.14	47.00
T3 (September Transplanting)	0	18.05	26.92	38.98	48.78	52.02
T4 (October Transplanting)	0	16.11	23.83	36.78	44.18	48.81
T5 (November Transplanting)	0	12.83	19.24	29.21	39.19	42.02
T6 (December Transplanting)	0	11.75	17.50	28.80	38.02	40.42
SE_m±	0	0.28	0.43	0.46	0.61	0.66
CD (p = 0.05)	0	0.84	1.31	1.38	1.85	1.98

The cumulative number of flowers per plant differed significantly due to different transplanting dates at all stages of crop growth *viz.*, 60, 90, 120, 150 and 180 days after transplanting (DAT). At 60 DAT, among the six transplanting dates, number of flowers per plant was observed maximum 18.05 in T3 treatment, which is significantly superior over the other five transplanting dates. The least number of flowers per plant 11.75 was recorded in T6 treatment. Similar results was also found at 90, 120 and 150 DAT.

Further at 180 DAT, regarding the character, number of flowers per plant, the effect of different treatments was again found significant. The timing of transplanting of tomato crop affects the flower retention because the micro climate at the different transplanting dates are different which affects the flower retention per plant and its setting in to fruit in that particular season.

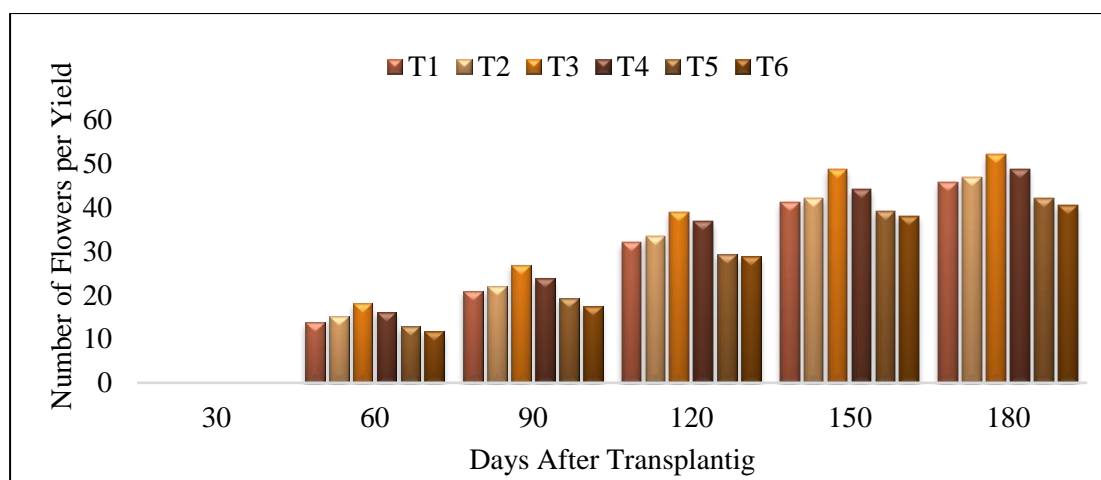


Fig. 4.17 Effect of different transplanting dates on number of flowers per plant

4.5.2.2 Number of fruits per plant

The data pertaining to the average number of fruits per plant as influenced by different transplanting dates are presented in Table 4.20. The graphical representation of number of fruits per plant and percent fruit set is shown in Fig 4.18.

Table 4.21 Effect of different transplanting dates on number of fruits per plant of tomato crop

Treatments	Number of fruits per plant
T1 (July Transplanting)	35.38
T2 (August Transplanting)	37.55
T3 (September Transplanting))	40.20
T4 (October Transplanting)	39.65
T5 (November Transplanting)	31.30
T6 (December Transplanting)	31.15
SE_m±	1.39
CD (p = 0.05)	4.19

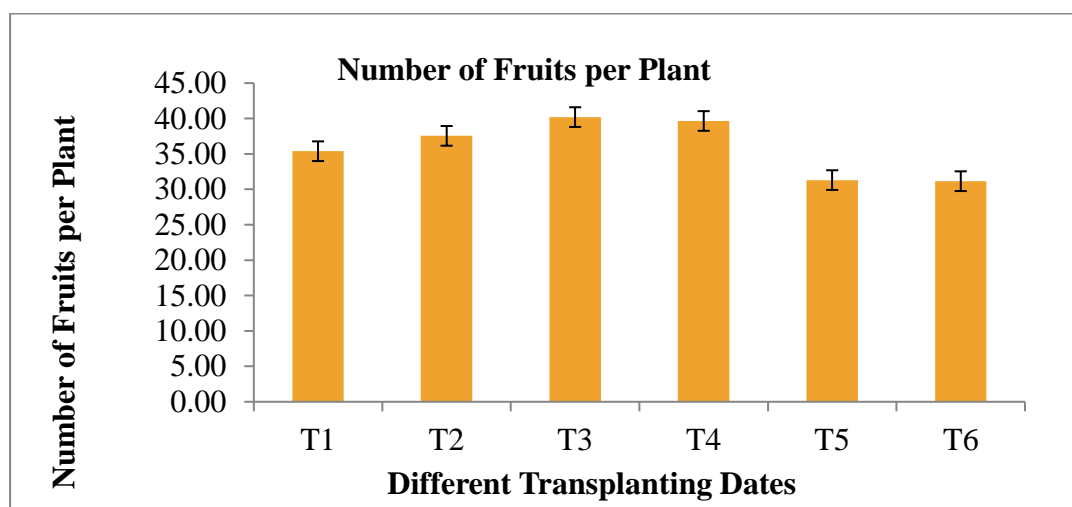


Fig. 4.18 Effect of different transplanting dates on number of fruits per plant

The cumulative number of fruits per plant of tomato differed significantly to the different transplanting dates. At last harvesting (180 DAT), among the six different transplanting dates, cumulative number of fruits per plant was observed maximum 40.20 in T3 treatment, which was significantly superior over in the all other treatments. The least number of fruits per plant 31.15 was recorded in T6 treatment. Cheena *et al.*, (2018) reported same results in tomato crop grown under polyhouse.

4.5.3 Yield Parameters

The data pertaining to individual fruit weight and yield of crop as influenced by different transplanting dates are presented in Table 4.21. Individual fruit weight, fruit yield per plant, fruit yield per square meter area and fruit yield per hectare (t ha⁻¹) is represented in Fig. 4.19, Fig. 4.20, Fig. 4.21 and Fig. 4.22, respectively. Among the different transplanting dates, the highest individual fruit weight (74.01 gm) was recorded in treatment T3 and the lowest individual fruit weight (63.81 gm) was recorded in treatment T6.

Table 4.22 Effect of different transplanting dates on quantity parameters of tomato crop

Treatments	Individual fruit weight (gm)	Fruit yield/plant (gm)	Fruit yield/sqm area (kg)	Fruit yield (t ha ⁻¹)
T1	68.37	2429.99	9.72	97.20
T2	71.57	2684.04	10.74	107.36
T3	74.01	2971.82	11.89	118.87
T4	72.27	2861.25	11.44	114.45
T5	65.17	2038.25	8.15	81.53
T6	63.81	1989.17	7.96	79.57
SEm±	2.30	118.89	0.48	1.76
CD (p=0.05)	6.92	358.37	1.43	14.33

However, the higher fruit yield per plant (2971.82 gm /plant) was recorded in treatment T3, which was significantly superior over the all other transplanting dates while the lowest yield (1989.17 gm/plant) was recorded in treatment T6. The similar trend was recorded for fruit yield per square meter area and fruit yield ton per hectare as that of fruit yield per plant. The fruit weight plays an important role in increasing the total yield in tomato. The weight of the fruits grown under treatment T3, were higher (74.01 gm) as compared to treatment T6.

This was largely due to the proper timing of transplanting of crop because which effect on the overall biometric and reproductive parameter performance of the crop and ultimately which affects the yield. This could be due to a proper micro-climate is available at the time of September transplanting as compare to December and other transplanting dates and buildup of sufficient photosynthesis enabling the increase in size of fruits (length and breadth), resulting in the increased fruit weight and its volume. Similar findings were recorded by Cheena *et al.*, (2018) in tomato. This shows that the appropriate date of transplanting of tomato in naturally

ventilated polyhouse is in month of September. Singh *et al.*, (2015) also reported that maximum yield of tomato was found for transplanting date in the month of September.

The marketable fruit yield of tomato was higher (2971.82 gm/plant and (118.87 t ha⁻¹) in treatment T3 as compared to treatment T6 (1989.17 gm/plant and 79.57 t ha⁻¹). This may be due to the micro-climate during the crop growth period maintain the proper aeration in root zone and proper absorption of nutrient by the plant, leading to higher fruit set, maximum fruit weight and fruit volume.

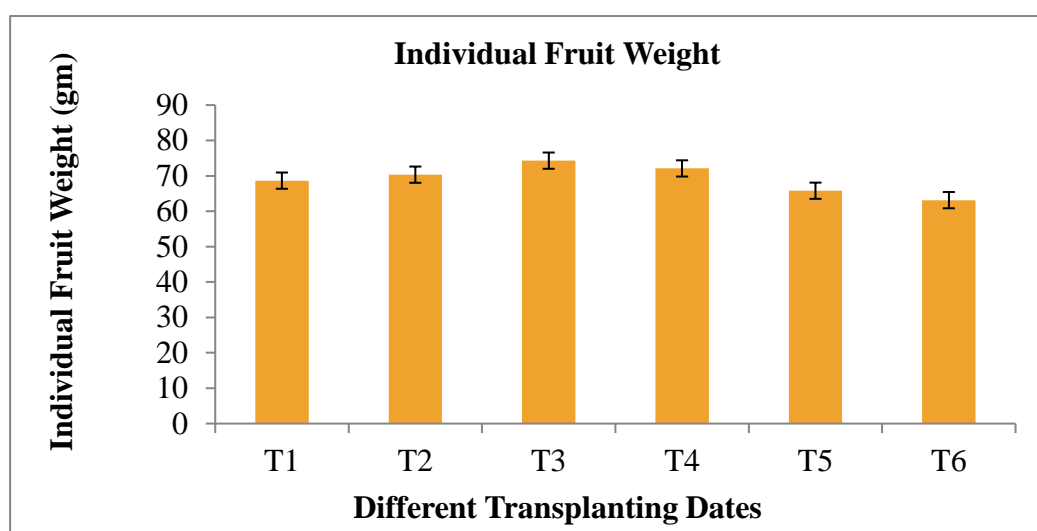


Fig. 4.19 Effect of different transplanting dates on individual fruit weight

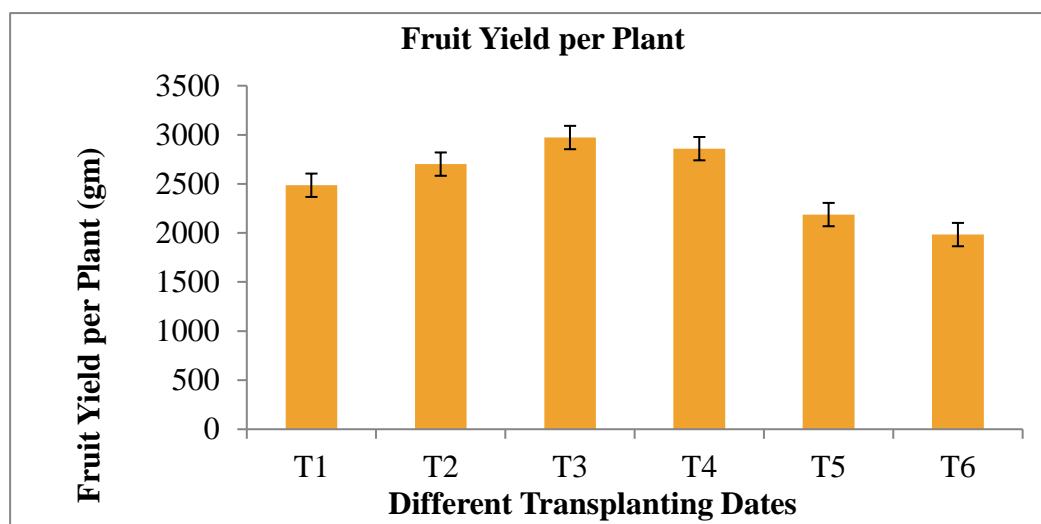


Fig. 4.20 Effect of different transplanting dates on fruit yield per plant

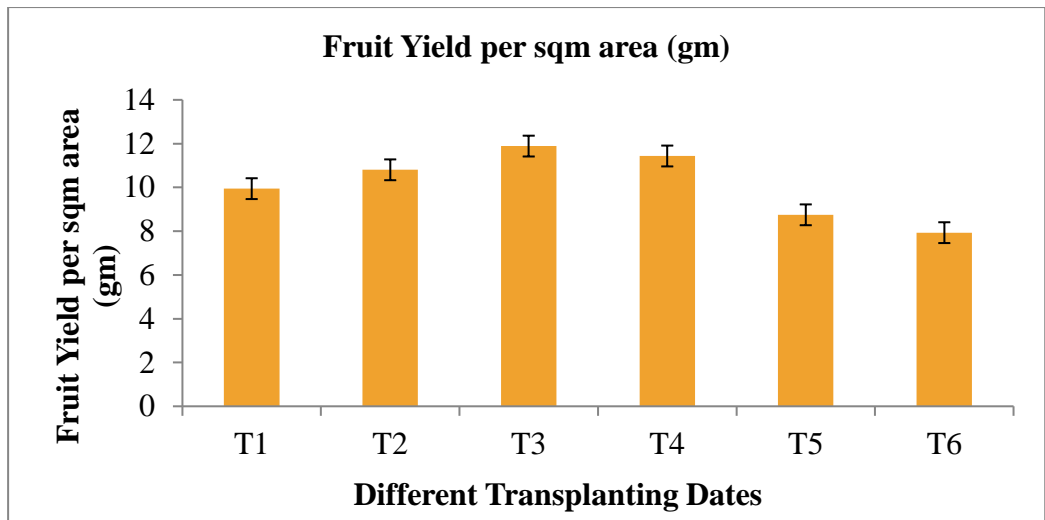


Fig. 4.21 Effect of different transplanting dates on fruit yield per sqm

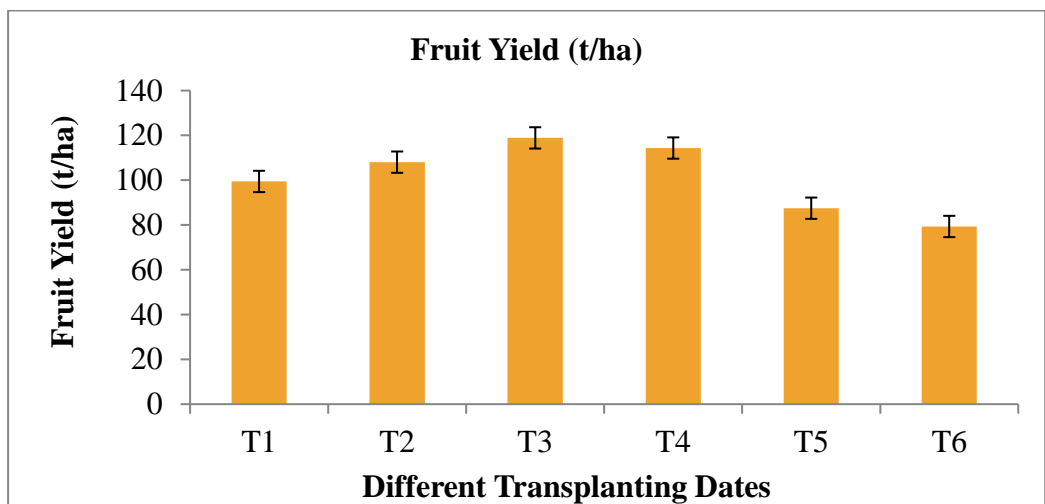


Fig. 4.22 Effect of different transplanting dates on fruit yield



Plate 4.2 Harvesting and observation of weight of tomato fruits per plant

Generally, crops are not profitable unless they are adopted to the region in which they are produced. Raising a crop successfully means the crop must be productive and economical to grow under prevailing conditions. Among the environmental factors, the temperature, relative humidity and light intensity are the factors which mainly influence the crop growth and development considerably.

Temperature is the major regulator of the development process. It influences the flower and fruit development. The effect of temperature on net photosynthesis is of vital concern in crop production. The higher temperature has more adverse influence on net photosynthesis than lower temperature leading to decrease production above a certain temperature (Bhatt and Rao, 1993).

The relative humidity increases the availability of net energy for crop growth and prolongs the survival of crops under moisture stress conditions, which leads to optimum utilization of nutrients.

4.6 MODELLING OF EFFECT OF VARIATION OF TEMPERATURE AND RELATIVE HUMIDITY ON GROWTH PARAMETERS AND YIELD OF TOMATO CROP

In this objective fruit yields were correlated with average air temperature and relative humidity between first flower anthesis and first fruit harvest. These correlations were made from data on tomato plants grown under different transplanting dates. Regression analysis is used to find out that relationship which gives the value coefficient of determination (r^2). Average of air temperature and relative humidity between the first flower anthesis and the first fruit harvesting were shown in table 4.22 and 4.23.

Table 4.23 Average air temperature and yield per plant for different transplanting dates.

Treatment	Average Temperature (°C)	Observed yield per plant (gm)	Developed model equation
T1	32.34	2652.66	$Y = -14.751x^2 + 786.81x - 7528.2$
T2	30.30	2667.97	
T3	29.10	2930.54	
T4	24.20	2919.16	
T5	18.75	1948.26	
T6	19.20	1904.26	
			R² = 0.92

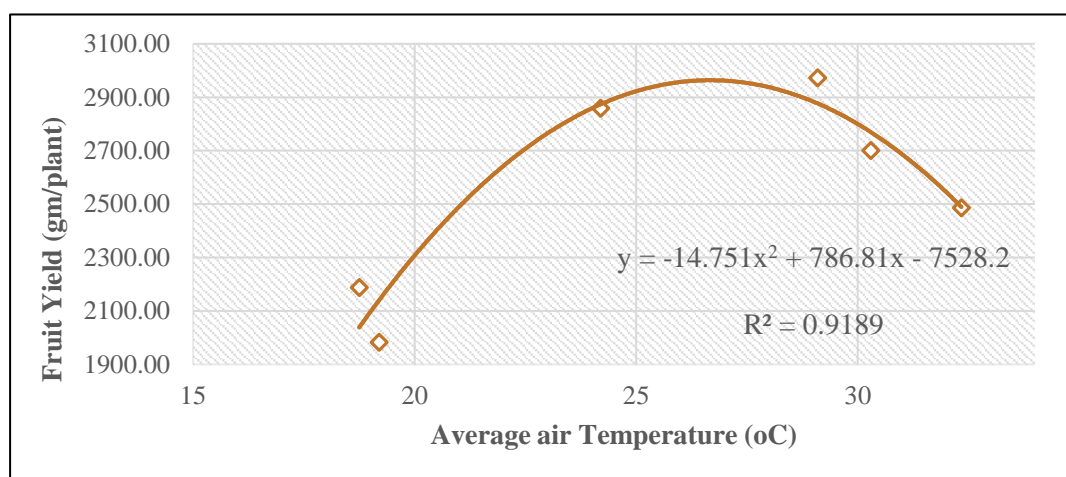


Fig. 4.23 Relationship between the fruit yield and the average air temperature

This analysis shows that the average air temperature between the first flower anthesis and the first fruit harvesting and yield per plant are quadratically correlated with each other. This analysis shows that the suitable temperature for the growing of tomato crop i.e. 29.1°C which gives 2930.54 kg yield/plant. It is observed that coefficient of determination of regression (r^2) is 0.92. This analysis also represents that, above and below with that particular temperature there is significance difference between the yields of tomato. From that graph it is very clear that tomato crop production is highly correlate with the air temperature during its maturity period.

Table 4.23 Relative humidity and yield per plant for different transplanting dates.

Treatment	Relative Humidity (%)	Observed yield (gm/plant)	Developed model equation
T1	56	2652.66	$y = 25.973x + 1020.6$
T2	67	2667.97	
T3	75	2930.54	
T4	69	2919.16	
T5	45	1948.26	
T6	37	1904.26	
$R^2 = 0.99$			

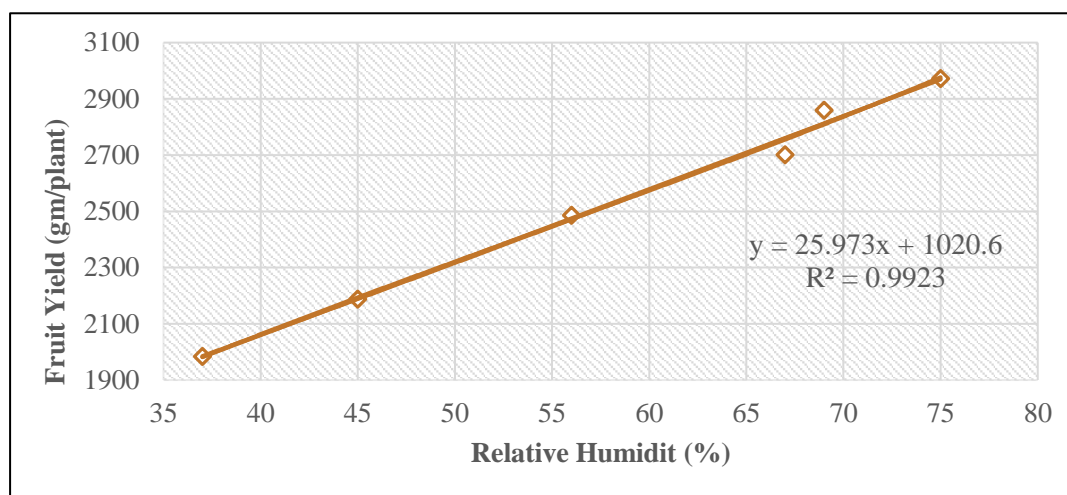


Fig. 4.24 Relationship between the fruit yield and the average relative humidity

Fig. 4.24 shows the relationship between the relative humidity between the first flower anthesis and the first fruit harvesting and yield and it is found that there is the linear relationship between them. Various parameters, including the photosynthetic rate, morphology, yield and disease occurrence, are affected by relative humidity. The study is applicable for the RH range 30-80%. The model shows that the appropriate relative humidity for the growing of tomato crop i.e. 75% and which gives the better production. In contrast, too much RH can stop transpiring and may result in turgor losses in plants. This model also represents that, above and below with that particular relative humidity there is significance difference between the yield of tomato.

4.7 WATER USE EFFICIENCY

Water use efficiency (WUE) refers to the ratio of yield to the amount of water depleted by the crop in the process of evapotranspiration i.e. the yield per unit area of land per unit depth of water used by the crop. Water use efficiency was worked out from the total yield realized. The influence of different transplanting dates on water use efficiency of tomato crop during different growing period of crop shown in Table 4.24 and Fig. 4.25

Table 4.25 Effect of different treatments on water use efficiency

Treatments	Water use efficiency kg/ha-cm
T1	2090.27
T2	2470.52
T3	2841.13
T4	2462.98
T5	1753.03
T6	1635.03

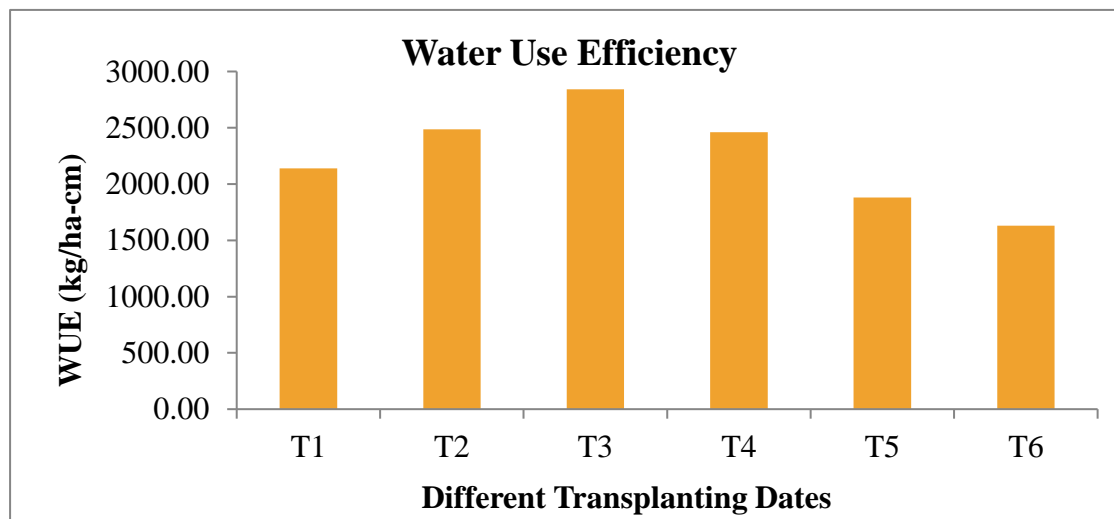


Fig. 4.25 Effect of different treatments on water use efficiency

From the result, the water use efficiency was found 2090.27 kg/ha-cm, 2470.52 kg/ha-cm, 2841.13 kg/ha-cm., 2462.98 kg/ha-cm , 1753.03 kg/ha-cm and 1635.03 kg/ha- cm. It has been found maximum under T3 and minimum under treatment T6.

4.8 ECONOMIC ANALYSIS

Relative economics of drip irrigated tomato production per m² under NVPH with different dates of transplanting was worked out by adopting the procedure as described in Appendix G.

4.8.1 Cost of Cultivation

Data regarding cost of cultivation is reported in Table 4.25 it reveals that the maximum cost of cultivation was observed in treatment T1 (834802 Rs/ha) and minimum is treatment T6 (809931Rs/ha).

4.8.2 Net Income

The value of net income observed in different transplanting dates treatments were worked out and is presented in Table 4.25. It reveals that maximum net income was gained from treatment T3 (1543074 Rs/ha) whereas minimum net income was reported in treatment T1 (623194 Rs/ha).

4.8.3 Output-Input Ratio

The computed value of output-input ratio in various transplanting dates were reported in Table 4.25. It reveals that, maximum output-input ratio was observed in treatment T3 (2.85) and minimum output-input ratio was reported in treatment T1 (1.75).

CHAPTER - V

SUMMARY AND CONCLUSIONS

Tomato (*Lycopersicon esculentum* Mill) is one of the most popular, cash earning and versatile vegetable crops for small farmers of India. It is also most important and remunerative vegetable crop in India and able to fetch very good rates from market due to its high demand in hotels and restaurants. Therefore, farmers can able to produce vegetables in off season and can sell them at higher price in the market. As the farmer can produce vegetables in off season, so the farmer can sell the product in higher price to the retail stores, restaurants and big hotels. Transplanting time has tremendous effect on the tomato fruit quality and seed yield because of widely varying agro climatic conditions and intricate crop-weather relationships. Optimum time of planting is one of the non-monetary inputs for increasing the productivity of the crop.

By concerning these issues the current study experiment entitled “Effect of modeling of climatic parameters on growth and yield of tomato crop during second half of the year grown under naturally ventilated polyhouse” has been undertaken at Plasticulture Farm of CTAE, Udaipur (Rajasthan), transplanting of tomato crop were made from 5th July 2018 to 5th December 2018. However final harvesting was done on 20th May 2019. In this study the tomato cv Dev has been grown under naturally ventilated polyhouse to provide optimum environmental medium for better crop growth in order to gain maximum yield and high-quality products.

The experiment was carried out with six main treatments as different transplanting dates i.e. T1: 5th July, T2: 5th August, T3: 5th September, T4: 5th October, T5: 5th November, and T6: 5th December with four replications. In this study tomato has been grown under NVPH. The irrigation has been done through gravity fed drip irrigation system. The transplanting was done 6 different dates of transplanting.

Weekly climatic data for the period 2013-2017 i.e. (5 years) have been used to determine weekly reference evapotranspiration (ET_0) outside NVPH. The meteorological data on important weather parameter were collected on daily basis from the meteorological observatory at CTAE, Udaipur. The daily reference evapotranspiration was estimated using Penman Monteith equation.

The crop evapotranspiration (ET_c) outside the naturally ventilated polyhouse was estimated from the daily reference evapotranspiration and daily K_c values. The total water requirement for all six treatments during entire cropping period was calculated as 523.87 mm, 465.73 mm, 435.15 mm, 442.81 mm, 513.09 mm and 634.30 mm respectively.

In this study the crop water requirement under the naturally ventilated poly house was determined by gravimetric method during the crop period. It was found that the crop evapotranspiration in T1, T2, T3, T4, T5 and T6 under the NVPH were observed 465.01 mm, 434.57 mm, 418.40 mm, 464.68 mm, 465.08 mm and 486.64 mm respectively for the entire crop periods respectively.

The climate is the aggregates of all external conditions which influence the growth and development of crop, which play dominant role in crop production and for that purpose statistical analysis is done. Statistical analysis of the observed data showed maximum average plant height (235.31 cm), average number of leaves per plant (39.95), early flower initiation (40.25 DAT), early first harvesting of plant (68.25 DAT), number of flower per plant (52.02), cumulative number of fruits per plant (40.20), individual fruit weight (74.01 gm) and fruit yield per plant (2971.82 gm/plant) in treatment T3 under the NVPH.

The fruit yields were correlated with average air temperature and relative humidity between first flower anthesis and first fruit harvest using regression analysis model. These analysis shows that there is linear polynomial relationship between the average air temperature and yield per plot and also between relative humidity and yield per plot. This model shows that the suitable temperature for the growing of tomato crop i.e. 29.1°C and 75% relative humidity which gives 2971.82 g/plant yield.

The WUE was 2090.27 kg/ha-cm, 2470.52 kg/ha-cm, 2841.13 kg/ha-cm., 2462.98 kg/ha-cm, 1753.03 kg/ha-cm and 1635.03 kg/ha- cm. In treatment T1, T2, T3, T4, T5 and T6 respectively. The higher water use efficiency reported in treatment T3 and lower in treatment T6. It was found that treatment T3 gave the highest net income of 1543074 Rs/ha and output-input ratio of 2.85.

CONCLUSIONS

Based on the results obtained from the present investigation, the following conclusions are drawn:

1. The crop water requirement under NVPH was obtained as 465.01 mm, 434.57 mm, 418.40 mm, 464.68 mm, 465.08 mm and 486.64 mm in T1, T2, T3, T4, T5 and T6 respectively for all crop seasons.
2. The appropriate date of transplanting of tomato in naturally ventilated polyhouse is in month of September. The maximum tomato yield of 118.87 t/ha was obtained under this treatment.
3. Vegetative parameters, reproductive parameter and quantity parameter was found maximum in treatment T3 i.e. transplanting of tomato crop in 5th September.
4. This analysis found that the average air temperature between the first flower anthesis and the first fruit harvesting and yield per plant are quadratically correlated with each other.
5. This analysis shows that the suitable temperature and appropriate relative humidity for the growing of tomato crop i.e. 29.1°C and 75% resp., which was found in T3 treatment and gives 2971.82 g/plant yield.
6. The highest WUE 2841.13 kg/ha-cm was recorded in treatment T3 as and lowest in T6 as 1635.03 kg/ha-cm.
7. The result reviewed that the maximum net income of 1543074 Rs/ha and maximum output- input ratio 2.85 in treatment T3 (i.e., Transplanting of tomato in 5th September) under NVPH tomato cultivation.

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ABSTRACT

The project was undertaken for study of “Effect of modeling of climatic parameters on growth and yield of tomato crop during second half of the year grown under naturally ventilated polyhouse” was conducted at the Plasticulture Farm of College of Technology & Engineering, Udaipur, transplanting of tomato crop were made from 5th July 2018 to 5th December 2018. However final harvesting was done on 20th May 2019. This study included objectives, to determine crop water requirement for tomato crop under different transplanting dates, to study the effect of climate on different dates of transplanting on growth and yield of tomato crop, modeling of effect of variation of temperature and relative humidity on growth parameters and yield of tomato crop and To estimate the water use efficiency under drip irrigated system in tomato. The experiment was laid out in randomized block design with six treatments as different transplanting dates i.e. T1: 5th July, T2: 5th August, T3: 5th September, T4: 5th October, T5: 5th November, and T6: 5th December with four replications.

The crop evapotranspiration under the treatments T1, T2, T3, T4, T5 and T6 under the NVPH were observed as 465.01 mm, 434.57 mm, 418.40 mm, 464.68 mm, 465.08 mm and 486.64 mm respectively for the entire crop periods. Transplanting on September 5th (T3) found maximum tomato yield of 118.87 t/ha. The maximum WUE (2841.13 kg/ha-cm) was observed in treatment T3 under the NVPH. Also the maximum output-input ratio (2.85) was observed in treatment T3 under the NVPH. The fruit yield per plant increased quadratically and linearly with average air temperature and relative humidity respectively from first flower anthesis to the first fruit harvest. This analysis shows that the best temperature for the growing of tomato crop i.e. 29.1°C and 75% relative humidity which gives 2971.82 g/plant yield.

Thus the overall findings of research revealed that, all the vegetative parameters, reproductive parameter and quantity parameter were found maximum in treatment T3 (i.e., transplanting of tomato in September month). For growing drip irrigated tomato, naturally ventilated polyhouse system with transplanting in September month gives better output in terms of crop yield and fruit quality. Also, at the same time productivity of water is increased without affecting yield of tomato crop.

अनुक्षेपन

"प्राकृतिक रूप से हवादार पॉलीहाउस के तहत उगाई गई वर्ष की दूसरी छमाही में टमाटर की फसल की वृद्धि और उपज पर जलवायु मापदंडों के मॉडलिंग के प्रभाव" का प्रयोग जुलाई, 2018 से मई, 2019 के दौरान उदयपुर के कॉलेज ऑफ टेक्नोलॉजी एंड इंजीनियरिंग के प्लास्टिकल्चर फार्म में किया गया था। इस अध्ययन में टमाटर की फसल के लिए फसल की पानी की आवश्यकता का निर्धारण करना, टमाटर की फसल की वृद्धि और उपज पर रोपाई की विभिन्न तिथियों पर जलवायु के प्रभाव का अध्ययन करना, तापमान के परिवर्तन के प्रभाव का मॉडलिंग और सापेक्षिक आर्द्रता शामिल है। प्रयोग छह उपचार और चार प्रतिकृति के साथ यादृच्छिक ब्लॉक डिजाइन में किया गया था। उपचार के तहत टी 1, टी 2, टी 3, टी 4, टी 5 और टी 6 के तहत एनवीपीएच के तहत फसल का वाष्पीकरण 465.01 मिमी, 434.57 मिमी, 418.40 मिमी, 464.68 मिमी, 465.08 मिमी और 486.64 मिमी के रूप में मनाया गया। परिणामों से पता चलता है कि सितंबर की रोपाई की तारीख के लिए न्यूनतम पानी की आवश्यकता और दिसंबर के लिए यह अधिकतम है।

5 सितंबर (T3) को रोपाई में अधिकतम टमाटर की पैदावार 118.87 t ha^{-1} मिली। अधिकतम WUE (2841.13 किग्रा / हेक्टेयर) एनवीपीएच के तहत उपचार टी 3 में देखा गया था। साथ ही NVPH के तहत उपचार T3 में अधिकतम आउटपुट-इनपुट अनुपात (2.85) देखा गया। प्रति पौधे के फल की उपज औसत हवा के तापमान और पहले फलों की कटाई के बाद क्रमशः औसत हवा के तापमान और सापेक्ष आर्द्रता के साथ चतुष्कोणीय और रैखिक रूप से बढ़ी। इस विश्लेषण से पता चलता है कि टमाटर की फसल के बढ़ने का सबसे अच्छा तापमान यानी $29.1 \text{ }^\circ\text{C}$ और 75% सापेक्ष आर्द्रता है जो 2971.82 g / पौध की उपज देती है।

इस प्रकार अनुसंधान के समग्र निष्कर्षों से पता चला है कि, उपचार के टी 3 (यानी, सितंबर महीने में टमाटर की रोपाई) में सभी वनस्पति मापदंडों, प्रजनन पैरामीटर और मात्रा पैरामीटर अधिकतम पाए गए थे। ड्रिप सिंचित टमाटर उगाने के लिए, सितंबर महीने में रोपाई के साथ प्राकृतिक रूप से हवादार पॉलीहाउस सिस्टम, फसल की उपज और फलों की गुणवत्ता के मामले में बेहतर उत्पादन देता है। इसके अलावा, एक ही समय में टमाटर की फसल की उपज को प्रभावित किए बिना पानी की उत्पादकता बढ़ जाती है।

APPENDIX A

Standard periods and weeks

Period No.	Week No.	Dated	Period No.	Week No.	Dated
I	1	January	VII	27	July
	2	“		28	“
	3	“		29	“
	4	“		30	“
	5	“		31	“
		1-7 8-14 15-21 22-28 29-4 February			2-8 9-15 16-22 23-29 30-5 August
II	6	February	VIII	32	August
	7	“		33	“
	8	“		34	“
	9	“		35	“
		5-11 12-18 19-25 26-4 March			6-12 13-19 20-26 27-2 September
III	10	March	IX	36	September
	11	“		37	“
	12	“		38	“
	13	“		39	“
		5-11 12-18 19-25 26-1 April			3-9 10-16 17-23 24-30 October
IV	14	April	X	40	October
	15	“		41	“
	16	“		42	“
	17	“		43	“
	18	“		44	“
		2-8 9-15 16-22 23-29 30-6 May			1-7 8-14 15-21 22-28 29-4 November
V	19	May	XI	45	November
	20	“		46	“
	21	“		47	“
	22	“		48	“
		7-13 14-20 21-27 28-3 June			5-11 12-18 19-25 26-2 December
VI	23	June	XII	49	December
	24	“		50	“
	25	“		51	“
	26	“		52	“
		4-10 11-17 18-24 25-1 July			3-9 10-16 17-23 24-31

APPENDIX B

Water application time data for each treatment on the basis of mean of climatic data of 2013 to 2017

Treatment 1 (T1)				Treatment 2 (T2)				Treatment 3 (T3)			
Day	Date	Water Requirement (Lit/day/plant)	Application Time (Hrs)	Day	Date	Water Requirement (Lit/day/plant)	Application Time (Hrs)	Day	Date	Water Requirement (Lit/day/plant)	Application Time (Hrs)
1	5-Jul	0.616	0.433	1	5-Aug	0.646	0.454	1	5-Sep	0.648	0.455
2	6-Jul	0.615	0.432	2	6-Aug	0.610	0.428	2	6-Sep	0.644	0.452
3	7-Jul	0.752	0.528	3	7-Aug	0.592	0.416	3	7-Sep	0.626	0.439
4	8-Jul	0.714	0.502	4	8-Aug	0.589	0.414	4	8-Sep	0.643	0.452
5	9-Jul	0.693	0.487	5	9-Aug	0.548	0.385	5	9-Sep	0.650	0.456
6	10-Jul	0.688	0.483	6	10-Aug	0.540	0.379	6	10-Sep	0.662	0.465
7	11-Jul	0.729	0.513	7	11-Aug	0.634	0.445	7	11-Sep	0.690	0.485
8	12-Jul	0.648	0.455	8	12-Aug	0.726	0.510	8	12-Sep	0.730	0.513
9	13-Jul	0.620	0.435	9	13-Aug	0.734	0.516	9	13-Sep	0.751	0.527
10	14-Jul	0.519	0.365	10	14-Aug	0.725	0.510	10	14-Sep	0.702	0.493
11	15-Jul	0.503	0.353	11	15-Aug	0.741	0.520	11	15-Sep	0.729	0.512
12	16-Jul	0.532	0.374	12	16-Aug	0.697	0.490	12	16-Sep	0.676	0.475
13	17-Jul	0.578	0.406	13	17-Aug	0.707	0.497	13	17-Sep	0.713	0.501
14	18-Jul	0.574	0.403	14	18-Aug	0.745	0.524	14	18-Sep	0.694	0.488
15	19-Jul	0.570	0.401	15	19-Aug	0.770	0.541	15	19-Sep	0.635	0.446
16	20-Jul	0.671	0.471	16	20-Aug	0.708	0.497	16	20-Sep	0.680	0.478
17	21-Jul	0.649	0.456	17	21-Aug	0.749	0.526	17	21-Sep	0.734	0.516
18	22-Jul	0.537	0.377	18	22-Aug	0.581	0.408	18	22-Sep	0.644	0.452

19	23-Jul	0.514	0.362	19	23-Aug	0.585	0.411	19	23-Sep	0.671	0.471
20	24-Jul	0.554	0.389	20	24-Aug	0.638	0.448	20	24-Sep	0.670	0.470
21	25-Jul	0.563	0.396	21	25-Aug	0.680	0.477	21	25-Sep	0.664	0.466
22	26-Jul	0.473	0.332	22	26-Aug	0.614	0.431	22	26-Sep	0.694	0.487
23	27-Jul	0.527	0.371	23	27-Aug	0.554	0.389	23	27-Sep	0.702	0.493
24	28-Jul	0.408	0.287	24	28-Aug	0.672	0.472	24	28-Sep	0.686	0.482
25	29-Jul	0.540	0.380	25	29-Aug	0.654	0.459	25	29-Sep	0.612	0.430
26	30-Jul	0.497	0.350	26	30-Aug	0.722	0.507	26	30-Sep	0.629	0.442
27	31-Jul	0.591	0.415	27	31-Aug	0.611	0.429	27	1-Oct	0.693	0.487
28	1-Aug	0.690	0.485	28	1-Sep	0.743	0.522	28	2-Oct	0.652	0.458
29	2-Aug	0.675	0.474	29	2-Sep	0.740	0.520	29	3-Oct	0.651	0.458
30	3-Aug	0.657	0.462	30	3-Sep	0.671	0.472	30	4-Oct	0.646	0.454
31	4-Aug	0.605	0.425	31	4-Sep	0.643	0.452	31	5-Oct	0.613	0.431
32	5-Aug	0.646	0.454	32	5-Sep	0.648	0.455	32	6-Oct	0.612	0.430
33	6-Aug	0.610	0.429	33	6-Sep	0.644	0.452	33	7-Oct	0.669	0.470
34	7-Aug	0.592	0.416	34	7-Sep	0.626	0.439	34	8-Oct	0.662	0.465
35	8-Aug	0.589	0.414	35	8-Sep	0.643	0.452	35	9-Oct	0.622	0.437
36	9-Aug	0.559	0.393	36	9-Sep	0.663	0.466	36	10-Oct	0.604	0.424
37	10-Aug	0.562	0.395	37	10-Sep	0.689	0.484	37	11-Oct	0.673	0.473
38	11-Aug	0.672	0.473	38	11-Sep	0.732	0.514	38	12-Oct	0.674	0.473
39	12-Aug	0.785	0.552	39	12-Sep	0.790	0.555	39	13-Oct	0.693	0.487
40	13-Aug	0.808	0.568	40	13-Sep	0.827	0.581	40	14-Oct	0.688	0.483
41	14-Aug	0.814	0.572	41	14-Sep	0.788	0.554	41	15-Oct	0.652	0.458
42	15-Aug	0.846	0.595	42	15-Sep	0.833	0.585	42	16-Oct	0.623	0.438
43	16-Aug	0.810	0.570	43	16-Sep	0.786	0.552	43	17-Oct	1.166	0.819
44	17-Aug	0.837	0.588	44	17-Sep	0.843	0.593	44	18-Oct	0.720	0.506
45	18-Aug	0.897	0.631	45	18-Sep	0.835	0.587	45	19-Oct	0.713	0.501
46	19-Aug	0.943	0.663	46	19-Sep	0.777	0.546	46	20-Oct	0.706	0.496

47	20-Aug	0.881	0.619	47	20-Sep	0.846	0.594	47	21-Oct	0.730	0.513
48	21-Aug	0.947	0.665	48	21-Sep	0.928	0.652	48	22-Oct	0.731	0.513
49	22-Aug	0.747	0.525	49	22-Sep	0.827	0.581	49	23-Oct	0.739	0.519
50	23-Aug	0.764	0.537	50	23-Sep	0.876	0.615	50	24-Oct	0.721	0.507
51	24-Aug	0.845	0.594	51	24-Sep	0.887	0.623	51	25-Oct	0.721	0.507
52	25-Aug	0.915	0.643	52	25-Sep	0.893	0.627	52	26-Oct	0.717	0.504
53	26-Aug	0.839	0.589	53	26-Sep	0.948	0.666	53	27-Oct	0.710	0.499
54	27-Aug	0.768	0.540	54	27-Sep	0.974	0.684	54	28-Oct	0.733	0.515
55	28-Aug	0.946	0.665	55	28-Sep	0.965	0.678	55	29-Oct	0.709	0.498
56	29-Aug	0.933	0.656	56	29-Sep	0.873	0.613	56	30-Oct	0.672	0.472
57	30-Aug	1.044	0.734	57	30-Sep	0.910	0.639	57	31-Oct	0.749	0.526
58	31-Aug	0.896	0.630	58	1-Oct	1.018	0.715	58	1-Nov	0.718	0.504
59	1-Sep	1.106	0.777	59	2-Oct	0.969	0.681	59	2-Nov	0.728	0.512
60	2-Sep	1.116	0.784	60	3-Oct	0.983	0.690	60	3-Nov	0.704	0.494
61	3-Sep	1.026	0.721	61	4-Oct	0.988	0.694	61	4-Nov	0.755	0.530
62	4-Sep	0.996	0.700	62	5-Oct	0.950	0.667	62	5-Nov	0.724	0.508
63	5-Sep	1.017	0.715	63	6-Oct	0.961	0.675	63	6-Nov	0.739	0.519
64	6-Sep	1.023	0.719	64	7-Oct	1.063	0.747	64	7-Nov	0.745	0.523
65	7-Sep	1.007	0.708	65	8-Oct	1.066	0.749	65	8-Nov	0.744	0.523
66	8-Sep	1.049	0.737	66	9-Oct	1.014	0.712	66	9-Nov	0.743	0.522
67	9-Sep	1.072	0.754	67	10-Oct	0.977	0.687	67	10-Nov	0.704	0.495
68	10-Sep	1.106	0.777	68	11-Oct	1.081	0.759	68	11-Nov	0.736	0.517
69	11-Sep	1.167	0.820	69	12-Oct	1.074	0.754	69	12-Nov	0.731	0.514
70	12-Sep	1.250	0.879	70	13-Oct	1.096	0.770	70	13-Nov	0.683	0.480
71	13-Sep	1.300	0.914	71	14-Oct	1.081	0.760	71	14-Nov	0.747	0.525
72	14-Sep	1.231	0.865	72	15-Oct	1.018	0.715	72	15-Nov	0.727	0.511
73	15-Sep	1.292	0.908	73	16-Oct	0.966	0.679	73	16-Nov	0.748	0.526
74	16-Sep	1.212	0.852	74	17-Oct	1.003	0.704	74	17-Nov	0.772	0.542

75	17-Sep	1.293	0.909	75	18-Oct	1.103	0.775	75	18-Nov	0.732	0.514
76	18-Sep	1.273	0.894	76	19-Oct	1.086	0.763	76	19-Nov	0.741	0.520
77	19-Sep	1.178	0.828	77	20-Oct	1.070	0.752	77	20-Nov	0.723	0.508
78	20-Sep	1.275	0.896	78	21-Oct	1.099	0.772	78	21-Nov	0.734	0.516
79	21-Sep	1.391	0.978	79	22-Oct	1.095	0.769	79	22-Nov	0.738	0.518
80	22-Sep	1.233	0.866	80	23-Oct	1.102	0.774	80	23-Nov	0.711	0.500
81	23-Sep	1.286	0.904	81	24-Oct	1.059	0.744	81	24-Nov	0.728	0.511
82	24-Sep	1.283	0.902	82	25-Oct	1.043	0.733	82	25-Nov	0.772	0.542
83	25-Sep	1.272	0.894	83	26-Oct	1.021	0.717	83	26-Nov	0.771	0.542
84	26-Sep	1.330	0.934	84	27-Oct	0.996	0.700	84	27-Nov	0.772	0.543
85	27-Sep	1.346	0.946	85	28-Oct	1.013	0.712	85	28-Nov	0.748	0.526
86	28-Sep	1.314	0.924	86	29-Oct	0.966	0.678	86	29-Nov	0.751	0.528
87	29-Sep	1.172	0.824	87	30-Oct	0.903	0.634	87	30-Nov	0.733	0.515
88	30-Sep	1.205	0.847	88	31-Oct	0.992	0.697	88	1-Dec	0.753	0.529
89	1-Oct	1.329	0.934	89	1-Nov	0.923	0.648	89	2-Dec	0.722	0.507
90	2-Oct	1.249	0.878	90	2-Nov	0.930	0.653	90	3-Dec	0.733	0.515
91	3-Oct	1.249	0.878	91	3-Nov	0.890	0.625	91	4-Dec	0.694	0.487
92	4-Oct	1.239	0.871	92	4-Nov	0.958	0.673	92	5-Dec	0.628	0.441
93	5-Oct	1.175	0.826	93	5-Nov	0.889	0.625	93	6-Dec	0.669	0.470
94	6-Oct	1.174	0.825	94	6-Nov	0.897	0.630	94	7-Dec	0.703	0.494
95	7-Oct	1.282	0.901	95	7-Nov	0.892	0.627	95	8-Dec	0.648	0.455
96	8-Oct	1.269	0.892	96	8-Nov	0.889	0.625	96	9-Dec	0.699	0.491
97	9-Oct	1.192	0.838	97	9-Nov	0.877	0.616	97	10-Dec	0.693	0.486
98	10-Oct	1.135	0.798	98	10-Nov	0.825	0.579	98	11-Dec	0.685	0.481
99	11-Oct	1.240	0.872	99	11-Nov	0.848	0.596	99	12-Dec	0.685	0.481
100	12-Oct	1.217	0.855	100	12-Nov	0.830	0.583	100	13-Dec	0.666	0.468
101	13-Oct	1.228	0.863	101	13-Nov	0.769	0.540	101	14-Dec	0.666	0.468
102	14-Oct	1.197	0.841	102	14-Nov	0.832	0.584	102	15-Dec	0.646	0.454

103	15-Oct	1.113	0.782	103	15-Nov	0.798	0.561	103	16-Dec	0.615	0.432
104	16-Oct	1.045	0.735	104	16-Nov	0.811	0.570	104	17-Dec	0.634	0.445
105	17-Oct	1.072	0.753	105	17-Nov	0.824	0.579	105	18-Dec	0.620	0.435
106	18-Oct	1.166	0.820	106	18-Nov	0.783	0.550	106	19-Dec	0.617	0.434
107	19-Oct	1.135	0.798	107	19-Nov	0.776	0.545	107	20-Dec	0.604	0.424
108	20-Oct	1.106	0.778	108	20-Nov	0.747	0.525	108	21-Dec	0.650	0.457
109	21-Oct	1.124	0.790	109	21-Nov	0.752	0.528	109	22-Dec	0.608	0.427
110	22-Oct	1.108	0.779	110	22-Nov	0.747	0.524	110	23-Dec	0.612	0.430
111	23-Oct	1.103	0.775	111	23-Nov	0.713	0.501	111	24-Dec	0.606	0.426
112	24-Oct	1.059	0.744	112	24-Nov	0.730	0.513	112	25-Dec	0.591	0.415
113	25-Oct	1.043	0.733	113	25-Nov	0.772	0.542	113	26-Dec	0.574	0.403
114	26-Oct	1.021	0.718	114	26-Nov	0.771	0.542	114	27-Dec	0.548	0.385
115	27-Oct	0.996	0.700	115	27-Nov	0.770	0.541	115	28-Dec	0.618	0.434
116	28-Oct	1.013	0.712	116	28-Nov	0.749	0.526	116	29-Dec	0.651	0.457
117	29-Oct	0.966	0.679	117	29-Nov	0.750	0.527	117	30-Dec	0.625	0.439
118	30-Oct	0.903	0.635	118	30-Nov	0.733	0.515	118	31-Dec	0.634	0.445
119	31-Oct	0.992	0.697	119	1-Dec	0.752	0.529	119	1-Jan	0.587	0.413
120	1-Nov	0.923	0.648	120	2-Dec	0.725	0.509	120	2-Jan	0.630	0.443
121	2-Nov	0.930	0.653	121	3-Dec	0.740	0.520	121	3-Jan	0.617	0.434
122	3-Nov	0.890	0.626	122	4-Dec	0.701	0.492	122	4-Jan	0.616	0.432
123	4-Nov	0.958	0.673	123	5-Dec	0.635	0.446	123	5-Jan	0.673	0.473
124	5-Nov	0.889	0.625	124	6-Dec	0.673	0.473	124	6-Jan	0.662	0.465
125	6-Nov	0.897	0.631	125	7-Dec	0.704	0.495	125	7-Jan	0.672	0.472
126	7-Nov	0.892	0.627	126	8-Dec	0.651	0.457	126	8-Jan	0.641	0.451
127	8-Nov	0.889	0.625	127	9-Dec	0.699	0.491	127	9-Jan	0.599	0.421
128	9-Nov	0.877	0.617	128	10-Dec	0.690	0.485	128	10-Jan	0.668	0.470
129	10-Nov	0.825	0.580	129	11-Dec	0.686	0.482	129	11-Jan	0.653	0.459
130	11-Nov	0.848	0.596	130	12-Dec	0.688	0.483	130	12-Jan	0.603	0.424

131	12-Nov	0.830	0.583	131	13-Dec	0.668	0.469	131	13-Jan	0.665	0.467
132	13-Nov	0.769	0.540	132	14-Dec	0.668	0.469	132	14-Jan	0.678	0.476
133	14-Nov	0.832	0.584	133	15-Dec	0.646	0.454	133	15-Jan	0.696	0.489
134	15-Nov	0.798	0.561	134	16-Dec	0.615	0.432	134	16-Jan	0.703	0.494
135	16-Nov	0.811	0.570	135	17-Dec	0.633	0.444	135	17-Jan	0.691	0.485
136	17-Nov	0.824	0.579	136	18-Dec	0.618	0.434	136	18-Jan	0.691	0.485
137	18-Nov	0.783	0.550	137	19-Dec	0.622	0.437	137	19-Jan	0.689	0.484
138	19-Nov	0.776	0.546	138	20-Dec	0.618	0.434	138	20-Jan	0.645	0.453
139	20-Nov	0.747	0.525	139	21-Dec	0.658	0.462	139	21-Jan	0.646	0.454
140	21-Nov	0.752	0.529	140	22-Dec	0.611	0.429	140	22-Jan	0.663	0.466
141	22-Nov	0.747	0.525	141	23-Dec	0.612	0.430	141	23-Jan	0.654	0.460
142	23-Nov	0.713	0.501	142	24-Dec	0.614	0.431	142	24-Jan	0.697	0.490
143	24-Nov	0.730	0.513	143	25-Dec	0.596	0.419	143	25-Jan	0.694	0.488
144	25-Nov	0.772	0.542	144	26-Dec	0.578	0.406	144	26-Jan	0.668	0.470
145	26-Nov	0.771	0.542	145	27-Dec	0.553	0.388	145	27-Jan	0.718	0.504
146	27-Nov	0.770	0.541	146	28-Dec	0.621	0.436	146	28-Jan	0.740	0.520
147	28-Nov	0.749	0.527	147	29-Dec	0.656	0.461	147	29-Jan	0.746	0.524
148	29-Nov	0.750	0.527	148	30-Dec	0.632	0.444	148	30-Jan	0.799	0.561
149	30-Nov	0.733	0.515	149	31-Dec	0.638	0.448	149	31-Jan	0.815	0.572
150	1-Dec	0.752	0.529	150	1-Jan	0.587	0.413	150	1-Feb	0.809	0.568
151	2-Dec	0.722	0.508	151	2-Jan	0.628	0.441	151	2-Feb	0.821	0.577
152	3-Dec	0.729	0.512	152	3-Jan	0.608	0.427	152	3-Feb	0.826	0.580
153	4-Dec	0.683	0.480	153	4-Jan	0.600	0.421	153	4-Feb	0.832	0.584
154	5-Dec	0.611	0.429	154	5-Jan	0.647	0.455	154	5-Feb	0.784	0.550
155	6-Dec	0.640	0.450	155	6-Jan	0.629	0.442	155	6-Feb	0.794	0.558
156	7-Dec	0.662	0.465	156	7-Jan	0.631	0.443	156	7-Feb	0.854	0.600
157	8-Dec	0.604	0.425	157	8-Jan	0.595	0.418	157	8-Feb	0.866	0.608
158	9-Dec	0.641	0.450	158	9-Jan	0.549	0.385	158	9-Feb	0.794	0.558

159	10-Dec	0.624	0.439	159	10-Jan	0.605	0.425	159	10-Feb	0.858	0.603
160	11-Dec	0.613	0.431	160	11-Jan	0.583	0.410	160	11-Feb	0.814	0.572
161	12-Dec	0.607	0.426	161	12-Jan	0.531	0.373	161	12-Feb	0.806	0.566
162	13-Dec	0.581	0.408	162	13-Jan	0.579	0.407	162	13-Feb	0.890	0.625
163	14-Dec	0.574	0.403	163	14-Jan	0.582	0.409	163	14-Feb	0.862	0.605
164	15-Dec	0.547	0.384	164	15-Jan	0.589	0.414	164	15-Feb	0.853	0.599
165	16-Dec	0.514	0.361	165	16-Jan	0.588	0.413	165	16-Feb	0.744	0.523
166	17-Dec	0.521	0.366	166	17-Jan	0.569	0.400	166	17-Feb	0.750	0.527
167	18-Dec	0.502	0.353	167	18-Jan	0.561	0.394	167	18-Feb	0.786	0.552
168	19-Dec	0.498	0.350	168	19-Jan	0.552	0.387	168	19-Feb	0.823	0.578
169	20-Dec	0.487	0.342	169	20-Jan	0.509	0.357	169	20-Feb	0.800	0.562
170	21-Dec	0.511	0.359	170	21-Jan	0.502	0.353	170	21-Feb	0.842	0.592
171	22-Dec	0.468	0.329	171	22-Jan	0.508	0.357	171	22-Feb	0.816	0.573
172	23-Dec	0.461	0.324	172	23-Jan	0.494	0.347	172	23-Feb	0.770	0.541
173	24-Dec	0.456	0.321	173	24-Jan	0.518	0.364	173	24-Feb	0.800	0.562
174	25-Dec	0.436	0.306	174	25-Jan	0.508	0.357	174	25-Feb	0.792	0.557
175	26-Dec	0.416	0.292	175	26-Jan	0.481	0.338	175	26-Feb	0.797	0.560
176	27-Dec	0.391	0.275	176	27-Jan	0.508	0.357	176	27-Feb	0.734	0.516
177	28-Dec	0.432	0.304	177	28-Jan	0.516	0.362	177	28-Feb	0.712	0.500
178	29-Dec	0.449	0.316	178	29-Jan	0.511	0.359	178	29Feb	0.157	0.110
179	30-Dec	0.426	0.299	179	30-Jan	0.538	0.378	179	1-Mar	0.783	0.550
180	31-Dec	0.422	0.297	180	31-Jan	0.539	0.379	180	2-Mar	0.670	0.470

Treatment 4 (T4)				Treatment 5 (T5)				Treatment 6 (T6)			
Day	Date	Water Requirement (Lit/day/plant)	Application Time (Hrs)	Day	Date	Water Requirement (Lit/day/plant)	Application Time (Hrs)	Day	Date	Water Requirement (Lit/day/plant)	Application Time (Hrs)
1	5-Oct	0.613	0.433	1	5-Nov	0.467	0.330	1	5-Dec	0.328	0.231
2	6-Oct	0.612	0.432	2	6-Nov	0.471	0.332	2	6-Dec	0.349	0.246
3	7-Oct	0.669	0.472	3	7-Nov	0.469	0.331	3	7-Dec	0.367	0.259
4	8-Oct	0.662	0.467	4	8-Nov	0.462	0.326	4	8-Dec	0.338	0.238
5	9-Oct	0.622	0.439	5	9-Nov	0.456	0.322	5	9-Dec	0.365	0.257
6	10-Oct	0.592	0.418	6	10-Nov	0.427	0.301	6	10-Dec	0.361	0.255
7	11-Oct	0.647	0.456	7	11-Nov	0.440	0.311	7	11-Dec	0.358	0.252
8	12-Oct	0.635	0.448	8	12-Nov	0.432	0.305	8	12-Dec	0.357	0.252
9	13-Oct	0.640	0.452	9	13-Nov	0.399	0.282	9	13-Dec	0.347	0.245
10	14-Oct	0.624	0.440	10	14-Nov	0.431	0.304	10	14-Dec	0.348	0.245
11	15-Oct	0.581	0.410	11	15-Nov	0.415	0.293	11	15-Dec	0.337	0.238
12	16-Oct	0.545	0.385	12	16-Nov	0.422	0.298	12	16-Dec	0.321	0.226
13	17-Oct	0.560	0.395	13	17-Nov	0.430	0.304	13	17-Dec	0.331	0.233
14	18-Oct	0.608	0.429	14	18-Nov	0.404	0.285	14	18-Dec	0.323	0.228
15	19-Oct	0.592	0.418	15	19-Nov	0.404	0.285	15	19-Dec	0.322	0.227
16	20-Oct	0.577	0.407	16	20-Nov	0.390	0.275	16	20-Dec	0.315	0.222
17	21-Oct	0.587	0.414	17	21-Nov	0.392	0.276	17	21-Dec	0.339	0.239
18	22-Oct	0.578	0.408	18	22-Nov	0.390	0.275	18	22-Dec	0.317	0.224
19	23-Oct	0.575	0.406	19	23-Nov	0.371	0.262	19	23-Dec	0.319	0.225
20	24-Oct	0.553	0.390	20	24-Nov	0.380	0.268	20	24-Dec	0.316	0.223
21	25-Oct	0.544	0.384	21	25-Nov	0.403	0.284	21	25-Dec	0.308	0.218
22	26-Oct	0.533	0.376	22	26-Nov	0.402	0.284	22	26-Dec	0.299	0.211
23	27-Oct	0.520	0.367	23	27-Nov	0.403	0.284	23	27-Dec	0.286	0.202
24	28-Oct	0.529	0.373	24	28-Nov	0.390	0.275	24	28-Dec	0.322	0.227
25	29-Oct	0.504	0.355	25	29-Nov	0.392	0.276	25	29-Dec	0.340	0.240

26	30-Oct	0.471	0.332	26	30-Nov	0.382	0.270	26	30-Dec	0.326	0.230
27	31-Oct	0.518	0.365	27	1-Dec	0.393	0.277	27	31-Dec	0.331	0.233
28	1-Nov	0.489	0.345	28	2-Dec	0.377	0.266	28	1-Jan	0.306	0.216
29	2-Nov	0.490	0.345	29	3-Dec	0.382	0.270	29	2-Jan	0.329	0.232
30	3-Nov	0.466	0.329	30	4-Dec	0.362	0.255	30	3-Jan	0.322	0.227
31	4-Nov	0.494	0.348	31	5-Dec	0.328	0.231	31	4-Jan	0.321	0.227
32	5-Nov	0.467	0.330	32	6-Dec	0.349	0.246	32	5-Jan	0.351	0.248
33	6-Nov	0.471	0.332	33	7-Dec	0.367	0.259	33	6-Jan	0.345	0.243
34	7-Nov	0.469	0.331	34	8-Dec	0.338	0.238	34	7-Jan	0.350	0.247
35	8-Nov	0.462	0.326	35	9-Dec	0.365	0.257	35	8-Jan	0.335	0.236
36	9-Nov	0.465	0.328	36	10-Dec	0.369	0.260	36	9-Jan	0.319	0.225
37	10-Nov	0.444	0.313	37	11-Dec	0.372	0.262	37	10-Jan	0.363	0.256
38	11-Nov	0.467	0.330	38	12-Dec	0.379	0.267	38	11-Jan	0.362	0.255
39	12-Nov	0.468	0.330	39	13-Dec	0.376	0.265	39	12-Jan	0.340	0.240
40	13-Nov	0.440	0.310	40	14-Dec	0.383	0.270	40	13-Jan	0.382	0.270
41	14-Nov	0.484	0.341	41	15-Dec	0.378	0.267	41	14-Jan	0.397	0.280
42	15-Nov	0.474	0.334	42	16-Dec	0.367	0.259	42	15-Jan	0.415	0.293
43	16-Nov	0.491	0.346	43	17-Dec	0.384	0.271	43	16-Jan	0.427	0.301
44	17-Nov	0.509	0.359	44	18-Dec	0.383	0.270	44	17-Jan	0.426	0.301
45	18-Nov	0.486	0.343	45	19-Dec	0.387	0.273	45	18-Jan	0.434	0.306
46	19-Nov	0.494	0.349	46	20-Dec	0.386	0.272	46	19-Jan	0.440	0.310
47	20-Nov	0.485	0.342	47	21-Dec	0.422	0.298	47	20-Jan	0.419	0.295
48	21-Nov	0.495	0.349	48	22-Dec	0.401	0.283	48	21-Jan	0.426	0.301
49	22-Nov	0.500	0.353	49	23-Dec	0.410	0.289	49	22-Jan	0.444	0.313
50	23-Nov	0.485	0.342	50	24-Dec	0.413	0.291	50	23-Jan	0.446	0.314
51	24-Nov	0.503	0.355	51	25-Dec	0.409	0.288	51	24-Jan	0.482	0.340
52	25-Nov	0.542	0.382	52	26-Dec	0.403	0.284	52	25-Jan	0.487	0.344
53	26-Nov	0.549	0.388	53	27-Dec	0.391	0.276	53	26-Jan	0.476	0.336
54	27-Nov	0.559	0.394	54	28-Dec	0.447	0.315	54	27-Jan	0.519	0.366

55	28-Nov	0.549	0.387	55	29-Dec	0.478	0.337	55	28-Jan	0.543	0.383
56	29-Nov	0.559	0.394	56	30-Dec	0.466	0.328	56	29-Jan	0.555	0.392
57	30-Nov	0.553	0.390	57	31-Dec	0.478	0.337	57	30-Jan	0.603	0.425
58	1-Dec	0.577	0.407	58	1-Jan	0.450	0.317	58	31-Jan	0.624	0.440
59	2-Dec	0.561	0.395	59	2-Jan	0.489	0.345	59	1-Feb	0.628	0.443
60	3-Dec	0.577	0.407	60	3-Jan	0.486	0.343	60	2-Feb	0.648	0.457
61	4-Dec	0.553	0.390	61	4-Jan	0.491	0.346	61	3-Feb	0.669	0.472
62	5-Dec	0.508	0.358	62	5-Jan	0.544	0.384	62	4-Feb	0.690	0.487
63	6-Dec	0.548	0.387	63	6-Jan	0.542	0.382	63	5-Feb	0.667	0.470
64	7-Dec	0.583	0.411	64	7-Jan	0.557	0.393	64	6-Feb	0.692	0.488
65	8-Dec	0.544	0.384	65	8-Jan	0.539	0.380	65	7-Feb	0.764	0.539
66	9-Dec	0.594	0.419	66	9-Jan	0.509	0.359	66	8-Feb	0.794	0.560
67	10-Dec	0.596	0.421	67	10-Jan	0.576	0.406	67	9-Feb	0.747	0.527
68	11-Dec	0.597	0.421	68	11-Jan	0.569	0.402	68	10-Feb	0.827	0.583
69	12-Dec	0.604	0.426	69	12-Jan	0.532	0.375	69	11-Feb	0.805	0.568
70	13-Dec	0.594	0.419	70	13-Jan	0.594	0.419	70	12-Feb	0.817	0.576
71	14-Dec	0.602	0.425	71	14-Jan	0.613	0.432	71	13-Feb	0.924	0.652
72	15-Dec	0.591	0.417	72	15-Jan	0.636	0.449	72	14-Feb	0.918	0.647
73	16-Dec	0.569	0.401	73	16-Jan	0.651	0.459	73	15-Feb	0.932	0.657
74	17-Dec	0.593	0.418	74	17-Jan	0.646	0.456	74	16-Feb	0.833	0.588
75	18-Dec	0.586	0.414	75	18-Jan	0.653	0.461	75	17-Feb	0.862	0.608
76	19-Dec	0.590	0.416	76	19-Jan	0.659	0.465	76	18-Feb	0.926	0.653
77	20-Dec	0.584	0.412	77	20-Jan	0.624	0.440	77	19-Feb	0.994	0.701
78	21-Dec	0.636	0.449	78	21-Jan	0.632	0.446	78	20-Feb	0.992	0.700
79	22-Dec	0.601	0.424	79	22-Jan	0.655	0.462	79	21-Feb	1.071	0.755
80	23-Dec	0.612	0.431	80	23-Jan	0.654	0.461	80	22-Feb	1.065	0.751
81	24-Dec	0.606	0.427	81	24-Jan	0.697	0.492	81	23-Feb	1.021	0.720
82	25-Dec	0.591	0.417	82	25-Jan	0.694	0.490	82	24-Feb	1.077	0.760
83	26-Dec	0.574	0.405	83	26-Jan	0.668	0.472	83	25-Feb	1.084	0.764

84	27-Dec	0.548	0.387	84	27-Jan	0.718	0.506	84	26-Feb	1.108	0.782
85	28-Dec	0.618	0.436	85	28-Jan	0.740	0.522	85	27-Feb	1.037	0.732
86	29-Dec	0.651	0.459	86	29-Jan	0.746	0.526	86	28-Feb	1.022	0.721
87	30-Dec	0.625	0.441	87	30-Jan	0.799	0.563	87	29 Feb	0.229	0.161
88	31-Dec	0.634	0.447	88	31-Jan	0.815	0.575	88	1-Mar	1.163	0.820
89	1-Jan	0.587	0.414	89	1-Feb	0.809	0.571	89	2-Mar	1.012	0.714
90	2-Jan	0.630	0.444	90	2-Feb	0.824	0.581	90	3-Mar	1.067	0.753
91	3-Jan	0.617	0.435	91	3-Feb	0.838	0.591	91	4-Mar	1.023	0.722
92	4-Jan	0.616	0.434	92	4-Feb	0.854	0.602	92	5-Mar	1.067	0.753
93	5-Jan	0.673	0.475	93	5-Feb	0.814	0.574	93	6-Mar	1.121	0.791
94	6-Jan	0.662	0.467	94	6-Feb	0.835	0.589	94	7-Mar	1.157	0.816
95	7-Jan	0.672	0.474	95	7-Feb	0.910	0.642	95	8-Mar	1.183	0.834
96	8-Jan	0.641	0.452	96	8-Feb	0.933	0.658	96	9-Mar	1.074	0.758
97	9-Jan	0.599	0.422	97	9-Feb	0.867	0.611	97	10-Mar	1.060	0.748
98	10-Jan	0.668	0.472	98	10-Feb	0.949	0.669	98	11-Mar	1.089	0.768
99	11-Jan	0.653	0.461	99	11-Feb	0.912	0.643	99	12-Mar	1.192	0.841
100	12-Jan	0.603	0.425	100	12-Feb	0.914	0.645	100	13-Mar	1.133	0.799
101	13-Jan	0.665	0.469	101	13-Feb	1.023	0.721	101	14-Mar	1.181	0.833
102	14-Jan	0.678	0.478	102	14-Feb	1.004	0.708	102	15-Mar	1.067	0.753
103	15-Jan	0.696	0.491	103	15-Feb	1.008	0.711	103	16-Mar	1.142	0.806
104	16-Jan	0.703	0.496	104	16-Feb	0.891	0.629	104	17-Mar	1.205	0.850
105	17-Jan	0.691	0.487	105	17-Feb	0.911	0.642	105	18-Mar	1.307	0.922
106	18-Jan	0.691	0.487	106	18-Feb	0.968	0.683	106	19-Mar	1.214	0.857
107	19-Jan	0.689	0.486	107	19-Feb	1.028	0.725	107	20-Mar	1.251	0.882
108	20-Jan	0.645	0.455	108	20-Feb	1.014	0.715	108	21-Mar	1.308	0.923
109	21-Jan	0.646	0.456	109	21-Feb	1.083	0.764	109	22-Mar	1.234	0.871
110	22-Jan	0.663	0.468	110	22-Feb	1.066	0.752	110	23-Mar	1.283	0.905
111	23-Jan	0.654	0.462	111	23-Feb	1.021	0.720	111	24-Mar	1.317	0.929
112	24-Jan	0.697	0.492	112	24-Feb	1.077	0.760	112	25-Mar	1.314	0.927

113	25-Jan	0.694	0.490	113	25-Feb	1.084	0.764	113	26-Mar	1.367	0.964
114	26-Jan	0.668	0.472	114	26-Feb	1.108	0.782	114	27-Mar	1.241	0.875
115	27-Jan	0.718	0.506	115	27-Feb	1.037	0.732	115	28-Mar	1.332	0.939
116	28-Jan	0.740	0.522	116	28-Feb	1.022	0.721	116	29-Mar	1.336	0.943
117	29-Jan	0.746	0.526	117	29-Feb	0.780	0.550	117	30-Mar	1.382	0.975
118	30-Jan	0.799	0.563	118	1-Mar	1.163	0.820	118	31-Mar	1.427	1.007
119	31-Jan	0.815	0.575	119	2-Mar	1.012	0.714	119	1-Apr	1.420	1.001
120	1-Feb	0.809	0.571	120	3-Mar	1.067	0.753	120	2-Apr	1.411	0.995
121	2-Feb	0.824	0.581	121	4-Mar	1.023	0.722	121	3-Apr	1.489	1.050
122	3-Feb	0.838	0.591	122	5-Mar	1.067	0.753	122	4-Apr	1.497	1.056
123	4-Feb	0.854	0.602	123	6-Mar	1.121	0.791	123	5-Apr	1.507	1.063
124	5-Feb	0.814	0.574	124	7-Mar	1.157	0.816	124	6-Apr	1.533	1.081
125	6-Feb	0.835	0.589	125	8-Mar	1.183	0.834	125	7-Apr	1.509	1.065
126	7-Feb	0.910	0.642	126	9-Mar	1.074	0.758	126	8-Apr	1.577	1.112
127	8-Feb	0.933	0.658	127	10-Mar	1.060	0.748	127	9-Apr	1.587	1.119
128	9-Feb	0.867	0.611	128	11-Mar	1.089	0.768	128	10-Apr	1.590	1.122
129	10-Feb	0.949	0.669	129	12-Mar	1.192	0.841	129	11-Apr	1.516	1.069
130	11-Feb	0.912	0.643	130	13-Mar	1.133	0.799	130	12-Apr	1.525	1.076
131	12-Feb	0.914	0.645	131	14-Mar	1.181	0.833	131	13-Apr	1.502	1.060
132	13-Feb	1.023	0.721	132	15-Mar	1.067	0.753	132	14-Apr	1.529	1.078
133	14-Feb	1.004	0.708	133	16-Mar	1.142	0.806	133	15-Apr	1.527	1.077
134	15-Feb	1.008	0.711	134	17-Mar	1.205	0.850	134	16-Apr	1.595	1.125
135	16-Feb	0.891	0.629	135	18-Mar	1.307	0.922	135	17-Apr	1.640	1.157
136	17-Feb	0.911	0.642	136	19-Mar	1.214	0.857	136	18-Apr	1.658	1.170
137	18-Feb	0.968	0.683	137	20-Mar	1.251	0.882	137	19-Apr	1.689	1.192
138	19-Feb	1.028	0.725	138	21-Mar	1.308	0.923	138	20-Apr	1.623	1.145
139	20-Feb	1.014	0.715	139	22-Mar	1.234	0.871	139	21-Apr	1.639	1.156
140	21-Feb	1.083	0.764	140	23-Mar	1.283	0.905	140	22-Apr	1.704	1.202
141	22-Feb	1.066	0.752	141	24-Mar	1.317	0.929	141	23-Apr	1.665	1.175

142	23-Feb	1.021	0.720	142	25-Mar	1.314	0.927	142	24-Apr	1.652	1.166
143	24-Feb	1.077	0.760	143	26-Mar	1.367	0.964	143	25-Apr	1.667	1.176
144	25-Feb	1.084	0.764	144	27-Mar	1.241	0.875	144	26-Apr	1.640	1.157
145	26-Feb	1.108	0.782	145	28-Mar	1.332	0.939	145	27-Apr	1.667	1.176
146	27-Feb	1.037	0.732	146	29-Mar	1.336	0.943	146	28-Apr	1.684	1.188
147	28-Feb	1.022	0.721	147	30-Mar	1.382	0.975	147	29-Apr	1.696	1.197
148	29Feb	0.779	0.550	148	31-Mar	1.427	1.007	148	30-Apr	1.773	1.251
149	1-Mar	0.502	0.354	149	1-Apr	1.420	1.001	149	1-May	1.865	1.315
150	2-Mar	1.151	0.812	150	2-Apr	1.411	0.995	150	2-May	1.814	1.279
151	3-Mar	1.009	0.712	151	3-Apr	1.489	1.050	151	3-May	1.792	1.264
152	4-Mar	1.063	0.750	152	4-Apr	1.493	1.053	152	4-May	1.799	1.269
153	5-Mar	1.010	0.713	153	5-Apr	1.485	1.048	153	5-May	1.873	1.321
154	6-Mar	1.044	0.737	154	6-Apr	1.493	1.053	154	6-May	1.826	1.288
155	7-Mar	1.075	0.758	155	7-Apr	1.452	1.025	155	7-May	1.755	1.238
156	8-Mar	1.104	0.779	156	8-Apr	1.499	1.058	156	8-May	1.809	1.276
157	9-Mar	1.115	0.786	157	9-Apr	1.491	1.051	157	9-May	1.771	1.249
158	10-Mar	0.993	0.700	158	10-Apr	1.475	1.041	158	10-May	1.770	1.249
159	11-Mar	0.944	0.666	159	11-Apr	1.389	0.980	159	11-May	1.776	1.253
160	12-Mar	1.013	0.714	160	12-Apr	1.379	0.973	160	12-May	1.768	1.247
161	13-Mar	1.079	0.761	161	13-Apr	1.341	0.946	161	13-May	1.729	1.220
162	14-Mar	0.997	0.703	162	14-Apr	1.348	0.951	162	14-May	1.641	1.158
163	15-Mar	1.027	0.725	163	15-Apr	1.328	0.937	163	15-May	1.647	1.162
164	16-Mar	0.897	0.633	164	16-Apr	1.369	0.966	164	16-May	1.600	1.129
165	17-Mar	0.994	0.701	165	17-Apr	1.388	0.979	165	17-May	1.674	1.181
166	18-Mar	1.014	0.715	166	18-Apr	1.385	0.977	166	18-May	1.714	1.209
167	19-Mar	1.016	0.716	167	19-Apr	1.392	0.982	167	19-May	1.702	1.201
168	20-Mar	1.032	0.728	168	20-Apr	1.318	0.930	168	20-May	1.650	1.164
169	21-Mar	1.034	0.730	169	21-Apr	1.312	0.925	169	21-May	1.581	1.115
170	22-Mar	1.010	0.712	170	22-Apr	1.344	0.948	170	22-May	1.764	1.244

171	23-Mar	0.969	0.684	171	23-Apr	1.294	0.913	171	23-May	1.662	1.172
172	24-Mar	0.974	0.687	172	24-Apr	1.265	0.893	172	24-May	1.641	1.158
173	25-Mar	0.981	0.692	173	25-Apr	1.258	0.887	173	25-May	1.571	1.108
174	26-Mar	0.991	0.699	174	26-Apr	1.218	0.859	174	26-May	1.537	1.085
175	27-Mar	1.008	0.711	175	27-Apr	1.219	0.860	175	27-May	1.512	1.066
176	28-Mar	0.892	0.629	176	28-Apr	1.212	0.855	176	28-May	1.485	1.048
177	29-Mar	0.943	0.665	177	29-Apr	1.201	0.847	177	29-May	1.491	1.052
178	30-Mar	0.928	0.654	178	30-Apr	1.235	0.871	178	30-May	1.476	1.041
179	31-Mar	0.952	0.671	179	1-May	1.277	0.901	179	31-May	1.405	0.991
180	1-Apr	0.965	0.681	180	2-May	1.221	0.861	180	1-Jun	1.353	0.954

APPENDIX C

Performance evaluation of drip irrigation system during season

Table B. Computation of Emission uniformity of drip irrigation system

Duration of time: 15 min

Operating head: 2.5 m

Location on lateral (A &B)	Lateral location on sub main							
	Inlet end	1/3 down	2/3 down	Far end	Inlet end	1/3 down	2/3 down	Far end
	Ml				Lit/hr			
A	540	515	485	490	2.16	2.06	1.94	1.96
B	520	525	475	500	2.08	2.1	1.9	2
Average	530	520	480	495	2.12	2.08	1.92	1.98
A	520	380	490	470	2.08	1.52	1.96	1.88
B	510	390	510	470	2.04	1.56	2.04	1.88
Average	515	385	500	470	2.06	1.54	2	1.88
A	375	370	356	395	1.5	1.48	1.424	1.58
B	385	370	350	405	1.54	1.48	1.4	1.62
Average	380	370	353	400	1.52	1.48	1.412	1.6
A	500	360	410	345	2	1.44	1.64	1.38
B	480	350	430	355	1.92	1.4	1.72	1.42
Average	490	520	420	350	1.96	2.08	1.68	1.7
Total average	1.79							
EU _f (%)	85.93							

APPENDIX D

Water application time data for each treatment under naturally ventilated polyhouse of 2018 to 2019

Treatment 1 (T1)				Treatment 2 (T2)				Treatment 3 (T3)			
Day	Date	Water Requirement (Lit/day/plant)	Application Time (Hrs)	Day	Date	Water Requirement (Lit/day/plant)	Application Time (Hrs)	Day	Date	Water Requirement (Lit/day/plant)	Application Time (Hrs)
1	5-Jul	0.756	0.510	1	5-Aug	0.779	0.526	1	5-Sep	0.698	0.471
2	6-Jul	0.783	0.528	2	6-Aug	0.761	0.514	2	6-Sep	0.682	0.460
3	7-Jul	0.740	0.499	3	7-Aug	0.787	0.531	3	7-Sep	0.673	0.454
4	8-Jul	0.652	0.440	4	8-Aug	0.782	0.528	4	8-Sep	0.685	0.462
5	9-Jul	0.647	0.437	5	9-Aug	0.753	0.508	5	9-Sep	0.667	0.450
6	10-Jul	0.797	0.538	6	10-Aug	0.778	0.525	6	10-Sep	0.650	0.438
7	11-Jul	0.492	0.332	7	11-Aug	0.757	0.511	7	11-Sep	0.714	0.481
8	12-Jul	0.396	0.267	8	12-Aug	0.788	0.532	8	12-Sep	0.683	0.461
9	13-Jul	0.458	0.309	9	13-Aug	0.769	0.519	9	13-Sep	0.657	0.443
10	14-Jul	0.569	0.384	10	14-Aug	0.749	0.505	10	14-Sep	0.677	0.456
11	15-Jul	0.550	0.371	11	15-Aug	0.745	0.503	11	15-Sep	0.637	0.430
12	16-Jul	0.508	0.343	12	16-Aug	0.743	0.501	12	16-Sep	0.638	0.430
13	17-Jul	0.450	0.304	13	17-Aug	0.750	0.506	13	17-Sep	0.643	0.434
14	18-Jul	0.449	0.303	14	18-Aug	0.636	0.429	14	18-Sep	0.616	0.415
15	19-Jul	0.383	0.258	15	19-Aug	0.539	0.364	15	19-Sep	0.587	0.396
16	20-Jul	0.379	0.256	16	20-Aug	0.584	0.394	16	20-Sep	0.590	0.398
17	21-Jul	0.418	0.282	17	21-Aug	0.367	0.248	17	21-Sep	0.565	0.381
18	22-Jul	0.517	0.349	18	22-Aug	0.408	0.276	18	22-Sep	0.616	0.416
19	23-Jul	0.417	0.282	19	23-Aug	0.498	0.336	19	23-Sep	0.470	0.317

20	24-Jul	0.446	0.301	20	24-Aug	0.476	0.321	20	24-Sep	0.598	0.403
21	25-Jul	0.420	0.284	21	25-Aug	0.413	0.279	21	25-Sep	0.601	0.405
22	26-Jul	0.413	0.279	22	26-Aug	0.725	0.489	22	26-Sep	0.576	0.388
23	27-Jul	0.568	0.383	23	27-Aug	0.732	0.494	23	27-Sep	0.560	0.378
24	28-Jul	0.772	0.521	24	28-Aug	0.587	0.396	24	28-Sep	0.561	0.378
25	29-Jul	0.740	0.499	25	29-Aug	0.504	0.340	25	29-Sep	0.544	0.367
26	30-Jul	0.761	0.513	26	30-Aug	0.556	0.375	26	30-Sep	0.552	0.373
27	31-Jul	0.727	0.490	27	31-Aug	0.554	0.374	27	1-Oct	0.536	0.361
28	1-Aug	0.510	0.344	28	1-Sep	0.736	0.497	28	2-Oct	0.537	0.362
29	2-Aug	0.567	0.383	29	2-Sep	0.738	0.498	29	3-Oct	0.504	0.340
30	3-Aug	0.798	0.539	30	3-Sep	0.722	0.487	30	4-Oct	0.523	0.353
31	4-Aug	0.765	0.516	31	4-Sep	0.695	0.469	31	5-Oct	0.507	0.342
32	5-Aug	0.779	0.526	32	5-Sep	0.698	0.471	32	6-Oct	0.513	0.346
33	6-Aug	0.761	0.514	33	6-Sep	0.682	0.460	33	7-Oct	0.529	0.357
34	7-Aug	0.787	0.531	34	7-Sep	0.673	0.454	34	8-Oct	0.469	0.317
35	8-Aug	0.782	0.528	35	8-Sep	0.685	0.462	35	9-Oct	0.469	0.316
36	9-Aug	0.769	0.518	36	9-Sep	0.678	0.457	36	10-Oct	0.471	0.318
37	10-Aug	0.810	0.546	37	10-Sep	0.672	0.453	37	11-Oct	0.470	0.317
38	11-Aug	0.803	0.542	38	11-Sep	0.749	0.505	38	12-Oct	0.485	0.327
39	12-Aug	0.852	0.575	39	12-Sep	0.740	0.499	39	13-Oct	0.493	0.332
40	13-Aug	0.847	0.571	40	13-Sep	0.722	0.487	40	14-Oct	0.464	0.313
41	14-Aug	0.840	0.567	41	14-Sep	0.756	0.510	41	15-Oct	0.362	0.244
42	15-Aug	0.852	0.574	42	15-Sep	0.722	0.487	42	16-Oct	0.394	0.266
43	16-Aug	0.864	0.583	43	16-Sep	0.733	0.495	43	17-Oct	0.350	0.236
44	17-Aug	0.888	0.599	44	17-Sep	0.750	0.506	44	18-Oct	0.308	0.208
45	18-Aug	0.766	0.517	45	18-Sep	0.728	0.491	45	19-Oct	0.371	0.250
46	19-Aug	0.659	0.445	46	19-Sep	0.714	0.481	46	20-Oct	0.486	0.328
47	20-Aug	0.726	0.490	47	20-Sep	0.728	0.491	47	21-Oct	0.509	0.343
48	21-Aug	0.464	0.313	48	21-Sep	0.706	0.476	48	22-Oct	0.507	0.342

49	22-Aug	0.525	0.354	49	22-Sep	0.780	0.526	49	23-Oct	0.479	0.323
50	23-Aug	0.650	0.438	50	23-Sep	0.603	0.407	50	24-Oct	0.499	0.337
51	24-Aug	0.631	0.425	51	24-Sep	0.777	0.524	51	25-Oct	0.497	0.335
52	25-Aug	0.556	0.375	52	25-Sep	0.791	0.534	52	26-Oct	0.491	0.331
53	26-Aug	0.991	0.668	53	26-Sep	0.777	0.524	53	27-Oct	0.479	0.323
54	27-Aug	1.015	0.685	54	27-Sep	0.766	0.517	54	28-Oct	0.481	0.324
55	28-Aug	0.825	0.557	55	28-Sep	0.776	0.523	55	29-Oct	0.476	0.321
56	29-Aug	0.719	0.485	56	29-Sep	0.762	0.514	56	30-Oct	0.486	0.328
57	30-Aug	0.804	0.542	57	30-Sep	0.782	0.528	57	31-Oct	0.489	0.330
58	31-Aug	0.814	0.549	58	1-Oct	0.768	0.518	58	1-Nov	0.518	0.349
59	1-Sep	1.095	0.739	59	2-Oct	0.779	0.525	59	2-Nov	0.527	0.355
60	2-Sep	1.114	0.751	60	3-Oct	0.747	0.504	60	3-Nov	0.537	0.362
61	3-Sep	1.103	0.744	61	4-Oct	0.784	0.529	61	4-Nov	0.494	0.333
62	4-Sep	1.077	0.726	62	5-Oct	0.769	0.519	62	5-Nov	0.471	0.318
63	5-Sep	1.096	0.739	63	6-Oct	0.787	0.531	63	6-Nov	0.477	0.322
64	6-Sep	1.085	0.732	64	7-Oct	0.820	0.553	64	7-Nov	0.464	0.313
65	7-Sep	1.083	0.731	65	8-Oct	0.735	0.496	65	8-Nov	0.491	0.332
66	8-Sep	1.117	0.754	66	9-Oct	0.750	0.506	66	9-Nov	0.473	0.319
67	9-Sep	1.100	0.742	67	10-Oct	0.749	0.505	67	10-Nov	0.468	0.316
68	10-Sep	1.086	0.733	68	11-Oct	0.742	0.501	68	11-Nov	0.494	0.333
69	11-Sep	1.207	0.814	69	12-Oct	0.750	0.506	69	12-Nov	0.435	0.294
70	12-Sep	1.169	0.789	70	13-Oct	0.758	0.511	70	13-Nov	0.550	0.371
71	13-Sep	1.137	0.767	71	14-Oct	0.710	0.479	71	14-Nov	0.528	0.356
72	14-Sep	1.186	0.800	72	15-Oct	0.551	0.372	72	15-Nov	0.486	0.328
73	15-Sep	1.129	0.762	73	16-Oct	0.594	0.401	73	16-Nov	0.530	0.357
74	16-Sep	1.143	0.771	74	17-Oct	0.525	0.354	74	17-Nov	0.510	0.344
75	17-Sep	1.166	0.787	75	18-Oct	0.460	0.311	75	18-Nov	0.520	0.350
76	18-Sep	1.129	0.761	76	19-Oct	0.552	0.372	76	19-Nov	0.540	0.364
77	19-Sep	1.087	0.734	77	20-Oct	0.719	0.485	77	20-Nov	0.517	0.349

78	20-Sep	1.107	0.747	78	21-Oct	0.739	0.499	78	21-Nov	0.596	0.402
79	21-Sep	1.070	0.722	79	22-Oct	0.734	0.495	79	22-Nov	0.544	0.367
80	22-Sep	1.180	0.796	80	23-Oct	0.696	0.470	80	23-Nov	0.490	0.331
81	23-Sep	0.901	0.608	81	24-Oct	0.724	0.488	81	24-Nov	0.477	0.322
82	24-Sep	1.146	0.773	82	25-Oct	0.708	0.478	82	25-Nov	0.477	0.322
83	25-Sep	1.152	0.777	83	26-Oct	0.698	0.471	83	26-Nov	0.470	0.317
84	26-Sep	1.103	0.744	84	27-Oct	0.672	0.454	84	27-Nov	0.498	0.336
85	27-Sep	1.074	0.725	85	28-Oct	0.666	0.449	85	28-Nov	0.482	0.325
86	28-Sep	1.075	0.725	86	29-Oct	0.651	0.439	86	29-Nov	0.461	0.311
87	29-Sep	1.043	0.704	87	30-Oct	0.649	0.438	87	30-Nov	0.470	0.317
88	30-Sep	1.059	0.714	88	31-Oct	0.647	0.436	88	1-Dec	0.435	0.294
89	1-Oct	1.027	0.693	89	1-Nov	0.677	0.456	89	2-Dec	0.451	0.305
90	2-Oct	1.029	0.694	90	2-Nov	0.680	0.459	90	3-Dec	0.488	0.329
91	3-Oct	0.966	0.651	91	3-Nov	0.678	0.458	91	4-Dec	0.489	0.330
92	4-Oct	1.002	0.676	92	4-Nov	0.618	0.417	92	5-Dec	0.492	0.332
93	5-Oct	0.972	0.656	93	5-Nov	0.583	0.393	93	6-Dec	0.480	0.324
94	6-Oct	0.984	0.664	94	6-Nov	0.583	0.394	94	7-Dec	0.443	0.299
95	7-Oct	1.014	0.684	95	7-Nov	0.562	0.379	95	8-Dec	0.453	0.306
96	8-Oct	0.900	0.607	96	8-Nov	0.583	0.393	96	9-Dec	0.426	0.287
97	9-Oct	0.898	0.606	97	9-Nov	0.555	0.374	97	10-Dec	0.462	0.312
98	10-Oct	0.888	0.599	98	10-Nov	0.544	0.367	98	11-Dec	0.479	0.323
99	11-Oct	0.871	0.588	99	11-Nov	0.568	0.383	99	12-Dec	0.434	0.293
100	12-Oct	0.871	0.588	100	12-Nov	0.491	0.331	100	13-Dec	0.429	0.289
101	13-Oct	0.872	0.588	101	13-Nov	0.614	0.414	101	14-Dec	0.397	0.268
102	14-Oct	0.808	0.545	102	14-Nov	0.584	0.394	102	15-Dec	0.396	0.267
103	15-Oct	0.621	0.419	103	15-Nov	0.533	0.359	103	16-Dec	0.339	0.229
104	16-Oct	0.657	0.443	104	16-Nov	0.575	0.388	104	17-Dec	0.319	0.215
105	17-Oct	0.575	0.388	105	17-Nov	0.543	0.366	105	18-Dec	0.374	0.252
106	18-Oct	0.499	0.337	106	18-Nov	0.548	0.370	106	19-Dec	0.410	0.277

107	19-Oct	0.593	0.400	107	19-Nov	0.564	0.381	107	20-Dec	0.417	0.281
108	20-Oct	0.766	0.517	108	20-Nov	0.536	0.361	108	21-Dec	0.413	0.279
109	21-Oct	0.780	0.526	109	21-Nov	0.606	0.409	109	22-Dec	0.400	0.270
110	22-Oct	0.767	0.518	110	22-Nov	0.549	0.370	110	23-Dec	0.336	0.226
111	23-Oct	0.715	0.482	111	23-Nov	0.490	0.331	111	24-Dec	0.323	0.218
112	24-Oct	0.736	0.497	112	24-Nov	0.477	0.322	112	25-Dec	0.417	0.281
113	25-Oct	0.715	0.482	113	25-Nov	0.477	0.322	113	26-Dec	0.387	0.261
114	26-Oct	0.698	0.471	114	26-Nov	0.470	0.317	114	27-Dec	0.407	0.274
115	27-Oct	0.672	0.454	115	27-Nov	0.498	0.336	115	28-Dec	0.380	0.256
116	28-Oct	0.666	0.449	116	28-Nov	0.482	0.325	116	29-Dec	0.370	0.250
117	29-Oct	0.651	0.439	117	29-Nov	0.461	0.311	117	30-Dec	0.410	0.277
118	30-Oct	0.649	0.438	118	30-Nov	0.470	0.317	118	31-Dec	0.564	0.381
119	31-Oct	0.647	0.436	119	1-Dec	0.435	0.294	119	1-Jan	0.398	0.269
120	1-Nov	0.677	0.456	120	2-Dec	0.451	0.305	120	2-Jan	0.400	0.270
121	2-Nov	0.680	0.459	121	3-Dec	0.488	0.329	121	3-Jan	0.428	0.289
122	3-Nov	0.678	0.458	122	4-Dec	0.489	0.330	122	4-Jan	0.398	0.268
123	4-Nov	0.618	0.417	123	5-Dec	0.492	0.332	123	5-Jan	0.418	0.282
124	5-Nov	0.583	0.393	124	6-Dec	0.480	0.324	124	6-Jan	0.402	0.272
125	6-Nov	0.583	0.394	125	7-Dec	0.443	0.299	125	7-Jan	0.339	0.228
126	7-Nov	0.562	0.379	126	8-Dec	0.453	0.306	126	8-Jan	0.332	0.224
127	8-Nov	0.583	0.393	127	9-Dec	0.426	0.287	127	9-Jan	0.402	0.272
128	9-Nov	0.555	0.374	128	10-Dec	0.462	0.312	128	10-Jan	0.431	0.291
129	10-Nov	0.544	0.367	129	11-Dec	0.479	0.323	129	11-Jan	0.426	0.287
130	11-Nov	0.568	0.383	130	12-Dec	0.434	0.293	130	12-Jan	0.448	0.302
131	12-Nov	0.491	0.331	131	13-Dec	0.429	0.289	131	13-Jan	0.433	0.292
132	13-Nov	0.614	0.414	132	14-Dec	0.397	0.268	132	14-Jan	0.440	0.297
133	14-Nov	0.584	0.394	133	15-Dec	0.396	0.267	133	15-Jan	0.427	0.288
134	15-Nov	0.533	0.359	134	16-Dec	0.339	0.229	134	16-Jan	0.470	0.317
135	16-Nov	0.575	0.388	135	17-Dec	0.319	0.215	135	17-Jan	0.497	0.335

136	17-Nov	0.543	0.366	136	18-Dec	0.374	0.252	136	18-Jan	0.461	0.311
137	18-Nov	0.548	0.370	137	19-Dec	0.410	0.277	137	19-Jan	0.363	0.245
138	19-Nov	0.564	0.381	138	20-Dec	0.417	0.281	138	20-Jan	0.367	0.247
139	20-Nov	0.536	0.361	139	21-Dec	0.413	0.279	139	21-Jan	0.530	0.358
140	21-Nov	0.606	0.409	140	22-Dec	0.400	0.270	140	22-Jan	0.529	0.357
141	22-Nov	0.549	0.370	141	23-Dec	0.336	0.226	141	23-Jan	0.493	0.333
142	23-Nov	0.490	0.331	142	24-Dec	0.323	0.218	142	24-Jan	0.512	0.346
143	24-Nov	0.477	0.322	143	25-Dec	0.417	0.281	143	25-Jan	0.342	0.231
144	25-Nov	0.477	0.322	144	26-Dec	0.387	0.261	144	26-Jan	0.464	0.313
145	26-Nov	0.470	0.317	145	27-Dec	0.407	0.274	145	27-Jan	0.481	0.325
146	27-Nov	0.498	0.336	146	28-Dec	0.380	0.256	146	28-Jan	0.488	0.329
147	28-Nov	0.482	0.325	147	29-Dec	0.370	0.250	147	29-Jan	0.536	0.361
148	29-Nov	0.461	0.311	148	30-Dec	0.410	0.277	148	30-Jan	0.577	0.390
149	30-Nov	0.470	0.317	149	31-Dec	0.564	0.381	149	31-Jan	0.590	0.398
150	1-Dec	0.435	0.294	150	1-Jan	0.398	0.269	150	1-Feb	0.550	0.371
151	2-Dec	0.451	0.305	151	2-Jan	0.400	0.270	151	2-Feb	0.563	0.380
152	3-Dec	0.488	0.329	152	3-Jan	0.428	0.289	152	3-Feb	0.591	0.399
153	4-Dec	0.489	0.330	153	4-Jan	0.398	0.268	153	4-Feb	0.635	0.429
154	5-Dec	0.492	0.332	154	5-Jan	0.418	0.282	154	5-Feb	0.598	0.403
155	6-Dec	0.480	0.324	155	6-Jan	0.402	0.272	155	6-Feb	0.597	0.403
156	7-Dec	0.443	0.299	156	7-Jan	0.339	0.228	156	7-Feb	0.588	0.397
157	8-Dec	0.453	0.306	157	8-Jan	0.332	0.224	157	8-Feb	0.585	0.395
158	9-Dec	0.426	0.287	158	9-Jan	0.402	0.272	158	9-Feb	0.564	0.381
159	10-Dec	0.462	0.312	159	10-Jan	0.431	0.291	159	10-Feb	0.631	0.426
160	11-Dec	0.479	0.323	160	11-Jan	0.426	0.287	160	11-Feb	0.646	0.435
161	12-Dec	0.434	0.293	161	12-Jan	0.448	0.302	161	12-Feb	0.625	0.421
162	13-Dec	0.429	0.289	162	13-Jan	0.433	0.292	162	13-Feb	0.630	0.425
163	14-Dec	0.397	0.268	163	14-Jan	0.440	0.297	163	14-Feb	0.620	0.418
164	15-Dec	0.396	0.267	164	15-Jan	0.427	0.288	164	15-Feb	0.621	0.419

165	16-Dec	0.339	0.229	165	16-Jan	0.470	0.317	165	16-Feb	0.667	0.450
166	17-Dec	0.315	0.212	166	17-Jan	0.497	0.335	166	17-Feb	0.701	0.473
167	18-Dec	0.365	0.246	167	18-Jan	0.461	0.311	167	18-Feb	0.722	0.487
168	19-Dec	0.396	0.267	168	19-Jan	0.363	0.245	168	19-Feb	0.659	0.444
169	20-Dec	0.397	0.268	169	20-Jan	0.367	0.247	169	20-Feb	0.801	0.541
170	21-Dec	0.390	0.263	170	21-Jan	0.530	0.358	170	21-Feb	0.823	0.555
171	22-Dec	0.372	0.251	171	22-Jan	0.529	0.357	171	22-Feb	0.826	0.558
172	23-Dec	0.309	0.208	172	23-Jan	0.493	0.333	172	23-Feb	0.848	0.572
173	24-Dec	0.294	0.198	173	24-Jan	0.512	0.346	173	24-Feb	0.812	0.548
174	25-Dec	0.374	0.252	174	25-Jan	0.342	0.231	174	25-Feb	0.838	0.565
175	26-Dec	0.342	0.231	175	26-Jan	0.464	0.313	175	26-Feb	0.848	0.572
176	27-Dec	0.355	0.239	176	27-Jan	0.481	0.325	176	27-Feb	0.780	0.526
177	28-Dec	0.327	0.221	177	28-Jan	0.488	0.329	177	28-Feb	0.784	0.529
178	29-Dec	0.314	0.212	178	29-Jan	0.536	0.361	178	1-Mar	0.844	0.569
179	30-Dec	0.344	0.232	179	30-Jan	0.577	0.390	179	2-Mar	0.963	0.650
180	31-Dec	0.466	0.315	180	31-Jan	0.590	0.398	180	3-Mar	0.848	0.572
181	1-Jan	0.324	0.219	181	1-Feb	0.545	0.368	181	4-Mar	0.834	0.563
182	2-Jan	0.321	0.217	182	2-Feb	0.549	0.370	182	5-Mar	0.843	0.569
183	3-Jan	0.339	0.229	183	3-Feb	0.570	0.385	183	6-Mar	0.818	0.552
184	4-Jan	0.310	0.209	184	4-Feb	0.608	0.410	184	7-Mar	0.848	0.572
185	5-Jan	0.321	0.217	185	5-Feb	0.562	0.379	185	8-Mar	0.869	0.586
186	6-Jan	0.305	0.206	186	6-Feb	0.556	0.375	186	9-Mar	1.023	0.690
-	-	-	-	187	7-Feb	0.542	0.366	187	10-Mar	0.831	0.561
-	-	-	-	188	8-Feb	0.529	0.357	188	11-Mar	0.868	0.586
-	-	-	-	189	9-Feb	0.505	0.341	189	12-Mar	0.823	0.555
-	-	-	-	190	10-Feb	0.560	0.378	190	13-Mar	0.801	0.540
-	-	-	-	191	11-Feb	0.561	0.379	191	14-Mar	0.783	0.528
-	-	-	-	192	12-Feb	0.538	0.363	192	15-Mar	0.778	0.525
-	-	-	-	193	13-Feb	0.537	0.362	193	16-Mar	0.791	0.534

-	-	-	-	194	14-Feb	0.517	0.349	194	17-Mar	0.797	0.537
-	-	-	-	195	15-Feb	0.513	0.346	195	18-Mar	0.820	0.553
-	-	-	-	196	16-Feb	0.545	0.368	196	19-Mar	0.832	0.561
-	-	-	-	197	17-Feb	0.560	0.378	197	20-Mar	0.844	0.569
-	-	-	-	198	18-Feb	0.571	0.385	198	21-Mar	0.841	0.567
-	-	-	-	199	19-Feb	0.516	0.348	199	22-Mar	0.774	0.522
-	-	-	-	200	20-Feb	0.613	0.414	200	23-Mar	0.765	0.516
-	-	-	-	201	21-Feb	0.623	0.420	201	24-Mar	0.857	0.578
-	-	-	-	202	22-Feb	0.618	0.417	202	25-Mar	0.811	0.547
-	-	-	-	203	23-Feb	0.620	0.418	203	26-Mar	0.858	0.579
-	-	-	-	204	24-Feb	0.586	0.395	204	27-Mar	0.887	0.598
-	-	-	-	205	25-Feb	0.597	0.403	205	28-Mar	0.855	0.576
-	-	-	-	206	26-Feb	0.590	0.398	206	29-Mar	0.803	0.541
-	-	-	-	207	27-Feb	0.540	0.365	207	30-Mar	0.797	0.538
-	-	-	-	208	28-Feb	0.541	0.365	-	-	-	-
-	-	-	-	209	1-Mar	0.578	0.390	-	-	-	-
-	-	-	-	210	2-Mar	0.657	0.443	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
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Treatment 4 (T4)				Treatment 5 (T5)				Treatment 6 (T6)			
Day	Date	Water Requirement (Lit/day/plant)	Application Time (Hrs)	Day	Date	Water Requirement (Lit/day/plant)	Application Time (Hrs)	Day	Date	Water Requirement (Lit/day/plant)	Application Time (Hrs)
1	5-Oct	0.523	0.353	1	5-Nov	0.322	0.217	1	5-Dec	0.255	0.172
2	6-Oct	0.507	0.342	2	6-Nov	0.304	0.205	2	6-Dec	0.257	0.173
3	7-Oct	0.513	0.346	3	7-Nov	0.304	0.205	3	7-Dec	0.250	0.169
4	8-Oct	0.529	0.357	4	8-Nov	0.293	0.198	4	8-Dec	0.231	0.156
5	9-Oct	0.469	0.317	5	9-Nov	0.304	0.205	5	9-Dec	0.236	0.159
6	10-Oct	0.469	0.316	6	10-Nov	0.290	0.195	6	10-Dec	0.222	0.150
7	11-Oct	0.463	0.313	7	11-Nov	0.284	0.191	7	11-Dec	0.241	0.163
8	12-Oct	0.454	0.307	8	12-Nov	0.297	0.200	8	12-Dec	0.250	0.168
9	13-Oct	0.454	0.307	9	13-Nov	0.256	0.173	9	13-Dec	0.226	0.153
10	14-Oct	0.455	0.307	10	14-Nov	0.320	0.216	10	14-Dec	0.224	0.151
11	15-Oct	0.422	0.284	11	15-Nov	0.305	0.206	11	15-Dec	0.207	0.140
12	16-Oct	0.324	0.219	12	16-Nov	0.278	0.188	12	16-Dec	0.206	0.139
13	17-Oct	0.343	0.231	13	17-Nov	0.300	0.202	13	17-Dec	0.177	0.119
14	18-Oct	0.300	0.202	14	18-Nov	0.283	0.191	14	18-Dec	0.166	0.112
15	19-Oct	0.261	0.176	15	19-Nov	0.286	0.193	15	19-Dec	0.195	0.132
16	20-Oct	0.309	0.209	16	20-Nov	0.294	0.199	16	20-Dec	0.214	0.144
17	21-Oct	0.400	0.270	17	21-Nov	0.280	0.189	17	21-Dec	0.217	0.147
18	22-Oct	0.407	0.274	18	22-Nov	0.316	0.213	18	22-Dec	0.216	0.146
19	23-Oct	0.400	0.270	19	23-Nov	0.287	0.193	19	23-Dec	0.209	0.141
20	24-Oct	0.373	0.252	20	24-Nov	0.256	0.173	20	24-Dec	0.175	0.118
21	25-Oct	0.384	0.259	21	25-Nov	0.249	0.168	21	25-Dec	0.169	0.114
22	26-Oct	0.373	0.252	22	26-Nov	0.249	0.168	22	26-Dec	0.218	0.147
23	27-Oct	0.364	0.246	23	27-Nov	0.245	0.166	23	27-Dec	0.202	0.136
24	28-Oct	0.351	0.237	24	28-Nov	0.260	0.175	24	28-Dec	0.212	0.143
25	29-Oct	0.348	0.234	25	29-Nov	0.251	0.169	25	29-Dec	0.198	0.134
26	30-Oct	0.340	0.229	26	30-Nov	0.241	0.162	26	30-Dec	0.193	0.130
27	31-Oct	0.339	0.229	27	1-Dec	0.245	0.165	27	31-Dec	0.214	0.144
28	1-Nov	0.337	0.228	28	2-Dec	0.227	0.153	28	1-Jan	0.294	0.199
29	2-Nov	0.353	0.238	29	3-Dec	0.236	0.159	29	2-Jan	0.208	0.140
30	3-Nov	0.355	0.239	30	4-Dec	0.255	0.172	30	3-Jan	0.208	0.141
31	4-Nov	0.354	0.239	31	5-Dec	0.255	0.172	31	4-Jan	0.223	0.151

32	5-Nov	0.322	0.217	32	6-Dec	0.257	0.173	32	5-Jan	0.208	0.140
33	6-Nov	0.304	0.205	33	7-Dec	0.250	0.169	33	6-Jan	0.218	0.147
34	7-Nov	0.304	0.205	34	8-Dec	0.231	0.156	34	7-Jan	0.210	0.142
35	8-Nov	0.293	0.198	35	9-Dec	0.236	0.159	35	8-Jan	0.177	0.119
36	9-Nov	0.304	0.205	36	10-Dec	0.222	0.150	36	9-Jan	0.177	0.119
37	10-Nov	0.290	0.195	37	11-Dec	0.245	0.165	37	10-Jan	0.218	0.147
38	11-Nov	0.284	0.191	38	12-Dec	0.258	0.174	38	11-Jan	0.239	0.161
39	12-Nov	0.302	0.203	39	13-Dec	0.241	0.163	39	12-Jan	0.240	0.162
40	13-Nov	0.265	0.178	40	14-Dec	0.242	0.163	40	13-Jan	0.257	0.173
41	14-Nov	0.336	0.227	41	15-Dec	0.228	0.154	41	14-Jan	0.253	0.171
42	15-Nov	0.325	0.219	42	16-Dec	0.231	0.156	42	15-Jan	0.262	0.177
43	16-Nov	0.301	0.203	43	17-Dec	0.200	0.135	43	16-Jan	0.258	0.174
44	17-Nov	0.330	0.223	44	18-Dec	0.191	0.129	44	17-Jan	0.289	0.195
45	18-Nov	0.316	0.213	45	19-Dec	0.231	0.156	45	18-Jan	0.311	0.210
46	19-Nov	0.324	0.219	46	20-Dec	0.257	0.173	46	19-Jan	0.293	0.198
47	20-Nov	0.338	0.228	47	21-Dec	0.265	0.178	47	20-Jan	0.234	0.158
48	21-Nov	0.326	0.220	48	22-Dec	0.266	0.179	48	21-Jan	0.241	0.162
49	22-Nov	0.374	0.253	49	23-Dec	0.261	0.176	49	22-Jan	0.354	0.239
50	23-Nov	0.344	0.232	50	24-Dec	0.222	0.150	50	23-Jan	0.358	0.242
51	24-Nov	0.311	0.210	51	25-Dec	0.219	0.148	51	24-Jan	0.340	0.229
52	25-Nov	0.311	0.210	52	26-Dec	0.287	0.193	52	25-Jan	0.358	0.241
53	26-Nov	0.315	0.213	53	27-Dec	0.269	0.182	53	26-Jan	0.242	0.163
54	27-Nov	0.315	0.212	54	28-Dec	0.286	0.193	54	27-Jan	0.334	0.225
55	28-Nov	0.338	0.228	55	29-Dec	0.271	0.183	55	28-Jan	0.351	0.237
56	29-Nov	0.331	0.223	56	30-Dec	0.267	0.180	56	29-Jan	0.361	0.244
57	30-Nov	0.321	0.216	57	31-Dec	0.303	0.205	57	30-Jan	0.402	0.271
58	1-Dec	0.331	0.223	58	1-Jan	0.422	0.285	58	31-Jan	0.439	0.296
59	2-Dec	0.311	0.209	59	2-Jan	0.301	0.203	59	1-Feb	0.455	0.307
60	3-Dec	0.326	0.220	60	3-Jan	0.306	0.206	60	2-Feb	0.430	0.290
61	4-Dec	0.357	0.241	61	4-Jan	0.331	0.223	61	3-Feb	0.446	0.301
62	5-Dec	0.361	0.244	62	5-Jan	0.311	0.210	62	4-Feb	0.474	0.320
63	6-Dec	0.368	0.248	63	6-Jan	0.334	0.225	63	5-Feb	0.516	0.348
64	7-Dec	0.363	0.245	64	7-Jan	0.325	0.220	64	6-Feb	0.492	0.332
65	8-Dec	0.339	0.229	65	8-Jan	0.277	0.187	65	7-Feb	0.498	0.336

66	9-Dec	0.351	0.237	66	9-Jan	0.274	0.185	66	8-Feb	0.497	0.335
67	10-Dec	0.333	0.225	67	10-Jan	0.336	0.227	67	9-Feb	0.500	0.337
68	11-Dec	0.366	0.247	68	11-Jan	0.364	0.246	68	10-Feb	0.488	0.329
69	12-Dec	0.383	0.258	69	12-Jan	0.367	0.247	69	11-Feb	0.552	0.373
70	13-Dec	0.351	0.237	70	13-Jan	0.389	0.263	70	12-Feb	0.572	0.386
71	14-Dec	0.350	0.236	71	14-Jan	0.381	0.257	71	13-Feb	0.559	0.377
72	15-Dec	0.328	0.221	72	15-Jan	0.390	0.263	72	14-Feb	0.571	0.385
73	16-Dec	0.330	0.223	73	16-Jan	0.382	0.258	73	15-Feb	0.568	0.383
74	17-Dec	0.286	0.193	74	17-Jan	0.425	0.287	74	16-Feb	0.576	0.388
75	18-Dec	0.271	0.183	75	18-Jan	0.458	0.309	75	17-Feb	0.625	0.422
76	19-Dec	0.322	0.217	76	19-Jan	0.429	0.289	76	18-Feb	0.664	0.448
77	20-Dec	0.357	0.241	77	20-Jan	0.341	0.230	77	19-Feb	0.692	0.467
78	21-Dec	0.370	0.249	78	21-Jan	0.348	0.234	78	20-Feb	0.638	0.431
79	22-Dec	0.370	0.250	79	22-Jan	0.507	0.342	79	21-Feb	0.784	0.529
80	23-Dec	0.362	0.244	80	23-Jan	0.510	0.344	80	22-Feb	0.814	0.549
81	24-Dec	0.307	0.207	81	24-Jan	0.485	0.327	81	23-Feb	0.826	0.557
82	25-Dec	0.298	0.201	82	25-Jan	0.508	0.343	82	24-Feb	0.848	0.572
83	26-Dec	0.388	0.262	83	26-Jan	0.342	0.231	83	25-Feb	0.812	0.548
84	27-Dec	0.363	0.245	84	27-Jan	0.464	0.313	84	26-Feb	0.838	0.565
85	28-Dec	0.385	0.260	85	28-Jan	0.481	0.325	85	27-Feb	0.848	0.572
86	29-Dec	0.363	0.245	86	29-Jan	0.488	0.329	86	28-Feb	0.787	0.531
87	30-Dec	0.357	0.241	87	30-Jan	0.536	0.361	87	1-Mar	0.798	0.538
88	31-Dec	0.400	0.270	88	31-Jan	0.577	0.390	88	2-Mar	0.874	0.590
89	1-Jan	0.555	0.374	89	1-Feb	0.590	0.398	89	3-Mar	1.007	0.679
90	2-Jan	0.395	0.266	90	2-Feb	0.550	0.371	90	4-Mar	0.894	0.603
91	3-Jan	0.400	0.270	91	3-Feb	0.563	0.380	91	5-Mar	0.888	0.599
92	4-Jan	0.428	0.289	92	4-Feb	0.591	0.399	92	6-Mar	0.915	0.617
93	5-Jan	0.398	0.268	93	5-Feb	0.635	0.429	93	7-Mar	0.896	0.604
94	6-Jan	0.418	0.282	94	6-Feb	0.598	0.403	94	8-Mar	0.938	0.633
95	7-Jan	0.402	0.272	95	7-Feb	0.597	0.403	95	9-Mar	0.971	0.655
96	8-Jan	0.339	0.228	96	8-Feb	0.588	0.397	96	10-Mar	1.164	0.785
97	9-Jan	0.332	0.224	97	9-Feb	0.585	0.395	97	11-Mar	0.956	0.645
98	10-Jan	0.402	0.272	98	10-Feb	0.564	0.381	98	12-Mar	1.008	0.680
99	11-Jan	0.431	0.291	99	11-Feb	0.631	0.426	99	13-Mar	0.966	0.652

100	12-Jan	0.426	0.287	100	12-Feb	0.646	0.435	100	14-Mar	0.960	0.647
101	13-Jan	0.448	0.302	101	13-Feb	0.625	0.421	101	15-Mar	0.947	0.639
102	14-Jan	0.433	0.292	102	14-Feb	0.630	0.425	102	16-Mar	0.951	0.642
103	15-Jan	0.440	0.297	103	15-Feb	0.620	0.418	103	17-Mar	0.978	0.660
104	16-Jan	0.427	0.288	104	16-Feb	0.621	0.419	104	18-Mar	1.007	0.679
105	17-Jan	0.470	0.317	105	17-Feb	0.667	0.450	105	19-Mar	1.048	0.707
106	18-Jan	0.497	0.335	106	18-Feb	0.701	0.473	106	20-Mar	1.075	0.725
107	19-Jan	0.461	0.311	107	19-Feb	0.722	0.487	107	21-Mar	1.103	0.744
108	20-Jan	0.363	0.245	108	20-Feb	0.659	0.444	108	22-Mar	1.124	0.758
109	21-Jan	0.367	0.247	109	21-Feb	0.801	0.541	109	23-Mar	1.047	0.706
110	22-Jan	0.530	0.358	110	22-Feb	0.823	0.555	110	24-Mar	1.188	0.801
111	23-Jan	0.529	0.357	111	23-Feb	0.826	0.558	111	25-Mar	1.151	0.777
112	24-Jan	0.493	0.333	112	24-Feb	0.848	0.572	112	26-Mar	1.234	0.832
113	25-Jan	0.512	0.346	113	25-Feb	0.812	0.548	113	27-Mar	1.291	0.871
114	26-Jan	0.342	0.231	114	26-Feb	0.838	0.565	114	28-Mar	1.260	0.850
115	27-Jan	0.464	0.313	115	27-Feb	0.848	0.572	115	29-Mar	1.214	0.819
116	28-Jan	0.481	0.325	116	28-Feb	0.787	0.531	116	30-Mar	1.222	0.825
117	29-Jan	0.488	0.329	117	1-Mar	0.798	0.538	117	31-Mar	1.186	0.800
118	30-Jan	0.536	0.361	118	2-Mar	0.874	0.590	118	1-Apr	1.143	0.771
119	31-Jan	0.577	0.390	119	3-Mar	1.007	0.679	119	2-Apr	1.176	0.793
120	1-Feb	0.590	0.398	120	4-Mar	0.894	0.603	120	3-Apr	1.185	0.799
121	2-Feb	0.550	0.371	121	5-Mar	0.888	0.599	121	4-Apr	1.249	0.842
122	3-Feb	0.563	0.380	122	6-Mar	0.915	0.617	122	5-Apr	1.299	0.876
123	4-Feb	0.591	0.399	123	7-Mar	0.896	0.604	123	6-Apr	1.254	0.846
124	5-Feb	0.635	0.429	124	8-Mar	0.938	0.633	124	7-Apr	1.315	0.887
125	6-Feb	0.598	0.403	125	9-Mar	0.971	0.655	125	8-Apr	1.265	0.854
126	7-Feb	0.597	0.403	126	10-Mar	1.164	0.785	126	9-Apr	1.299	0.876
127	8-Feb	0.588	0.397	127	11-Mar	0.956	0.645	127	10-Apr	1.311	0.885
128	9-Feb	0.585	0.395	128	12-Mar	1.008	0.680	128	11-Apr	1.321	0.891
129	10-Feb	0.564	0.381	129	13-Mar	0.966	0.652	129	12-Apr	1.313	0.886
130	11-Feb	0.631	0.426	130	14-Mar	0.960	0.647	130	13-Apr	1.324	0.893
131	12-Feb	0.646	0.435	131	15-Mar	0.947	0.639	131	14-Apr	1.305	0.880
132	13-Feb	0.625	0.421	132	16-Mar	0.951	0.642	132	15-Apr	1.281	0.864
133	14-Feb	0.630	0.425	133	17-Mar	0.978	0.660	133	16-Apr	1.234	0.832

134	15-Feb	0.620	0.418	134	18-Mar	1.007	0.679	134	17-Apr	1.268	0.855
135	16-Feb	0.621	0.419	135	19-Mar	1.048	0.707	135	18-Apr	1.334	0.900
136	17-Feb	0.667	0.450	136	20-Mar	1.075	0.725	136	19-Apr	1.363	0.920
137	18-Feb	0.701	0.473	137	21-Mar	1.103	0.744	137	20-Apr	1.251	0.844
138	19-Feb	0.722	0.487	138	22-Mar	1.124	0.758	138	21-Apr	1.279	0.863
139	20-Feb	0.659	0.444	139	23-Mar	1.047	0.706	139	22-Apr	1.330	0.898
140	21-Feb	0.801	0.541	140	24-Mar	1.188	0.801	140	23-Apr	1.377	0.929
141	22-Feb	0.823	0.555	141	25-Mar	1.151	0.777	141	24-Apr	1.336	0.901
142	23-Feb	0.826	0.558	142	26-Mar	1.234	0.832	142	25-Apr	1.356	0.915
143	24-Feb	0.848	0.572	143	27-Mar	1.291	0.871	143	26-Apr	1.331	0.898
144	25-Feb	0.812	0.548	144	28-Mar	1.260	0.850	144	27-Apr	1.338	0.903
145	26-Feb	0.838	0.565	145	29-Mar	1.214	0.819	145	28-Apr	1.374	0.927
146	27-Feb	0.848	0.572	146	30-Mar	1.222	0.825	146	29-Apr	1.449	0.977
147	28-Feb	0.787	0.531	147	31-Mar	1.186	0.800	147	30-Apr	1.443	0.973
148	1-Mar	0.798	0.538	148	1-Apr	1.143	0.771	148	1-May	1.796	1.212
149	2-Mar	0.874	0.590	149	2-Apr	1.176	0.793	149	2-May	1.398	0.943
150	3-Mar	1.007	0.679	150	3-Apr	1.185	0.799	150	3-May	1.404	0.947
151	4-Mar	0.894	0.603	151	4-Apr	1.249	0.842	151	4-May	1.438	0.970
152	5-Mar	0.888	0.599	152	5-Apr	1.299	0.876	152	5-May	1.413	0.953
153	6-Mar	0.915	0.617	153	6-Apr	1.254	0.846	153	6-May	1.420	0.958
154	7-Mar	0.896	0.604	154	7-Apr	1.315	0.887	154	7-May	1.401	0.945
155	8-Mar	0.938	0.633	155	8-Apr	1.265	0.854	155	8-May	1.449	0.977
156	9-Mar	0.971	0.655	156	9-Apr	1.299	0.876	156	9-May	1.418	0.957
157	10-Mar	1.164	0.785	157	10-Apr	1.311	0.885	157	10-May	1.394	0.941
158	11-Mar	0.956	0.645	158	11-Apr	1.321	0.891	158	11-May	1.438	0.970
159	12-Mar	1.008	0.680	159	12-Apr	1.313	0.886	159	12-May	1.307	0.882
160	13-Mar	0.966	0.652	160	13-Apr	1.324	0.893	160	13-May	1.284	0.866
161	14-Mar	0.960	0.647	161	14-Apr	1.305	0.880	161	14-May	1.305	0.881
162	15-Mar	0.947	0.639	162	15-Apr	1.281	0.864	162	15-May	1.299	0.876
163	16-Mar	0.951	0.642	163	16-Apr	1.234	0.832	163	16-May	1.275	0.860
164	17-Mar	0.978	0.660	164	17-Apr	1.268	0.855	164	17-May	1.251	0.844
165	18-Mar	1.007	0.679	165	18-Apr	1.311	0.885	165	18-May	1.242	0.838
166	19-Mar	1.048	0.707	166	19-Apr	1.328	0.896	166	19-May	1.207	0.814
167	20-Mar	1.075	0.725	167	20-Apr	1.196	0.807	167	20-May	1.184	0.798

168	21-Mar	1.103	0.744	168	21-Apr	1.212	0.818	168	21-May	1.152	0.777
169	22-Mar	1.124	0.758	169	22-Apr	1.238	0.835	169	22-May	1.114	0.751
170	23-Mar	1.047	0.706	170	23-Apr	1.269	0.856	170	23-May	1.096	0.740
171	24-Mar	1.188	0.801	171	24-Apr	1.208	0.815	-	-	-	-
172	25-Mar	1.151	0.777	172	25-Apr	1.214	0.819	-	-	-	-
173	26-Mar	1.234	0.832	173	26-Apr	1.169	0.789	-	-	-	-
174	27-Mar	1.291	0.871	174	27-Apr	1.164	0.785	-	-	-	-
175	28-Mar	1.260	0.850	175	28-Apr	1.171	0.790	-	-	-	-
176	29-Mar	1.214	0.819	176	29-Apr	1.222	0.824	-	-	-	-
177	30-Mar	1.222	0.825	177	30-Apr	1.192	0.804	-	-	-	-
178	31-Mar	1.186	0.800	178	1-May	1.453	0.980	-	-	-	-
179	1-Apr	1.143	0.771	179	2-May	1.119	0.755	-	-	-	-
180	2-Apr	1.166	0.786	180	3-May	1.099	0.741	-	-	-	-
181	3-Apr	1.154	0.778	181	4-May	1.113	0.751	-	-	-	-
182	4-Apr	1.205	0.813	182	5-May	1.069	0.721	-	-	-	-
183	5-Apr	1.242	0.838	183	6-May	1.062	0.716	-	-	-	-
184	6-Apr	1.177	0.794	184	7-May	1.023	0.690	-	-	-	-
185	7-Apr	1.224	0.826	185	8-May	1.046	0.705	-	-	-	-
186	8-Apr	1.166	0.787	186	9-May	1.014	0.684	-	-	-	-
187	9-Apr	1.174	0.792	187	10-May	0.999	0.674	-	-	-	-
188	10-Apr	1.175	0.792	188	11-May	1.020	0.688	-	-	-	-
189	11-Apr	1.171	0.790	189	12-May	0.929	0.627	-	-	-	-
190	12-Apr	1.141	0.770	190	13-May	0.903	0.609	-	-	-	-
191	13-Apr	1.140	0.769	-	-	-	-	-	-	-	-
192	14-Apr	1.112	0.750	-	-	-	-	-	-	-	-
193	15-Apr	1.069	0.721	-	-	-	-	-	-	-	-
194	16-Apr	1.019	0.687	-	-	-	-	-	-	-	-
195	17-Apr	1.036	0.699	-	-	-	-	-	-	-	-
196	18-Apr	1.068	0.720	-	-	-	-	-	-	-	-
197	19-Apr	1.079	0.728	-	-	-	-	-	-	-	-
198	20-Apr	0.979	0.660	-	-	-	-	-	-	-	-
199	21-Apr	0.979	0.660	-	-	-	-	-	-	-	-
200	22-Apr	1.006	0.679	-	-	-	-	-	-	-	-
201	23-Apr	1.030	0.695	-	-	-	-	-	-	-	-

202	24-Apr	0.976	0.658	-	-	-	-	-	-	-	-
203	25-Apr	0.979	0.660	-	-	-	-	-	-	-	-
204	26-Apr	0.949	0.640	-	-	-	-	-	-	-	-
205	27-Apr	0.931	0.628	-	-	-	-	-	-	-	-
206	28-Apr	0.944	0.637	-	-	-	-	-	-	-	-
207	29-Apr	0.983	0.663	-	-	-	-	-	-	-	-
208	30-Apr	0.953	0.643	-	-	-	-	-	-	-	-
209	1-May	1.171	0.790	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E

Statistical analysis of plant height

Character	plant height at 30 DAT								
Treat	6	Rep	4						
	R ₁	R ₂	R ₃	R ₄	Total	Mean			
T ₁	50.4	43.0	61.2	58.6	213.20	53.30			
T ₂	51.5	53.2	57.8	56.2	218.70	54.68			
T ₃	66.2	64.0	69.6	67.2	267.00	66.75			
T ₄	61.0	59.6	62.2	53.2	236.00	59.00			
T ₅	51.4	52.5	53.8	48.2	205.90	51.48			
T ₆	43.8	40.2	45.9	42.7	172.60	43.15			
Total	324.30	312.50	350.50	326.10	1313.40	54.73			
SOV	df	SS	MSS	F-cal	F-tb	Sig	SEM	CD	5%
Rep	3	127.218	42.406	3.170	3.287	NS	1.83	5.51	
Treatment	5	1237.810	247.562	18.508	2.901	*			
Error	15	200.637	13.376	CV(%) = 6.68					

*= Significant at 5 per cent level of significance

Character	plant height at 60 DAT								
Treat	6	Rep	4						
	R ₁	R ₂	R ₃	R ₄	Total	Mean			
T ₁	96.2	100.8	93.6	98.4	389.00	97.25			
T ₂	99.2	101.8	91.6	102.4	395.00	98.75			
T ₃	118.2	123.3	119.4	127.5	488.40	122.10			
T ₄	105.4	95.6	109.2	114.8	425.00	106.25			
T ₅	91.8	85.5	103.1	96.4	376.80	94.20			
T ₆	86.6	93.6	89.12	83.3	352.62	88.16			
Total	597.40	600.60	606.02	622.80	2426.82	101.12			
SOV	df	SS	MSS	F-cal	F-tb	Sig	S.Em	CD	5%
Rep	3	63.895	21.298	0.627	3.287	NS	2.91	8.78	
Treatment	5	2812.195	562.439	16.558	2.901	*			
Error	15	509.523	33.968	CV(%) = 5.76					

Character	plant height at 90 DAT								
Treat	6	Rep	4						
	R ₁	R ₂	R ₃	R ₄	Total	Mean			
T ₁	157.4	140.8	153.2	148.6	600.00	150.00			
T ₂	160.6	138.8	156	173.8	629.20	157.30			
T ₃	180.2	160.1	155	175.2	670.50	167.63			
T ₄	172.2	160.6	157.6	151.2	641.60	160.40			
T ₅	145.6	136.2	158.3	148.6	588.70	147.18			
T ₆	142.6	143	136	155	576.60	144.15			
Total	958.60	879.50	916.10	952.40	3706.60	154.44			
SOV	df	SS	MSS	F-cal	F-tb	Sig	S.Em.	CD	5%
Rep	3	669.715	223.238	2.770	3.287	NS	4.49	13.53	
Treatment	5	1583.693	316.739	3.930	2.901	*			
Error	15	1208.850	80.590	CV(%) = 5.81					

Character	plant height at 120 DAT								
Treat	6	Rep	4						
	R ₁	R ₂	R ₃	R ₄	Total	Mean			
T ₁	176.8	185.7	177.4	170.9	710.80	177.70			
T ₂	165.8	179.4	185.7	207.8	738.70	184.68			
T ₃	190.5	182.4	188.3	205.7	766.9	191.73			
T ₄	172.3	187.6	187.1	202.4	749.40	187.35			
T ₅	172.8	158.3	185.2	174.0	690.30	172.58			
T ₆	151.3	157.6	179.3	174.0	662.2	165.55			
Total	1029.50	1051.00	1103.00	1134.80	4318.30	179.93			
SOV	df	SS	MSS	F-cal	F-tb	Sig	S.Em.	CD	5%
Rep	3	1153.761	384.587	3.801	3.287	NS	5.03	15.16	
Treatment	5	1930.187	386.037	3.815	2.901	*			
Error	15	1517.881	101.192	CV(%) = 5.59					

Character	plant height at 150 DAT								
Treat	6	Rep	4						
	R ₁	R ₂	R ₃	R ₄	Total	Mean			
T ₁	190.5	196.4	203.2	210.1	800.20	200.05			
T ₂	214.8	199.0	197.7	224.0	835.50	208.88			
T ₃	235.9	225.1	242.4	207.0	910.40	227.60			
T ₄	211.3	215.7	194.6	228.5	850.10	212.53			
T ₅	192.5	186.4	201.4	205.9	786.20	196.55			
T ₆	199.8	201.4	182.7	181.6	765.50	191.38			
Total	1244.80	1224.00	1222.00	1257.10	4947.90	206.16			
SOV	df	SS	MSS	F-cal	F-tb	Sig	S.Em	CD 5%	
Rep	3	143.141	47.714	0.294	3.287	NS			
Treatment	5	3423.354	684.671	4.213	2.901	*	6.37	19.21	
Error	15	349.75	23.32	CV(%) = 6.18					

Character	plant height at 180 DAT								
Treat	6	Rep	4						
	R ₁	R ₂	R ₃	R ₄	Total	Mean			
T ₁	221.36	235.40	226.40	214.90	898.06	224.52			
T ₂	214.70	265.40	201.30	230.10	911.50	227.88			
T ₃	252.63	272.10	260.86	242.61	1028.20	257.05			
T ₄	209.40	256.20	225.93	245.60	937.13	234.28			
T ₅	229.1	211.3	225.4	216.4	882.20	220.55			
T ₆	210.36	221.40	207.07	219.89	858.72	214.68			
Total	1337.55	1461.80	1346.96	1369.50	5515.81	229.83			
SOV	df	SS	MSS	F-cal	F-tb	Sig	S.Em	CD 5%	
Rep	3	1615.144	538.381	2.677	3.287	NS			
Treatment	5	4433.861	886.772	4.409	2.901	*	7.09	21.37	
Error	15	275.03	18.34	CV(%) = 6.17					

APPENDIX F

Cost of cultivation and output-input ratio of tomato crop under naturally ventilated polyhouse.

S. No.	Item	T ₁	T ₂	T ₃	T ₄	T ₅	T ₆
A	Fixed cost						
1	Depreciation Value @ 6.67% + Interest @ 9% + Maintenance Charge @ 2% of structure with drip Irrigation system in one hectare @ Rs. 775/sqm per crop of 6 months	684583	684583	684583	684583	684583	684583
2	Seeds @ 125 gm/ha @ Rs. 70000/- per kg	8750	8750	8750	8750	8750	8750
3	Field preparation @ Rs. 400/hr for 5hrs	2000	2000	2000	2000	2000	2000
4	FYM, 250 q/ha @Rs.1500/ton	37500	37500	37500	37500	37500	37500
5	Fertilizer (Rs/ha)	7500	7500	7500	7500	7500	7500
6	Pesticides (Rs/ha)	4800	4800	4800	4800	4800	4800
7	Labour charges @labour/day/hectare @ Rs. 200/- per day (Half amount of total charges/crop)	40000	40000	40000	40000	40000	40000
		100550	100550	100550	100550	100550	100550

B	Variable Cost						
1	Irrigation Water Charges	4000	3600	3400	3800	4000	4500
2	Working capital	143750	143550	143350	143150	142750	119950
4	Half amount/crop of Interest on working capital @ 9% p.a.	6469	6460	6451	6442	6424	5398
	Total (A+B) (Cost of cultivation)	150219	150010	149801	149592	149174	125348
A.1	Depreciation Value @ 6.67% + Interest @ 9% + Maintenance Charge @ 2% of structure with drip Irrigation system in one hectare area @ Rs.775/sqm (Half amount of total charges/crop)	684583	684583	684583	684583	684583	684583
	Total Cost of cultivation/ha (Cost of cultivation +cost of structure setup)	834802	834593	834384	834175	833757	809931
	Yield of produce (kg/ha)	97199.7078	107361.50	118872.92	114449.97	81530.11	79566.99
	Selling price, (Rs/kg)	15	15	20	20	20	20

	Gross income (Rs/ha)	1457995.61	1610422.5	2377458.45	2288999.4	1630602.24	1591339.9
	Net income/ha	623194	775829	1543074	1454824	796845	781409
	Output-input ratio	1.75	1.93	2.85	2.74	1.97	1.96