EFFECT OF FERTIGATION TIMING ON GROWTH, YIELD AND NUTRIENT MOBILITY FOR TOMATO IN INCEPTISOL

by

Miss. Bhoi Sangita Pratap
(Reg. No. Ph.D./014/068)

A Thesis submitted to the
MAHATMA PHULE KRISHI VIDYAPEETH
RAHURI – 413 722, DIST. AHMEDNAGAR
MAHARASHTRA, INDIA

in partial fulfilment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY (AGRICULTURE)

in

IRRIGATION WATER MANAGEMENT

INTERFACULTY DEPARTMENT OF IRRIGATION WATER MANAGEMENT

POST GRADUATE INSTITUTE
MAHATMA PHULE KRISHI VIDYAPEETH
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2021

CANDIDATE'S DECLARATION

I hereby declare that this thesis or part
there of has not been submitted
by me or other person to any
other University or Institution
for a Degree or
Diploma

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This is to certify that the thesis entitled, **"EFFECT OF FERTIGATION TIMING ON GROWTH, YIELD AND NUTRIENT MOBILITY FOR TOMATO IN INCEPTISOL"** submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar (M.S.) in partial fulfilment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **IRRIGATION WATER MANAGEMENT,** embodies the results of a piece of *bona fide* research work carried out by **Miss. BHOI SANGITA PRATAP** under my guidance and supervision and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been duly acknowledged.

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Now, as I carry this thesis in my hand, I carry with me memories that will enrich my nostalgia.

Place : M.P.K.V., Rahuri

Date : / /2021 (Sangita P. Bhoi)

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LIST OF ABBREVIATIONS

@	:	At the rate of
%	:	Per cent
ASM	:	Available Soil Moisture
^{O}B	:	Degree brix
BARI	:	Bangladesh Agriculture Research Institute
BPM	:	Black Plastic Mulch
Ca	:	Calcium
C.D.	:	Critical Difference
CEC	:	Cation Exchange Capacity
CF	:	Conventional fertilizer
cm	:	Centimetre (s)
CPE	:	Cumulative Pan Evaporation
^{0}C	:	Degree Celsius
DI	:	Drip Irrigation
DAT	:	Days After Transplanting
DAP	:	Days After Planting
DAS	:	Days After Sowing
dSm^{-1}	:	Desi Simen per meter
EC	:	Electrical Conductivity
Ep	:	Pan Evaporation
ER	:	Effective Rainfall
ET	:	Evapo-Transpiration
ET_0	:	Reference evapotranspiration
et al.	:	And others

etc.	:	Etcetera
FAO	:	Food and Agriculture Organisation
Fig.	:	Figure
FT	:	Fertigation Time
FUE	:	Fertilizer Use Efficiency
FWUE	:	Field Water Use Efficiency
g	:	Gram (s)
g plant^{-1}	:	Gram par plant
GOI	:	Government of India
ha	:	hectare (s)
ha-mm	:	Hectare-millimetre (s)
hr	:	Hour (s)
HP	:	Horsepower
i.e.	:	That is
IR	:	Irrigation requirement
IRGA	:	Infra Red Gas Analyser
IT	:	Irrigation Time
K	:	Potassium
Kc	:	Crop coefficient
kg ha^{-1}	:	kilogram per hectare
kg ha^{-1} mm^{-1}	:	Kilogram per hectare per millimetre
Kp	:	Pan coefficient
LAI	:	Leaf Area Index
LAD	:	Leaf Area Duration
LLDPE	:	Linear Low Density Polyethylene
lph	:	Litre per hour

m	:	mètre (s)
MAP	:	Mono Ammonium Phosphate
MKP	:	Mono Potassium Phosphate
ml	:	Millilitre (s)
mm	:	Millimètre (s)
M ha	:	Million hectare
Max.	:	Maximum
Min.	:	Minimum
MOP	:	Murate of Potash
MPUAT	:	Maharana Pratap University of Agriculture and Technology
MS	:	Maharashtra
MT	:	Million tonne (s)
N	:	Nitrogen
NF	:	Number (s)
NS	:	Normal fertilizer
NUE	:	Nitrogen Use Efficiency
OD	:	Optimal Density
P	:	Phosphorus
PE	:	Pan evaporation
pH	:	Potential of Hydrogen
Ph.D.	:	Doctor of Philosophy
ppm	:	Parts per million
PR	:	Paired row
PVC	:	Polyvinyl chloride
RBD	:	Randomized Block Design

RCA	:	Rajasthan College of Agriculture, Udaipur
RDF	:	Recommended Dose of Fertilizer
Rs	:	Rupee (s)
Rs ha^{-1}	:	Rupee (s) per hectare
RH	:	Relative Humidity
S	:	Sulphur
SADD	:	Chlorophyll content in leaf
S.Em. $\pm$	:	Standard Error of mean
SI	:	Surface Irrigation
SCY	:	Seed Cotton Yield
SOP	:	Potassium Sulphate
SSP	:	Single Super Phosphate
SAR	:	Soil Absorbance Ratio
t ha^{-1}	:	ton per hectare
TNAU	:	Tamil Nadu Agricultural University
TSS	:	Total Soluble Solids
USWB	:	United States Weather Bureau
viz.	:	Videlicet (Namely)
WSF	:	Water Soluble Fertilizer
WUE	:	Water Use Efficiency
VA	:	Alternate day fertigation with irrigation
VW	:	Weekly fertigation with irrigation
VF	:	Fortnightly fertigation with irrigation
VM	:	Monthly fertigation with irrigation

ABSTRACT

EFFECT OF FERTIGATION TIMING ON GROWTH, YIELD AND NUTRIEN MOBILITY FOR TOMATO IN INCEPTISOL

By

Miss. Bhoi Sangita Pratap

A candidate for the degree of
DOCTOR OF PHILOSOPHY (AGRICULTURE)
in
IRRIGATION WATER MANAGEMENT
2021

Research Guide	**:**	**Dr. D.D. Pawar**
Department	**:**	**Irrigation Water Management**

The present investigation entitled, “Effect of fertigation timing on growth, yield and nutrient mobility for tomato in Inceptisol ” was conducted during the *Rabi* season of the year 2014-15 and 2015-2016 at the Research Farm of Interfaculty Department of Irrigation Water Management, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, District Ahmednagar, Maharashtra, India with the objectives to standardize the fertigation timing during ferti-irrigation period, to study the effect of fertigation on yield of tomato, to study the moisture distribution pattern under drip for tomato and to study the nutrient mobility and availability in soil and total NPK uptake by tomato.

The present experiment was laid out in randomized block design with three replications. Eleven treatment combinations included different fertilization technologies viz. fertigation timings and spilt applications of fertilizers. The experiment comprised of T_1-100% fertigation in the first tertile of the irrigation period, T_2-100% fertigation in the second tertile of the irrigation period, T_3-100% fertigation in the third tertile of the irrigation period, T_4-100% fertigation during complete irrigation period, T_5-75% fertigation + 25% soil application, T_6-50% fertigation + 50% soil application, T_7-25% fertigation + 75% soil application, T_8-Drip irrigation with 100 % CF, T_9-Surface irrigation with 100 % CF + foliar spray, T_{10}-SI with 100 % CF, T_{11}-DI with no fertilizers. The last two treatments were included as control treatments.

In 100% fertigated treatments, the application of fertilizer in the third tertile of the irrigation period produced significantly maximum plant height (117.23 and 115.22 cm), number of branches plant^{-1} (12.70 and 12.37) at last harvesting stage, whereas the number of leaves plant^{-1} (75.87 and 74.43), leaf area plant^{-1} (179.70 and 177.73 dm^2) were significantly higher at 120 days after transplanting during 2014-15 and 2015-16, respectively. Application of fertilizers in the second tertile of the irrigation period found second in rank in respect of above growth attributes during both the years. The application of fertilizer during complete irrigation period resulted into lower values as compared to first three treatments in respect of above growth attributes during both the years. However, the application of fertilizer in the second tertile of the irrigation period resulted into significantly more dry matter (106.50 and 109.50 g plant^{-1}) during both the years. Among split fertilized treatments, the 75% fertigation + 25% soil application produced significantly higher plant height (110.56 and 108.62 cm), number of branches plant^{-1} (11.57 and 11.30) at last harvesting stage, whereas the number of leaves plant^{-1} (73.20 and 72.30), leaf area plant^{-1} (177.33 and 176.10 dm^2) were also significantly higher at 120 days after transplanting. However 50% fertigation + 50% soil application soil application found second in rank in respect of above growth attributes during both the year. The control treatment, drip with no fertilizers (T11) resulted into lowest values in respect of all the growth attributes at all growth stages during both the years.

The application of fertilizers in the third tertile of the irrigation period produced significantly higher number of fruits plant^{-1} (73.35 and 73.22) as well as fruit weight plant^{-1} (2.72 and 2.71 kg) during both the years and thereby produced significantly maximum fruit yield of 78.50 and 87.53 tha^{-1} during 2014-15 and in pooled means, respectively and the application of fertilizer in the second tertile of the irrigation period registered significantly higher fruit yield of 98.27 t ha^{-1} during 2015-16. The 75% fertigation + 25% soil application produced significantly higher fruit yield, number of fruits plant^{-1} as well as fruit weight plant^{-1} (64.37 and 73.33 t ha^{-1}, 65.57 and 64.54 and 2.41 and 2.40 kg plant^{-1}) during 2014-15 and 2015-16, respectively as compared to other split fertilized treatments.

The application of fertilizer in the third tertile of the irrigation period produced significantly higher photosynthetic rate, stomatal conductance, stomatal resistance, transpiration rate and co_2 concentration at all the crop growth stages during both the years followed by the application of the fertilizers in the second tertile of the irrigation period.

Application of fertilizers during complete irrigation period produced minimum micrometeorological parameters at all the crop growth stages during both the years. The 75% fertigation + 25% soil application produced significantly maximum photosynthetic rate, stomatal conductance, stomatal resistance, transpiration rate and co_2 concentration at all the crop growth stages during both the year. The drip irrigation with 100% conventional fertilizer produced significantly higher values of all the micrometeorological parameters at all the crop growth stages during both the years as compared to surface irrigation with 100% conventional fertilizers.

The application of fertilizers in the second tertile of the irrigation period resulted into significantly maximum uptake and availability of nitrogen, phosphorus and potassium during both the years and pooled mean. While application of fertilizer in the third tertile of the irrigation period found second in order in respect of uptake and availability of nitrogen, phosphorus and potassium during both the years and pooled mean. The 75% fertigation + 25% soil application observed significantly maximum uptake of nitrogen, phosphorous and potassium during first year, second year and pooled mean. The drip irrigation with 100% conventional fertilizers produced significantly maximum uptake and availability of nitrogen as compared to conventional irrigation with conventional fertilizers during both the years. Drip irrigation with no fertilizers resulted minimum uptake and availability of nitrogen, phosphorus and potassium among all eleven treatments during both the years and in pooled mean.

The mobility of nutrients was observed to be function of quantum of nutrients applied, source of nutrients, irrigation system and crop growth stage. The fertigation using 100% water soluble fertilizers resulted into maximum N (45 cm vertically and horizontally), P (15 cm vertically and 30 cm horizontally) and K (30 cm

vertically and horizontally) movement at 60 days after transplantation. The nutrient movement in split fertilizer treatments and in case of conventional fertilizers was less.

The application of fertilizers in the third tertile of the irrigation period found superior in total net income, B:C ratio, net extra income over control and water productivity (₹ 1489968 ha^{-1}, 5.98, ₹ 302696 and ₹ 1010 ha-mm and ₹ 1652125, 6.67, ₹ 350596, ₹ 1192 ha-mm) during first year and pooled mean and application of fertilizer in second tertile of the irrigation period (₹ 839161 ha^{-1}, ₹ 1843768 ha^{-1}, 7.49, ₹ 415896, 1415 ha-mm) during second year. Among the split fertilized treatments, the 75% fertigation + 25 % soil application resulted into maximum net seasonal income, total net income, B:C ratio, net extra income over control and water productivity during both the years and in pooled mean followed by 50% fertigation + 50% soil application. The drip irrigation with 100% conventional fertilizers were found to be significantly superior in respect of all economical parameters during both the years and in pooled mean as compared to surface irrigation with 100% conventional fertilizer and drip irrigation with no fertilizer.

On the basis of the results obtained, it is concluded that, the application of water soluble fertilizers in the second and third tertile of the irrigation period through drip registered maximum growth and yield attributes, fruit yield of tomato crop, better fruit quality, improved nutrient availability and uptake and total net income, B:C ratio and water productivity.

1. INTRODUCTION

Tomato is considered as the 2nd greatest significant vegetable crop in the world after potato. Tomato is a member of the family *Solanaceae*. The botanical name of tomato is *Solanum lycopersicon* L. Tomato is one of the most important "protective foods" because of its special nutritive value. Naturally, the tomato is a perennial plant, but it is cultivated annually because of having a great economical and commercial advantages. It can be grown in most places all over the world, like growing in the field, greenhouses and net houses. The tomato crop is grown and used for both fresh market and processing and it is an adaptable crop.

There are different varieties of tomato, round, oval, "cherry", but all have the same nutritional characteristics, being an important source of potassium, phosphorus, magnesium, iron, so necessary to the normal activity of nerves and muscles; tomato is the third most important source of vitamin C in our diet and the fourth most important source for vitamin A, through its content in beta-carotene or pro vitamin A. It also contains phytosterols, compounds that help to keep cholesterol under control, folic acid, which helps eliminate homocysteine, an amino acid whose metabolism is dependent on the metabolism of vitamins from B complex. The red pigment contained in tomatoes is called lycopene. This compound appears to act as an antioxidant, neutralizing free radicals that can damage cells in the body. Israeli researchers have found that lycopene is a powerful inhibitor of lung, breast, and endometrial cancer cells. Research has also indicated that the lycopene in tomatoes can help older people stay active longer. When choosing your tomatoes, be sure to chose pick with the most brilliant shades of red. These indicate the highest amounts of betacarotene and lycopene (Bhowmik *et al.* 2012)

The area under tomato during 2013-2014 in India was 882.0 M ha with total production of 18735.9 MT and average productivity 21.2 t/ha. Whereas, in Maharashtra it was 50.00 M ha with total production of 1200.00 MT and average productivity 24.0 t/ha. Andhra Pradesh has the highest area (167.72 M ha) and production (3354.47 MT) while Madhya Pradesh has the highest productivity of 33.9 tons/ha (Anonymous, 2013-14).

Table 1.1 Tomato in India : Area, Production and Productivity

State	Area (M ha)	Production (M T)	Productivity (tons/ha)
Andhra Pradesh	167.72	3354.47	20.0
Karnataka	61.04	2068.38	29.5
Madhya Pradesh	65.72	1937.37	33.9
Teleangana	74.19	1483.71	20.2
Odisha	97.02	1385.96	14.3
Gujrat	44.57	1259.01	28.2
Maharashtra	50.00	1200.00	24.0
West Bengal	56.50	1141.50	20.2
Bihar	47.69	1061.77	22.3
Chhatishgarh	50.38	814.22	16.2
Himachal Pradesh	29.42	627.28	21.3
Other	137.8	240.2	17.4
Total	882.0	18735.9	21.2

Irrigation water management is the act of timing and regulating irrigation period water applications in a way that will satisfy the water requirement of the crop without the waste of water, soil, plant nutrients, or energy. It means applying water according to crop needs in amounts that can be held in the soil available to crops and at rates consistent with the intake characteristics of the soil and the erosion hazard of the site (Chapter 9).

Fertilizer management practices are agricultural production technologies and practices developed through scientific principles and verified in farmers' fields to maximize social and includes "4Rs" i.e., using the right fertilizers at the right rate, right time and right place. This implies that fertilizer management practices must include information on the type of nutrients that need to be applied, their source, the amount to be applied, time of application and the method of application. Besides, fertilizers are integrated with organic manures and biofertilizers to achieve improved fertilizer use efficiency, identification of deficient nutrients in soil by soil testing and application of fertilizers for correcting the nutrient deficiencies (Prakash *et al.*, 2013).

Vegetable being an important sources of vitamins, mineral nutrients, dietary fibre and antioxidants, play a major role in providing nutrition for better health and nutritional security. In the present scenario of producing more vegetable from less natural resources for more people, fertilizer will continue to play a major role in boosting crop yields. However, the concerns of environment degradation, 1oss of soil fertility and emergence of multi-nutrient deficiencies, low fertilizer use efficiency and stagnation of crop yields due to indiscriminate and imbalanced use of fertilizer with little or no addition of organic matter suggests that we must resort to best fertilizer management practices to tackle these problems affecting Indian agriculture. It is envisaged that, efficient and eco-friendly best fertilizer management practices involv soil test based fertilizer application; balanced fertigation through integrated nutrient management involving all available sources of plant nutrients, be it fertilizer, organic manures or bio fertilizers and non-conventional sources of nutrients; fertigation useing of water soluble and slow release fertilizers to improve fertilizer use efficiency. Precision fertilizer management/site specific nutrient management through fertigation would lead to increased and Profitable production of quality vegetable crops while maintaining improved soil health and fertility. Especially, fertigation technique is the need of this hour considering the acute shortage of water in many areas and huge investment in terms of foreign exchange by GOI for importing the fertilizer materials during last two decades (Prakash *et al.*2013).

Water availability - Global scenario

Although our earth is called the 'Blue Planet' as 70 per cent of the earth is covered by water, yet only 2.5 per cent of the world's water is fresh, while 97.5 per cent is saline being oceans. Of this small percentage of freshwater, only 0.3 per cent of this freshwater is available from rivers, lakes and reservoirs, 30 per cent from the groundwater, while the rest is stored in distant glaciers, ice sheets, mountainous areas, places that we can hardly access. This is the scenario of global water distribution when no intervention is anticipated. As we are aware that numerous interventions are taking place every day in the total environment, and thus actual freshwater availability in the form of surface water and groundwater resources are much different to what it appears from the global water distribution. Water use is increasing everywhere every year. Currently, on a global basis, 69 per cent of all water withdrawn for human use on an annual basis is soaked up by agriculture (mostly in the form of irrigation); industry accounts for 23 per

cent and domestic use (household, drinking water, sanitation) accounts for about 8 per cent (Muneer, 2014).

Water Availability - Indian Scenario

The geographical area of India is about 329 million hectares (2.45% of the earth's land mass) and its population is 1,027 million based on the 2001 census, which is about 16 per cent of that of the world. The renewable fresh water resources of the country are 1,869 km^3 $year^{-1}$, which are only about 4 per cent of those of the world. As in many other countries, water resources of this country are not evenly distributed in space and time. Although some water is received from the upstream countries, precipitation is the main source of water availability. The annual rainfall varies from more than 10,000 mm in parts of Meghalaya in the north-east to less than 500 mm in semi-arid parts of Rajasthan and Gujarat. In arid regions, it is even less than 100 mm. Much of the water is received during monsoon season, about four months in a year and more crucial is that it occurs in about 100 hours of the rainy days (Munner, 2014).

At the time of independence in 1947, the per capita availability of water in India was 6,008 cubic meters per year. It become 1,820 cubic meters a year in 2001. According to midterm appraisal (MTA) of the 10^{th} Plan, per capita availability of water to fall down to 1,340 cubic meters in 2025 and 1,140 cubic meters in 2050. In India, 82 % of available water is being used for irrigated agriculture leaving very small proportion for other areas. One billion nearly $1/6^{th}$ of the world's population are already facing water shortage on a daily basis. The United Nations FAO states that by 2025, 1.9 billion people will be living in countries or region with absolute water scarcity, and two thirds of the world population could be under stress condition. The 780 million people lack access to clean water and inadequate access to safe drinking water for about 884 million people. In the 20^{th} century, population grew 3 fold but water demand grew to 6 folds (Munner, 2014).

A variable option to save large amount of water in agriculture sector and make available to other sectors is drip irrigation. It is also known as trickle irrigation or microirrigation, is an irrigation method that allows a grower to control the application of water and fertilizer by allowing water to drip slowly near the plant roots through a network of valves, pipes, tubing, and emitter. Drip irrigation requires less than half of the water for flood or furrow irrigation and less than three-quarters of the water for sprinkler

irrigation. Water use efficiency is increased because plants can be supplied with water in precise amounts. Disease presence may be less because plant leaves remain dry. Water is applied directly to the plant root zone. No applications are made between rows or other non-productive areas, resulting in better weed control and significant water savings. Field practices such as harvesting can continue during irrigation because areas between rows remain dry. Fertilizers can be applied efficiently through the drip system. Irrigation can be done under a wide range of field conditions. Compared to sprinkler irrigation, soil erosion and nutrient leaching can be reduced (Pawar *et al.*, 2013).

Fertigation - a modem agrotechnique, combining water and fertilizer application through irrigation - provides an excellent opportunity to both maximize yield and minimize environmental pollution (Magen, 1995; Shani *et al.,* 1988 and Sneh, 1987). In drip fertigation, fertilizer can be applied directly to the effective root zone of plant. Fertilizer application is synchronized and optimized with plant need and the amount and form of nutrient supply is regulated as per the need of the critical growth stages of plant. Nutrients can be applied any time during the growing season based on crop need, thus saving in amount of fertilizer applied, due to better fertilizer use efficiency and reduction in leaching due to unseasonal weather. It reduces labour and energy cost by making use of water distribution systems for nutrient application. Timely application of small but precise amounts of fertilizers directly to the roots zone, which improves fertilizer use efficiency and reduces nutrient leaching below the root zone. It ensures a uniform flow of water and nutrients causing minimal crop damage. Smaller amounts of fertilizer can be applied quickly through fertigation to address any deficiency issues and highly mobile nutrients such as nitrogen can be carefully managed to ensure rapid crop uptake. It is a safer application method, as it eliminates the danger affecting roots due to higher dose. However, good quality water is very essential for avoiding clogging inside the emitter (Pawar *et al.*, 2013).

The drop has the potential to save large amount of water in tomato crop when compared to surface irrigation (Pawar *et al.,* 2013). The higher tomato yield through fertigation is obtained than banded and furrow irrigation or banded and then trickle irrigated (Hebbar *et al.*, 2004).

Many studies have been take up on standardizing the different levels of fertigation, depth of fertigation, frequency of fertigation, different doses of fertilizers and

their effect on growth and yield of the crop. Through there experimentation technologies in respect of requirement and water application schedule under drip, NPK fertilizer ratio and quantities to be applied at different crop growth stages, planting layout under drip etc. have already been developed and many farmers in state of Maharashtra and in India are using these technologies. However, due to fear of yield loss, owing to relatively lower dose of fertilizers in fertigation, farmers have the tendency to apply additional fertilizers and water. This may result into crop damage, lower yields and lower profits. Similarly, refinement in technologies related to fertilizer application time and possible combination of water soluble fertilizer and conventional fertilizers to improve upon the fertilizer are efficiency and economics of fertigation technology was felt in many deliberations. Therefore, the present study was undertaken to standardize the fertigation timing for tomato crop for increasing the growth, yield and quality. The fertilizers need to be applied precisely with irrigation water by calculating the irrigation time. Considering the importance of fertigation application in crop production this research work was undertaken with the following specific objectives.

i. To standardize the fertigation timing during ferti-irrigation.
ii. To study the effect of fertigation on yield of tomato.
iii. To study the moisture distribution pattern, under drip for tomato.
iv. To study the nutrient mobility and availability in soil and total NPK uptake by tomato.

2. REVIEW OF LITERATURE

Tomato as a protective food has its special nutritive value. As a perennial plant, but it is cultivated annually because of having a great economical and commercial advantages. It can be grown in most places all over the world, like growing in the field, greenhouses and net houses. To achieve the higher yields, quality produce and fertilizer use efficiency in vegetable production, it is essential to manage plant nutrition in a precise and efficient manner through application of nutrient at the right place in a right manner and the right time. Fertigation ensures that the right combination of water and nutrients is made available at the root zone. The concept of fertigation timing in tomato crop is relatively a resent in India and information available on fertigation timing is limited. Therefore, the available literature related to the impact of fertigation timing on growth, yield and nutrient mobility for tomato in inceptisol is briefly reviewed in this chapter under following sub-headings.

2.1 Drip for tomato
2.1.1 Yield and growth under drip
2.1.2 Water saving and water use efficiency
2.1.3 Moisture distribution under drip
2.1.4 Economics under drip
2.2 Fertigation for tomato
2.2.1 Yield and growth under fertigation
2.2.2 Nutrient availability, uptake
2.2.3 Nutrient mobility
2.3.4 Economics under fertigation

2.1 Drip for Tomato

2.1.1 Yield and growth under drip

Ajmalkhan (2000) stated that fertigation of recommended dose of nitrogen as urea and K_2O as muriate of potash applied in 15 equal splits at eight days interval starting from 8 DAP to 120 DAP through drip system recorded higher tomato yield as compared to surface irrigation with conventional method of fertilizer application on sandy loam soil at Madurai (TNAU) in Tamil Nadu.

Singandhupe *et al.* (2003) reported that application of nitrogen through the drip irrigation in ten equal splits at 8 days interval saved 20 to 40 per cent nitrogen as

compared to the furrow irrigation when nitrogen was applied in two equal splits (at planting and 1 month thereafter). Similarly, 3.7 to 12.5 per cent higher fruit yield with 31 to 37 per cent saving of water was obtained in the drip system. Water use efficiency in drip irrigation, on an average over nitrogen level was 68 and 77 per cent higher over surface irrigation in 1995 and 1996, respectively. At 120 kg N ha^{-1}, maximum tomato fruit yield of 27.4 and 35.2 t ha^{-1} in 2 years was recorded. Total nitrogen uptake in drip irrigation was 8 to 11 per cent higher than that of furrow irrigation. At the highest level of applied nitrogen (120 kg N ha^{-1}), total average N uptake of 2 years was 64.5 (1995) and 104.7 kg ha^{-1} (1996). The apparent N recovery was 82.5 per cent at 48 kg N ha^{-1} in comparison with 47.9 per cent at 120 kg N ha^{-1} during 1996. Stomatal resistance was higher in furrow irrigation than that of drip system at various plant heights. Lower leaf had less resistance than upper leaf irrespective of irrigation period methods.

Hebbar *et al.* (2004) conducted experiment on NPK drip fertigation in field grown tomato. There were eight treatments including furrow-irrigated and drip-irrigated controls, which was replicated three times. The investigations revealed that the total dry matter production and Leaf Area Index were significantly higher in drip irrigation (165.8 g and 3.12, respectively) over furrow irrigation (140.2 g and 2.25, respectively). Water-soluble fertilizer fertigation recorded significantly higher total dry matter and LAI (181.9 g and 3.69, respectively) over drip irrigation. The fruit yield of tomato was 19.9 per cent higher in drip irrigation (71.9 Mg ha^{-1}) over furrow irrigation (59.50 Mg ha^{-1}).

Anant (2006) reported that the highest yield of tomato was noticed when N (urea) was supplied in 8 or 10 split doses with 100 per cent ETo through drip irrigation.

Kadam and Karthikeyan (2006) reported that the number of fruits and weight of fruits per plant were greatest in plants treated with 100 % of the recommended NPK applied through drip. The quality parameters such as pH, TSS and lycopene content under this treatment were superior to solid fertilizers + surface irrigation.

Ismail *et al.* (2007) observed that irrigation at early morning every 3 days increased yield by 10 per cent over the highest yield of 1-day frequency. Irrigation at early morning every 3 days was the best irrigation timing because it increases the yield by 15 and 14 per cent compared to afternoon and night irrigation respectively. For 1-day frequency irrigation at night was better than irrigation at early morning or afternoon

because it increases the yield by 11 and 3 per cent comparedd to early morning and afternoon irrigation timings respectively.

Sampathkumar and Pandian (2010) observed that the effect of drip fertigation levels and frequencies on growth and yield of hybrid maize. By using the recommended dose of fertilizer (RDF) 150:75:75 and 150 per cent of RDF 225:112.5:112.5 of NPK kg ha^{-1}. Nitrogen, phosphorus and potash were applied in the form of urea, single super phosphate and muriate of potash, respectively. Phosphorus was applied basally as soil application in all treatments except absolute control. Urea and muriate of potash were applied through irrigation water through fertigation as per the schedule. Four fertigation frequencies (once in 6, 9, 12 and 15 days), two fertilizer levels (100 and 150 per cent of RDF), surface irrigation with 100 per cent RDF and Absolute control (no fertilizer) were included as treatments in this study. Application of 150 per cent of RDF once in 6 days (T_5) recorded significantly higher grain yield (8,957 kg ha^{-1}) than 100 per cent of RDF (7,915 kg ha^{-1}). Irrespective of fertilizer levels, fertigation frequency scheduled once in 6 days registered higher grain yield and it was on par with other frequencies. No significant difference in grain yield among different fertigation frequencies. Absolute control (T_{10}) recorded the lowest grain yield (4,680 kg ha^{-1}) followed by surface irrigation with 100 per cent RDF (T_9). The increased percentage of grain yield over lower dose of RDF and absolute control was 13.2 and 91.3, respectively. Maize crop responded well to fertigation and application of nutrients up to 150 per cent of RDF and maximized the grain yield. The results of this study revealed that scheduling of drip fertigation with 150 per cent of RDF applied once in 6 days could be the optimal management practice for getting higher yield in hybrid maize.

Tanaskovik *et al.* (2011) studied the best irrigation and fertigation practice for tomato crop (*Lycopersicon esculentum* Mill.) in order to achieve highest yield with maximum water use efficiency (WUE). Five experimental treatments tested in this study included the following: the first three treatments (T_1, T_2 and T_3) included a combination of drip irrigation and fertigation, treatment four (T_4) included drip irrigation, but with conventional application of fertilizer, and the fifth treatment, (T_5), included furrow irrigation practice with conventional application of fertilizer. The results of this study show that the drip fertigation treatments (T_1, T_2, and T_3) gave significantly higher tomato yields in comparison with treatments T_4 and T_5 almost 24 and 39 per cent.

Treatments under drip fertigation showed almost 28 per cent more water use efficiency in comparison with the treatment with conventional application of fertilizer and drip irrigation).

Kumar *et al.* (2016) stated that the seven treatments comprising of three irrigation depths, two intervals and a farmers practice that is T_1 : 0.25 cm irrigation daily, T_2 : 0.25 cm irrigation at alternate day, T_3 : 0.50 cm irrigation daily, T_4 : 0.50 cm irrigation at alternate day, T_5 : 0.75 cm irrigation daily, T_6 : 0.75 cm irrigation at alternate day, T_7 : Farmer's practice (Two times irrigation week-1 till the establishment of seedlings and later on 1–1.5 cm irrigation with canes/pipes twice a week). The amount of water through drip irrigation system was based on evapo-transpiration basis (climatological approach). The treatment with 0.50 cm of irrigation at alternate day resulted in maximum fruit breadth (6.53 cm), average fruit weight (95.20 g), number of fruits plant^{-1} (18.26), total biomass production (165.38 g plant^{-1}) and highest economic yield plot (36.17 kg plot^{-1}) and along with moderate water productivity (0.25 kg m^{-2} cm^{-1}), may be recommended for commercial cultivation of capsicum in the hilly regions under naturally ventilated polyhouses. However, the treatment with 0.25 cm of irrigation at alternate day recorded maximum water productivity (0.43 kg m^{-2} cm^{-1}) and total soluble solids (5.30 %) with moderate yield (30.58 kg plot^{-1}) and lowest root rot incidence (2.76 %).

Ankush and Sharma (2017) carried out an experiment to study the impact of drip fertigation in tomato crop at RCA, MPUAT, Udaipur during *rabi* season 2015-16 in split plot designed with three irrigation schedules [100 (I_1), 75 (I2) and 50 % PE (I3) through drip] and five fertilization schedules [100 % RDF (F1), 75 % RDF (F2), 75 % RDF + 2 foliar spray of 1 % urea phosphate (F3), 50 % RDF (F4), 50 % RDF + 2 foliar spray of 1 % urea phosphate (F5)]. Higher number of nodes per plant (21.20 and 19.89) and yield (169.03 and 186.38 q/ha) were registered with treatments receiving drip irrigation at 75 % PE and 75 % RDF through fertigation + 2 foliar spray of 1 % urea phosphate, respectively. Quality characteristics were enhanced with combined use of I_2F_3 treatment. The highest water use efficiency *i.e.* 26.37 ka/ha-cm was recorded under I_3F_3 treatment and fertilizer use efficiency with I_2F_5 treatment combination (165.78, 254.31 and 381.46 kg/kg NPK, respectively).

Pawar *et al*. (2018) observed maximum grain yield was obtained in treatment T_2 that is drip with 100 % fertigation with three foliar sprays 39.47 q ha^{-1}, but it was at par with treatment T_1 (37.74 q ha^{-1}) and was 32.31 % more than conventional method of irrigation and fertilizer application (T_8). The drip irrigation with conventional fertilizer (T_6) produced 10.86 per cent more yield than surface irrigation with conventional fertilizer application (29.07 q ha^{-1}). The better performance of drip irrigation over surface irrigation was due to the application of right quantity of water at right time and at right place which resulted in appropriate moisture content in root zone. The different treatment was drip with 100 % fertigation (T_1), drip with 100 % fertigation and three foliar sprays of 17:44:0 at 30, 45 and 60 days after sowing (DAS) (T_2), drip with 80 % fertigation (T_3), drip with 60 % fertigation (T_4), drip with 100 % conventional fertilizers (CF) of which N and K through drip (fertigation) and P through soil (T_5), drip with 100 % conventional fertilizers applied as basal dose through soil (T_6), drip with no fertilizers (T_7), surface irrigation with CF (T_8) and surface irrigation and CF and three foliar sprays (T_9).

Kale *et al.* (2018) studied the effect of water soluble fertilizer and conventional fertilizer with drip irrigation and surface irrigation through seven treatments comprised of drip fertigation among four water soluble phosphatic fertilizer. The results indicated that the application of water soluble P fertilizers significantly enhanced the yield of tomato. The significantly higher yield of tomato was obtained in 80 % RD of fertigation through 24:24:00 (T_4, 65.01 t ha^{-1}); however, it was at par with 80 % RD of fertigation through 12:61:00 (T_7, 63.08 t ha^{-1}) and 80 % RD of fertigation through 13:40:13 (T_6, 62.92 t ha^{-1}). The drip method used lowest water use of 436.0 mm as compared with 900.0 mm in surface irrigation method thus resulted in 51.5 per cent water saving. The maximum water use efficiency of 149.1 kg ha^{-1} mm was recorded in DI with 80 % RD of fertigation through 24:24:00 (T_4) and lowest WUE of 49.2 kg ha^{-1} mm in SI with 100 % CF (T_2). On the basis of the results obtained, it can be concluded that drip irrigation with 80 % RD of fertigation through 12:61:00 in 18 weekly splits as per schedule was the best treatment for higher yield, water use and economics of tomato (var. Abhinav) cultivated in silty clay loam soils of western Maharashtra.

Jena and Aladakatti (2018) reported that the physiological characters like leaf area index (LAI), chlorophyll content in leaf (SPAD value) at 90 and 120 DAS and

leaf area duration (LAD) at 90 to 120 DAS influenced significantly due to different fertigation levels with conventional and water soluble fertilizers applied in six equal splits. Significantly higher LAI (1.86 and 2.54), SPAD value (42.20 and 47.63) at 90 and 120 DAS and LAD (66.05) at 90 to120 DAS was recorded in PR sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through CF applied in six equal splits (T_9) over other treatments and was on par with PR sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through WSF and 25 per cent RDF through CF applied in six equal split *i.e.* T_5 (1.66 and 2.31, 39.93 and 43.70 and 59.58, respectively). High LAI, LAD and SPAD value was mainly due to higher frequency of irrigation and increased availability of soil moisture under drip irrigation coupled with fertigation might have led to effective absorption and utilization of nutrients and better proliferation of roots resulting in better canopy growth.

2.1.2 Water saving and water use efficiency

Ahluwalia *et al.* (1993) studied drip irrigation system- its hydraulic performance and influence on tomato and cauliflower crops at PAU, Ludhiana. Compared to conventional system, drip system saved up to 57 and 37 per cent irrigation water in tomato and cauliflower crops, respectively, resulting in tremendous increase in water use efficiency.

Magar and Lamn (1995) noted that, drip irrigation saved water to 64.3 per cent and increased yield by 21.6 per cent and recorded almost double WUE when compared with surface irrigation.

Yohannes and Teshome (1998) conducted an experiment at Dire Dawa, Ethiopia on a deep clay loam soil during 1991-92 and 1992-93 and revealed that the higher yields of tomato were obtained with drip irrigation in both seasons as compared to furrow irrigation. A similar trend was also observed on the effect of irrigation systems on fruit size and plant height and the water use efficiency-WUE and irrigation application efficiency were determined for both irrigation systems and it was found that the drip system showed the highest values as compared to furrow irrigation.

Singandhupe *et al.* (2003) revealed that application of nitrogen through the drip irrigation in ten equal splits at 8-days interval saved 20-40 per cent nitrogen as compared to the furrow irrigation when nitrogen was applied in two equal splits (at planting and 1 month thereafter). They reported that, 31-37 per cent saving of water was

obtained in the drip system. Water use efficiency in drip irrigation, on an average over nitrogen level was 68 and 77 per cent higher over surface irrigation in 1995 and 1996, respectively.

Vijayakumar *et al.* (2010) conducted field experiment with three irrigation levels 100, 75 and 50 per cent of pan evaporation (PE) along with three fertigation levels viz., 125, 100 and 75 per cent of recommended N and K fertigation through drip. The highest water use efficiency of 111.5 kg ha^{-1} mm^{-1} was recorded in drip irrigation at 75 % of PE with fertigation of 75 % of recommended N and K.

Tanaskovik *et al.* (2011) conducted the field experiments at Republic of Macedonia. The results of this study show that during three years of research treatments under drip fertigation showed almost 28 per cent more water use efficiency in comparison with the treatment with conventional application of fertilizer and drip irrigation and 87 per cent more than the treatment with furrow irrigation and conventional application of fertilizer. So, it is clear that the drip fertigation led to an increased yield, indicating enhanced water use efficiency.

Kumari and Kaushal (2014) conducted an experiment on drip fertigation in sweet pepper which results in saving of fertilizer up to 25 per cent, water to 40 percent significant increase in yield and water use efficiency.

Ughade and Mahadkar (2014) reported maximum field water use efficiency (FWUE) i.e. 46.91 q ha-1-cm in treatment combination of plant spacing S3 (17550×50 cm) with 60% ET and 100% RDF through drip.

Gupta et al. (2015) resulted that the combined effects of drip irrigation and fertigation, the treatment combination of 80% ET through drip + 60% recommended NPK through drip recorded maximum water use efficiency (49.9 q/ha-cm) and fertilizer use efficiency 10.99q/kg N, 18.32q/kg P and 27.48 q/kg K.

2.1.3 Moisture distribution pattern

Earl and Jury (1977) observed the water movement pattern for a discharge rate of 8lph and noted that it was moved in both horizontal and vertical directions upto 30-40cm distance. For discharge rate of 4lph, the moisture content after 48 hours at the surface (below the emitter) was decreased from 37.8 to 27.8 per cent. The moisture content after 48 hours at 30 cm depth below the dripper was found to be stabilized at 23.9

per cent in 0-30 cm depth. Discharge rate of 4lph, the moisture content for 40cm distance away from the dripper was 21.8-22.7 per cent.

Ahluwalia *et al.* (1993) reported that the soil moisture content after 6 hours irrigation was the maximum in 30-45 cm depth interval at all points along the radial distance between two emitters. Further, the moisture content at a radial distance of 30 cm was the lowest from a given emitter at all soil depths. However, the moisture content was increased with decreasing radial distance from the emitter with maximum value obtained at the point source.

Singandhupe *et al.* (2002) found that the soil moisture front remained stable even after irrigation period at 45 and 60 cm soil depth. This may be due to low water retention capacity of lower layer. But in upper layer i.e. 15 and 30 cm depth, there was an increase in water content just after surface irrigation and depletion occurred when redistribution started. In case of the drip irrigation, at the source of emitter, the soil moisture in 45 and 60 cm soil depth was higher as compared to surface irrigation because of frequent irrigation. Higher soil moisture in drip irrigation period towards both vertical and horizontal direction showed a well designed lateral and emitter spacing, which can provide adequate amount of water in adopted paired row planting.

Li *et al.* (2004) reported that water distribution in horizontal direction is more when water application rate is increased, while decreasing the rate allows more water to distribute in vertical direction. The wetted zone geometry was affected by soil type, the volume of water applied to the soil and emitter discharge rate.

Amin and Ekhmaj (2006) stated that under drip irrigation system, available soil moisture was almost consistent and nearer to field capacity as against wide fluctuation under surface irrigation. Adequate soil moisture availability ensures successful cotton production under any type of cultivation. Higher available soil moisture (ASM) was observed in drip irrigation plots as compared to furrow irrigation period in two soil depths of 0-15 cm and 15-30 cm.

Mady *et al.* (2012) reported the moisture distribution contour lines recorded under surface drip irrigation line for the first, second and third irrigation periods without using of the Geotextile material sheets, respectively, once after 24 and 48 hours from irrigation process. It was clear that the contour lines were closed to each other at 24 hr after the first irrigation (one hour operating or 8 liters). Also, the maximum moisture

content was directly under the dripper that by increasing the soil depth the moisture content decreased, as well as increasing the horizontal distance from the dripper. It was observed that the moisture distribution was very symmetrical that the moisture contour lines moved downward after 48 hours from the irrigation process. Therefore, the moisture contour lines were far from each other more than obtained after 24 hours from the irrigation. This action of water was expected, but the moisture content decreased in the first 10 cm of the soil surface. The moisture content was concentrated under the dripper. There was excessive water which could be lost by the deep percolation. Near 50 cm from the soil surface, the maximum moisture content appeared. On the contrary, different trend of the water movement, where the water moved toward the soil surface following the capillary rise theory, especially under the dripper, and the moisture distribution was improved more than after one day from the second irrigation process. These results were obtained because the exits of moisture in the soil layers before the second irrigation (approximately the soil was semi saturated).

Patel *et al.* (2015) reported that sandy loam soil needed frequent irrigation with less amount of water per irrigation. Tomato is deep- rooted crop and in deep soils, some roots penetrate up to 1.5 m. The maximum rooting depth is reached about 60 days after transplanting. Over 80 per cent of the total water uptake occurs in the first 0.5 to 0.7 m and 100 per cent of the water uptake of a full grown crop occurs from the first 0.7 to 1.2 m therefore soil moisture content up to depth of 120 cm was measured. Change in volumetric water content at 0-15, 15-30, 30-45, 45- 60, 60-75, 75-90, 90-120 cm soil depths at 0, 15, 30 cm away from lateral (in all treatments) were monitored fortnightly. With growth of crop the root system of plant develops, water requirement of crop increases and soil moisture was increases in lower soil profile. Uptake of moisture was more up to developmental stage. Because of frequent irrigation, the soil moisture was high at about field capacity (~ 25.6 %) near the dripper. Soil water content just below the dripper i.e. 0 cm away from lateral was more throughout the crop season i.e. 25.6, 25.5 and 25.6 per cent, in treatments VA, VW, and VF, respectively. Soil water content did not decrease significantly with the increasing depth of soil from 15 to 120 cm. Soil water content was found decreasing with increasing distance from the lateral pipe.

2.1.4 Economics under drip

Hugar (1996) reported that the B:C was much higher in tomato under drip irrigation when the water so saved was assumed to be utilized to cover additional area of same crop than conventional irrigation.

Jha *et al.* (2017) evaluated of drip and furrow irrigation methods in participatory mode at the farmer's field with an aim to develop understanding about potential benefits of drip irrigation system among the tribal farming community of the eastern plateau and hill region. Comparative assessment in terms of yield gain, water productivity (WP) and net returns was carried out for tomato, potato, cauliflower, french bean and pea cultivated in the farmers' fields at Saraitoli village of Ranchi district of Jharkhand. The study revealed that, for the selected vegetables, adoption of drip irrigation improved the yields in the range of 38.2 to 65.8 per cent over furrow irrigation with highest yield increase in case of pea (65.8 %) and tomato (58.7 %). Drip irrigation consistently recorded higher water productivity (WP) with more than five folds increase in case of potato and cauliflower. The average WP was higher under drip irrigation (6.89 kg m-3) as compared to furrow method (1.31 kg m-3). Economic analysis revealed that the average cost-benefit (CB) ratio of all drip irrigated crops was about 33 per cent higher over furrow method of water application. Among all the crops drip irrigated cauliflower was found to be the most remunerative crop with higher net returns (1,98,336 ₹ ha^{-1}) and highest CB ratio of 2.98. The comparative economic analysis of drip and furrow irrigated crops presented in this study will assist the farmers in crop selection. Precise use of water with better productivity and higher net returns from the drip irrigated vegetable crops motivated the farmers to adoption drip irrigation technology.

2.2 Fertigation for tomato

2.2.1 Yield and growth under fertigation

Singh and Singh (1992) conducted a study on the effect of four levels of nitrogen (0, 75, 100 and 125 kg ha^{-1}). The results revealed that the application of nitrogen at 125 kg ha^{-1} increased the yield (237.5 q ha^{-1}) when compared to 0, 75 and 100 kg ha^{-1}.

Aramini *et al.* (1995) reported that when percentages of fertigated N and K were increased above 75 per cent, yields increased in sandy loam soil.

Nanadal *et al.* (1998) compared four levels of each of phosphorus and potash with tomato as showed that increasing levels of phosphorus up to 50 kg P_2O_5 and

potash up to 80 kg K_2O/ha improved the height of plant, number of flowers, weight of fruit, early and total yield, ascorbic acid content, total soluble solids (TSS) and reducing and non reducing sugars in the fruit. Though the higher doses of 75 kg P_2O_5/ha and 120 kg K_2O/ha increased fresh and dry weight of plant and advanced flowering and fruiting, they deteriorated the quality of fruit.

Alcantar *et al.* (1999) stated that the tomatoes are an important crop grown and fertigated in open fields and in protected cultures. Fertigated tomatoes yielded more, had higher dry matter and improved quality parameters (size, firmness and soluble sugars) compared to conventionally irrigated and fertilized crops.

Pan *et al.* (1999) compared conventional drip irrigation and fertilization with drip fertigation and reported that the fertigated tomatoes produced a red fruit yield of 72 t ha^{-1} while those under conventional irrigation and fertilization yielded only 44 t ha^{-1}. Fertigation doubled the number of fruits. Improved nutrient availability provided by fertigation was considered to be one of the important factors causing the increase in yield.

Reist *et al.* (1999) reported the fertigation, in addition to giving large yields also gives additional benefits. Tomatoes grown in soil-less culture in glasshouse with good fertigation practices are least likely to suffer from plant diseases and in the long-term maintain large yields.

Gupta and Sengar (2000) observed that application of nitrogen, resulted in appreciable improvement in plant height, number of fruits per plant and yield of tomato fruit. Application of nitrogen at 120 kg ha^{-1} yield was significantly high except TSS, which reduced at higher level. Potassium exhibited pronounced effect in improving the vegetable growth, yield and TSS content. Application of potassium at 60 kg ha^{-1} increased growth parameters like plant height, number of branches.

Kumar *et al.* (2003) assessed different rates of nitrogen (60, 120 and 180 kg ha^{-1}) and phosphorus (40, 120 and 180 kg ha^{-1}) application among which 180 kg N ha^{-1} and 120 kg P_2O_5 ha^{-1} increased plant height, than other treatments, enriched TSS (23.30 B) and ascorbic acid (6.6 mg 100 g^{-1}).

Chaurasia *et al.* (2005) observed that the maximum plant height (125.4 cm), number branches (4.2), fruit length (4.90 cm), fruit diameter (4.51 cm) and number of fruits (24.6) were found in the treatments with foliar sprays of water soluble formulation NPK 19:09:19, sprayed 5 times followed by NPK 19:19:19, sprayed five

times. However, the average fruit weight 81.6 g was recorded in the 5 foliar sprays of multi K. The increase in plant height, number of branches, number of fruits and individual fruit weight were high with 5 foliar sprays in all the combinations of NPK might be a reason of supplying more nutrients at the critical growth stage, i.e. flowering and fruit set. Jeybal *et al.* (1998), Vibhute (1988) and Naik *et al.* (2002) also reported similar findings. This increase is also might be due to the increased vegetative growth under abundance of nitrogenous fertilizers for photosynthesis activity. Application of water-soluble fertilizer also increases the yield with 5 sprays compared to 3 sprays. The maximum yield (631.66 q/ha) recorded in the 5 foliar application of the NPK 19:09:19.The increase in the yield might be due to greater availability of nutrients, increased uptake of nutrients and water, resulting in more photosynthesis and enhanced food accumulation in edible part of the fruits.

Rana *et al.* (2005) conducted study with hybrid tomato on a sandy soil in Bikaner, Rajasthan, during the *rabi* season with drip fertigation treatments 25, 50, 75 and 100 per cent of the recommended dose of NPK (180:120:80 kg ha^{-1}) compared with 100 % of NPK dose applied through conventional method. The drip fertigation with 100 % of NPK recommended dose increased parameters such as mean fruit weight (70.75 g), number of fruits per plant (43.50 %), yield per plant (3.07 kg) as well as yield ha^{-1} (50.59 t). The quality characteristics such as titrable acidity, total soluble solids, reducing sugars and ascorbic acid content were increased significantly due to drip fertigation with 75 and 100 % of NPK recommended dose in comparison to 100 % of NPK dose application through conventional method.

Bahadur *et al.* (2006) conducted a study on drip fertigation in tomato to find out an optimum amount of water and N fertigation frequency in tomato cv. DVRT-1. Results indicated that the maximum number of fruits, fruit weight, fruit yield (3.99 kg/plant) and marketable fruit yield (63.83 t ha^{-1}) was recorded at 100 % ETo. N fertigation scheduling did not affect the yield parameters. The highest fruit yield of 67.73 and 69.38 t ha^{-1} was noticed at 100 % ETo, and N (urea) was supplied in 8 and 10 split doses, respectively. The maximum WUE (53.85 q/ha-cm) was recorded when irrigation was scheduled at 40 % ETo. Drip irrigation scheduling at 100 and 80 % ETo saved 45.8 and 56.5 per cent water, respectively over surface irrigation.

Akanda *et al. (*2007) studied feasibility of fertigation for tomato and brinjal cultivation in winter. An experiment was conducted to evaluate the performance of fertilizer on summer tomato (BARI hybrid tomato-4) with 4 fertigation and 2 (two) irrigation period levels. The fertigation levels were N:250 P:95 K:125, N:150 P:95 K:75, N:100 P:95 K:50 and N:75 P:95 K:35 and irrigation period levels were- drip irrigation period at 2 days interval and drip irrigation at 3 days interval during 2005-2006 and 2006-2007. In the second year, the highest marketable yield of summer tomato (30.98 t ha^{-1}) was obtained from the fertigation treatment with fertilizer doses N:75 P:95 K:35 kg ha^{-1} irrigated at 3 days interval and in the first year, the highest marketable yield of summer tomato (32.42 t ha^{-1}) was also obtained from the same treatment. The lowest yield 19.12 t ha^{-1} and 14.28 t ha^{-1} were observed from the treatment with recommended fertilizer doses N:250 P:95 K:125 kg ha^{-1} irrigated at 2 days interval in the first and second year respectively.

Kavitha *et al.* (2007) carried out an experiment at Department of Vegetable Crops, Tamil Nadu Agriculture University, Coimbatore to elucidate the effect of shade and fertigation on yield and quality of tomato. The results revealed that, application of 100 % water soluble fertilizer under shade improved the growth parameters viz., plant height, primary branches $plant^{-1}$, leaf area index and dry matter production as well as yield contributing characters like number of fruits $plant^{-1}$ and fruit weight $plant^{-1}$ over the 75 and 50 % RDF. The highest fruit yield (99.8, 109.5 and 106.7 t ha^{-1}) during seasons I, II and III respectively were noticed under 100 % RDF as compared to 75 and 50 % RDF.

Kavitha *et al.* (2007) reported that the lycopene content improved with the application of 100 % water soluble fertilizer under shade. Contrastingly, Yan-feng *et al.* (2006-07) found that fertigation strategies and frequencies had an insignificant effect on the quality of tomato.

Badr and Abou *et al.* (2007) observed that drip irrigation provides an efficient method of fertilizer delivery and allows precise timing and uniform distribution of applied nutrients. Fertilizer application through drip irrigation (fertigation) can reduce fertilizer usage and minimize groundwater pollution due to fertilizer leaching from excessive irrigation. Fertigation events can be scheduled as often as irrigation, up to several times per season. Optimum fertigation interval for drip-irrigated crops in general

and for tomato in particular, is meager. A two-year field experiment was conducted on a sandy soil with subsurface drip-irrigated tomato to determine the effects of two N application rates and four-fertigation frequencies (intervals of 1, 3, 7, and 14 days) on tomato yield, N uptake and soil N status. Total tomato yield and yield components were responsive to N rate and to decreased fertigation frequency. The highest total fruit yields averaged (67.75, 65.13 and 63.29 t ha^{-1}) with the frequencies of 1, 3 and 7 days respectively.

Kavitha *et al.* (2007) reported that the effect of shade and fertigation on yield and quality of tomato using the hybrid 'Ruchi' under open and shade (35 %) as main plot and three levels of (50, 75 and 100 % RDF) each of water soluble and straight fertilizers as sub-plot treatments. The results revealed that the application of 100per cent water soluble fertilizer under shade improved the growth parameters namely plant height, primary braches per plant, leaf area index and dry matter production at different stages of growth. The nitrate reductase activate was higher at flowering stage, which declined towards maturity. Early flowering was noticed with the application of 100 per cent water soluble fertilizer under open condition, whereas number of flowers per cluster, flowers per plant was the highest at 100 per cent water soluble fertilizer under shade. The yield parameters like number of fruits per plant and fruit weight were the highest at 100 per cent water soluble fertilizer under shade. The highest yield per hectare (99.8, 109.5 and 106.7 tonnes) during seasons I, II and III respectively were observed in the treatment with 100 per cent water soluble fertilizer under shade condition. The fruit quality parameters viz., fruit firmness, ascorbic acid, lycopene and carotene were improved with the application of 100 per cent water soluble fertilizer under shade.

Shaymaa *et al.* (2009) reported that total fruit yield was significantly higher in 75 and 100 % NPK fertigation (54.16 and 58.76 t/ha) respectively than 50 % fertigation rate, which accounted to 12 and 22 per cent yield increase, respectively. However, the soil of the experimental site was very low in available NPK besides; the high relative yield potential of tomato variety (Castel rock) was expected to respond well at higher fertigation rate. Because of these reasons, the yield was significantly lower with 50 and 75 per cent fertigation than 100 per cent fertigation rate. Increase in fruit yield per plant could be related to significantly higher number of fruits per plant in drip irrigation (14.5) over furrow irrigation period (12.4) and in 100 % NPK fertigation (16.8) over drip

irrigation period. Mean fruit weight and fruit yield per plant was also significantly higher in 100 % fertigation rate (117 g and 1.84 kg/plant) compared to control (86 g and 1.07 kg/plant) and drip irrigation (103 g and 1.37 kg/plant respectively). Fertigation rate with 100 % NPK water soluble fertilizers also resulted in increased late season extra large and large fruit yields compared to yield response with soil applied NPK.

Yasser *et al.* (2009) carried out an experiment at Ain Shams University, EL- Bustan Region, Beheira to study the impact of fertigation scheduling on tomato yield under arid ecosystem and revealed that, maximum tomato yield and vegetative growth were observed under 100 % fertigation level than 75 and 50 per cent fertigation level.

Soumya *et al. (*2009) conducted a field experiment to study the effect of fertigation with different sources and levels of fertilizer on growth and yield of tomato. The experiment consisted of 12 treatments viz. four sources (Urea, SSP, MOP; MAP, MOP; MAP, KNO_3; Soil application of Urea, SSP, MOP) and three levels of NPK (75, 100 and 125 % Rec. NPK). Significantly higher number of leaves plant-1 was recorded with the application of Mono Ammonium Phosphate (MAP) and Potassium Nitrate (KNO_3) at 125 per cent of recommended (Rec.) NPK through drip irrigation (58.6) at 60 days after transplanting (DAT). Significantly higher leaf area was recorded with the application of MAP, at 100 per cent Rec. NPK (98.1 dm^2 $plant^{-1}$) at 60 DAT through drip irrigation. Significantly lower total dry matter was recorded in soil application of Urea, SSP and MOP at 75 per cent Rec. NPK (130.43 g $plant^{-1}$) at 60 DAT. Significantly higher marketable fruit yield was recorded with the application of MAP, KNO_3 at 100 per cent Rec. NPK (94.50 t ha^{-1}) with the higher water use efficiency of 143.11 kg $ha.mm^{-1}$.
Sanchita *et al.* (2010) found that the total soluble solids of tomato were highest in 100 per cent fertigation level, whereas the highest titrable acidity was recorded by 50 per cent fertigation level.

Imamsaheb *et al.* (2011) conducted an field experiment at New Orchard of Main Agriculture Research Station, Raichur, Karnataka, to study the effect of different levels of fertigation (50, 75, 100 % recommended NPK) on productivity and nutrients uptake in processing tomato genotypes. Fertigation with 100 % RDF NPK recorded significantly higher number of flowers $cluster^{-1}$ (6.30), number of fruits $cluster^{-1}$ (4.82), per cent fruit set (78.24), number of fruits $plant^{-1}$ (40.71), average fruit weight (60.89 g),

yield plant^{-1} (2.36 kg), yield plot^{-1} (53.65 kg) and yield ha^{-1} (56.98 t ha^{-1}) as compared to 75 and 50 per cent fertigation levels

Jagadeeshkanth and Sankaranarayanan (2014) reported that précised application of fertilizers through fertigation had significant influence of growth and yield traits. Fertigation of curry leaf with 100 % RDF significantly increased the plant height, number of primary branches, number of secondary branches, number of leaflets per leaf and green leaf yield per plant. Application of 100 % RDF through fertigation (T_6) recorded highest number of leaflets per leaf at 1st cutting stage (18.25), 2nd cutting stage (20.56) and 3rd cutting stage (21.43) and green leaf yield per plant at 1st cutting stage (424.80 g), 2nd cutting stage (580.40 g) and 3rd cutting stage (797.84 g). It was followed by 25 % of N, P, K as soil application + 75 % of fertigation (T_5) which recorded 17.34, 20.06 and 21.26 number of leaflets per leaf and 397.50 g, 520.84 g and 745.64 g of green leaf yield per plant at 1st, 2nd and 3rd cutting stages. Whereas the lowest number of leaflets per leaf was recorded the treatment (T_1) without fertilizer application (15.4, 17.76 and 19.36) and green leaf yield per plant (246.10 g, 360.25 g and 592.40 g) at all the three cutting stages. 100 % of fertigation shows highest green leaf yield per plant might be due to higher plant height, higher number of primary branches, secondary branches and leaflets per leaf which make the plants vegetative vigorous thus results in higher yield. Recommended dose of fertilizers applied through fertigation resulted in higher availability of nutrients in soil solution which obviously led to increased growth, ultimately increased the yield.

Vasanthi *et al.* (2017) carried out front line demonstration on farmer's field of Doddaballapur Taluk, Bengaluru Rural district, Karnataka, India to study the fertigation levels and schedules on growth, yield and economics of tomato. The treatments included 3 fertigation levels (T_1 – 60 % of recommended dose of fertilizer (RDF), T_2 – 80 % of RDF and T_3 – 100 % of RDF) with 3 fertigation schedules (T_1 - farmers practice 30 equal splits of RDF at every 3 days interval, T_2 - IIHR practice 37 equal splits of RDF at every 3 days interval and T_3 - TNAU practice 40 equal splits of RDF at every 3 days interval). The results indicated that fertigation of 100 per cent RD of NPK in 40 equal splits at every 3 days interval upto 120 days after transplanting was found significantly superior in case of growth (plant height 138.83 cm), yield attributes (number of fruits per plant 100.83) and fruit yield (71.89 t ha^{-1}) of tomato. The economic

benefits of drip irrigation resulted in maximum gross returns (₹ 3,59,450 ha^{-1}) and B: C of 2.84 in T_3 treatment.

Selvaperumal and Muthuchamy (2017) studied that the effect of drip fertigation and plastic mulching on the plant growth and yield attributes of chilli (*Capsicum annuum* L). The three fertigation levels 80, 100, and 120 per cent recommended dose of fertilizers (RDF) and three different mulching treatments 25, 50 micron black plastic mulch (BPM) and no mulch which were replicated thrice. In chilli, maximum yield of 128 numbers of fruits $plant^{-1}$ which is worked out as 12.27 t ha^{-1} was observed for the treatments T_3. The total quantity of water applied uniformly to all the treatments was 75.83 liters as per the crop water requirement. Maximum water use efficiency observed in T_3 (66.36 kg $ha^{-1}mm^{-1}$). The maximum N, P and K fertilizer use efficiency of 109.95, 164.94 and 164.94 kg ha^{-1} respectively, were observed in T_1. The highest benefit cost ratio was recorded under both T_2 (BPM of 25 micron thickness with 100 per cent RDF) and T_3 (BPM of 25 micron thickness with 120 % RDF). From economic viability point the T_2 treatment registered results that were economically viable with highest profit. Increased yield in fertigation treatments might be due to better availability of plant nutrients and irrigation water throughout the crop growth period under drip fertigation system.

Abdelraouf and Ragab (2018) assessed the impact of fertigation frequency and fertigation time on wheat production. The field experiment included nine treatments over two seasons, 2014/2015 and 2015/2016. The same amount of water and nitrogen fertilizer was given for all treatments, either over 1 day, divided over 2 days or over 3 days. Three fertigation times (FT, period of injecting fertilizers in irrigation water) as a fraction of the irrigation period were also applied. In FT strategies, nitrogen is given either during the same period of the irrigation from the start to the end, at the last three-quarters of the irrigation period or at the second half of the irrigation period, IT [FT = IT, FT = 0.75IT and FT = 0.5IT]. The observed and simulated nitrogen uptake and grain nitrogen content showed an increasing trend when fertigation frequencies increased and fertigation time decreased. The field and modelling results indicated that increasing fertigation frequencies and decreasing fertigation time have benefits particularly for sandy soils, including higher yields and less pollution. In conclusion, the use of the

fertigation frequency of 3 days and fertilizer injection in the second half of the irrigation period is a good fertigation strategy for sandy soils.

Thanari and Suma (2018) conducted the experiment comprising of six treatments that is T_1 : 100 % soil application, T_2 : 50 % soil application + 50 % fertigation (Schedule 1), T_3 : 50 % soil application + 50 % fertigation (Schedule 2), T_4 : 25 % soil application + 75 % fertigation (Schedule 1), T_5 : 25 % soil application + 75 % fertigation (Schedule 2), T6: 100 % fertigation. Following two different nutrient application schedule. In schedule-1 nutrient application rate and time was retained closer to recommendation that is per cent RD N: P_2O_5 : K_2O as 20:20:20 as basal, 50:50:50 at active growth stage and 30:30:30 at rest period. But in schedule-2 per cent rate at basal and rest application was reduced to 5:15:15 and 20:10:10 per cent RD N: P_2O_5 : K_2O respectively. High nutrient rate (75:75:75 % RD N: P_2O_5 : K_2O) was applied during active growth stage. The highest marketable fruit yield of 18.49 kg plant^{-1} and 9.12 t ha^{-1} was recorded in T_5 (25 % SA + 75 % F with schedule-2) that was on par with T6 (100 % F) recording 16.89 kg plant^{-1} and 8.31 t ha^{-1} fruit yield. Application of 100 per cent soil application recorded the lowest fruit yield 11.36 kg plant^{-1} and 5.60 t ha^{-1}. Partial supplementation of major nutrients through fertigation enhanced the fruit yield recording 14.98 kg plant^{-1}, 13.46 kg plant^{-1} and 12.06 kg plant^{-1} in T_3, T_4 and T_2, respectively. This could be attributed to slower vegetative growth during bahar initiation and profuse flowering at later stages, higher number of hermaphrodite flowers, higher number of fruits and fruit weight in these treatments. Keeping lower dose of basal application of major nutrients (5:15:15 % RD N: P_2O_5: K_2O) and applying relatively higher quantity (75:75:75 % RD N: P_2O_5: K_2O) during active growth stages with higher number of split application has resulted in maximum of high amount of nutrient availability at critical growth stages. All these factors might have contributed to higher fruit production in these treatments compared other treatments.

Ghiyal and Bhatia (2018) stated that the differential drip fertigation treatments were started 20 days after planting. The crop was subjected to four levels of nitrogen i.e. N_1 : 90 kg/ha, N_2 : 120 kg/ha, N_3 : 150 kg/ha and N_4 : 180 kg/ha. Each nitrogen level was coupled with three fertigation frequencies *viz.,* every 3rd day in 30 split doses (F_1), every 6th day in 12 split doses (F_2) and every 9th day in 8 split doses (F_3). Hence, twelve treatment combinations were used for conducting present study. The

irrigation period was applied at every 3rd day though drip. The total tuber yield (q/ha) was significantly influenced by fertigation frequency and nitrogen levels. It is evident from the results that the maximum average total tuber yield (296.50 q/ha) was obtained with F_1 followed by F_2 and minimum (268.00 q/ha) with F_3. The maximum average total tuber yield (292.33 q/ha) was observed with N_2, while minimum yield (264.69 q/ha) was recorded in N4 (nitrogen 180 kg/ha). The tuber yield also varied significantly due to the interaction of fertigation frequency and nitrogen levels. Interaction effect revealed maximum (307.78 q/ha) total tuber yield with F1N2 followed by F1N3 (299.06 q/ha) while F3N4 recorded lower (252.80 q/ha) total tuber yield.

Wabela (2018) studied that the effect of split application of nitrogen fertilizer at various growth stages of tomato under furrow irrigation period. The yield of treatment that was applied 50 % of urea at transplanting time and 50 % at development period higher than all other treatments. The next higher yield was obtained at treatment of 25 % of urea at transplanting time and 75 % at development period. Applications of 100 % of nitrogen (urea) fertilizer at transplanting time or at development period attained lower yield than all split applied treatments. This might be due to leaching out of nitrogen required by the crop by irrigation water before critical nutrient required stage of the crop and initial requirement for vegetative growth initiator. Tomato requires enough amount of urea at transplanting time and later at development period to develop high yield.

Jena and Aladakatti (2018) studied that the effect of different fertigation levels with conventional and water soluble fertilizers on growth and yield of Bt cotton. The result indicated that the different fertigation levels with conventional and water soluble fertilizers had marked and favourable influence on growth and yield parameters *viz*., number of sympodia plant^{-1}, dry matter production, number of bolls plant^{-1}, seed cotton yield plant^{-1}. These favourable influences on these parameters were reflected on seed cotton yield (SCY) due to various treatments. PR sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through CF applied in six equal splits (T_9) favourably increased the yield attributes *viz.,* number of bolls plant^{-1} and seed cotton yield plant^{-1} (54.40 and 275.20 g, respectively), than other lower levels of fertigation. However, it was on par with PR sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through WSF and 25 per cent RDF through CF applied in six equal split *i.e.* T_5 (50.07 and 251.43 g, respectively) and PR sowing with fertigation of 25 per cent RDF

(37.5:19:19 kg ha^{-1}) through WSF and 25 per cent RDF through CF applied in six equal splits *i.e.* T_6 (48.13 and 243.27 g, respectively). Mean boll weight was found non-significant among the treatments. Higher number of bolls $plant^{-1}$ and seed cotton yield $plant^{-1}$ with higher levels of fertigation than lower levels was due cumulative effect of various growth attributes *viz.* number of sympodia $plant^{-1}$, functional leaves.

Snehitha *et al.* (2019) noted that drip irrigation period is an irrigation period method that saves water and provides the most economical method of applying fertilizer by utilizing fertilizer injectors that operate without any external power supply. Fertigation use soluble fertilizers that flow directly towards the plant root zone through the drip system, drip emitters or micro sprinkler system. A liquid fertilizer solution or soluble fertilizer is injected into the system at the desired rate. Proper application of fertilizers through different source play a vital role enhancing vegetative growth and quality flower production. Different doses of water soluble fertilizers were given through drip with following treatments viz., T_1 - Control (no fertilizers), T_2 - 100 % RDF (Recommended Dose of Fertilizers) through conventional (Urea, SSP, MOP) fertilizers, T_3 – 100 % Nitrogen through drip, T_4, T_5 and T_6 – 100, 75 and 50 per cent RDF through water soluble fertilizers. The yield attributes like number of flower buds, number of flowers, flower surface area, fresh weight of flowers, no of pickings, no of flowers per kilogram and flower yield per plot were studied. The average number of branches, flower buds and maximum flower sizes were highest in T_4 – 100 % RDF and lowest was observed in T_1 – Control (no fertilizers). The highest yield was recorded in T_4 followed by T_5, T_3, T_2, T_6, and T_1. The highest flower yield was recorded with the nutrient level of 100 % RDF through water soluble fertilizers (T_4). The next best flower yield recorded in75 % RDF through water soluble fertilizers (T_5), 100 % water nitrogen through drip P, K soil application (T_3), with significant disparity between them. Higher level of biomass accrual and efficient translocation of photosynthates to the reproductive parts due to supply of adequate nutrient levels might be responsible for the production of elevated level of yield structure.

Tanari *et al.* (2019) observed the highest marketable fruit yield of 18.49 kg $plant^{-1}$ was recorded in T_5 (25 % SA+ 75 % F with schedule-2) that was on par with T_6 (100 % F- 16.89 kg $plant^{-1}$). The treatment receiving 100 % soil application of primary nutrients recorded the lowest fruit yield 11.36 kg $plant^{-1}$. Further, partial supplementation

of major nutrients through fertigation enhanced the fruit yield recording 14.98 kg plant^{-1}, 13.46 kg plant^{-1} and 12.06 kg plant^{-1} in T_3, T_4 and T_2 respectively. This could be attributed to slower vegetative growth during bahar initiation followed by higher number of hermaphrodite flowers, higher number of fruits and fruit weight in these treatments. Keeping lower dose of basal application of major nutrients (5:15:15 % RD N: P_2O_5 : K_2O) and applying relatively higher quantity (75:75:75 % RD N: P_2O_5: K_2O) during active growth stages with higher number of split application has resulted in high amount of nutrient availability at critical growth stages.

Mohammadullah Nikzad *et al.* (2020) stated that the effect of fertigation levels on growth and yield of Cabbage. Fertigation of 100 % RDF (150:100:125 kg NPK ha^{-1}) in 12 equal splits at 5 days intervals registered significantly higher cabbage yield per plot (33.00 kg) and yield per hectare (43.22 t ha^{-1}) than rest of the fertigation levels. However, minimum yield per hectare was recorded in T_7 (control). He noted that yield as a complex character involves the interaction of several intrinsic and external factors. It largely depends upon the production and mobilization of carbohydrates, uptake of water and nutrients from the soil, in addition to several environmental factors to which plants is exposed during the growing period. At higher dose of fertigation level, crop might meet out its nutritional requirement at respective growth stages leads to luxurious growth resulted in more interception of light and more translocation of photosynthates from source (vegetative part) to sink (reproductive part) which enhanced the yield.

2.2.2 Nutrient availability, uptake

Bacon and Davey (1982) studied nutrient availability under trickle irrigation with phosphate fertilization. They found that the placement of superphosphate (9 % P, 12 % S, 20 % Ca) at the trickle outlet increased phosphate availability to at least 22 cm depth and the volume of soil containing more readily available phosphate increased with increasing application rate.

Singandhupe *et al.* (2003) reported that nitrogen uptake was significantly influenced by the irrigation schedule during first year. Due to frequent application of irrigation and fertilizer in drip, irrigation, nitrogen was effectively utilized, as there was direct contact with the root system with negligible N loss through leaching, as applied irrigation water did not move beyond 30 cm soil depth. But in furrow irrigation period, since nitrogen was applied only in two equal splits, effective utilization was reduced

particularly during the drying cycle as soil moisture was depleted with time. Hence, total N uptake of plants in furrow irrigation was reduced by 10 % during 1995 as compared to the drip method.

Hebbar *et al.* (2003) WSF fertigation had significantly higher N, P and K uptake over drip irrigation and control. Uptake of nitrogen in subsurface drip fertigation, NK fertigation and 1/2 soil–1/2 fertigation remained close to WSF fertigation. Similar trend in the uptake of P and K was noticed. The higher uptake was the result of significantly higher dry matter production at 120 DAT. Secondly, there was no dilution of NPK as dry matter production per plant increased in different plant parts and concentration of the nutrients in plant parts also followed the trend of total uptake. Also, fertilizer application through fertigation had an impact on the K concentrations in stem, leaves and fruit). This increase in uptake per plant was due to the better availability of nutrients in root zone as a result of frequent application of nutrients coupled with better root activity. Further, it was also due to the reduced loss of nutrients primarily because of leaching in fertigation compared to soil application of fertilizer. Similar observations of increased uptake as a result of fertigation have been reported earlier by Vasane *et al.* (1996).

El-Yazied *et al.* (2007) reported that total N uptake was appreciably higher with increasing N rate and with more frequent than with less frequent fertigation in tomato.

Shaymaa *et al.* (2009) reported that the higher uptake of NPK was the result of significantly higher dry matter production at 90 days after transplanting. In addition, it seems that the availability of nutrients evenly with frequent fertigation was responsible for the improvement of nutrient uptake and recovery in the root zone coupled with reduced loss of nutrients primarily because of less leaching under higher fertigation rates.

Shedeed *et al.* (2009) reported that phosphate transport in soil applied treatments was too slow for the average rate of root growth into the soil, since P fertilizers are prone to fixation at the point of application. Most of the applied P may be turned to non-soluble form in a short time after its application, and the observed concentrations build up in the upper soil layer could affect root growth and create unfavorable conditions for P uptake. The accumulation of available P at 25-50 cm was

tended to be higher in fertigation treatments (8- 15 mg kg^{-1} soil) because of frequency of fertigation and complete solubility of phosphoric acid compared to soil application in furrow and drip irrigation (3 mg kg^{-1} soil) reported K leaching losses when soil applied in furrow and drip irrigated tomato compared to K fertigation. They found that fertigation with water soluble fertilizers registered higher available K concentration (194-272 kg/soil) than furrow or drip irrigation. In sandy soil with low CEC and K fixation, potassium ions move along with water and thus, it will be prudent to apply K fertilizers through drip irrigation in more splits to achieve maximum nutrient use efficiency. Frequent supplementation of nutrients with irrigation water increased the availability of N, P and K in the root zone and which in turn influenced the yield and quality of tomato.

Al-Mohammadi and Alzubi (2011) carried out an experiment in greenhouse during winter season at Experimental Station, Al-Balqa University, Jordan to evaluate irrigation and fertigation levels on yield and quality of tomato crop. The results indicated that content of nitrogen, phosphorus and potassium in tomato leaf significantly increased with increase in levels of fertilizers and quantity of water.

Imamsaheb *et al.* (2011) showed that higher uptake of nitrogen, phosphorus and potassium by tomato plant was recorded with 100 % recommended NPK as compared with 75 and 50 % recommended NPK.

Kakade *et al.* (2017) showed that the different fertigation levels and soil application method had significant influence on nutrients (N, P and K) uptake by plant. The nutrient uptake was favourably increased with higher level of fertigation compared with lower levels and soil application method. Higher uptake of N, P and K were observed at 125 per cent levels of N and K fertigation. Progressive increase in applied level of N and K correspondingly increased the nutrient uptake and lower uptake was noticed at lower level of fertigation (50 %). However, drip fertigation at 75 per cent RDNK ha^{-1} and soil application method (T1) were comparable in respect of N, P and K uptake. The concentration and availability of various nutrients in the soil for plant uptake depends on soil solution phase which is mainly determined by soil moisture availability. The higher available soil moisture provided due to continuous water supply at alternate days under drip irrigation led to higher availability of nutrients in the soil and thereby increased the nutrient uptake under drip fertigation levels in splits was the result of

increased biomass production due to continuous availability of water and nutrients to the crop.

Ahmet Demirbas (2017) reported the greatest yield for 75 % fertigation treatment (75:13.5:87.7 g N, P, K year^{-1}) with a yield of 37.21 t ha^{-1}. The 0 % fertigation dose (conventional fertilizer application) with a yield of 44.29 t ha-1 had higher yield than 25 and 50 % fertigation treatments and the differences from 75 % fertigation treatment were not Significant Considering the effects of treatments on N contents of watermelon plants, it was observed that 75 % fertigation doses had the greatest N content with 3.78 per cent. The 0 % fertigation doses (conventional method) had the lowest N content with 3.43 per cent. As compared to 0 % fertigation dose, other treatments increased N contents of plants more. Similar to N contents, 75 % fertigation treatments had the greatest P content with 0.31 per cent and 0 % fertigation treatment had the least P content with 0.25 per cent. Such a case may be resulted from direct application of plant nutrients, especially hard-to-transport phosphorus to soil through fertigation. Again as it was in N and P contents, all fertigation treatments, except for 0 %, increased plant K contents.

Kakade *et al.* (2017) reported that the higher uptake of N, P and K were observed at 125 per cent levels of N and K fertigation. Progressive increase in applied level of N and K correspondingly increased the nutrient uptake and lower uptake was noticed at lower level of fertigation (50 %) at all the stages. The five treatments having four different levels of drip fertigation in five splits at 50, 75, 100 and 125 per cent of recommended dose of N and K of fertilizers given through fertigation and P as basal compared with 100 per cent soil application of fertilizers. The recommended dose of fertilizers (N&K) was applied as per the treatments through fertigation tank of 90 lit. capacity. Phosphorus (50 Kgha^{-1}) was applied as basal and N and K as urea and murate of potash respectively through drip irrigation in five splits as per the treatments and growth stages of cotton (10 % at basal, 20 % at 20 DAS, 25 % at 40 DAS, 25 % at 60 DAS and 20 % at 80 DAS.) In conventional soil application method, half nitrogen and full dose of P and K were applied as basal at sowing and remaining half dose of N was top dressed at 30 DAS and 60 DAS. Drip fertigation at higher level of 125 per cent fertigation recorded an increased yield of 25.55 per cent and 24.26 per cent over conventional soil application during the year 2011-12 and 2012-13, respectively. Increased nutrient availability and

absorption by the crop at the optimum moisture supply coupled with frequent and higher nutrient supply by fertigation and consequent better formation and translocation of assimilates from source to sink might have increased seed cotton yield under fertigation. Fertilizer application of 100 per cent N and K through drip increased yield significantly over 100 per cent NPK through soil.

Pawar *et al.* (2018) reported significantly higher uptake of nutrients (NPK) as influenced significantly due to different treatments. The significantly maximum total NPK uptake was observed in 100 % fertigation with three foliar sprays (127.3, 30.1 and 121.0 kg ha^{-1} NPK uptake, respectively) at harvest over surface irrigation with conventional fertilizer. However, it was at par with T_1 (100 % fertigation). The fertigation resulted into more concentration of readily available nutrients in soil and optimum availability of water in soil increased nutrient uptake.

Pawar *et al.* (2018) reported that the maximum nutrient availability in soil was observed in treatment T_2 that is 100 % fertigation with three foliar sprays (164.0: 21.7 and 613.7 kg ha^{-1} NPK, respectively). However, it was at par with T_1 (100 % fertigation). The sources of fertilizer also resulted into moderate change in NPK availability in the root zone soil of wheat. The water soluble fertilizers resulted into more availability of NPK in soil as compared to conventional fertilizers. As more quantum of water was available just beneath the dripper, the corresponding increase in nutrient availability was observed in drip as compared to conventional water application method.

2.2.3 Nutrient mobility

Zende and Kalbhor (1958) observed that deeper application of different fertilizers at 4 inch depth, the movement of nitrate ions in lateral and vertically downward direction was influenced by factors like concentration of NH_3 and nitrifying capacity of soil.

Datta and Khera (1969) revealed that the mobility of P in alkali soil is presumed to be governed by the cationic bonding energy of sodium ion.

Sen and Gupta (1969) reported that the, organic matter production in soil decreased P mobility with increase in SAR.

Rauschkolb *et al.* (1976) reported that inorganic P is precipitated and strongly adsorbed in most soils and if applied uniformly on the soil surface at usual fertilization rates, P will not normally move more than 20 or 30 mm with the irrigation

period water. Thus, if the fertilizer is not mechanically worked deeply into the soil, most of it will remain near the soil surface, where availability will be limited to plant roots. The problem of P immobility in soil can be greatly alleviated by banding fertilizer below the seed at planting time. If an adequate amount of P is placed in the plant root zone, the plant generally can obtain the P placed in the plant root zone. The plant generally can obtain the P, if needed, although even banded P fertilizer is often used inefficiently by the plants. Orthophosphate movement is much greater when applied through a trickle irrigation period system than other application methods.

Anonymous (1977) reported that the K moved in the soil by diffusion dependent upon the soil moisture and soil solution concentration, a light soil showed a better K saturation in soil solution at equal moisture status and exchangeable K content, consequently diffusion proceeded faster in light soil than heavy soil.

Goode *et al.* (1978) reported that the movement of K in the soil dependent upon CEC of soil and rate of fertilizer application. Potassium distribution in the soil was more uniform with slightly higher concentration from upper soil layer and near to wetting front.

Hawkes *et al.* (1980) found that the $NH^{+}4$ was fixed on the soil complex, while NO_3^- -N moved with water along the wetting front and NH_4^+ has strong diffusion gradient to move downward to oxidized soil layer where it is nitrified to NO_2 – N and NO^-_3-N, oxidized species has tendency to move downward to anaerobic soil layer serving at least partly as a substrate for denitrification, after irrigation period water moves it was not strongly absorbed by the soil and moved deeper below emitter than ammonium salt.

Kafkafi and Bar-Yosef (1980) found that K distribution in the soil was more uniform with slightly higher concentration into the upper layer and near to the wetting front.

Rolston *et al.* (1986) reported that urea is the best source for fertilizing tomato through trickle irrigation and it was mainly due to its relatively high solubility (78 %) (Hawkes *et al.*, 1980) in irrigation water. Secondly, it was not strongly adsorbed by soil and so it will move deeper below the emitter than the ammonium volatilization loss. The ammonical N is fixed on the soil complex while NO^-_3- N will move with the water along the wetting front, NO^-_3- N has a strong diffusion gradient to move upward to the oxidized soil layer, where it is nitrified to NO^-_3- N. This oxidized N species have a

tendency to move downward to the anaerobic soil layer serving at least partly as a substrate for denitrification.

Bafna (1987) conducted a field experiment on summer tomato crop (hybrid cv. Rupali) grown on vertisol and showed that drip irrigation improved the recovery of applied N. The lateral movement of applied N was more under drip than surface irrigation and the applied N tended to move towards the point of water application (dripper).

Mikkelson and Jorvell, (1987) reported application of urea phosphate and urea sulphate to a drip irrigated tomatoes, P from urea phosphate moved in the soil proportional to the rate of application.

Bhargava *et al.* (1992) observed that added potassium was more concentrated in the surface soil and it moves horizontal at a distance of 20 to 40 cm from plant and also reported that upward translocation of K from lower depth was due to rise in capillary forces of ground water, where as movement of K (water soluble and exchangeable) to greater soil depth was more under irrigated than under unirrigated conditions

Santos *et al.* (1997) pointed out that NO_3^--N fate and transport is strongly dependent on the soil water content and its movement. Mass flow is the major factor responsible for NO_3^--N movement in the soil and it can diffuse fast enough with adjacent moving water to deeper soil layers.

Bangar *et al.* (1998) while, studying the effect of water soluble fertilizers applied through drip in Inceptisols of Rahuri on the nutrient mobility reported that available N was moved upto 15 cm laterally and upto 30 cm vertically along the wetting front with application of liquid fertilizers through drip, nitrogen mobility and availability in soil was higher than P and K (Bangar and Chaudhary, 2000) and nutrient mobility of P was moved upto 5 cm laterally and upto 10 cm vertically along the wetting front and nutrient mobility of K was moved upto 15 cm laterally and 15-30 cm vertically along the wetting front.

Li *et al.* (2003) who found that NO_3^--N ion is very mobile in the soil and fertigation treatments maintained high concentration of NO_3^--N at shallow depth.

Hebbar *et al.* (2003) observed lower NO^-_3- N at 30-45 cm soil layer in fertigation treatments such as WSF fertigation (55 kg ha^{-1}), NF fertigation (54 kg ha^{-1})

and NK fertigation (53 kg ha^{-1}) compared to entirely soil applied treatments such as control (65 kg ha^{-1}) and drip irrigation period (66 kg ha^{-1}). Similar trend of NO^{-}_{3}- N distribution was recorded in 45-60 cm layer, which was due to higher amount of leaching fraction of fertilizer applied. Alva and Mozzafari (1995) also reported that fertigation treatments maintained high concentration of NO^{-}_{3}- N at shallow depth than deeper layer.

Hebbar *et al.* (2003) reported P distribution in soil at all layers at a higher levels (>24.2 kg ha^{-1}) except at a deeper depth of 45–60 cm). The accumulation of assimilable P at 0–15 and 15–30 cm was significantly higher in WSF fertigation (111.4 kg ha^{-1}) because of complete solubility of mono ammonium phosphate and frequent and small application rates compared to soil application (92.8 kg ha^{-1}), drip irrigation (95.2 kg ha^{-1}) and NK fertigation (97.3 kg ha^{-1}). The level of assimilable P was significantly higher in 15–30 cm (62.0 kg ha^{-1}), 30-45 cm (35.6 kg ha^{-1}) and 45–60 cm (22.4 kg ha^{-1}) depths in subsurface drip irrigation compared to other treatment because P fertilizer was delivered 20 cm below the surface by means of buried laterals. P fertilizers are more prone to fixation at the point of application. Since the point of application was deeper by 20 cm, more concentration of P was observed at deeper depths.

Hebbar *et al.* (2003) found exchangeable K accumulation was higher at deeper layers (45–60 cm) in furrow (92.9 kg ha^{-1}) and drip irrigation period (95.4 kg ha^{-1}) where entire K fertilizers was one time soil applied, indicating potential leaching risk. The leaching aspect under one time soil application followed by irrigation period can be related to the study of Papadopoulos (1988).

Sathya *et al.* (2008) reported that the right combination of water and nutrients is the key for increasing the yield and quality of produce. The availability of N, P and K nutrient was found to be higher in root zone area of drip fertigated plot. Nitrogen and potassium moved laterally from point source up to 15 cm and vertically up to 15-25 cm and P moved 5 cm both laterally and vertically and thereafter dwindled. Fertigation frequency enables to reduce the concentration of immobile elements such as P, K and trace elements in irrigation period water. Fertigation of nutrients significantly increased saving of fertilizer nutrients up to 40 per cent without affecting the yield of crops compared to the conventional method of nutrient application.

Badr *et al.* (2010) conducted experiment to evaluate the effect of sources and methods of fertilizer application on nutrient distribution, uptake, recovery and fruit

yield of tomato grown in a sandy soil. Equal amounts of NPK were applied in solid form or through fertigation at levels of 0, 50, 75 and 100 per cent with the remainder 100, 50 and 25 per cent applied as solid fertilizers to the soil. Available NO^-_3- N and K were confined to the root zone of tomato in 75 and 100 per cent NPK fertigation levels, while they moved beyond the root zone when they applied in two equal splits as solid fertilizers with drip (0 % fertigation) and furrow irrigation. The mobility of P was greater in the root zone following its application through fertigation compared to a solid application as super phosphate. Drip irrigation showed significantly higher absolute growth rate, total dry weight and leaf area index of tomato over furrow irrigation. Moreover, tomato plants were able to utilize applied nutrients more efficiently in fertigation system than with conventional solid fertilizer application. Highest absolute growth rate, total dry weight and leaf area index were recorded when nutrients were applied to 100 % by drip fertigation. The fruit yield of tomato was higher with drip irrigation (58.62 t ha^{-1}) than with furrow irrigation, (47.37 t ha^{-1}). Maximum fruit yield was recorded with 100 % NPK fertigation (74.87 t ha^{-1}) and was associated with a higher number of fruits per plant and a bigger fruit size than the solid applied fertilizers under both drip and furrow irrigation period. On average, tomato accumulated more NPK across the fertigation levels than with drip and furrow irrigation. Similarly, the more controlled application of nutrients in fertigation treatments improved NPK recovery and fertilizer use efficiency (FUE) and resulted in lesser leaching of NO^-_3- N and K to deeper soil layers.

Fanish and Muthukrishnan (2013) concluded that drip fertigation provides an efficient method of fertilizer delivery and if properly managed and can reduce overall fertilizer application rates and minimizes the adverse environmental impact on crop production. The availability of nutrients at root zone of the crops influences the uptake and yield of the crop. The nitrogen availability steadily increased with increased depth upto 30 cm after that declined in all the distances. The highest available phosphorus in soil was confined to 0-15 cm of soil layer under all fertigation levels. The available phosphorous decreased with increase in distance and soil depth. With regards to potassium, soil K content was significantly higher in the surface soil than in the subsoil, this might be due to majority of applied K was held in the surface soil and the downward movement was slow. Among the different treatments, drip fertigation with 100 % RDF in which 50 % P and K as WSF increased the maize grain yield to the tune of 15.5 per cent

as compared to drip fertigation of 100 % RDF with normal fertilizer. The increase in yield under 100 % RDF with P and K as WSF might be due to the fact that fertigation with more readily available form obviously resulted in higher availability of all the three (NPK) major nutrients in the soil solution which led to higher uptake and better translocation of assimilates from source to sink thus in turn increased the yield.

Patel *et al.* (2015) was observed NO^-_3- N in all four-fertigation frequencies i.e. VA, VW, VF and VM. In the treatment VD, NO^-_3- N concentration first increased in 0-15 cm soil depth from 50.1 to 86.37 mg kg^{-1} of soil (ppm) (initial and developmental stage) then starts decreasing from 86.37 to 41.13 ppm. NO^-_3- N concentration in 0-15 cm soil depth was found more than in 30, 45 and 60 cm soil depth at initial and developmental stage. The soil samples were collected to determine the initial NO^-_3- N status of the field. Initially, the maximum NO^-_3- N concentration 28.6 ppm was present at surface but decreased downward up to the depth of 60 cm depth (below the ground surface). It was observed that after 45 DAT the tomato the maximum NO^-_3- N concentration of 46.8 ppm at 15-0 cm, 29.5 ppm at 30-15 cm and 44.2 ppm 30-15 cm was observed under treatments VA, VW, VF and VM, respectively.

Patel *et al.* (2015) determined K_2O concentration and its distribution in the soil profile on 45, 60, 75, 90, 120 and 150 DAT of tomato crop. It was observed that the throughout the crop season the maximum K_2O concentration of about 55 ppm was found at 15 cm soil depth except at 150 DAT when maximum potassium was found at 30 cm soil depth As distance from dripper increases from 0 to 30, the concentration of K_2O decreases significantly at all soil depth. It was observed that with growth of crop the K_2O concentration tends to increase in lower soil depth. It was found that at 0 cm away from lateral pipe and at 30, 45 and 60 cm soil depth, the potassium concentration at 45 DAT was found 35.9 ppm, 18.8 ppm and 14.0 ppm respectively, while on 120 DAT, the concentration increases from 35.9 to 48.5 ppm, 18.8- 37.1 ppm and 14.0 to 16.4 ppm.

Patel *et al.* (2015) determined P_2O_5 concentration and its distribution in the soil profile were on 45, 60, 75, 90, 120 and 150 DAT. It was observed that after 45 DAT, the maximum P_2O_5 concentration of 18 ppm at 15 cm soil depth. There is no specific trend was found in the distribution of P_2O_5 in the soil profile. But with depth, the P_2O_5 concentration decreases with increase in soil depth.

2.2.4 Economics under fertigation

Kavitha *et al.* (2007) conducted experiment on elucidate the effect of shade and fertigation on the growth, yield and quality of tomato hybrid 'Ruchi'. Treatments consisted of open or shade (35 %) conditions in the main plot and fertigation with 50, 75 and 100 % dose each of water-soluble (Polyfeed 19:19:19) and straight fertilizers (urea, super phosphate and potash) in the sub-plot. Application of 100 % water-soluble fertilizer under shade recorded the highest values for different growth (plant height, primary branches per plant, leaf area index, dry matter production), yield (fruits per plant, fruit weight) and quality parameters (fruit firmness, ascorbic acid, lycopene and carotene). However, application of 100 % dose of straight fertilizer under shade recorded the highest net returns and benefit: cost ratios.

Zhang *et al.* (2010) conducted a field study to evaluate the yield and economic responses of drip fertigated processing tomatoes to additions of fertilizer nitrogen (N) and phosphorus (P). The experiment was arranged in a factorial design with four levels of fertilizer N (0, 120, 240, and 360 kg N ha^{-1}) and three levels of fertilizer P (0, 100, and 200 kg P_2O_5 ha^{-1}). They revealed that the fertilizer N should be applied at an increased rate for processing tomatoes with drip fertigation to maximize the economic return.

Amala amd Syriac (2016) carried out an investigation maximum dry matter production (219.42 g $plant^{-1}$), fruit set per cent (62.77), fruits $plant^{-1}$ (33.67) and fruit yield (42.36 t ha^{-1}) for 125 per cent recommended dose of N and K. Higher leaf area index (1.87), dry matter production (224.21 g $plant^{-1}$), fruit set per cent (60.74), fruits $plant^{-1}$ (35.53), and fruit yield (44.25 t ha^{-1}) were recorded for fertigation at four days interval. Economic analysis revealed that 125 % RD of N and K registered the highest net income (₹ 4,55,466 ha^{-1}) and B: C ratio (2.16) compared to other fertigation levels and fertigation at four days interval registered significantly higher net income (₹ 4,93,051 ha^{-1}) and B: C (2.26) ratio compared to fertigation at eight days interval.

Kale *et al.* (2018) reported that the B:C ratio was improved under fertigation treatments as compared to surface irrigation with CF. All treatments recorded B:C ratio between 1.51 to 2.20. Maximum B:C ratio was recorded in treatment T_7 (80 % RD of fertigation through 1_2 : 61:00) i.e. 2.20 followed by T_6 (DI with 80 % of RD of fertigation through 13:40:13 with urea and SOP as per schedule) i.e. 2.16. The lower B:C ratio (1.51) was observed in T_1 (Drip irrigation (DI) with no fertilizer).

3. MATERIALS AND METHODS

The present investigation entitled, “Effect of fertigation timing on growth, yield and nutrient mobility for tomato in Inceptisol” was conducted during the *Rabi* season of the year 2014-15 and 2015-2016. The details of materials used and the methods adopted are described in this chapter.

3.1 Details of Experimental Materials

3.1.1 Location of the experimental site

The field experiment was conducted at research farm of the Inter Faculty Department of Irrigation Water Management, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri Dist. Ahmednagar.

3.1.2 Location and climatic conditions

A. General

Geographically the Mahatma Phule Krishi Vidyapeeth, Rahuri is situated 33 km for Ahmednagar, on Ahmednagar - Manmad state highway. It lies between $19^0$48 N and $19^0$57 N latitude and $74^0$32 E and $74^0$19 E longitude. The altitude varies from 495 to 569 mm mean sea level. This tract is lying on the eastern side of Western ghat and falls under rain shadow area.

Climatologically, this area falls in a semi-arid tropics with annual rainfall varying from 307 to 619 mm. The average annual precipitation is 520 mm. Out of total annual rainfall, about 80 per cent rains are received from South-West monsoon (June to September), while the rest receives from North-East monsoon (October-November). The number of rainy days varies from 15-45 days in a year. The annual mean maximum temperature of the area is 37.5^0C with range of 24.9 and 39.5^0C. The annual mean minimum temperature is 17^0C with a range of 6.1 to 24.6^0C. The mean relative humidity at 8.00 and 14.00 hr is 77 and 49 %, respectively. The mean pan evaporation ranges from 2.2 to 7.6 mm day^{-1}. Agro-climatically the location is in the drought prone area of Maharashtra state, characterized by low, erratic rainfall with less rainy day.

B. Nature and season during the experimental period

The meteorological data on different weather parameters during the period of experimentation was recorded at a meteorological observatory located at Water

Management Project, Mahatma Phule Krishi Vidyapeeth, Rahuri and presented in Table 3.1 and 3.2.

Table 3.1 Meteorological data for the year 2014 -2015

Meteorological week	Date	Temperature (^{0}C)		Humidity (%)		Wind speed (km hr^{-1})	Rainfall (mm)
		Maximum	Minimum	RH-I	RH-II		
December, 2014							
49	3-9	29.1	10.9	55	32	0.5	0
50	10-16	29.2	14.6	67	47	1.3	0
51	17-23	25.7	7.5	52	34	1.0	0
52	24-31	27.2	8.2	26	37	0.7	0
January, 2015							
1	1-7	24.9	12.7	74	55	0.4	0
2	8-14	27.2	6.8	48	26	0.8	0
3	15-21	28.6	10.5	54	33	0.5	0
4	22-28	29.4	14.0	62	37	0.9	0
5	29-04	30.1	12.9	52	35	1.2	0
February, 2015							
6	05-11	31.3	12.3	51	24	1.8	0
7	12-18	33.0	13.0	53	23	0.8	0
8	19-25	33.2	13.7	54	23	1.2	0
9	26-04	28.9	13.0	65	37	2.4	0
March, 2015							
10	05-11	31.9	14.8	52	37	1.2	0
11	12-18	31.0	16.8	67	39	1.5	0
12	19-25	35.3	19.2	45	23	1.0	0
13	26-01	36.4	19.4	54	20	1.2	0
April, 2015							
14	02-08	37.5	18.4	36	19	1.8	0
15	09-15	37.2	17.9	46	17	2.0	0
16	16-22	37.8	21.2	59	26	1.9	0
17	23-29	38.7	21.6	46	20	1.9	0

Table 3.2 Meteorological data for the year 2015 -2016

Meteoro logical week	Date	Temperature (^{0}C)		Humidity (%)		Wind speed (km hr^{-1})	Rainfall (mm)
		Maximum	Minimum	RH-I	RH-II		
December, 2015							
49	3-9	31.6	13.9	57	32	0.4	0
50	10-16	32.3	16.0	49	33	0.7	0
51	17-23	31.1	13.7	64	35	0.4	0
52	24-31	28.3	7.8	37	22	1.2	0
January, 2016							
1	1-7	31.4	11.6	47	26	0.4	0
2	8-14	30.3	11.8	47	27	0.2	0
3	15-21	28.7	11.8	54	30	1.6	0
4	22-28	29.4	9.3	46	22	0.6	0
5	29-04	33.5	12.0	47	25	0.2	0
February, 2016							
6	05-11	32.4	13.4	53	24	1.0	0
7	12-18	32.8	14.9	64	27	1.3	0
8	19-25	35.0	17.5	52	23	0.7	0
9	26-04	35.3	18.6	56	28	0.9	0
March, 2016							
10	05-11	34.5	17.1	51	22	0.8	0
11	12-18	35.8	17.3	40	20	1.5	0
12	19-25	37.1	18.7	35	17	2.7	0
13	26-01	39.0	19.3	34	18	1.2	0
April, 2016							
14	02-08	39.0	21.5	40	22	1.3	0
15	09-15	39.0	20.6	37	20	1.6	0
16	16-22	39.9	22.7	38	22	1.5	0
17	23-29	39.0	20.6	41	19	2.2	0

Data on weekly means of meteorological parameters during the experimental period *i.e. rabi* 2014-15 (Table 3.1) indicated that the rainfall was not received during the entire crop growth period. The mean maximum temperature was ranged from 24.9 to 38.7^{0}C and minimum from 6.8 to 21.6^{0}C. The maximum temperature (38.7^{0}C) was observed during 17th meteorological week, whereas minimum temperature (6.8^{0}C) was noticed during 2nd meteorological week. The mean maximum relative humidity was ranged from 26 to 74 per cent at morning hours and 17 to 55 per cent at

evening hours. The maximum relative humidity (74 %) was observed during 1st meteorological week at morning hours and minimum in 15th meteorological week (17 %) at evening hours. The mean wind speed was 0.4 to 2.4 km hr^{-1}.

Data on weekly means of meteorological parameters during the experimental period *i.e. rabi* 2015-16 (Table 3.2) indicated that the rainfall was not received during the entire crop growth period. The mean maximum temperature was ranged from 28.3 to 39.9^{0}C and minimum from 7.8 to 22.7^{0}C. The maximum temperature (39.9^{0}C) was observed during 16th meteorological week, whereas minimum temperature (7.8^{0}C) was noticed during 52nd meteorological week. The mean maximum relative humidity was ranged from 34 to 64 per cent at morning hours and 17 to 35 per cent at evening hours. The maximum relative humidity (64 %) was observed during 51th and 7th meteorological week at morning hours and minimum in 12th meteorological week (17 %) at evening hours. The mean wind speed was 0.4 to 2.7 km hr^{-1}.

3.1.3 Soil

The soil of experimental site was uniform and leveled. It was well drained, silty clay loam in texture with 35 cm depth. A composite soil sample from 0-30 cm soil layer was collected prior to planting and analyzed for physical and chemical properties. The relevant data on the physical and chemical properties of the soil of experimental site along with the analytical methods used are presented in Table 3.3. The soil of experimental field was low in available nitrogen (167.47 kg ha^{-1}), medium in phosphorus (18.79 kg ha^{-1}) and high in potassium (334.26 kg ha^{-1}) with slightly alkaline in reaction (pH 7.90). The electrical conductivity was 0.28 dSm^{-1} and organic carbon content 0.5 per cent.

Table 3.3 Physical and chemical characteristics of soil from the experimental site

Sr. No.	Characteristics	Composition	Method adopted	Reference
I	**Physical Properties**			
1.	**Soil Texture**			
	Course sand (%)	20.98	International pipette Method	Piper (1966)
	Fine sand (%)	15.21		
	Silt (%)	37.84		
	Clay (%)	25.37		
	Textural class	Silty Clay Loam		

Table 3.3 contd…

Sr. No.	Characteristics	Composition	Method adopted	Reference
II.	**Soil moisture constants**			
1.	Field Capacity (%)	36.10	Pressure plate apparatus	Richards (1947)
2.	Available Soil Moisture (%)	19.00	Gravimetric method	-
3.	Permanent Wilting Point (%)	17.10	Pressure plate apparatus	Richards (1947)
4.	Bulk Density (Mg m^{-3})	1.28	Core sampler	Dastane (1972)
5.	Infiltration rate (cm hr^{-1})	3.24	Double ring infiltrometer	Klute (1986)
III.	**Chemical Properties**			
1.	pH (1:2.5)	7.90	pH meter	Piper (1966)
2.	EC (dSm^{-1}) (1 : 2.5)	0.28	Conductivity meter	Piper (1966)
3.	Available N (kg ha^{-1})	164.47	Alkaline permanganate	Subbiah and Asija (1956)
4.	Available P (kg ha^{-1})	18.79	0.5 M $NaHCO_3$ (pH 8.5)	Olsen *et al.* (1954)
5.	Available k (kg ha^{-1})	334.26	Flame photometer	Hanway and Heidal (1967)
IV	**Plant analysis**			
1.	Total nitrogen	-	Micro-Kjeldhal A.O.A.C. (1982)	Jackson (1973)
2.	Total phosphorous	-	Vanadomolybdate yellow colour method (Jackson, 1973)	Piper (1966)
3.	Total potassium	-	Flame photometric (Hanway and Heidal, 1967)	Jackson (1973)

3.1.4 Water source

The source of water for the experimental plot was from tube well with submersible pump capacity of 5 HP. The water was stored in a tank 40,000 lit capacity and used for irrigation as and when required.

3.1.5 Cropping history

The cropping history of the experimental field for the previous three years is presented in Table 3.4. From the cropping history of the experimental plot it is observed that the present investigation was carried out on plot preceded by soybean.

Table 3.4 Cropping history of experimental site

Year	Kharif	Rabi	Summer
2012-2013	Soybean	Potato	Fallow
2013-2014	Soybean	Potato	Fallow
2014-2015	Soybean	Tomato	-

3.2 Methodology

3.2.1 Details of irrigation systems

3.2.1.1 Drip irrigation system

Drip irrigation system was used to irrigate the field plots as per treatments. The lateral for each row of tomato was provided at 20.25 m and spacing between the lateral was 1.05 m. The emitter spacing in both the planting systems was 0.50 m. Scheduling of irrigation was done at every alternate day on the basis of cumulative pan evaporation (CPE) and crop coefficients (Kc).

3.2.1.2 Surface irrigation system

The irrigation was applied at 50 mm CPE. Depth of irrigation water was determined with the help of moisture content as suggested by Pawar and Dingre (2014). Volume of water to be applied plot^{-1} was computed by using equation.

$$V = D \times L \times W \quad \text{..... (3.1)}$$

Where,

V = Volume of water to be applied (lit.)

D = Depth of water (mm)

L = Length of plot (m)

W = Width of plot (m)

3.2.1.3 Planting method

A plot of size 4.20 x 6.75 m were drawn forming ridges and furrows. A spacing of 1.05 x 0.45 cm, recommended for tomato was adopted. The 4 weeks old age seedlings were used for transplanting before transplanting seedlings were treated as root dipping in solution bavistin @ 10 g per 10 liter water for 10 minutes.

3.2.1.4 Details of fertigation

The recommended fertilizer dose for tomato was applied through water soluble fertilizer and conventional fertilizer. Water soluble fertilizer used for fertigation

plots during experimentation were urea (46 % N), urea phosphate (17:44:0) and muriate of potash (0:0:60). Straight fertilizers viz, urea, single super phosphate and muriate of potash were used as conventional fertilizer for surface irrigation. Fertigation was done according to different treatments like, 100% fertigated treatments, split fertilized treatments and conventional fertilizer treatments. In 100 % fertigated treatments fertigation was done according to irrigation time that means meaning of tertile is application of fertilizer in 1/3rd part of the irrigation period that is nitrogen is given either during the same period of the irrigation from the start to the end, in third tertile of the irrigation period, in second tertile of the irrigation period and in first tertile of the irrigation period. In split fertilized treatments fertilizers applied through fertigation and soil application, 75% fertilizer applied through fertigation after 30 days of transplanting and 25% fertilizer applied through soil application, 50% fertilizer applied through fertigation after 45 days of transplanting and 50% fertilizer applied through soil application and 25% fertilizer applied through fertigation after 60 days of transplanting and 75% fertilizer applied through soil application. In conventional fertilizer treatments fertilizers applied through soil application and 2 % foliar spray of 17:44:00 at 30, 45 and 60 days after transplanting. Initially common quantity of required water soluble fertilizers was calculated and dissolved separately in water. The dissolved solution of water soluble fertilizers was poured in fertilizer tank and mixed gently. Then with the help of Automatic Fertigation Unit water soluble fertilizer solution was applied to tomato crop.

3.2.2 Layout

The experiment was laid out in random block design with three replications. Only eleven treatment combinations including fertigation timing and spilt application (Fig. 3.3).

3.2.3 Experimental details

Crop	: Tomato
Variety	: Abhinav
Season	: Rabi
Date of Planting	: December, 2014 and 2015
Spacing	: 1.05 x 0.45 m
Plot size	: 4.20 x 6.75 m
Design	: RBD

The present experiment was laid out in random block design with three replications. Eleven treatment combinations including fertigation timing and spilt application. The detail of treatment are given below.

3.2.4 Treatment Details

In the experimentations, following 11 treatments were studied.

Particular	Treatment Details
100 % Fertigated treatments (As per schedule A)	T_1 -100 % FII (Fertigation– Irrigation–Irrigation) fertigation in the first tertile of the irrigation period
	T_2 -100 % IFI (Irrigation-Fertigation-Irrigation) fertigation in the second tertile of the irrigation period
	T_3 - 100% IIF (Irrigation-Irrigation-Fertigation) fertigation in the third tertile of the irrigation period
	T_4 - 100 % FFF (Fertigation during complete irrigation period)
Split fertilized treatments	T_5 - 75 % fertigation (as per schedule B) + 25 % soil application
	T_6 - 50 % fertigation (as per schedule C) + 50 % soil application
	T_7 - 25 % fertigation (as per schedule D) + 75 % soil application
	T_8 - DI with 100 % CF (NK-drip and P-soil)
Conventional fertilized treatments	T_9 - SI with 100 % CF + 2 % foliar spray of 17:44:00 at 30, 45 and 60 DAP
	T_{10} - SI with 100 % CF
Control treatment	T_{11} - DI with no fertilizer

3.2.5 Cultural practices

The detail of the important cultural operations carried out in the experimental field during 2013-14 and 2014-15 are given in Table 3.6 and 3.7.

3.2.6 Seeds

The 4 weeks old age seedlings of Abhinav variety were purchased from private nursery used for transplanting.

3.2.7 Transplanting

Seedlings were transplanted at an age of 4 weeks. These seedlings were purchased from private nursery and used for transplanting operation. Before transplanting seedlings were treated as root dipping in solution bavistin @ 10 g per 10 liter water for 10 minutes.

3.2.8 Fertigation

The water soluble fertilizer and conventional fertilizer used for fertigation. Fertigation was scheduled at every week commencing from seven days after transplanting as per the treatments. In 100% fertigation treatments, the fertilizers are applied in specific portion of the irrigation period e.g. in T_1, fertigation is applied in first tertile means first one third part of irrigation period and during next two third part of irrigation period only water is applied through drip; thus followed a fertigation – irrigation – irrigation cycle in irrigation period. Similar pattern was followed in T_2 and T_3; whereas, in T_4, the water soluble fertilizers were applied for complete irrigation duration. In fertigation in different treatments were carried out as per schedule given in Table 3.5.

Table 3.5 Fertigation schedule for tomato

Schedule A. Fertigation schedule for 100 % fertigation

- Percent nutrients to be applied in 18 weekly splits

Days after transplanting	**Nitrogen (N)**		**Phosphorus (P)**		**Potassium (K)**	
	%	**Kg**	**%**	**Kg**	**%**	**Kg**
1-28 (4 weeks)	15	45	20	30	15	22.5
29-56 (4 weeks)	40	120	35	52.5	30	45
57-98 (6 weeks)	30	90	35	52.5	35	52.5
98-126 (4weeks)	15	45	10	15	20	30
Total	**100**	**300**	**100**	**150**	**100**	**150**

Schedule B. Fertigation schedule for 75 % fertigation

- Percent nutrients to be applied in 14 weekly splits

Days after transplanting	**Nitrogen (N)**		**Phosphorus (P)**		**Potassium (K)**	
	%	**Kg**	**%**	**Kg**	**%**	**Kg**
1-28 (4 weeks)						
29-56 (4 weeks)	35	105	30	45	25	38
57-98 (6 weeks)	25	75	35	53	30	45
98-126 (4weeks)	15	45	10	15	20	30
Total	**75**	**225**	**75**	**113**	**75**	**113**

Schedule C. Fertigation schedule for 50 % fertigation

- Percent nutrients to be applied in 14 weekly splits

Days after transplanting	Nitrogen (N)		Phosphorus (P)		Potassium (K)	
	%	Kg	%	Kg	%	Kg
1-28 (4 weeks)						
29-56 (4 weeks)	10	30	10	15	5	7.5
57-98 (6 weeks)	25	75	30	45	25	37.5
98-126 (4weeks)	15	45	10	15	20	30
Total	**50**	**150**	**50**	**75**	**50**	**75**

Schedule D : Fertigation schedule for 25 % fertigation

- Percent nutrient to be applied in 10 weekly splits

Days after transplanting	Nitrogen (N)		Phosphorus (P)		Potassium (K)	
	%	Kg	%	Kg	%	Kg
1-28 (4 weeks)						
29-56 (4 weeks)						
57-98 (6 weeks)	15	45	20	30	10	15
98-126 (4weeks)	10	30	05	7.5	15	22.5
Total	**25**	**75**	**25**	**37.5**	**25**	**37.5**

3.2.9 Gap filling

To maintain the desired plant population, gap filling was done at 8 days after transplanting during both the years.

3.2.10 Weeding

Three hand weedings were carried out on 16.1.2014, 30.1.2014 and 14.2.2014 as well as on 20.1.2015, 15.02.2015 and 29.2.2015 to control the weed growth in experimental plot.

3.2.11 Irrigation

In drip irrigation treatments, the irrigation scheduling was done on the basis of pan evaporation approach. Irrigation was scheduled on alternate days and in surface irrigation the irrigation was applied at 50 mm CPE.

3.2.12 Plant protection

The sprayings of recommended systemic insectides were followed o avoid the incidence of sucking pests like aphids, jassids and white fly causing viral diseases and also leaf miner,. Similar to avoid the incidence of wilt and blight, sprayings of fungicides

were done as per the recommendation at regular days interval as given in Table 3.6 and 3.7.

Table 3.6. Schedule of cultural operations carried out during the experimental period (2014-15)

Sr. No.	Field operations	Frequency	Date of operation
A.	**Preparatory tillage**		
1.	Ploughing	1	12.10.2014
2.	Harrowing	2	26.10.2014,13.11.2014
B.	Preparation of layout	1	21.11.2014
C.	Design and installation of drip irrigation system	1	24.11.2014
D.	Basal dose of fertilizer	1	10.12.2014
E.	Transplanting of tomato seedling	1	10.12.2014
F.	Drip irrigation		As per treatment
G.	**Post sowing operations**		
1.	Gap filling	1	21.12.2014
2.	Weeding	3	16.1.2014, 30.1.2014,14.2.2014
3.	Staking	1	13.2.2014
H.	**Irrigation**		
1.	Drip irrigation		As per treatment
2.	Surface irrigation		As per treatment
I.	**Plant protection**		
a.	Phorate 10 G	1	20.12.2014.
b.	Dimethoate 30 EC	1	13.2.2015
c.	Tebuconazole 25.5 EC	2	15.1.2015,23.2.2015
d.	Copper-oxy-chloride	1	7.1.2015
e.	e.Mancozeb 75 WP	2	24.1.2015,12.3.2015
J.	**Harvesting**	11	11.3.2015,18.3.2015,22.3.2015, 30.3.2015,4.4.2015,9.4.2015,13. 4.2015,18.4.2015,25.4.2015,3.5. 2015,8.5.2015
K.	**Uprooting of plants**	1	13.5.2015

Table 3.7. Schedule of cultural operations carried out during the experimental period (2015-16)

Sr. No.	Field operations	Frequency	Date of operation
A.	**Preparatory tillage**		
1.	Ploughing	1	06.10.2015
2.	Harrowing	2	18.10.2015,30.11.2015
B.	Preparation of layout	1	07.12.2015
C.	Design and installation of drip irrigation system	1	11.12.2015
D.	Basal dose of fertilizer	1	14.12.2015
E.	Transplanting of tomato seedling	1	14.12.2015
F.	Drip irrigation		As per treatment
G.	**Post sowing operations**		
1.	Gap filling	1	23.12.2015
2.	Weeding	3	20.1.2016, 15.02.2016,29.2.2016
3.	Staking	1	12.02.2016
H.	**Irrigation**		
1.	Drip irrigation		As per treatment
2.	Surface irrigation		As per treatment
I.	**Plant protection**		
a.	Phorate 10 G	1	13.12.2015.
b.	Dimethoate 30 EC	1	10.2.2016
c.	Tebuconazole 25.5 EC	2	19.1.2016,20.2.2016
d.	Copper-oxy-chloride	1	09.01.2016
e.	Mancozeb 75 WP	2	12.01.2016,08.03.2016
J.	**Harvesting**	11	07.03.2016,14.03.2016,19.03.2016, 26.3.2016,6.4.2016,13.4.2016,19.4. 2016,24.4.2016,30.4.2016,5.5.2016
K.	**Uprooting of plants**	1	19.5.2016

3.2.13 Harvesting

Eleven pickings of tomato fruits were done as soon as the adequate number of fruits turned light red. After final picking of tomato fruits, plants were uprooted and removed the root parts. The above ground part were washed with tap water and then with deionised water to make them dust free and free from clay particles. The washed plant samples were dried in diffused sunlight and then in oven at 70^0C temperature till constant weight. The dry weight of plant sample was recorded after oven drying of samples.

3.3 Biometric and Other Observations

3.3.1 Biometric observations

3.3.1.1 Sampling technique

For recording various growth attributes, five plants were selected from each net plot through random sampling technique and plastic coated labels were tied to each observational plant for easy identification. All the observations like plant height, number of branches plant^{-1}, number of leaflets plant^{-1}, leaf area plant^{-1}, dry matter plant^{-1} at last harvest, days required for first flower initiation, number of fruits plant^{-1}, fruit weight and fruit weight plant^{-1} were recorded on these observational plants. The detail schedule adopted for recording various growth observations are presented in Table 3.8.

3.3.1.2 Plant population

The initial and final plant population was recorded by counting the number of plants from each net plot at 15 days after transplanting and at last harvesting.

3.3.1.3 Plant height (cm)

Five selected plants were used for observation of the plant height. The plant height was recorded in centimeters from ground level to the growing tip of the main stem with the help of meter scale, at an interval of 30 days starting from transplanting to last harvest of the tomato fruits.

3.3.1.4 Number of primary branches plant^{-1}

The number of primary branches at 30, 60, 90, 120, 150 and at harvest were recorded by taking actual count at various stages of tomato.

3.3.1.5 Dry matter plant^{-1} (g plant^{-1})

Dry matter plant^{-1} was recorded at first harvest of the tomato. Five plants randomly selected from net plot of each treatment. These plants were first sun dried for

fifteen days and then dried in an oven at 65^0C temperature till constant weight was obtained. Average of five plants was considered as dry matter plant^{-1}.

3.3.2 Yield attributes

3.3.2.1 Number of fruits plant^{-1}

At the time of each picking, number of fruits picked plant^{-1} were recorded from observational plants from each treatment.

Table 3.8. Observations recorded

Sr. No.	Particulars	Frequency	Period
A.	**Pre harvest studies**		
1.	Plant population	2	At 15 DAT and at last picking (harvest)
2.	Plant height (cm)	06	30, 60, 90, 120,150 and at harvest
3.	Number of branches plant $^{-1}$	06	30, 60, 90, 120, 150 and at harvest
4.	Days to first flower initiation	1	-
B.	**Physiological studies**		
1.	Leaf area (m^2)	06	30, 60, 90, 120, 150 and at harvest
2.	Photosynthetic rate (μ mol CO_2 m^{-2} s^{-1})	04	45, 90, 135 and at harvest
3.	Stomatal conductance (m mol m^{-2} s^{-1})	04	45, 90, 135 and at harvest
4.	Stomatal resistance (m mol m^{-2} s^{-1})	04	45, 90, 135 and at harvest
5.	CO_2 concentration (μ mol CO_2 m^{-2} s^{-1})	04	45, 90, 135 and at harvest
6.	Transpiration rate (m mol H_2O m^{-2} s^{-1})	04	45, 90, 135 and at harvest
C.	**Post harvest studies**		
1.	Number of fruits plant $^{-1}$	-	At each picking
2.	Weight of fruits plant $^{-1}$ (kg)	-	At each picking
3.	Total yield of tomato (q/ha)	-	Total of all pickings
D.	**Fruit Quality studies**		
1.	pH	1	At harvest
2.	Total soluble solids (TSS)	1	At harvest
3.	Acidity (%)	1	At harvest
4.	Lycopene content (mg $100g^{-1}$)	1	At harvest

Table 3.8 contd….

Sr. No.	Particulars	Frequency	Period
E.	**Chemical studies**		
1.	Nutrient availability	6	30, 60, 90, 120, 150 and at harvest
2.	Nutrient uptake	6	30, 60, 90, 120, 150 and at harvest
F.	**Moisture dynamics**		
1.	Moisture distribution pattern	6	30, 60, 90, 120, 150 and at harvest
2.	Water requirement	-	Alternate day water requirement

3.3.2.2 Weight of fruit plant-1 (g)

At each picking all mature fruits from five sample plants were harvested separately. The mean fruit weight was computed by total weight of fruit divided by number of sampled fruits.

3.3.2.3 Fruit yield plot^{-1} (kg)

The yield of tomato fruits was recorded by adding the yield obtained from five observational plants and the yield obtained in a net plot at each picking for each treatment plot. This fresh fruit yield of net plot was then converted on hectare basis and presented in tonnes ha^{-1}.

3.3.3 Physiological studies

3.3.3.1 Leaf area plant^{-1} (dm^2)

The functional leaflets were carefully separated from the stem of tomato plant and inserted into the automatic leaf area meter Model AM-100 (ADC Bioscientific Ltd. Herts, England). The leaf area was measured in mm^2 and converted into dm^2. The total leaf area plant^{-1} was recorded at 30 days interval after transplanting.

3.3.3.2 Flowering

Days required to flower initiation was recorded for each treatment plot.

3.4 Meteorological Studies

3.4.1 Photosynthetic rate, stomatal conductance, leaf temperature, CO_2 concentration

The Infra Red Gas Analyzer (IRGA) LI-COR make LI-6400 XT is an open system, which means that measurement of photosynthesis is based on the differences in CO_2 and H_2O in an air stream that is flowing through the leaf cuvette. Physiological parameters *viz*., rate of photosynthesis (µ mol m^{-2} s^{-1}) and stomatal conductance (mol H_2O m^{-2} s^{-1}) as well as the leaf temperature (OC) and the intercellular CO_2 concentration (µ mol m^{-2} s^{-1}) were measured at an interval of 45 days after transplanting. The observations were recorded on the five randomly selected tagged plants on the upper, lower and middle leaves and then averaged for per plant. The observations were recorded between 10-11 AM at every time.

3.5 Fruit Quality Study

3.5.1 pH

The ripened tomato fruits were crushed in the mixer grinder. The crushed mixture filtered through filter paper. Then pH of filtrate was directly measured with the help of pH meter (Elico made) as per the treatment.

3.5.2 Total soluble solids (TSS)

The total soluble solids of tomato fruit was measured by extracting the tomato fruit juice by crushing the 3 or 4 fruits. A drop of tomato fruit was taken on hand refractometer and used to measure the total soluble solids (TSS) in the range of 0 to 32^0B.

3.5.3 Titrable acidity (%)

Two-three fully ripened and firm tomato fruits were crushed in mixer grinder. Juice was filtered through filter paper and collected the sample in conical flask. Then 10 ml of this sample was taken into conical flask and 2-3 drops of phenolphthalein indicator were added. Then it was titrated with 0.1 N NaOH solution (Ranganna, 1986).

$$\% \text{ Total acid} = \frac{\text{Titrate x Normality of alkali x Equivalent weight of acid x 100}}{\text{Volume of sample taken for estimation x 1000}} \quad \ldots\ldots (3.2)$$

3.5.4 Lycopene (mg 100 g^{-1} fruit juice)

Ten grams of fruit sample was crushed and extracted repeatedly with acetone until residues become colourless. This acetone extract was transferred to separating funnel containing 15 ml of petroleum ether and mixed gently. To this, 5 ml of

5 % sodium sulphate solution in water was added and mixed thoroughly by shaking. This aided in separating out any water present in the separating funnel and helped to from a clear extract. The lower phase (petroleum ether extract containing carotenoid) was transferred to another separating funnel to remove any residual acetone and finally the extract was transferred to amber coloured bottle. The extraction procedure with petroleum ether was repeated till the acetone phase become colourless. Acetone phase was discarded and small quantity of anhydrous sodium sulphate was added to the petroleum ether extract. Then petroleum ether extract was transferred to 50 ml volumetric flask and diluted to 50 ml with petroleum ether and from this, 5 ml was again diluted to 50 ml with petroleum ether for colour measurement. Optimal density (OD) of the extract was measured at 503 nm in spectrophotometer using petroleum ether as a blank (Ranganna, 1986). Lycopene content of the sample was calculated using the relationship that an optimal density (OD) of 1.0 = 3.1206 µg of lycopene per ml.

$$\text{Lycopene (mg/100 g)} = \frac{3.1206 \times \text{OD of sample} \times \text{volume made up} \times \text{dilution}}{1 \times \text{Weight of sample} \times 1000} \times 100 \quad \text{..... (3.3)}$$

3.6 Chemical Analysis

3.6.1 Soil sampling

Soil samples with the help of screw auger 24 hours before irrigation were taken from the location of 0, 15, 30 and 45 cm vertically and horizontally. The soil samples were collected in aluminium boxes and transferred immediately into hot air oven after weighing. The samples were dried for 24 hours at 105 $^{\circ}$C in oven. The 16 samples from each treatment were taken for periodical nutrient mobility and nutrient availability. The gravimetric moisture content was estimated by following formula.

$$\text{Moisture content (\%)} = \frac{\text{Weight of moist soil} - \text{Weight of dry soil}}{\text{Weight of dry soil}} \times 100 \quad \text{..... (3.4)}$$

The moisture content (d/d) values were used to depict the soil moisture distribution pattern in each treatment. The distribution curves were drawn using software SURFER. The contour maps were derived from 25 observations. These 25 points arranged in a matrix of 3 columns and the program (SURFER 10) was used for developing moisture profile lines. Kringing method was used for the calculation of the intermediate points at equal distances (Dough *et al.,* 2013).

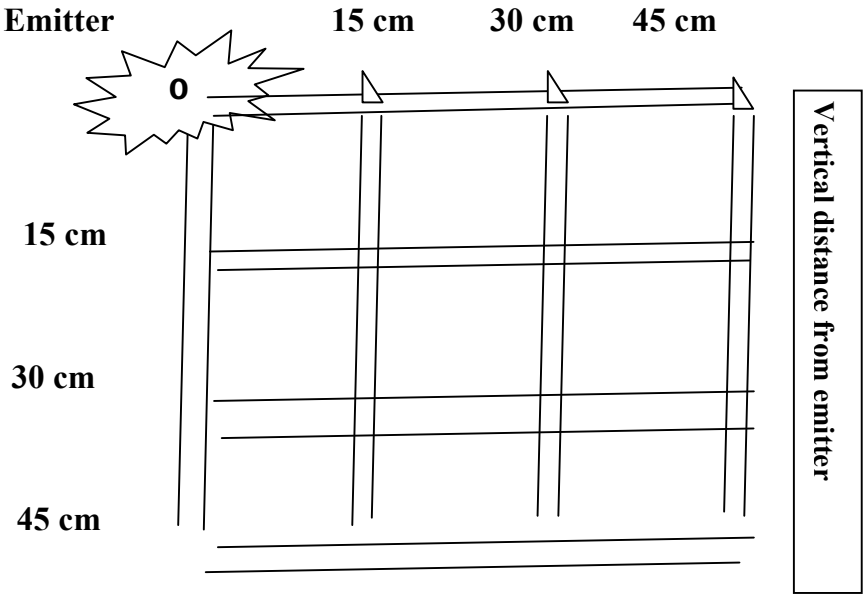

Fig 3.4. Moisture sampling pattern

3.6.2 Plant sampling

Periodical plant sampling was done at 30, 60, 90, 120, 150 and at harvest five plants were selected randomly from each plot of every treatment and from all its replications separately. The plant samples were dried under shade followed by oven drying. The sample was chopped mixed thoroughly and composite sample was used for estimation of nutrient concentration.

3.6.3 Plant analysis

Tomato plant samples from different treatments at 30, 60, 90, 120, 150 and at harvest were analyzed for total N, P, and K content by adopting standard methods. The ground sample of 0.2 g were digested with 1:1 mixture of concentrated H_2SO_4 and 30 per cent H_2O_2 (Parkinson and Allen, 1975) and acid extract was used for determination of N, P and K concentration.

3.6.4 Soil analysis

Soil samples was collected before planting and analyzed for available N, P and K content.

3.6.4.1 Available nitrogen (N)

Available nitrogen in the soil was estimated by alkaline permagnate method (Subbiah and Asija, 1956). The 20 g soil with 2.5% NaOH, 0.32% $KMNO_4$ and

distilled water was put in microkjeldhal flask. After connecting flask with condenser, the tip of condenser was merged into beaker of boric acid and mixed indicators. It was titrated with 0.01N H_2SO_4 till the end point of pink colour obtained. Nitrogen was calculated by difference between blank and above reading.

3.6.4.2 Available phosphorous (P)

Olsen's extractant of 40 ml (0.5 M NaHCO3) was used in 2 g of soil sample and shaked for 30 minutes (Olsen *et al.*, 1954). Extrant was filtered and 5 ml extractant with drop of P nitrophenol indicator was acidified with 2.5 N H_2SO_4. The 4 ml of reagent B was added and the volume of 25 ml with distilled water was made. The contents were shaked and after 10 minutes the intensity of blue colour (absorbance) was measured at 680 nm wave length in a spectrophotometer. The absorbance value was incorporated in the standard graph and the concentration of P in the colored solution was obtained.

3.6.4.3 Available potassium (K)

The method described by Knudsen *et al.* (1982) was used to determine potassium in soil. In this method, 5 g soil mixed with 25 mL 1N NH_4OAc was shaken in centrifuge tube for 10 minutes. At 1000 rpm and the supernent liquid was decanted into a 100 ml volumetric flask. Three additional extractions were made in the same manner. The combined extraction was diluted to 100 ml with 1N NH_4OAc and potassium was determined by flame photometer (Hanway and Heidal, 1967).

3.6.4.4 Plant analysis

Tomato plant samples collected at 30, 60, 90, 120, 150 days after transplanting and at harvest were first sun dried and then oven dried at 65^0C ±1 and used for chemical analysis after grinding it in grinding mill. The oven dried samples were digested by adding 5 ml H_2O_2 and 5 ml H_2SO_4 in digestion unit for 12 hrs (Parkinson and Allen, 1975).

3.6.4.5 Concentration of nitrogen

Transferred the plant digests into a kjeldahl distillation flask and placed with 25 ml of 2% boric acid with mixed indicator at the end of delivery tube. After completion of distillation process, 10 ml distillate was collected and titrated against standard H_2SO_4 (0.01 N) till the bluish green colour turns pink (A.O.A.C., 1982).

3.6.4.6 Concentration of phosphorous

Plant digests of 5 ml were mixed with 10 ml of Barton's reagent. The mixture was shaked well and the volume of 25 ml was made and allowed 30 minutes for yellow colour development. The colour intensity was measured at 420 nm in a spectrophotometer. The absorbance value in the standard graph was used to obtain the concentration of P (Jackson, 1973).

3.6.4.7 Concentration of potassium

Plant cane digest of 5 ml diluted with distilled water was used to make the volume of 25 ml. The standards were aspirated and then the sample was taken to the flame and the meter reading was noted. The K content was calculated by referring to the standard curve (Hanway and Heidal, 1967).

3.6.4.8 Nutrient use efficiency

Nutrient use efficiency (kg yield kg^{-1} nutrient applied) was worked out by following equation.

$$NUE = \frac{\text{Yield of treated plot - Yield of control plot}}{\text{Nutrient applied}} \quad \text{..... (3.5)}$$

3.6.4.9 Uptake of nutrients

The uptake of major nutrients was worked out by multiplying dry matter accumulation to N, P and K concentration at different growth stages of crop by using the following equation.

$$\text{Uptake (kg ha}^{-1}\text{)} = \frac{\text{Total dry matter (kg ha}^{-1}\text{) x \% concentration of element}}{100} \quad \text{..... (3.6)}$$

3.7 Irrigation Studies

3.7.1 Drip irrigation set

The components of drip irrigation system such as suction pipe, pumping unit and delivery pipes were connected to main, sub mains, manifolds, laterals and emitters. The central head unit was comprised of sand filter, screen filter, back flush assembly, electric motor, pumpset, control valve, bypass valve, pressure gauges and fertilizer tank. The details of drip irrigation system are given in Table 3.9.

Table 3.9 Details of irrigation system used for tomato

Sr. No.	Aspect	Size/Specifications
1.	Type of main and sub main	Poly-vinyl chloride (PVC)
2.	Type of laterals	Linear Low Density Polyethylene LLDPE
3.	Size of main	75 mm
4.	Size of sub main	63 mm
5.	Size of laterals	16 mm
6.	Type of dripper	Inline dripper
7.	Discharge of emitter	4 lph
8.	No of laterals/treatment	4
9.	Spacing between emitters	0.50 m
10.	Spacing between laterals	1.05 m

3.7.2 Water Management

The daily pan evaporation data was recorded from USWB class pan A pan evaporimeter. The quantity of irrigation water was be calculated by using the following formula given in FAO paper No.56 (Vermerien and Jobling, 1980).

$$Etc = Ep \times Kp \times Kc \quad \text{..... (3.7)}$$

In which,

Etc = Evapotranspiration of crop (mm/day)

Ep =Pan evaporation (mm)

Kp = Pan factor (0.7)

Kc = Crop coefficient (Table 3.10)

The gross volume of water applied per plant in liter was calculated as follows.

ETCa = Etc x Wa (Karmeli and Keller, 1975).

Where,

ETCa = Actual evapotranspiaration of crop (mm)

Wa = Wettable area (60 %) (Keller and Karmeli, 1974).

$$X = Ep \times Kp \times Kc \times Ls \times Es \times Wa / EU \quad \text{..... (3.8)}$$

Where,

X = Water requirement, (lit)

Ls = Spacing between two laterals (m)

Es = Spacing between two emitters (m)

EU = Emission uniformity.

The operating time of system was calculate by

Time = X/Emitter discharge(lph)

3.7.3 Effective rainfall

Effective rainfall is the part of total rainfall, which is used directly or indirectly to meet the evapotranspiration requirement of the crop (Dastane, 1972).

In the present study, effective rainfall was computed during the irrigation period from daily crop evapotranspiration. The rainfall event of more than 2.5 mm was considered effective if it meets the crop water demand. If the rainfall was greater than the crop water demand, the rainfall equal to crop water demand was considered as the effective and the difference between rainfall and crop water demand was considered as percolation and surface runoff (Doorenbos and Pruitt, 1977). If not, the rest of the crop water demand was fulfilled by irrigation and entire rainfall was considered as effective rainfall.

Drip irrigation scheduling is influenced by rain, but not always in the obvious way. In general less than 2.5 mm of rain can be ignored since most of it all evaporated from the soil surface rather than be used by the plant. Rainfall of 0.1 inches considered effective, in the sense that much of it may reach and stay, in the root zone (Doorenbos and Pruitt, 1977).

Table 3.10. Crop coefficient used for estimating tomato water requirement

Sr. No.	DAP	Kc values
1	0-7	0.60
2	8-14	0.60
3	15-21	0.70
4	22-28	0.80
5	29-35	0.90
6	36-42	1.00
7	43-49	1.15
8	50-56	1.15
9	57-63	1.15
10	64-70	1.15
11	71-77	1.15
12	78-84	1.15
13	85-91	1.15

Table 3.10 contd….

Sr. No.	DAP	Kc values
14	92-98	1.15
15	99-105	1.15
16	106-112	1.15
17	113-119	1.15
18	120-126	1.15
19	127-133	1.15
20	134-140	0.90
21	141-147	0.90
22	148-154	0.80
23	155-161	0.80
24	162-168	0.80
25	169-175	0.70
26	176-182	0.70

3.7.3 Field water use efficiency (FWUE)

Field water use efficiency (FWUE) is defined as the ratio of yield of marketable produce of the crop and the amount of total consumptive use of water during the period of process of evapotranspiration. The water use efficiency was thus worked out by the formula.

$$FWUE = \frac{Y}{ETc} \quad \text{..... (3.9)}$$

Where,

FWUE = Field water use efficiency (kg ha^{-1}-mm)

Y = Marketable yield per unit area (kg ha^{-1})

ETc = Evapotranspiration (mm)

3.8 Economic Analysis

3.8.1 Cost of cultivation

The total cost of production was estimated by considering the various field operation charges such as wages, irrigation charges, input, plant protection measures, machinery charges, interest on working capital etc.

3.8.2 Net seasonal income

Net seasonal income was worked out by subtracting the cost of production from the gross returns for each treatment.

3.8.3 Total net income

The total net income (₹ ha^{-1}) is influenced by different treatments. The additional area is considered and calculated by addition of the corresponding values of the seasonal net income and additional net income.

3.8.4 Benefit : cost ratio

The treatment wise B:C ratio was worked out by dividing the gross monetary returns with the cost of cultivation of respective treatment.

$$\text{B:C ratio} = \frac{\text{Gross monetary returns (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}} \quad \text{..... (3.10)}$$

3.8.5 Net extra income over control

Net extra income over control (ha^{-1}) as influenced by different treatments was calculated by substracting the corresponding value of the net seasonal income from the values of the net seasonal income of control treatment.

3.8.6 Statistical analysis

For statistical analysis, a standard method of analysis of variance was used for analyzing the data using RBD design. The 'F' test of significance was used for testing the null hypothesis and appropriate standard error (SE) for each treatment effect were worked out (Panse and Sukhatme, 1967).

4. RESULTS AND DISCUSSION

The present investigation entitled, “Effect of fertigation timing on growth, yield and nutrient mobility for tomato in Inceptisol” was conducted during the *Rabi* season of the year 2014-15 and 2015-16 on the research farm of the Inter Faculty Department of Irrigation Water Management, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri.The results obtained during course of investigation are statistically analyzed and are discussed in this chapter to have clear understanding about the effect of fertigation timing on growth, yield and nutrient mobility of tomato. The results are discussed under different subheadings as below.

4.1 Plant Population

The plant population of any crop at the time of harvest is the deciding factor of yield because yield is a function of plant population at harvest per unit area and yield per plant. The mean initial and final plant population as influenced by different treatments is presented in Table 4.1. The mean initial and final plant count was 20800 and 20775 plants ha^{-1} for the year 2014-15, while it was 20669 and 20597 plants ha^{-1} for the year 2015-16.

The initial and final plant population was influenced significantly due to different fertigation timings and split aplications of fertilizers during both the year of experiment. However, the variation was very minimal (1 to 3.5% in 2014-15 and 1 to 4.5% in 2015-16). The uniform plant population was observed in all the tratments.

4.2 Growth Attributes

The various growth attributes of tomato *viz.,* plant height (cm), number of branches and number of leaves as well as leaf area (dm^2) $plant^{-1}$ was influenced significantly due to different fertigation timings and split aplications of fertilizers during both the year of investigation. The beneficial effect of fertigation on growth and development of tomato crop is well established with reference to different growth, yield attributes and yield.

4.2.1 Plant height

The plant height of tomato as influenced periodically by different treatments are presented in Table 4.2 and graphically presented in Fig 4.1 and 4.2. The mean plant height at 30, 60, 90, 120 ,150 days after transplanting and at last harvest were 56.53, 102.67, 105.94, 108.27, 109.62 and 110.87 cm, respectively for the year 2014-15, while it was 53.11, 101.43, 103.30, 104.86, 106.90 and 108.45 cm, respectively for the year 2015-16.

Table 4.1 Plant population influenced periodically by different treatments

Treatment	Plant population							
	2014-2015				2015-2016			
	Initial		Final		Initial		Final	
	Per ha	Per cent	Per ha	Per cent	Per ha	Per cent	Per ha	Per cent
T_1 : 100% fertigation in first tertile of the irrigation period	21000	99.23	20990	99.18	20800	98.28	20780	98.19
T_2 : 100% fertigation in second tertile of the irrigation period	21050	99.46	21030	99.37	20950	98.99	20900	98.75
T_3 : 100% fertigation in third tertile of the irrigation period	21100	99.70	21090	99.65	21000	99.23	20970	99.08
T_4 : 100% fertigation during complete irrigation period	20950	98.99	20900	98.75	20750	98.04	20700	97.81
T_5 : 75% fertigation + 25% soil application	20900	98.75	20850	98.52	20700	97.81	20650	97.57
T_6 : 50% fertigation + 50% soil application	20800	98.28	20760	98.09	20600	97.34	20560	97.15
T_7 : 25% fertigation + 75% soil application	20750	98.04	20700	97.81	20580	97.24	20540	97.05
T_8 : DI with 100% CF	20650	97.57	20640	97.52	20550	97.10	20420	96.48
T_9 : SI with 100% CF + foliar spray	20600	97.34	20600	97.34	20500	96.86	20300	96.39
T_{10} : SI with 100% CF	20550	97.10	20540	97.05	20480	96.77	20280	96.15
T_{11} : DI with no fertilizer	20450	96.63	20430	96.53	20450	96.63	20270	95.92
SE±	86.03	-	50.21	-	97.23	-	56.94	-
C.D. at 5 %	253.79	-	148.12	-	286.84	-	167.98	-
General mean	20800	-	20775	-	20669	-	20597	-

Table 4.2 Height of tomato influenced periodically by different treatments

Treatment	Plant height (cm)																	
	2014-2015						2015-2016						Pooled mean					
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest
T_1 : 100% fertigation in first tertile of the irrigation period	57.76	104.43	107.07	109.67	111.26	112.36	54.13	103.62	105.51	107.33	109.47	111.17	55.95	104.03	106.29	108.50	110.36	111.77
T_2 : 100% fertigation in second tertile of the irrigation period	58.33	105.26	108.33	110.67	113.47	115.42	56.69	104.41	106.33	109.38	110.31	112.85	57.51	104.84	107.33	110.02	111.89	114.14
T_3 : 100% fertigation in third tertile of the irrigation period	59.53	107.20	110.32	112.87	114.52	117.23	57.30	106.68	108.67	110.42	112.41	115.22	58.42	106.94	109.49	111.64	113.47	116.23
T_4 : 100% fertigation during complete irrigation period	56.92	103.84	106.27	109.20	110.63	111.25	53.93	102.87	104.22	106.48	108.23	109.56	55.43	103.35	105.24	107.84	109.43	110.41
T_5 : 75% fertigation + 25% soil application	56.73	103.26	105.73	108.73	109.57	110.56	53.15	101.75	103.39	105.28	107.71	108.62	54.94	102.50	104.56	107.01	108.64	109.59
T_6 : 50% fertigation + 50% soil application	56.27	102.90	105.48	108.13	109.21	110.36	52.82	100.52	102.78	104.36	106.25	107.56	54.55	101.71	104.13	106.25	107.73	108.96
T_7 : 25% fertigation + 75% soil application	55.80	102.29	104.82	107.53	108.45	109.58	51.43	99.56	101.61	102.53	105.24	106.23	53.61	100.93	103.22	105.03	106.85	107.90
T_8 : DI with 100% CF	56.27	101.72	105.27	107.00	108.31	109.41	52.55	100.40	102.41	103.29	105.73	108.16	54.41	101.06	103.84	105.15	107.02	108.79
T_9 : SI with 100% CF + foliar spray	55.92	101.00	104.63	106.62	107.53	108.62	50.47	98.77	100.43	101.44	104.32	105.53	53.19	99.89	102.53	104.03	105.92	107.07
T_{10} : SI with 100% CF	54.90	101.00	103.92	105.54	106.65	107.58	52.17	99.75	101.68	102.69	103.58	104.39	53.53	100.37	102.80	104.12	105.12	105.99
T_{11} : DI with no fertilizer	53.35	96.47	103.46	105.00	106.23	107.24	49.57	97.42	99.25	100.25	102.68	103.69	51.46	96.94	101.35	102.63	104.46	105.47
SE±	1.02	1.41	0.71	1.20	0.72	0.80	0.73	1.33	1.01	1.31	1.04	0.77	0.89	1.38	0.88	1.26	0.90	0.79
C.D. at 5 %	3.03	4.18	2.10	3.54	2.12	2.36	2.17	3.93	2.98	3.87	3.09	2.29	2.56	3.94	2.50	3.60	2.57	2.26
General mean	56.53	102.67	105.94	108.27	109.62	110.87	53.11	101.43	103.30	104.86	106.90	108.45	54.82	102.05	104.62	106.56	108.26	109.66

The mean plant height increased with the advancement of age of the plant due to indeterminate habit of tomato. The plant growth rate in terms of plant height increased per day was maximum during the period of 30 to 60 days after transplanting and there after, the rate of growth decreased.

The plant height was significantly influenced by 100% fertigated treatments. Fertilizer was applied for the same duration within the irrigation period from the start to the end of crop period, in the first tertile of the irrigation period, in the second tetrile of the irrigation period and in the third tertile of the irrigation period. Application of fertilizer in the third tertile of the irrigation period exhibited higher plant height at all the crop growth stages as compared to application of fertilizer in the second tetrile of the irrigation period and during complete irrigation period and at par with application of fertilizer in the second tetrile of the irrigation period.

The plant height was significantly influenced by split fertilized treatments. The plant height was significantly influenced by fertigation and soil application of fertilizer during different growing periods of the crop. Among the spilt fertilized treatments the 75% fertigation + 25% soil application showed higher plant height as compared to 25% fertigation + 75% soil application and drip irrigation with 100% conventional fertilizer (NK-drip and P-soil) and it was at par with 50% fertigation + 50% soil application during both the years.

Among the conventional fertilized treatments, the surface irrigation with 100% conventional fertilizer + foliar spray resulted into higher plant height as compared to surface irrigation with 100% conventional fertilizer.

In control tretments drip irrigation with no fertilizer showed minimum plant height as compared to other tretments.

Among the 100% fertigated treatments, the application of fertilizer in the third tertile of the irrigation period exhibited higher plant height at all the crop growth stages as compared to application of fertilizer in the first tertile of the irrigation period and during complete irrigation period during both the year. It was reached to its maximum of 117.23 and 115.22 cm at last harvest and at par with application of fertilizer in the second tertile of the irrigation period during both the years. However, lower plant height 111.25 and 109.56 cm were recorded by application of fertilizer during complete

irrigation period during both the years. It might be due to precise application of nitrogen, phosphorus and potassium through drip irrigation period. Plant easily absorbed nutrients and moisture from soil which resulted into increased cell multiplication and enhanced the net assimilation rate and hence increased the plant height. Abdelraouf and Ragab (2018) reported the similar impact of fertigation frequency and fertigation time on crop production.

In the spilt fertigated treatmets, the 75% fertigation (as per schedule B) + 25% soil application showed maximum plant height of 110.56 and 108.62 cm at last harvest as compared to 50% fertigation (as per schedule C) + 50% soil application. However, lowest plant height was recorded by drip irrigation with 100% conventional fertilizer (NK-drip and P-soil) 109.41 and 108.16 cm at last harvest and 25% fertigation (as per schedule D) + 75% soil application 109.58 and 106.23 cm at last harvest during 2014-15 and 2015-16. The higher dose of fertilizer applied through fertigation resulted in higher availability of nutrients in soil solution. This result was in close agreement with those obtained by Thanari and Suma (2018). Due to higher availability of major nutrient at initial stages, owing to their high amount of application and uptake by plant might have increased the vegetative growth. Similar result observed by Mohammadullah Nikzad *et al.* (2020) and Jagadeeshkanth and Sankaranarayanan (2014).

4.2.2 Number of branches plant^{-1}

Data regarding number of branches plant^{-1} of tomato as influenced by different treatments during the year 2014-15 and 2015-16 are presented in Table 4.3 and graphically presented in Fig 4.3 and 4.4. The mean number of branches plant^{-1} were 1.67, 5.11, 7.91, 9.08, 10.38 and 11.37 as well as 1.46, 5.34, 8.13, 9.24, 10.49 and 11.16 at 30, 60, 90, 120,150 days after transplanting and at last harvest during the year 2014-15 and 2015-16, respectively.

Among the eleven treatments application of fertilizer in the third tertile of the irrigation period resulted into maximum number of branches plant^{-1} as 12.70 and 12.37 at last harvest as compared to drip irrigation with no fertiliszer (10.07 and 10.17) during 2014-15 and 2015-16, respectively.

Table 4.3 No of branches as influenced periodically by different treatments

Treatment	Number of branches plant^{-1}																	
	2014-2015						2015-2016						Pooled mean					
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest
T_1 : 100% fertigation in first tertile of the irrigation period	1.92	5.73	8.53	9.80	11.10	12.03	1.77	5.87	8.63	9.90	11.00	11.93	1.84	5.80	8.58	9.85	11.05	11.98
T_2 : 100% fertigation in second tertile of the irrigation period	2.00	6.13	8.83	10.30	11.40	12.40	1.83	6.03	8.90	10.10	11.17	12.13	1.92	6.08	8.87	10.20	11.28	12.27
T_3 : 100% fertigation in third tertile of the irrigation period	2.07	6.60	9.47	10.73	11.77	12.70	2.00	6.13	9.03	10.27	11.30	12.37	2.03	6.37	9.25	10.50	11.53	12.53
T_4 : 100% fertigation during complete irrigation period	1.80	5.53	8.23	9.53	10.87	11.83	1.63	5.67	8.37	9.70	10.80	11.67	1.72	5.60	8.30	9.62	10.83	11.75
T_5 : 75% fertigation + 25% soil application	1.73	5.37	8.07	9.20	10.63	11.57	1.50	5.53	8.20	9.40	10.47	11.30	1.62	5.45	8.13	9.30	10.55	11.43
T_6 : 50% fertigation + 50% soil application	1.67	5.13	7.77	9.07	10.37	11.37	1.37	5.27	8.07	9.20	10.30	11.07	1.52	5.20	7.92	9.13	10.33	11.22
T_7 : 25% fertigation + 75% soil application	1.50	4.67	7.47	8.40	9.83	10.83	1.23	5.13	7.77	8.87	9.77	10.57	1.37	4.90	7.62	8.63	9.80	10.70
T_8 : DI with 100% CF	1.53	5.00	7.57	8.77	10.07	11.17	1.57	5.50	8.13	9.03	10.50	10.70	1.58	5.25	7.85	8.90	10.28	10.93
T_9 : SI with 100% CF + foliar spray	1.47	4.33	7.20	8.27	9.67	10.73	1.17	4.87	7.67	8.63	10.20	10.53	1.32	4.60	7.43	8.45	9.93	10.63
T_{10} : SI with 100% CF	1.40	3.93	7.07	8.10	9.47	10.33	1.03	4.63	7.47	8.40	10.07	10.37	1.22	4.28	7.27	8.25	9.77	10.35
T_{11} : DI with no fertilizer	1.27	3.73	6.83	7.70	9.00	10.07	1.00	4.07	7.20	8.13	9.80	10.17	1.13	3.90	7.02	7.92	9.40	10.12
SE±	0.09	0.3	0.16	0.20	0.07	0.10	0.06	0.23	0.14	0.20	0.07	0.10	0.08	0.29	0.16	0.20	0.08	0.11
C.D. at 5 %	0.26	1.01	0.48	0.59	0.22	0.32	0.18	0.68	0.44	0.59	0.22	0.29	0.22	0.84	0.45	0.58	0.22	0.30
General mean	1.67	5.11	7.91	9.08	10.38	11.37	1.46	5.34	8.13	9.24	10.49	11.16	1.57	5.22	8.02	9.16	10.43	11.27

The number of branches is another important morphological character contributing for spread of canopy. Among the 100% fertigated treatments the application fertilizer in the third tertile of the irrigation period significantly produced higher number of branches at all the crop growth stages. It was reached to its maximum of 12.70 and 12.37 at last harvest and it was at par with application of fertilizer in the first tertile of the irrigation period and in the second tertile of the irrigation period during both the year. The better availability of plant nutrients in the root zone through drip irrigation produced higher number of branches plant^{-1}. The similar result obtained by Selvaperumal and Muthuchamy (2017).

The number of branches plant^{-1} was significantly influenced by split fertigated tretments. Among the split fertigated tretments, 75% fertigation (as per schedule B) + 25% soil application recorded higher number of branches at all the crop growth stages. It was reached to its maximum of 11.57 and 11.30 at last harvest and it was at par with 50% fertigation (as per schedule C) + 50% soil application during 2014-15 and 2015-16. The 25% fertigation (as per schedule D) + 75% soil application showed minimum number of branches plant^{-1} as compared to other treatments during 2014-15 and 2015-16. Its might be due to better availability of nutrients to the plants. The result are in line with the findings of Rajaraman *et al.* (2011) in coriander. Jagadeeshkanth and Sankaranarayanan (2014) and Maya (1996) proposed that the increased number of branches might be due to better sink developed by auxiliary branches by large amount of available nutrients.

Among the conventional fertigated treatments, surface irrigation with 100% conventional fertilizer + 2% foliar spray at 30, 45 and 60 days after transplanting produced maximum number of branches plant^{-1} at all the crop growth stages. It was reached to its maximum of 10.79 and 10.53 at last harvest during 2014-15 and 2015-16, respectively. Surface irrigation with 100% conventional fertilizer resulted into minimum number of branches plant^{-1} (10.33 and 10.37) at last harvest during 2014-15 and 2015-16. This results are in close agreement with result obtained by Kakade *et al.* (2017) and Hebbar *et al.* (2004).

In control treatment, drip irrigation with no fertilizer produced minimum number of branches plant^{-1} 10.07 and 10.17 at last harvest during 2014-15 and 2015-16, respectively as compared to other treatments.

4.2.3 Number of leaves and Leaf Area plant^{-1}

Data regarding number of leaves plant^{-1} of tomato as influenced by different treatments during the year 2014-15 and 2015-16 are presented in Table 4.4 and graphically presented in Fig 4.5 and 4.6. The mean number of leaves plant^{-1} were 22.44, 36.31, 54.74, 72.87, 67.61 and 48.31 as well as 22.23, 35.94, 54.43, 72.29, 65.31 and 47.01 at 30, 60, 90, 120,150 days after transplanting and at last harvest during the year 2014-15 and 2015-16, respectively.

Among the eleven tratments, application of fertilizer in the third tertile of the irrigation period resulted into maximum number of leaves plant^{-1} as compared to all other treatments during the year 2014-15 and 2015-16.

The number of leaves plant^{-1} of tomato was significantly influenced by 100% fertigated treatments at all stages of crop growth. The application of fertilizer in the third tertile of the irrigation period produced higher number of leaves at all the crop growth stages as compared to application of fertilizer in the first tertile of the irrigation period and during complete irrigation period during both the year. However, it was at par with application of fertilizer in the second tertile and first tertile of the irrigation period during both the year. Significantly minimum number of leaves plant^{-1} were observed under application of fertilizer during complete irrigation period at all the crop growth stages during both the year.

The number of leaves plant^{-1} was significantly influenced by split fertilized treatments during growing period of crop. Out of the split fertilized treatments, the 75% fertigation (as per schedule B) + 25% soil application produced significantly higher number of leaves plant^{-1} as compared to 25% fertigation (as per schedule D) + 75% soil application and drip irrigation with 100% conventional fertilizer (NK-drip and P-soil) and it was at par with 50% fertigation (as per schedule C) + 50% soil application during 2014-15 and 2015-16, respectively. Minimum number of leaves plant^{-1} were observed under 25% fertigation (as per schedule D) + 75% soil application during both the years.

Table 4.4 Number of leaves as influenced periodically by different treatments

Treatment	Number of leaves plant^{-1}																	
	2014-2015						2015-2016						Pooled mean					
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest
T_1 : 100% fertigation in first tertile of the irrigation period	23.27	37.27	56.10	74.20	71.69	49.77	23.10	36.60	55.37	73.13	68.51	47.73	23.18	36.93	55.73	73.67	70.10	48.75
T_2 : 100% fertigation in second tertile of the irrigation period	23.77	37.67	56.63	74.77	72.66	50.17	23.27	37.83	55.67	73.53	69.24	48.47	23.52	37.75	56.15	74.15	70.95	49.32
T_3 : 100% fertigation in third tertile of the irrigation period	24.43	38.73	57.47	75.87	73.58	50.63	24.07	38.07	56.07	74.43	70.61	49.57	24.25	38.40	56.77	75.15	72.10	50.10
T_4 : 100% fertigation during complete irrigation period	23.07	36.63	55.57	73.77	69.64	49.30	22.80	36.20	55.03	72.70	67.27	47.40	22.93	36.42	55.30	73.23	68.46	48.35
T_5 : 75% fertigation + 25% soil application	22.90	36.33	55.17	73.20	68.55	48.60	22.67	35.90	54.70	72.30	66.39	47.13	22.78	36.12	54.93	72.75	67.47	47.87
T_6 : 50% fertigation + 50% soil application	22.60	36.00	54.73	72.63	67.62	48.13	22.27	35.60	54.37	72.07	65.58	46.60	22.43	35.80	54.55	72.35	66.60	47.37
T_7 : 25% fertigation + 75% soil application	21.73	35.53	53.57	72.13	65.48	47.37	21.57	35.17	53.77	71.60	63.64	46.20	21.65	35.35	53.67	71.87	64.56	46.78
T_8 : DI with 100% CF	22.60	36.47	54.63	73.27	66.61	48.30	22.40	36.20	54.60	72.40	64.35	47.03	22.50	36.33	54.62	72.83	65.48	47.67
T_9 : SI with 100% CF + foliar spray	21.47	35.37	53.20	71.47	63.51	47.07	21.33	35.03	53.47	71.47	62.57	46.10	21.40	35.20	53.33	71.47	63.04	46.58
T_{10} : SI with 100% CF	20.73	35.10	52.93	70.77	62.48	46.53	20.77	34.60	53.10	71.20	60.53	45.70	20.75	34.85	53.02	70.98	61.50	46.12
T_{11} : DI with no fertilizer	20.30	34.30	52.17	69.53	61.84	45.53	20.31	34.17	52.57	70.40	59.74	45.20	20.31	34.23	52.37	69.97	60.79	45.37
SE±	0.76	0.35	0.14	0.19	0.80	0.19	0.12	0.11	0.15	0.12	0.56	0.10	0.55	0.26	0.15	0.16	0.70	0.16
C.D. at 5 %	2.26	1.03	0.43	0.56	2.37	0.56	0.37	0.33	0.46	0.35	1.66	0.32	1.57	0.75	0.44	0.46	1.99	0.45
General mean	22.44	36.31	54.74	72.87	67.61	48.31	22.23	35.94	54.43	72.29	65.31	47.01	22.34	36.13	54.58	72.58	66.46	47.66

Out of the conventional fertilized treatments, the surface irrigation with 100% conventional fertilizer + 2% foliar spray at 30, 45 and 60 days after transplanting produced significantly higher number of leaves plant^{-1} as compared to surface irrigation with 100% conventional fertilizer during 2014-15 and 2015-16.

The control treatment, drip irrigation with no fertilizer resulted into minimum number of leaves plant^{-1} during 2014-15 and 2015-16.

Leaf area

Whereas, data regarding leaf area plant^{-1} of tomato as influenced by different treatments during the year 2014-15 and 2015-16 are presented in Table 4.5 and graphically presented in Fig 4.7 and 4.8. The mean leaf area plant^{-1} was 9.62, 128.0, 169.31, 177.45, 69.48 and 53.56 as well as 9.94, 126.98, 167.10, 175.92, 168.95 and 51.60 at 30, 60, 90, 120, 150 days after transplanting and at last harvest during the year 2014-15 and 2015-16, respectively.

Out of eleven treatmnets, application of fertilizer in the third tertile of the irrigation period resulted into significantly higher number of leaves and leaf area plant^{-1} at all growth stages. The higher number of leaves (75.87 and 74.43) as well as in consonance maximum leaf area was (179.70 and 177.73 dm^2) noticed at 120 days after transplanting during 2014-15 and 2015-16. The drip irrigation with no fertilizer showed minimum number of leaves and leaf area plant^{-1} at all growth stages.

In 100% fertigated treatments, the application of fertilizer in the third tertile of the irrigation period produced significantly higher number of leaves and leaf area plant^{-1} at all growth stages and was at par with application of fertilizer in the second tertile and first tertile of the irrigation period during 2014-15 and 2015-16. The minimum number of leaves and leaf area plant^{-1} were observed under application of fertilizer during complete irrigation period at all growth stages during 2014-15 and 2015-16. The higher number of leaves 75.87 and 74.43 and maximum leaf area 179.70 and 177.73 dm^2 was noticed at 120 days after transplanting during both the years. Thereafter, number of leaves and leaf area were reduced up to last harvest due to senescence.The higher values of these parameters in 100% fertigated treatments might be due sufficient soil moisture available for pronounced crop growth which supported the maximum absorbance of moisture and nutrients by crop and reflected in higher cell growth. The similar results are

Table 4.5 Leaf area of tomato influenced periodically by different treatments

Treatment	Leaf area plant^{-1}																	
	2014-2015						2015-2016						Pooled mean					
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest
T_1 : 100% fertigation in first tertile of the irrigation period	10.37	129.33	170.40	178.23	170.70	54.67	10.43	127.77	168.10	176.57	169.63	52.67	10.40	128.55	169.25	177.40	170.17	53.67
T_2 : 100% fertigation in second tertile of the irrigation period	10.67	129.63	170.67	178.60	171.63	55.20	10.77	128.07	168.43	177.30	170.33	53.37	10.72	128.85	169.55	177.95	170.98	54.28
T_3 : 100% fertigation in third tertile of the irrigation period	11.13	130.53	171.13	179.70	172.47	55.77	11.03	128.43	168.73	177.73	170.67	53.77	11.08	129.48	169.93	178.72	171.57	54.77
T_4 : 100% fertigation during complete irrigation period	9.77	128.50	170.10	177.83	170.33	54.20	10.30	127.50	167.67	176.33	169.40	52.33	10.03	128.00	168.88	177.08	169.87	53.27
T_5 : 75% fertigation + 25% soil application	9.43	128.13	169.60	177.33	170.07	53.67	10.07	127.13	167.43	176.10	169.13	51.73	9.75	127.63	168.52	176.72	169.60	52.70
T_6 : 50% fertigation + 50% soil application	9.23	127.77	169.23	177.07	169.57	53.27	9.77	126.70	167.10	175.67	168.70	51.43	9.50	127.23	168.17	176.37	169.13	52.35
T_7 : 25% fertigation + 75% soil application	9.07	127.27	168.73	176.73	168.67	52.73	9.33	126.30	166.53	175.10	168.40	52.43	9.20	126.78	167.63	175.92	168.53	52.58
T_8 : DI with 100% CF	9.60	126.67	169.30	177.57	169.17	53.40	10.20	127.17	167.23	176.20	169.07	51.17	9.90	126.92	168.27	176.88	169.12	52.28
T_9 : SI with 100% CF + foliar spray	9.10	127.33	168.30	176.60	167.73	52.53	9.57	126.23	166.20	175.13	168.23	50.60	9.33	126.78	167.25	175.87	167.98	51.57
T_{10} : SI with 100% CF	8.87	126.63	167.73	176.47	167.43	52.20	9.13	125.90	165.47	174.67	167.70	49.33	9.00	126.27	166.60	175.57	167.57	50.77
T_{11} : DI with no fertilizer	8.63	126.17	167.20	175.77	166.53	51.53	8.70	125.60	165.20	174.27	167.23	48.73	8.67	125.88	166.20	175.02	166.88	50.13
SE±	0.09	0.12	0.13	0.13	0.18	0.11	0.06	0.09	0.10	0.10	0.12	0.10	0.08	0.11	0.12	0.12	0.15	0.11
C.D. at 5 %	0.26	0.37	0.39	0.40	0.53	0.32	0.18	0.28	0.30	0.31	0.35	0.30	0.22	0.32	0.34	0.35	0.44	0.30
General mean	9.62	128.0	169.31	177.45	69.48	53.56	9.94	126.98	167.10	175.92	168.95	51.60	9.78	127.49	168.20	176.68	169.22	52.58

observed by Sanchita *et al.* (2010). The increased fertilizer dose in water soluble form, increased the uptake of nutrients which might have improved the photosynthetic efficiency of plants and thus resulted in improvement in leaf area index.

Among split fertilized tretaments, the 75% fertigation and 25% soil application produced significantly higher number of leaves and leaf area plant^{-1} at all the growth stages as compared to 50% fertigation + 50% soil application, 25% fertigation + 75% soil application and drip irrigation with 100% conventional fertilizer (NK-drip and P-soil) during both 2014-15 and 2015-16. The higher number of leaves (73.20 and 72.30) and as well as leaf area (177.33 and 176.10 dm^2) was noticed at 120 days after transplanting during 2014-15 and 2015-16. This might be due to adequate amount of nutrient supply through fertigation lead to better crop growth, which in turn resulted in increased plant height and ultimately more number of leaves and better leaf development. Thereafter, number of leaves and leaf area were reduced up to last harvest due to senescence. This results are in close agreement with those obtained by Hebbar *et al.* (2004), Shaymaa *et al.* (2009) and Sampathkumar and Pandian (2010). Higher leaf area index with drip irrigation than furrow irrigation has been reported by Chawla and Narda (2000).

The surface irrigation with 100% conventional fertilizer + foliar spray produced significantly higher number of leaves and leaf area plant^{-1} at all the growth stages during 2014-15 and 2015-16. The higher number of leaves (71.47 and 71.47) and as well as leaf area (176.60 and 175.13 dm^2) was noticed in this treatment at 120 days after transplanting during 2014-15 and 2015-16 as compared to surface irrigation with 100% conventional fertilizer (70.77 and 71.20) and (176.47 and 174.67 dm^2) noticed at 120 days after transplanting during 2014-15 and 2015-16, respectively. This might be due to the effect of nutrinets on promoting growth to enhance synthesis and accumulation of proteins, amino acids and enzymes responsible for cell division and cell elongation.

In control treatments drip irrigation with no fertilizer resulted into significantly minimum number of leaves (69.53 and 70.40) and as well as leaf area (175.77 and 174.27 dm^2) at 120 days after transplanting during 2014-15 and 2015-16, respectively.

4.3 Yield Attributes and Fruit Yield

4.3.1 Number of fruits

The data regarding number of fruits per plant as influenced by different treatments during both the years and pooled mean basis are presented in Table 4.6. The mean number of fruit yield was 62.10, 61.83 and 61.97 plant^{-1} during 2014-2015, 2015-2016 and pooled mean, respectively.

Among the eleven treatments, the application of fertilizer in the third tertile of the irrigation period resulted into maximum number of fruits plant^{-1} 73.35, 73.22 and 73.29 during 2014-2015, 2015-2016 and pooled mean as compared to other tretments

Table 4.6 Number of fruits per plant of tomato influenced periodically by different treatments

Treatment	Number of fruits plant^{-1}		
	2014-2015	**2015-2016**	**Pooled mean**
T_1 : 100% fertigation in first tertile of the irrigation period	69.27	68.43	68.85
T_2 : 100% fertigation in second tertile of the irrigation period	71.50	71.29	71.39
T_3 : 100% fertigation in third tertile of the irrigation period	73.35	73.22	73.29
T_4 : 100% fertigation during complete irrigation period	67.48	67.41	67.45
T_5 : 75% fertigation + 25% soil application	65.57	64.54	65.06
T_6 : 50% fertigation + 50% soil application	62.24	62.10	62.17
T_7 : 25% fertigation + 75% soil application	59.34	59.24	59.29
T_8 : DI with 100% CF	56.16	56.06	56.11
T_9 : SI with 100% CF + foliar spray	55.23	55.17	55.20
T_{10} : SI with 100% CF	52.44	52.36	52.40
T_{11} : DI with no fertilizer	50.56	50.29	50.43
SE±	0.65	0.67	0.66
C.D. at 5 %	1.92	1.96	1.88
General mean	62.10	61.83	61.97

In 100% fertigated treatments, the application of fertilizer in the third tertile of the irrigation period exhibited significantly maximum number of fruits plant^{-1} as 73.35, 73.22 and 73.29 during 2014-2015, 2015-2016 and pooled mean and the application of fertilizer during complete irrigation period registered significantly lower

number of fruits plant^{-1} 67.48, 67.41 and 67.45 during 2014-2015, 2015-2016 and pooled mean. The application of nutrients directly around plant root system with drip irrigation become quite useful as there was no leaching loss and the optimum soil moisture which was prevailing resulted in a better utilization of applied nutrients. Similar result observed by Hebbar *et al.* (2004) and Badr *et al.* (2010).

In split fertilized treatments, the 75% fertigation + 25% soil application recorded higher number of fruits plant^{-1} 65.57, 64.54 and 65.06 during 2014-2015, 2015-2016 and pooled mean, respectively. The drip irrigation with 100% conventional fertilizer exhibited minimum number of fruits plant^{-1} 56.16, 56.06 and 56.11 during first, second year and pooled mean, respectively.

The normal fertilizer however, generally tends to cause uneven distribution of fertilizers in the root zone. Alternatively, all of the soluble N, P and K fertilizer can be applied via fertigation through drip system, to obtain proper distribution in soil. This is the evidence for the longer activity in fertigation where nutrients were applied through 12 split doses to match the nutrients uptake by the crop. This enhanced the photosynthesis for developing fruit leading to the development of fruit to marketable size and producing more number of fruits per plant and fruit weight in fertigation treatments compared to soil application treatments. Similar result recorded by Shaymaa *et al.* (2009). The drip fertigation at 80 per cent of recommended N and K level with water soluble fertilizers registered higher tomato yield (22.3 t ha^{-1}) compared to 100 per cent and 60 per cent of recommended levels in drip irrigation period (Muralidhar *et al.*, 1999 and Badr *et al.,* 2010).

In conventional fertilized treatments, the surface irrigation with 100% conventional fertilizer + foliar spray at 30 resulted significantly higher number of fruits plant^{-1} 55.23, 55.17 and 55.20 during 2014-2015, 2015-2016 and pooled mean, respectively. Surface irrigation with 100% conventional fertilizer exhibited significantly minimum number of fruits plant^{-1} 52.44, 52.36 and 52.40 during 2014-2015, 2015-2016 and pooled mean. This result was in close agreement with result obtained by Hebbar *et al.* (2004), Snehitha *et al.* (2019) and Pawar *et al.* (2018).

In control treatment of drip irrigation with no fertilizer resulted minimum number of fruits plant^{-1} 50.56, 50.29 and 50.43 during 2014-2015, 2015-2016 and pooled mean, respectively.

4.3.2 Weight of fruits

The data regarding weight of fruits plant^{-1} as influenced by different treatments during both the year and pooled mean basis are presented in Table 4.7. The mean weight of fruits plant^{-1} was 2.22, 2.20 and 2.21 during 2014-2015, 2015-2016 and pooled mean respectively.

Table 4.7 Weight of fruits per plant of tomato influenced periodically by different treatments

Treatment	Weight of fruits plant^{-1}		
	2014-2015	**2015-2016**	**Pooled mean**
T_1 : 100% fertigation in first tertile of the irrigation period	2.63	2.62	2.63
T_2 : 100% fertigation in second tertile of the irrigation period	2.68	2.67	2.67
T_3 : 100% fertigation in third tertile of the irrigation period	2.72	2.71	2.72
T_4 : 100% fertigation during complete irrigation period	2.54	2.52	2.53
T_5 : 75% fertigation + 25% soil application	2.41	2.40	2.41
T_6 : 50% fertigation + 50% soil application	2.36	2.34	2.35
T_7 : 25% fertigation + 75% soil application	2.20	2.18	2.19
T_8 : DI with 100% CF	1.86	1.84	1.85
T_9 : SI with 100% CF + foliar spray	1.80	1.79	1.80
T_{10} : SI with 100% CF	1.65	1.63	1.64
T_{11} : DI with no fertilizer	1.53	1.52	1.53
SE±	0.01	0.01	0.17
C.D. at 5 %	0.04	0.03	0.06
General mean	2.22	2.20	2.21

Among the eleven traetments, the application of fertilizer in the third tertile of the irrigation period resulted significantly higher weight of fruits plant^{-1} as 2.72, 2.71 and 2.72 kg and drip irrigation with no fertilizer exhibited minimum weight of fruits

plant^{-1} 1.53, 1.52 and 1.53 kg during 2014-2015, 2015-2016 and pooled mean, respectively.

In 100% fertigated treatments, the application of fertilizer in the third tertile of the irrigation period exhibited significantly higher weight of fruits plant^{-1} as 2.72, 2.71 and 2.72 during 2014-2015, 2015-2016 and pooled mean and the application of fertilizer during complete irrigation period resulted significantly lower weight of fruits plant^{-1} 2.54, 2.52 and 2.53 during 2014-2015, 2015-2016 and pooled mean. The application of nutrients uniformly around plant root system with drip became quite useful as there was no leaching loss and the optimum soil moisture which hepled in a better utilization of applied nutrients. Similar result observed by Hebbar *et al.* (2004) and Badr *et al.* (2010).

Out of the split fertilized treatments, the 75% fertigation + 25% soil application observed higher weight of fruits plant^{-1} as 2.41, 2.40 and 2.41 during 2014-2015, 2015-2016 and pooled mean. The drip irrigation with 100% conventional fertilizer (NK-drip and P-soil) resulted lower weight of fruits plant^{-1} 1.86, 1.84 and 1.85 during first, second year and pooled mean.

In conventional fertilized treatments, the surface irrigation with 100% conventional fertilizer and foliar sprays resulted into significantly higher weight of fruits plant^{-1} as 1.80, 1.79 and 1.80 during 2014-2015, 2015-2016 and pooled mean. Its might be due to efficient translocation of photosynthates to the reproductive parts due to supply of adequate nutrient levels might be responsible for the production of elevated level of yield structure. This result was in close agreement with result obtained by Hebbar *et al.* (2004), Snehitha *et al.* (2019) and Pawar *et al.* (2018).

In control treatments drip irrigation with no fertilizer resulted minimum weight of fruits plant^{-1} 1.53, 1.52 and 1.53 during 2014-2015, 2015-2016 and pooled mean, respectively.

4.3.3 Fruit yield

The data regarding yield of tomato as influenced by different treatments during both the year and pooled mean basis are presented in Table 4.8 and graphically presented in Fig 4.9 and 4.10. The mean fruit yield was 61.24, 73.51 and 67.37 t ha^{-1} during 2014-2015, 2015-2016 and pooled mean, respectively.

Table 4.8 Fruit yield of tomato influenced by different treatments

Treatment	Fruit yield (t ha^{-1})		
	2014-2015	**2015-2016**	**Pooled mean**
T_1 : 100% fertigation in first tertile of the irrigation period	75.68	90.61	83.15
T_2 : 100% fertigation in second tertile of the irrigation period	75.81	98.27	87.04
T_3 : 100% fertigation in third tertile of the irrigation period	78.50	96.56	87.53
T_4 : 100% fertigation during complete irrigation period	72.89	93.52	83.21
T_5 : 75% fertigation + 25% soil application	64.37	73.33	68.85
T_6 : 50% fertigation + 50% soil application	56.36	63.01	59.68
T_7 : 25% fertigation + 75% soil application	55.06	63.35	59.21
T_8 : DI with 100% CF	56.96	65.97	61.47
T_9 : SI with 100% CF + foliar spray	51.51	58.73	55.12
T_{10} : SI with 100% CF	45.78	54.25	50.02
T_{11} : DI with no fertilizer	30.75	40.96	35.86
SE±	1.20	1.33	0.80
C.D. at 5 %	3.57	4.15	2.10
General mean	60.33	72.60	66.47

Out of the eleven treatments, application of fertilizer in the third tertile of the irrigation period resulted into significantly maximum fruit yield of 78.50 and 87.53 t ha^{-1} during 2014-2015 on pooled mean, respectively. Whereas, the application of fertilizer in the second tertile of the irrigation period produced higher fruit yield of 98.27 during 2015-2016 and on pooled mean, respectively. The drip irrigation with no fertilizer resulted minimum fruit yield of 30.75, 40.96 and 35.86 during 2014-2015, 2015-2016 and on pooled mean, respectively.

Among the 100% fertigated treatments, the application of fertilizer in the third tertile of the irrigation period produced significantly maximum fruit yield of 78.50 t ha^{-1} during 2014-2015 and the application of fertilizer in the second tertile of the irrigation period registered maximum fruit yield of 98.27 and 87.04 t ha^{-1} during 2015-2016 and on pooled mean, respectively. The application of fertilizer during complete irrigation period indicated significantly lower fruit yield of 72.89 t ha^{-1} during 2014-2015 and application of fertilizer in the first tertile of the irrigation period indicated significantly minimum fruit yield of 90.61 t ha^{-1} and 83.15 t ha^{-1} during 2015-2016 and

pooled mean, respectively. The Irrigation – Fertigation – Irrigation cycle in this treatment might have created the complete wetting of root zone in first tertile, application of water soluble fertilizers uniformly in atready wetted soil in second terile and moving fertilizers further in vertical and horizontal direction through were water application in third tertile. The whole process has resulted into uniform water and fertilizer application in larger proportion of root zone through out the crop growth period. This way of application of nutrients directly around plant root system with drip irrigation become quite useful as there was no leaching loss and the optimum soil moisture was maintained throught prevailing season resulted in a better utilization of applied nutrients. Similar result observed by Hebbar *et al.* (2004) and Rimcharoen and Wonprasaid (2016).

In split fertilized treatments, the 75% fertigation + 25% soil application registered higher fruit yield of 64.37, 73.33 and 68.85 t ha^{-1} during 2014-2015, 2015-2016 and on pooled mean as compared to 50% fertigation + 50% soil application, 25% fertigation + 75% soil application and drip irrigation with 100% conventional fertilizer (NK-drip and P-soil). It might be due to higher plant height, higher number branches and leaves which make the plants vegetative vigorous thus results in higher yield. Maximum proportion of recommended dose of fertilizers applied through fertigation resulted in higher availability of nutrients in soil solution which obviously led to increased growth, ultimately increased the yield. Similar results are reported by Jagadeeshkanth and Sankaranarayanan (2014). Soluble N, P and K fertilizer applied via fertigation through drip system enhanced the photosynthesis leading to the development of fruit to marketable size and producing more number of fruits per plant and fruit weight in fertigation treatments compared to soil application treatments (Shaymaa *et al.* 2009, Muralidhar *et al.* 1999).

Out of the conventional fertigated treatments, surface irrigation with 100% conventional fertilizer and foliar spray produced significantly higher fruit yield of 51.51, 58.73 and 55.12 t ha^{-1} during 2014-2015, 2015-2016 and on pooled mean as compared to surface irrigation with 100% conventional fertilizer. Its might be due to efficient translocation of photosynthates to the reproductive parts due to supply of adequate nutrients through foliar application might be responsible for the production of elevated

level of yield structure. This result was in close agreement with result obtained Hebbar *et al.* 2004, Snehitha *et al.* (2019) and Pawar *et al.* (2018).

4.4 Micrometeorological Studies

4.4.1 CO_2 concentration

Data regarding CO_2 concentration as influenced by different treatments at all the growth stages of tomato during 2014-15 and 2015-16 are presented in Table 4.9 and graphically presented in Fig 4.11 and 4.12. The mean CO_2 concentration was 364.01, 379.74, 355.40 and 340.76 as well as 361.77, 377.21, 354.40 and 336.64 μ mol m^{-2} s^{-1} at 45, 90, 135 days after transplanting and at last harvest during first and second year, respectively.

In eleven teatments, the application of fertilizer in the third tertile of the irrigation period registered significantly higher co_2 concentration at all the crop growth stages during 2014-15 and 2015-16 and drip irrigation with no fertilizer resulted into minimum co_2 concentration at all the crop growth stages during 2014-15 and 2015-16.

Out of the 100% fertigated treatments, the application of fertilizer in the third tertile of the irrigation period registered significantly higher co_2 concentration at all the crop growth stages during both the year and it was at par with application of fertilizer in the second tertile of the irrigation period at 45, 90, 135 days after transplanting during first year and at 45 and 135 days after transplanting during second year and the application of fertilizer during complete irrigation period showed lower co_2 concentration at all the crop growth stages during 2014-15 and 2015-16.

In split fertilized treatments, the application of 75% fertigation + 25% soil application registered significantly higher co_2 concentration during both the year and it was at par with 50% fertigation + 50% soil application at 45, 90, 135 days after transplanting and at last harvest during first year and at 45, 90 and at last harvest during second year. The 25% fertigation (as per schedule D) + 75% soil application produced significantly lower co_2 concentration during both the years.

Among conventional fertilized treatments, the surface irrigation with 100% conventional fertilizer and foliar spray registered significantly higher CO_2 concentration at all the crop growth stages during both the year as compared to surface irrigation with 100% conventional fertilizer.

Table 4.9 CO_2 concentration of tomato influenced periodically by different treatments

Treatment	CO_2 concentration (μ mol m^{-2} s^{-1})											
	2014-2015				2015-2016				Pooled mean			
	45 DAT	90 DAT	135 DAT	At harvest	45 DAT	90 DAT	135 DAT	At harvest	45 DAT	90 DAT	135 DAT	At harvest
T_1 : 100% fertigation in first tertile of the irrigation period	367.65	383.25	360.42	343.29	365.93	380.63	359.45	340.41	366.79	381.94	359.94	341.85
T_2 : 100% fertigation in second tertile of the irrigation period	369.56	384.75	362.73	344.83	366.08	381.56	360.81	341.45	367.82	383.15	361.77	343.14
T_3 : 100% fertigation in third tertile of the irrigation period	371.38	385.21	363.87	346.42	367.29	383.47	361.42	343.58	369.34	384.34	362.65	345.00
T_4 : 100% fertigation during complete irrigation period	366.84	382.66	358.19	342.26	363.87	379.24	357.46	339.16	365.35	380.95	357.83	340.71
T_5 : 75% fertigation + 25% soil application	364.70	381.60	355.54	341.84	362.41	378.89	356.26	337.49	363.55	380.24	355.90	339.66
T_6 : 50% fertigation + 50% soil application	363.67	380.28	354.13	340.70	361.78	377.67	354.84	336.47	362.73	378.98	354.49	338.59
T_7 : 25% fertigation + 75% soil application	361.76	376.40	352.63	338.35	360.30	375.40	351.91	334.63	361.03	375.90	352.27	336.49
T_8 : DI with 100% CF	362.82	378.57	353.37	339.62	361.27	376.20	352.64	335.54	362.05	377.39	353.01	337.58
T_9 : SI with 100% CF + foliar spray	360.56	376.18	350.54	338.61	358.53	373.44	350.54	332.74	359.55	374.81	350.54	335.68
T_{10} : SI with 100% CF	358.41	374.93	349.60	336.83	356.57	372.19	347.96	331.54	357.49	373.56	348.78	334.19
T_{11} : DI with no fertilizer	356.74	373.30	348.35	335.64	355.38	370.63	345.10	330.05	356.06	371.96	346.73	332.84
SE±	0.80	0.86	0.62	0.79	0.82	0.76	1.06	0.56	0.81	0.82	0.88	0.69
C.D. at 5 %	2.38	2.56	1.85	2.35	2.42	2.24	3.15	1.65	2.33	2.34	2.50	1.97
General mean	364.01	379.74	355.40	340.76	361.77	377.21	354.40	336.64	362.89	378.48	354.90	338.70

In control treatments, drip irrigation with no fertilizer resulted minimum co_2 concentration during 2014-15 and 2015-16.

4.4.2 Photosynthetic rate

Data pertaining photosynthetic rate as influenced by different treatments at all the growth stages of tomato during 2014-15 and 2015-16 are presented in Table 4.10 and graphically presented in Fig 4.13 and 4.14. The mean photosynthetic rate was 20.71, 22.87, 13.36 and 36.85 as well as 19.04, 20.74, 11.81 and 6.34 μ mol m^{-2} s^{-1} at 45, 90, 135 days after transplanting and at last harvest during first and second year, respectively.

Among the eleven treatments, the application of fertilizer in the third tertile of the irrigation period registered significantly higher photosynthetic rate at all the crop growth stages during 2014-15 and 2015-16 and drip irrigation with no fertilizer resulted lower photosynthetic rate at all the crop growth stages during 2014-15 and 2015-16.

Out of the 100% fertigated treatments, the application of fertilizer in the third tertile of the irrigation period registered significantly higher photosynthetic rate at all the crop growth stages during both the year and it was at par with application of fertilizer in the second tertile, first tertile and during complete irrigation period at 45, 90, 135 days after transplanting and at last harvest during first and second year.

In split fertilized tretments, the application of 75% fertigation + 25% soil application registered significantly maximum photosynthetic rate during both the year and it was at par with 50% fertigation + 50% soil application at 45, 90, 135 days after transplanting and at last harvest during first year and at 45 days after transplanting during second year and drip irrigation with 100% conventional fertilizer at 45, 90, 135 days after transplanting during 2014-15 and 2015-16. The 25% fertigation + 75% soil application registered significantly lowest photosynthetic rate during both the years.

In conventional fertilized treatments, the surface irrigation with 100% conventional fertilizer and foliar spray exhibited significantly higher photosynthetic rate at all the crop growth stages during both the years as compared to the surface irrigation with 100% conventional fertilizer.

In control treatment of drip irrigation with no fertilizer exhibited significantly lower photosynthetic rate at all the crop growth stages during 2014-15 and 2015-16.

Table 4.10 Photosynthetic rate of tomato influenced periodically by different treatments

Treatment	Photosynthetic rate (μ mol m^{-2} s^{-1})											
	2014-2015				2015-2016				Pooled mean			
	45 DAT	90 DAT	135 DAT	At harvest	45 DAT	90 DAT	135 DAT	At harvest	45 DAT	90 DAT	135 DAT	At harvest
T_1 : 100% fertigation in first tertile of the irrigation period	23.72	25.51	15.56	9.53	21.77	24.62	14.56	8.72	22.75	25.07	15.06	9.12
T_2 : 100% fertigation in second tertile of the irrigation period	24.22	26.60	16.75	10.46	22.75	25.73	15.66	9.63	23.49	26.17	16.20	10.05
T_3 : 100% fertigation in third tertile of the irrigation period	25.42	27.76	17.67	11.34	23.60	26.81	16.45	10.09	24.51	27.29	17.06	10.71
T_4 : 100% fertigation during complete irrigation period	22.33	24.79	14.41	8.51	20.80	23.11	13.59	8.51	21.57	23.95	14.00	8.51
T_5 : 75% fertigation + 25% soil application	21.54	23.71	13.61	7.53	19.50	22.51	12.43	7.96	20.52	23.11	13.02	7.75
T_6 : 50% fertigation + 50% soil application	20.65	22.78	12.36	6.44	18.54	20.46	10.72	5.63	19.59	21.62	11.54	6.03
T_7 : 25% fertigation + 75% soil application	18.63	20.80	11.41	4.70	16.82	18.57	9.68	3.67	17.73	19.69	10.55	4.18
T_8 : DI with 100% CF	19.51	21.25	12.45	5.51	17.47	19.43	10.23	4.65	18.49	20.34	11.34	5.08
T_9 : SI with 100% CF + foliar spray	17.58	20.52	11.29	4.21	16.41	17.49	9.35	4.16	16.99	19.01	10.32	4.18
T_{10} : SI with 100% CF	17.42	19.56	11.03	3.75	16.20	15.12	8.84	3.68	16.81	17.34	9.94	3.71
T_{11} : DI with no fertilizer	16.75	18.25	10.44	3.40	15.55	14.33	8.37	3.10	16.15	16.29	9.40	3.25
SE±	0.70	0.78	0.70	0.47	19.04	20.74	11.81	6.34	0.69	0.73	0.61	0.49
C.D. at 5 %	2.07	2.32	2.08	1.40	0.669	0.672	0.503	0.506	1.96	2.09	1.75	1.41
General mean	20.71	22.87	13.36	6.85	1.973	1.983	1.484	1.493	19.87	21.81	12.58	6.60

4.4.3 Stomatal conductance

Data regarding stomatal conductance as influenced by different treatments at all the growth stages of tomato during 2014-15 and 2015-16 are presented in Table 4.11. The mean stomatal conductance was 0.54, 0.62, 0.29 and 0.13 as well as 0.52, 0.60, 0.27 and 0.12 mol H_2O m^{-2} s^{-1} at 45, 90, 135 days after transplanting and at last harvest during first and second year, respectively.

Among the eleven treatments, the application of fertilizer in the third tertile of the irrigation period showed significantly higher stomatal conductance at all the crop growth stages during 2014-15 and 2015-16 and drip irrigation with no fertilizer exhibited lowest stomatal conductance at all the crop growth stages during 2014-15 and 2015-16.

In 100% fertigated treatments, the application of fertilizer in the third tertile of the irrigation period showed significantly higher stomatal conductance at all the crop growth stages during both the years and it was at par with application of fertilizer in the second tertile, first tertile and during complete irrigation period at 45 days after transplanting and at last harvest during first and second year.

Among the split fertilized treatments, the application of 75% fertigation + 25% soil application exhibited significantly higher stomatal conductance during both the years and it was showed at par value with 50% fertigation + 50% soil application at 45, 90, 135 days after transplanting and at last harvest during first year and at 90 days after transplanting and at last harvest during second year. The 25% fertigation + 75% soil application registered significantly lower stomatal conductance during both the years.

In conventional fertilized treatments, the surface irrigation with 100% conventional fertilizer + foliar sprays showed significantly higher stomatal conductance at all the crop growth stages during both the year as compared to surface irrigation with 100% conventional fertilizer.

In control treatment of drip irrigation with no fertilizer exhibited minimum stomatal conductance at all the crop growth stages during 2014-15 and 2015-16 as compared to all other treatments.

Table 4.11 Stomatal conductance of tomato influenced periodically by different treatments

Treatment	Stomatal conductance (mol H_2O m^{-2} s^{-1})											
	2014-2015				2015-2016				Pooled mean			
	45 DAT	90 DAT	135 DAT	At harvest	45 DAT	90 DAT	135 DAT	At harvest	45 DAT	90 DAT	135 DAT	At harvest
T_1 : 100% fertigation in first tertile of the irrigation period	0.59	0.68	0.33	0.17	0.57	0.67	0.31	0.15	0.58	0.67	0.32	0.16
T_2 : 100% fertigation in second tertile of the irrigation period	0.60	0.69	0.35	0.18	0.58	0.68	0.32	0.17	0.59	0.69	0.34	0.18
T_3 : 100% fertigation in third tertile of the irrigation period	0.61	0.72	0.36	0.19	0.59	0.70	0.33	0.18	0.60	0.71	0.35	0.19
T_4 : 100% fertigation during complete irrigation period	0.58	0.66	0.32	0.16	0.55	0.64	0.30	0.14	0.57	0.65	0.31	0.15
T_5 : 75% fertigation + 25% soil application	0.57	0.64	0.30	0.14	0.54	0.62	0.29	0.13	0.56	0.63	0.30	0.14
T_6 : 50% fertigation + 50% soil application	0.56	0.63	0.29	0.13	0.52	0.61	0.27	0.12	0.54	0.62	0.28	0.12
T_7 : 25% fertigation + 75% soil application	0.54	0.59	0.27	0.11	0.54	0.58	0.25	0.10	0.54	0.59	0.26	0.11
T_8 : DI with 100% CF	0.55	0.61	0.28	0.12	0.51	0.59	0.26	0.11	0.53	0.60	0.27	0.12
T_9 : SI with 100% CF + foliar spray	0.48	0.57	0.26	0.10	0.47	0.55	0.23	0.09	0.48	0.56	0.24	0.10
T_{10} : SI with 100% CF	0.44	0.53	0.24	0.09	0.43	0.49	0.22	0.08	0.44	0.51	0.23	0.09
T_{11} : DI with no fertilizer	0.42	0.47	0.23	0.08	0.39	0.45	0.20	0.08	0.41	0.46	0.22	0.08
SE±	0.54	0.62	0.29	0.13	0.52	0.60	0.27	0.12	0.01	0.01	0.01	0.01
C.D. at 5 %	0.006	0.007	0.007	0.007	0.006	0.008	0.007	0.006	0.02	0.02	0.02	0.02
General mean	0.019	0.021	0.022	0.023	0.018	0.025	0.020	0.019	0.53	0.61	0.28	0.13

4.4.4 Stomatal resistance

Data regarding stomatal resistance as influenced by different treatments at all the growth stages of tomato during 2014-15 and 2015-16 are presented in Table 4.12. The mean stomatal resistance was 5.50, 2.43, 4.36 and 10.07 as well as 5.09, 2.19, 4.00 and 9.56 mol H_2O m^{-2} s^{-1} at 45, 90, 135 days after transplanting and at last harvest during first and second year, respectively.

In eleven treatments, the application of fertilizer in the third tertile of the irrigation period exhibited significantly maximum stomatal resistance at all the crop growth stages during 2014-15 and 2015-16 and drip irrigation with no fertilizer resulted into minimum stomatal resistance at all the crop growth stages during 2014-15 and 2015-16.

Out of the 100% fertigated treatments, the application of fertilizer in the third tertile of the irrigation period registered significantly maximum stomatal resistance at all the crop growth stages during both the year and it was showed at par value with application of fertilizer in the second tertile, first tertile and during complete irrigation period at 45, 90, 135 days after transplanting and at last harvest during first and second year.

Among the split fertilized treatments, the application of 75% fertigation + 25% soil application resulted into significantly higher stomatal resistance during both the years and it was at par with 50% fertigation + 50% soil application and drip irrigation with 100% conventional fertilizer application at 45, 90, 135 days after transplanting and at last harvest during 2014-15 and 2015-16. The 25% fertigation + 75% soil application showed minimum stomatal resistance at 45, 90, 135 days after transplanting and at last harvest during first and second year.

In conventional fertilized tretments, the surface irrigation with 100% conventional fertilizer + foliar spray registered significantly higher stomatal resistance at all the crop growth stages during 2014-15 and 2015-16 as compared to surface irrigation with 100% conventional fertilizers during both the years.

4.4.5 Transpiration rate

Data regarding transpiration rate as influenced by different treatments at all the growth stages of tomato during 2014-15 and 2015-16 are presented in Table 4.13 and graphically presented in Fig 4.15 and 4.16. The mean transpiration rate was 9.92, 10.93, 9.36 and 7.63 as well as 9.68, 10.57, 9.09 and 7.36 μ mol. CO_2 m^{-2} s^{-1} at 45, 90, 135 days after transplanting and at last harvest during first and second year, respectively.

Table 4.12 Stomatal resistant of tomato influenced periodically by different treatments

Treatment	Stomatal resistant (mol H_2O m^{-2} s^{-1})											
	2014-2015				2015-2016				Pooled mean			
	45 DAT	90 DAT	135 DAT	At harvest	45 DAT	90 DAT	135 DAT	At harvest	45 DAT	90 DAT	135 DAT	At harvest
T_1 : 100% fertigation in first tertile of the irrigation period	6.28	3.10	5.18	11.65	6.07	2.87	5.03	10.72	6.18	2.99	5.11	11.19
T_2 : 100% fertigation in second tertile of the irrigation period	6.76	3.44	5.65	12.56	6.19	3.07	5.33	11.57	6.47	3.25	5.49	12.07
T_3 : 100% fertigation in third tertile of the irrigation period	7.44	3.74	5.81	13.53	6.66	3.14	5.48	12.48	7.05	3.44	5.65	13.01
T_4 : 100% fertigation during complete irrigation period	5.83	2.86	4.74	10.59	5.28	2.75	4.48	10.40	5.56	2.81	4.61	10.49
T_5 : 75% fertigation + 25% soil application	5.68	2.66	4.59	10.18	5.14	2.41	4.18	10.07	5.39	2.53	4.38	10.12
T_6 : 50% fertigation + 50% soil application	5.47	2.43	4.45	9.76	5.10	2.10	4.05	9.45	5.17	2.27	4.25	9.60
T_7 : 25% fertigation + 75% soil application	4.71	1.80	3.75	8.76	4.47	1.73	3.43	8.29	4.59	1.77	3.59	8.53
T_8 : DI with 100% CF	5.26	2.29	4.15	9.44	4.87	2.01	3.63	9.08	5.20	2.15	3.89	9.26
T_9 : SI with 100% CF + foliar spray	4.51	1.66	3.52	8.58	4.24	1.44	3.13	8.13	4.38	1.55	3.32	8.36
T_{10} : SI with 100% CF	4.45	1.44	3.43	8.09	4.13	1.31	2.86	7.77	4.29	1.37	3.14	7.93
T_{11} : DI with no fertilizer	4.15	1.32	2.71	7.68	3.84	1.28	2.47	7.20	3.99	1.30	2.59	7.44
SE±	0.08	0.07	0.06	0.09	0.14	0.11	0.09	0.08	0.12	0.10	0.08	0.09
C.D. at 5 %	0.25	0.21	0.18	0.27	0.43	0.34	0.27	0.24	0.35	0.28	0.23	0.25
General mean	5.50	2.43	4.36	10.07	5.09	2.19	4.00	9.56	5.30	2.31	4.18	9.82

Table 4.13 Transpiration rate of tomato influenced periodically by different treatments

Treatment	Transpiration rate (µ mol. CO_2 m^{-2} s^{-1})											
	2014-2015				2015-2016				Pooled mean			
	45 DAT	90 DAT	135 DAT	At harvest	45 DAT	90 DAT	135 DAT	At harvest	45 DAT	90 DAT	135 DAT	At harvest
T_1 : 100% fertigation in first tertile of the irrigation period	11.31	12.39	10.21	8.34	11.10	12.03	10.06	8.09	11.20	12.21	10.14	8.22
T_2 : 100% fertigation in second tertile of the irrigation period	11.55	12.54	10.47	8.63	11.17	12.31	10.13	8.28	11.36	12.43	10.30	8.46
T_3 : 100% fertigation in third tertile of the irrigation period	11.63	12.77	10.77	8.81	11.30	12.45	10.41	8.49	11.46	12.61	10.59	8.65
T_4 : 100% fertigation during complete irrigation period	10.61	11.68	9.72	8.14	10.51	11.43	9.60	7.79	10.56	11.56	9.66	7.96
T_5 : 75% fertigation + 25% soil application	10.51	11.40	9.54	7.78	10.36	11.18	9.32	7.58	10.44	11.29	9.43	7.68
T_6 : 50% fertigation + 50% soil application	9.68	10.57	9.37	7.66	9.41	10.38	9.18	7.44	9.54	10.48	9.28	7.55
T_7 : 25% fertigation + 75% soil application	9.44	10.31	8.69	7.53	9.19	10.05	8.35	7.18	9.32	10.22	8.52	7.36
T_8 : DI with 100% CF	9.55	10.53	9.21	7.58	9.23	10.12	9.03	7.30	9.39	10.29	9.12	7.44
T_9 : SI with 100% CF + foliar spray	8.65	9.72	8.49	6.74	8.43	9.42	8.30	6.49	8.54	9.57	8.40	6.62
T_{10} : SI with 100% CF	8.51	9.58	8.36	6.50	8.35	8.71	8.05	6.21	8.43	9.15	8.21	6.36
T_{11} : DI with no fertilizer	7.67	8.73	8.15	6.20	7.46	8.19	7.56	6.08	7.57	8.46	7.86	6.14
SE±	0.058	0.053	0.089	0.060	0.069	0.112	0.097	0.060	0.06	0.09	0.09	0.06
C.D. at 5 %	0.17	0.15	0.26	0.17	0.20	0.33	0.28	0.17	0.18	0.25	0.27	0.17
General mean	9.92	10.93	9.36	7.63	9.68	10.57	9.09	7.36	9.80	10.75	9.23	7.49

Among the eleven treatments, the application of fertilizer in the third tertile of the irrigation period resulted into significantly higher transpiration rate at all the crop growth stages during 2014-15 and 2015-16 and drip irrigation with no fertilizer exhibited lowest transpiration rate at all the crop growth stages during 2014-15 and 2015-16.

In 100% fertigated treatments, the application of fertilizer in the third tertile of the irrigation period found significantly higher transpiration rate at all the crop growth stages during both the years and it was at par with application of fertilizers in the second tertile, first tertile and during complete irrigation period at 45, 90, 135 days after transplanting and at last harvest during 2014-15 and 2015-16. The application of fertilizer during complete irrigation period registered lower values of transpiration rate at 45, 90, 135 days after transplanting and at last harvest during 2014-15 and 2015-16.

Out of the split fertilized treatments, the application of 75% fertigation + 25% soil application exhibited significantly higher transpiration rate during both the year and it was showed at par values with 50% fertigation + 50% soil application and drip irrigation with 100% conventional fertilizer (NK-drip and P-soil) at 45, 90, 135 days after transplanting and at last harvest during 2014-15 and 2015-16. The 25% fertigation + 75% soil application showed lower values of transpiration rate at all the crop growth stages during 2014-15 and 2015-16.

In conventional fertilized treatments, the surface irrigation with 100% conventional fertilizer + foliar sprays resulted significantly higher transpiration rate at all the crop growth stages during 2014-15 and 2015-16 as compared to surface irrigation with 100% conventional fertilizer.

In control treatment of drip irrigation with no fertilizer resulted minimum values of transpiration rate at all the crop growth stages during 2014-15 and 2015-16.

Similar results were observed by Chowdhury and Varma (1998), Ravindrakumar and Robinson (2003), Singandhupe *et al.* (2003).

4.5 Quality Parameters

The quality of tomato fruit was assessed in terms of pH, titrable acidity, total soluble solids and lycopene content during 2014-15 and 2015-16 and is presented in Table 4.14 and graphically presented in Fig 4.17 and 4.18.

pH

The mean pH of tomato fruit juice was 4.30 and 4.18 during first and second year, respectively.

Titrable acidity

The mean titrable acidity of tomato fruit was 0.34 and 0.33 during 2014-15 and 2015-16.

Total soluble solids

The mean total soluble solids were 4.54 and 4.51 ^{0}B during 2014-15 and 2015-16.

Lycopene

The mean lycopene content in tomato fruit was 3.96 mg 100 g^{-1} fruit juice during 2014-15 and 2015-16, respectively.

In all eleven treatments, the application of fertilizer in the third tertile of the irrigation period exhibited significantly maximum pH, titrable acidity, total soluble solids and lycopene content as 4.37, 0.38 %, 4.88 ^{0}B and 4.12 mg 100 g^{-1} fruit juice and 4.33, 0.37 %, 4.81 ^{0}B and 4.11 mg 100 g^{-1} fruit juice during 2014-15 and 2015-16 and drip irrigation with no fertilizer resulted minimum pH, titrable acidity, total soluble solids and lycopene content as 4.24, 0.31 %, 4.25^{0}B and 3.50 mg 100 g^{-1} fruit juice and 4.03, 0.31 %, 4.22 ^{0}B and 3.36 mg 100 g^{-1} fruit juice during 2014-15 and 2015-16, respectively.

The quality parameters of tomato fruit like pH, titrable acidity, total soluble solids and lycopene content was influenced significantly due to 100% fertigated treatments. The application of fertilizer in the third tertile of the irrigation period registered significantly maximum pH, titrable acidity, total soluble solids and lycopene content in tomato fruit as 4.37, 0.38 %, 4.88 ^{0}B and 4.12 mg 100 g^{-1} fruit juice and 4.33, 0.37 %, 4.81 ^{0}B and 4.11 mg 100 g^{-1} fruit juice during first and second year.

It might be due to adequate and continuous supply of nutrient at all the growth stages of the crop. Similar result are reported by Hebber *et al.* (2004) revealed significant difference in titrable acidity and ascorbic acid concentration while other quality parameters remained equal with each other. Anac and Colcoglu (1995) found that K can increased the ascorbic acid concentration and titrable acidity in tomato fruits.

Table 4.14 Tomato fruit quality attributes as influenced periodically by different treatments

Treatment	Fruit quality attributes											
	2014-2015				2015-2016				Pooled mean			
	pH	Titrable acidity (%)	Total soluble solids (^{0}B)	Lycopene (mg 100 g^{-1} fruit juice)	pH	Titrable acidity (%)	Total soluble solids (^{0}B)	Lycopene (mg 100 g^{-1} fruit juice)	pH	Titrable acidity (%)	Total soluble solids (^{0}B)	Lycopene (mg 100 g^{-1} fruit juice)
T_1 : 100% fertigation in first tertile of the irrigation period	4.33	0.36	4.70	4.10	4.27	0.35	4.69	4.09	4.30	0.36	4.70	4.10
T_2 : 100% fertigation in second tertile of the irrigation period	4.34	0.37	4.78	4.11	4.30	0.36	4.73	4.10	4.32	0.36	4.76	4.11
T_3 : 100% fertigation in third tertile of the irrigation period	4.37	0.38	4.88	4.12	4.33	0.37	4.81	4.11	4.35	0.37	4.85	4.12
T_4 : 100% fertigation during complete irrigation period	4.32	0.35	4.64	4.09	4.23	0.34	4.61	4.08	4.28	0.35	4.63	4.08
T_5 : 75% fertigation + 25% soil application	4.31	0.34	4.58	4.08	4.20	0.33	4.54	4.07	4.26	0.34	4.56	4.07
T_6 : 50% fertigation + 50% soil application	4.30	0.34	4.51	4.07	4.17	0.33	4.49	4.06	4.23	0.34	4.50	4.06
T_7 : 25% fertigation + 75% soil application	4.28	0.32	4.43	4.04	4.13	0.31	4.40	4.04	4.21	0.32	4.42	4.04
T_8 : DI with 100% CF	4.29	0.33	4.49	4.05	4.15	0.32	4.44	4.05	4.22	0.33	4.47	4.05
T_9 : SI with 100% CF + foliar spray	4.27	0.33	4.38	3.77	4.10	0.32	4.34	4.03	4.19	0.32	4.36	3.90
T_{10} : SI with 100% CF	4.26	0.32	4.31	3.67	4.07	0.31	4.29	3.53	4.16	0.32	4.30	3.60
T_{11} : DI with no fertilizer	4.24	0.31	4.25	3.50	4.03	0.31	4.22	3.36	4.14	0.31	4.24	3.43
SE±	0.013	0.006	0.077	0.068	0.062	0.008	0.037	0.07	0.05	0.01	0.06	0.07
C.D. at 5 %	0.039	0.020	0.22	0.20	0.185	0.023	0.109	0.21	NS	0.02	0.17	0.20
General mean	4.30	0.34	4.54	3.96	4.18	0.33	4.51	3.96	4.24	0.34	4.52	3.96

Among the split fertilized treatments, the application of 75% fertigation + 25% soil application exhibited significantly higher pH, titrable acidity, total soluble solids and lycopene content as 4.31, 0.34 %, 4.58 ^{0}B and 4.08 mg 100 g^{-1} fruit juice and 4.20, 0.33 %, 4.54 ^{0}B and 4.07 mg 100 g^{-1} fruit juice during first and second year respectively as compared to 50% fertigation + 50% soil application and drip irrigation with 100% conventional fertilizer (NK-drip and P-soil). It might be due to better availability of nutrient throughout the growing period of the crop. Similar result are observed by Hebber *et al.* (2004).

In conventional fertilized treatments, the surface irrigation with 100% conventional fertilizer + foliar sprays observed significantly higher pH, titrable acidity, total soluble solids and lycopene content 4.27, 0.33 %, 4.38 ^{0}B and 3.77 mg 100 g^{-1} fruit juice and 4.10, 0.32 %, 4.34 ^{0}B and 4.03 mg 100 g^{-1} fruit juice during 2014-15 and 2015-16.

In control treatments, drip irrigation with no fertilizer showed minimum pH, titrable acidity, total soluble solids and lycopene content as 4.24, 0.31 %, 4.25^{0}B and 3.50 mg 100 g^{-1} fruit juice and 4.03, 0.31 %, 4.22 ^{0}B and 3.36 mg 100 g^{-1} fruit juice during first and second year.

4.6 Nutrient Availability

4.6.1 Nitrogen availability

The data regarding availability of nitrogen to tomato as influenced periodically by different treatments are presented in Table 4.15 and graphically presented in Fig 4.19 and 4.20. The mean availability of nitrogen at 30, 60, 90, 120,150 days after transplanting and at last harvest were 218.9, 233.69, 209.75, 177.80, 172.36 and 158.05 kg ha^{-1} respectively for the year 2014-15, while it was 213.25, 229.74, 206.47, 175.94, 170.27 and 156.55 kg ha^{-1} respectively for the year 2015-16 and 215.67, 231.72, 208.11, 176.87, 171.31and 157.30 kg ha^{-1} during pooled mean.

Among the eleven treatments, the application of fertilizer in the second tertile of the irrigation period exhibited significantly maximum availability of nitrogen as 214.18, 258.03, 233.75, 194.29, 189.91, 164.41 and 209.68, 252.49, 228.51, 187.30, 182.49, 164.40 and 211.93, 255.26, 228.74, 189.95, 184.89 and 163.50 kg ha^{-1} respectively at 30, 60, 90, 120, 150 and at harvest during 2014-15, 2015-16 and pooled mean.

Table 4.15 Nitrogen availability in soil as influenced by different treatments

Treatment	Nitrogen availability (kg/ha)																	
	2014-2015						2015-2016						Pooled mean					
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest
T_1 : 100% fertigation in first tertile of the irrigation period	210.78	246.03	220.60	190.04	185.66	161.04	205.54	242.52	214.66	183.52	179.54	159.51	208.16	244.28	217.63	186.78	182.60	160.28
T_2 : 100% fertigation in second tertile of the irrigation period	214.18	258.03	233.75	194.29	189.91	164.41	209.68	252.49	228.51	187.30	182.49	164.40	211.93	255.26	228.74	189.95	184.89	163.50
T_3 : 100% fertigation in third tertile of the irrigation period	213.39	249.06	230.23	193.23	185.85	163.29	208.59	248.24	224.52	185.49	181.45	162.33	210.99	248.65	227.37	189.36	183.65	162.81
T_4 : 100% fertigation during complete irrigation period	211.12	247.12	228.97	192.60	187.29	162.60	207.58	243.45	221.53	184.37	179.58	161.37	209.35	245.29	227.64	189.33	184.74	162.89
T_5 : 75% fertigation + 25% soil application	220.20	240.73	219.48	187.67	181.17	160.04	217.65	235.51	213.52	182.50	176.59	158.43	218.92	238.12	216.50	185.09	178.88	159.24
T_6 : 50% fertigation + 50% soil application	230.49	244.79	221.36	179.04	170.29	159.42	225.64	239.17	212.54	176.62	170.59	156.48	228.06	241.98	216.95	177.83	170.44	157.95
T_7 : 25% fertigation + 75% soil application	232.47	230.33	218.23	176.86	169.27	158.79	227.65	225.44	202.64	174.48	171.43	155.46	230.06	227.89	210.43	175.67	170.35	157.12
T_8 : DI with 100% CF	237.34	235.51	198.92	171.48	167.73	156.67	232.53	232.68	214.65	178.55	168.44	157.59	234.94	234.09	206.79	175.02	168.09	157.13
T_9 : SI with 100% CF + foliar spray	235.65	233.36	191.87	159.37	157.12	152.58	230.65	230.73	199.61	170.59	162.51	154.52	233.15	232.05	195.74	164.98	159.81	153.55
T_{10} : SI with 100% CF	234.57	230.47	189.82	157.32	151.32	150.08	229.71	229.67	193.50	167.38	158.72	153.42	232.14	230.07	191.66	162.35	155.02	151.75
T_{11} : DI with no fertilizer	158.84	155.16	154.04	153.91	150.35	149.61	150.54	147.26	145.48	144.58	141.62	138.51	154.69	151.21	149.76	149.24	145.99	144.06
SE±	2.421	2.075	5.919	4.288	4.203	0.834	0.237	0.258	0.228	0.255	0.142	0.169	1.72	1.48	4.19	3.04	2.97	0.60
C.D. at 5 %	7.142	6.123	17.46	12.64	12.400	2.462	0.701	0.762	0.674	0.752	0.419	0.500	4.92	4.23	11.97	8.68	8.50	1.72
General mean	218.09	233.69	209.75	177.80	172.36	158.05	213.25	229.74	206.47	175.94	170.27	156.55	215.67	231.72	208.11	176.87	171.31	157.30

The drip irrigation with no fertilizer resulted into minimum availability of nitrogen at all growth stages during 2014-15, 2015-16 and pooled mean.

In 100% fertigated treatments, the maximum availability of nitrogen was noticed under application of fertilizer in the second tertile of the irrigation period as 214.18, 258.03, 233.75, 194.29, 189.91, 164.41 and 209.68, 252.49, 228.51, 187.30, 182.49, 164.40 and 211.93, 255.26, 228.74, 189.95, 184.89 and 163.50 kg ha^{-1} respectively at 30, 60, 90, 120, 150 and at harvest during 2014-15, 2015-16 and pooled mean as compared to application of fertilizer in the first tertile of the irrigation period, third tertile of the irrigation period and during complete irrigation period. Minimum nitrogen availability was observed under the application of fertilizer during first tertile of the irrigation period at all the crop growth stages during first year, second year and pooled mean. Application of fertilizer with irrigation water increases the availability of nutrients. Similar results were found by Abdelraouf and Ragab (2018).

Out of the split fertilized treatments, the 50% fertigation + 50% soil application exhibited significantly maximum availability of nitrogen as 244.79, 221.36 and 239.17, 212.54, and 241.98, 216.95, kg ha^{-1}, respectively at 60 and 90 days after transplanting during 2014-15, 2015-16 and pooled mean. It might be due to split application of water soluble fertilizer and high fertilizer frequency. Increase in fertigation frequency increases the availability of nutrients. These results are in line with the findings of Nalina *et al.* (2009). Increased nutrient availability under fertigation of water soluble fertilizers than conventional method are reported by Pawar *et al.* (2018) and Rimcharoen and Wonprasaoid (2016).

Among the conventional fertilized treaatments, the maximum nitrogen availability was noticed under surface irrigation with 100% conventional fertilizer + foliar spray at 30, 60, 90, 120, 150 days after transplanting and at harvest were 235.65, 233.36, 191.87, 159.37, 157.12, 152.58 and 230.65, 230.73, 199.61, 170.59, 162.51, 154.52 and 233.15, 232.05, 195.74, 164.98, 159.81, 153.55 kg ha^{-1} during 2014-15, 2015-16 and pooled mean as compared to surface irrigation with 100% conventional fertilizer.

4.6.2 Phosphorus availability

The data regarding availability of phosphorus by tomato plant as influenced periodically by different treatments are presented in Table 4.16 and graphically presented in Fig 4.21 and 4.22. The mean availability of phosphorus at 30, 60, 90, 120,150 days after transplanting and at last harvest were 28.24, 33.89, 28.92, 23.74, 19.39 and 15.84 kg ha^{-1} respectively for the year 2014-15, while it was 27.08, 33.00, 27.45, 23.15, 19.25 and 13.28 kg ha^{-1} respectively for the year 2015-16 and 27.66, 33.44, 28.18, 23.44, 19.32 and 14.56 kg ha^{-1} during pooled mean.

Out of the eleven treatments, the application of fertilizer in the second tertile of the irrigation period exhibited significantly maximum availability of phosphorus as 30.25, 39.32, 38.30, 30.55, 26.87, 17.00 and 29.41, 39.52, 35.57, 28.61, 24.33, 15.71 and 29.83, 39.42, 35.14, 27.75, 23.04, 17.21 kg ha^{-1} at 30, 60, 90, 120, 150 days after transplanting and at last harvest during 2014-15, 2015-16 and pooled mean, respectively, except at 60 DAT, at harvest during 2014-15, 60, 90, 120 and 150 DAT in pooeld mean.

The drip irrigation with no fertilizer resulted into minimum availability of phosphorus as 16.49, 15.92, 14.43, 14.20, 13.87, 11.13 and 13.63, 11.53, 10.54, 10.00, 9.73, 8.47 and 15.06, 13.73, 12.48, 12.10, 11.80 kg ha^{-1} at 30, 60, 90, 120, 150 days after transplanting and at last harvest during 2014-15, 2015-16 and pooled mean, respectively.

In 100% fertigated treatments, the application of fertilizer in the second tertile of the irrigation period resulted significantly more availability of phosphorus as 30.25, 39.32, 38.30, 30.55, 26.87, 17.00 and 29.41, 39.52, 35.57, 28.61, 24.33, 15.71 and 29.83, 39.42, 35.14, 27.75, 23.04, 17.21 kg ha^{-1} at 30, 60, 90, 120, 150 days after transplanting and at last harvest during 2014-15, 2015-16 and pooled mean, respectively as compared to application of fertilizer in the third tertile of the irrigation period and during complete irrigation period, except at 60 DAT and at harvest during 2014-15, 60, 90, 120 and 150 DAT in pooeld mean. Hoevever it was at par with T_3.

The application of fertilizer in the first tertile of the irrigation period exhibited significantly less phosphorus availability at all the crop growth stages during first year, second year and pooled mean. It might be due to application of water soluble fertilizer with irrigation water. The increase in fertigation level increases the availability of nutrients as observed by Abdelraouf and Ragab (2018) and Shaymaa *et al.* (2009).

Table 4.16 Phosphorus availability in soil as influenced by different treatments

Treatment	Phosphorus availability (kg/ha)																	
	2014-2015						2015-2016						Pooled mean					
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest
T_1 : 100% fertigation in first tertile of the irrigation period	27.12	37.24	32.12	24.93	19.63	16.90	26.49	36.59	32.69	25.32	21.69	13.77	26.80	36.92	32.41	25.13	20.66	15.33
T_2 : 100% fertigation in second tertile of the irrigation period	30.25	39.32	38.30	30.55	26.87	17.00	29.41	39.52	35.57	28.61	24.33	15.71	29.83	39.42	35.14	27.75	23.04	17.21
T_3 : 100% fertigation in third tertile of the irrigation period	29.15	42.21	37.30	27.34	22.72	17.52	28.54	38.60	34.36	27.62	23.50	14.77	28.84	40.41	35.83	27.48	23.11	16.14
T_4 : 100% fertigation during complete irrigation period	28.21	42.96	34.71	26.89	21.74	18.70	27.61	37.52	33.58	26.66	22.51	14.48	27.91	40.24	35.94	28.60	24.69	15.74
T_5 : 75% fertigation + 25% soil application	24.64	35.63	30.33	26.87	21.75	16.20	23.49	35.65	27.59	24.42	20.54	13.71	24.07	35.64	28.96	25.64	21.14	14.96
T_6 : 50% fertigation + 50% soil application	25.86	33.88	27.54	22.37	17.68	15.74	24.55	34.63	26.52	23.41	18.39	13.36	25.21	34.26	27.03	22.89	18.04	14.55
T_7 : 25% fertigation + 75% soil application	27.62	34.13	29.11	24.54	19.23	15.57	26.56	32.47	25.49	22.71	17.63	13.28	27.09	33.30	27.30	23.62	18.43	14.43
T_8 : DI with 100% CF	35.24	31.87	26.37	21.55	17.48	16.40	33.43	35.46	27.49	23.73	19.46	13.60	34.34	33.66	26.93	22.64	18.47	15.00
T_9 : SI with 100% CF + foliar spray	33.50	30.50	24.25	21.75	16.75	14.75	32.65	31.52	24.51	21.57	17.45	12.70	33.07	31.01	24.38	21.66	17.10	13.73
T_{10} : SI with 100% CF	32.52	29.11	23.61	20.11	15.61	14.37	31.49	29.49	23.57	20.58	16.57	12.20	32.00	29.30	23.59	20.35	16.09	13.28
T_{11} : DI with no fertilizer	16.49	15.92	14.43	14.20	13.87	11.13	13.63	11.53	10.54	10.00	9.73	8.47	15.06	13.73	12.48	12.10	11.80	9.80
SE±	1.462	0.567	0.422	0.284	0.132	0.739	0.236	0.136	0.205	0.129	0.117	0.149	1.05	0.41	0.33	0.22	0.13	0.53
C.D. at 5 %	4.314	1.674	1.247	0.839	0.389	2.182	0.696	0.403	0.605	0.381	0.346	0.440	2.99	1.18	0.95	0.63	0.36	1.53
General mean	28.24	33.89	28.92	23.74	19.39	15.84	27.08	33.00	27.45	23.15	19.25	13.28	27.66	33.44	28.18	23.44	19.32	14.56

Among the split fertilized treatments, 75% fertigation + 25% soil application registered significantly maximum availability of phosphorus as 35.63, 30.33, 26.87, 21.75, 16.20 and 35.65, 27.59, 24.42, 20.54, 13.71 and 35.64, 28.96, 25.64, 21.14, 14.96 kg ha^{-1} at 60, 90, 120, 150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively as compared to 50% fertigation + 50% soil application, 25% fertigation + 75% soil application and drip irrigation with 100% conventional fertilizer (NK-drip and P-soil). The phosphorus availability was increased with period from sowing up to 60 days after transplanting and afterwards decreased up to harvesting stage. The decreased phosphorus availability in soil after 60 days after transplanting may be due to higher uptake of phosphorus by plants at fruit formation stage. The levels of fertilizer had influenced the phosphorus availability in soil up to some extent. The nutrient availability was increased with increase in fertigation level. These results are in line with the findings of Nalina *et al.* (2009), Pawar *et al.* (2018) and Rimcharoen and Wonprasaoid (2016).

In conventional fertilized treatments, the surface irrigation with 100% conventional fertilizer and foliar spray at 30, 60, 120, 150 days after transplanting registered higher availability of phosphorus as 33.50, 30.50, 24.25, 21.75, 16.75, 14.75 and 32.65, 31.52, 24.51, 21.57, 17.45, 12.70 and 33.07, 31.01, 24.38, 21.66, 17.10, 13.73 kg ha^{-1} at 30, 60, 120, 150 ays after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively. Similar results were noted by Pawar *et al.* (2018) and Rimcharoen and Wonprasaoid (2016).

Minimum availability of phosphorus noticed under drip irrigation with no fertilizer as 16.49, 15.92, 14.43, 14.20, 13.87, 11.13 and 13.63, 11.53, 10.54, 10.00, 9.73, 8.47 and 15.06, 13.73, 12.48, 12.10, 11.80 kg ha^{-1} at 30, 60, 90, 120, 150 days after transplanting and at last harvest during 2014-15, 2015-16 and pooled mean, respectively.

4.6.3 Potassium availability

The data regarding availability of potassium by tomato plant as influenced periodically by different treatments are presented in Table 4.17 and graphically presented in Fig 4.23 and 4.24. The mean availability of potassium at 30, 60, 90, 120,150 days after transplanting and at last harvest were 348.43, 353.62, 335.43, 328.95, 324.68 and 321.40 kg ha^{-1} respectively for the year 2014-15, while it was 347.00, 349.37, 334.40, 323.30, 320.37 and 314.37 kg ha^{-1} respectively for the year 2015-16 and 347.72, 351.50, 334.92, 326.12, 322.53 and 317.88 kg ha^{-1} during pooled mean.

Table 4.17 Potassium availability in soil as influenced by different treatments

Treatment	Potassium availability (kg/ha)																	
	2014-2015						2015-2016						Pooled mean					
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest
T_1 : 100% fertigation in first tertile of the irrigation period	342.22	359.57	340.47	332.53	328.58	324.42	344.22	355.40	340.44	329.39	326.49	320.41	343.22	357.48	340.46	330.96	327.54	322.42
T_2 : 100% fertigation in second tertile of the irrigation period	350.46	370.22	351.46	339.56	334.61	327.68	348.55	358.40	343.54	332.56	329.59	323.52	349.51	364.31	347.50	336.06	332.10	325.60
T_3 : 100% fertigation in third tertile of the irrigation period	348.37	367.50	348.60	338.47	333.44	326.54	346.62	357.55	342.54	331.41	328.47	322.64	347.50	362.53	345.57	334.94	330.96	324.59
T_4 : 100% fertigation during complete irrigation period	346.27	361.35	346.47	337.66	332.61	325.31	345.54	356.19	341.71	330.58	327.60	321.60	345.91	358.77	344.09	334.12	330.11	323.46
T_5 : 75% fertigation + 25% soil application	340.72	356.60	336.48	330.34	324.43	322.44	343.81	353.50	338.56	327.56	322.62	316.45	342.26	355.05	337.52	328.95	323.53	319.45
T_6 : 50% fertigation + 50% soil application	352.60	355.42	333.23	327.28	322.45	320.51	352.63	352.46	337.32	326.43	324.54	318.67	352.62	353.94	335.28	326.86	323.50	319.59
T_7 : 25% fertigation + 75% soil application	354.67	349.42	329.46	324.54	321.55	319.43	353.53	350.28	335.49	324.41	322.37	316.54	354.10	349.85	332.48	324.48	321.96	317.99
T_8 : DI with 100% CF	359.29	354.76	334.55	326.54	323.53	321.65	356.43	353.72	339.48	326.57	323.68	317.52	357.86	354.24	337.02	326.55	323.61	319.58
T_9 : SI with 100% CF + foliar spray	357.52	348.45	326.44	323.45	320.46	318.64	355.47	349.59	333.34	322.55	320.60	314.50	356.50	349.02	329.89	323.00	320.53	316.57
T_{10} : SI with 100% CF	355.47	346.25	325.38	322.65	319.34	317.55	354.55	347.46	331.38	320.60	318.56	312.62	355.01	346.86	328.38	321.62	318.95	315.09
T_{11} : DI with no fertilizer	325.17	320.29	317.17	315.45	310.53	311.20	315.64	308.53	294.64	284.21	279.57	273.58	320.40	314.41	305.90	299.83	295.05	292.39
SE±	0.895	1.239	0.467	328.95	0.229	0.241	0.233	0.159	0.143	0.176	0.141	0.094	347.72	351.50	334.92	326.12	322.53	317.88
C.D. at 5 %	2.641	3.657	1.380	0.262	0.677	0.713	0.687	0.469	0.424	0.521	0.418	0.279	0.65	0.88	0.35	0.22	0.19	0.18
General mean	348.43	353.62	335.43	0.775	324.68	321.40	347.00	349.37	334.40	323.30	320.37	314.37	1.87	2.53	0.99	0.64	0.55	0.53

Out of eleven treatments, the application of fertilizer in the second tertile of the irrigation period resulted significantly maximum availability of potassium as 350.46, 370.22, 351.46, 339.56, 334.61, 327.68 and 348.55, 358.40, 343.54, 332.56, 3329.59, 323.52 and 349.51, 364.31, 347.50, 336.06, 332.10, 325.60 kg ha^{-1} at 30, 60, 90, 120 150 and at harvest during 2014-15, 2015-16 pooled mean, respectively. The drip irrigation with no fertilizer resulted minimum availability of potassium at all growth stages during both the years.

Among the 100 % fertigated treatments, the application of fertilizer in the second tertile of the irrigation period resulted significantly maximum availability of potassium as 350.46, 370.22, 351.46, 339.56, 334.61, 327.68 and 348.55, 358.40, 343.54, 332.56, 3329.59, 323.52 and 349.51, 364.31, 347.50, 336.06, 332.10, 325.60 kg ha^{-1} at 30, 60, 90, 120 150 and at harvest except 30 DAT during 2014-15, 2015-16 and pooled mean, respectively and it showed at par values with application of fertilizer in the third tertile of the irrigation period at 120, 150 days after transplanting and at harvest during first year, 60, 90, 120,150 days after transplanting and at harvest during second year and at harvest during pooled mean. Application of fertilizer in the first tertile of the irrigation period showed lower availability of potassium at all the crop growth stages during first year, second year and pooled mean. The availability of potassium in soil increased with period from transplanting up to 60 days after transplanting and decreased up to harvesting stage in all the treatments. The decreased availability of potassium in soil after 60 days after transplanting may be due to higher uptake of potassium by plants at fruit formation stage. Similar results were found by Abdelraouf and Ragab (2018) and Shaymaa *et al.* (2009).

In split fertilized treatments, the maximum availability of potassium was noticed under 75% fertigation + 25% soil application as 356.60, 336.48, 330.34, 324.43, 322.44 and 353.50, 338.56, 327.56, 322.62, 316.45 and 355.05, 337.52, 328.95, 323.53, 319.45 kg ha^{-1} at 60, 90, 120,150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively as compared to 50% fertigation + 50% soil application, 25% fertigation + 75% soil application and drip irrigation with 100% conventional fertilizer (NK-drip and P-soil). Availability of potassium increased with increase in fertigation levels. These results are in line with the findings of Shedeed *et al.* (2009). They found that fertigation with water soluble fertilizers registered higher

available K concentration. They also envisaged the suitability of K fertigation through drip in more splits it achieve maximum nutrient use efficiency especialy in lighter soils where potassium ions moves along with irrigation water and leach out beyond root zone. Frequent supplementation of nutrients with irrigation water increased the availability of N, P and K in the root zone and which in turn influenced the yield and quality of tomato and Rimcharoen and Wonprasaoid (2016).

In conventional fertilized treatments, the maximum availability of potassium was noticed under surface irrigation with 100% conventional fertilizer + foliar spray as 357.52, 348.45, 326.44, 323.45, 320.46, 318.64 and 355.47, 349.59, 333.34, 322.55, 320.60, 314.50 and 356.50, 349.02, 329.89, 323.00, 320.53, 316.57 kg ha^{-1} at 30, 60, 90, 120 150 and at harvest during 2014-15, 2015-16 and pooled mean, respectively as compared to the surface irrigation with 100% conventional fertilizer.

In control treatments, the drip irrigation with no fertilizer registered significantly minimum availability of potassium as 325.17, 320.29, 317.17, 315.45, 310.53, 311.20 and 315.64, 308.53, 294.64, 284.21, 279.57, 273.58 and 320.40, 314.41, 305.90, 299.83, 295.05, 292.39 kg ha^{-1} at 30, 60, 90, 120 150 and at harvest during 2014-15, 2015-16 and pooled mean.

4.7 Nutrients Uptake

4.7.1 Nitrogen uptake

The data regarding uptake of nitrogen by tomato plant and fruit as influenced periodically by different treatments are presented in Table 4.18 and graphically presented in Fig 4.25 and 4.26. The mean nitrogen uptake at 30, 60, 90, 120 ,150 days after transplanting and at last harvest were 11.25, 19.76, 36.77, 38.22, 48.14 and 51.59, 149.62 and 201.22 kg ha^{-1}, respectively for the year 2014-15, while it was 11.76, 20.64, 39.88, 41.49, 49.39 and 52.18, 176.70 and 288.88 kg ha^{-1}, respectively for the year 2015-16 and 11.25, 11.51, 20.20, 38.33, 48.76 and 51.89, 163.16 and 215.05 kg ha^{-1} during pooled mean.

Out of the eleven treatments, the application of fertilizer in the second tertile of the irrigation period exhibited significantly maximum uptake of nitrogen as 13.63, 21.57, 38.54, 44.71, 51.14, 55.22, 191.04, 246.26 and 14.34, 22.60, 42.27, 47.79, 52.75, 55.62, 244.10, 299.72 and 13.99, 22.08, 40.51, 46.25, 51.95, 55.42, 217.57 and

272.99 kg ha^{-1} at 30, 60 90, 120, 150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively. The drip irrigation with no fertilizer resulted into minimum uptake of nitrogen during 2014-15, 2015-16 and pooled mean.

Among the 100% fertigated treatments, the application of fertilizer in the second tertile of the irrigation period recorded significantly maximum nitrogen uptake as 13.63, 21.57, 38.54, 44.71, 51.14, 55.22, 191.04, 246.26 and 14.34, 22.60, 42.27, 47.79, 52.75, 55.62, 244.10, 299.72 and 13.99, 22.08, 40.51, 46.25, 51.95, 55.42, 217.57 and 272.99 kg ha^{-1} at 30, 60 90, 120, 150 days after transplanting and at harvest during first, second year and pooled mean, respectively. Minimum uptake of nitrogen was observed under application of fertilizer in the first tertile of the irrigation period. The nitrogen uptake was increased with increase in age of the crop and maximum uptake was observed at harvesting stage. It might be due to frequent application of nutrients in the vicinity of root zone of the crop created congenial condition for enhancing the uptake of these nutrients upto fruiting period. Similar result were found by Hebber *et al.* (2004). Abdelraouf and Ragab (2018) observed increasing trend nitrogen uptake and grain nitrogen content when fertigation frequencies increased and fertigation time decreased. He concluded that 3 days fertigation frequency and fertilizer application in second half of the irrigation period is good fertigation strategy in sandy soils.

In the split fertilized treatments, the drip irrigation with 100% conventional fertilizer (NK-drip and P-soil) showed significantly maximum uptake of nitrogen as 11.75, 20.56, 37.63, 38.33, 49.73, 52.66, 138.75, 191.42 and 12.25, 21.67, 40.97, 41.33, 50.53, 53.07, 183.24, 236.31 and 12.00, 21.11, 39.30, 39.83, 50.13, 52.87, 161.00, 213.87 kg ha^{-1} at 30, 60 90, 120, 150 days after transplanting and at harvest during first year, second year and pooled mean, respectively. Further, it was also at par with 50% fertigation + 50% soil application at 30, 60 90, 120, 150 days after transplanting and in plant at harvest during first year, second year and pooled mean.

The uptake of nitrogen increased with increase in age of crop. This is might be due to the better availability of nutrients in root zone as a result of frequent application of nutrients coupled with better root activity. Further, it was also due to the reduced loss of nutrients primarily because of minimized leaching in fertigation as compared to soil application of fertilizer. The application of N given through fertigation not only stimulated vegetative growth and foraging capacity of roots, but also encouraged

Table 4.18 Nitrogen uptake influenced by different treatments

Treatment	Nitrogen uptake (kg/ha)																							
	2014-2015								2015-2016								Pooled mean							
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest			30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest			30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest		
						Plant	Fruit	Total						Plant	Fruit	Total						Plant	Fruit	Total
T_1 : 100% fertigation in first tertile of the irrigation period	11.80	19.79	37.27	38.33	49.99	51.77	181.63	233.40	12.56	20.75	40.59	41.50	50.50	52.42	218.55	270.97	12.18	20.27	38.93	39.92	50.25	52.10	200.09	252.18
T_2 : 100% fertigation in second tertile of the irrigation period	13.63	21.57	38.74	44.71	51.14	55.22	191.04	246.26	14.34	22.60	42.27	47.79	52.75	55.62	244.10	299.72	13.99	22.08	40.51	46.25	51.95	55.42	217.57	272.99
T_3 : 100% fertigation in third tertile of the irrigation period	12.75	20.71	38.31	41.50	50.40	53.61	195.94	249.55	13.44	21.67	41.67	44.80	52.17	54.63	230.06	284.69	13.10	21.19	39.99	43.15	51.28	54.12	213.00	267.12
T_4 : 100% fertigation during complete irrigation period	12.34	20.28	37.89	40.11	49.93	52.88	179.31	232.19	13.04	21.25	41.23	43.43	51.23	53.90	236.38	290.28	12.69	20.77	39.56	41.77	50.58	53.39	207.85	261.24
T_5 : 75% fertigation + 25% soil application	9.96	18.56	35.79	36.22	46.67	49.90	155.26	205.16	10.34	19.51	38.56	39.27	48.03	50.28	173.35	223.64	10.15	19.04	37.18	37.75	47.35	50.09	164.31	214.40
T_6 : 50% fertigation + 50% soil application	10.87	19.23	36.18	36.92	47.64	50.70	155.96	206.66	11.17	20.11	38.97	40.63	48.81	51.09	149.71	200.80	11.02	19.67	37.58	38.77	48.22	50.90	152.84	203.73
T_7 : 25% fertigation + 75% soil application	11.49	19.60	36.71	37.20	48.29	51.16	133.47	184.63	11.81	20.48	39.54	41.53	49.48	51.78	152.04	203.82	11.65	20.04	38.13	39.37	48.89	51.47	142.75	194.23
T_8 : DI with 100% CF	11.75	20.56	37.63	38.33	49.73	52.66	138.75	191.42	12.25	21.67	40.97	41.33	50.53	53.07	183.24	236.31	12.00	21.11	39.30	39.83	50.13	52.87	161.00	213.87
T_9 : SI with 100% CF + foliar spray	9.85	19.84	35.66	36.26	46.03	50.48	123.62	174.11	10.30	20.53	38.71	39.21	47.37	51.09	136.72	187.81	10.08	20.19	37.19	37.73	46.70	50.79	130.17	180.96
T_{10} : SI with 100% CF	9.72	18.74	35.27	35.70	45.27	49.90	117.07	166.97	10.14	19.47	38.30	38.80	46.60	50.28	125.64	175.93	9.93	19.11	36.78	37.25	45.93	50.09	121.35	171.45
T_{11} : DI with no fertilizer	9.57	18.45	35.03	35.17	44.45	49.22	73.80	123.02	10.01	19.03	37.89	38.10	45.79	49.82	93.88	143.70	9.79	18.74	36.46	36.63	45.12	49.52	83.84	133.36
SE±	0.20	0.17	0.25	0.21	0.18	0.13	0.19	0.17	0.18	0.14	0.17	0.08	0.14	0.14	0.09	0.19	0.20	0.19	0.15	0.21	0.16	0.14	0.15	0.18
C.D. at 5 %	0.60	0.49	0.73	0.63	0.52	0.40	0.57	0.50	0.54	0.41	0.50	0.24	0.40	0.40	0.26	0.57	0.60	0.55	0.44	0.61	0.45	0.39	0.41	0.52
General mean	11.25	19.76	36.77	38.22	48.14	51.59	149.62	201.22	11.76	20.64	39.88	41.49	49.39	52.18	176.70	228.88	11.25	11.51	20.20	38.33	48.76	51.89	63.16	215.05

the absorption and translocation of more nutrients under higher drip fertigation levels. Due to improved growth characters the plants tend to take more nutrients from the soil since it was available nearer to root zone at required level. Reducing the fertilizer dose resulted in reduced availability of nutrients which might be the reason for lower uptake of nutrients by crop at lower doses of fertilizers. These result are in line with the findings of Hebbar *et al.* (2003). The fertigation resulted into more concentration of readily available nutrients in soil and optimum availability of water in soil increased nutrient uptake (Pawar *et al*., 2018).

In conventional fertilized treatments surface irrigation with 100% conventional fertilizer + foliar spray exhibited significantly maximum nitrogen uptake as compared to surface irrigation with 100% conventional fertilizer. It was 9.85, 19.84, 35.66, 36.26, 46.03, 50.48, 123.62, 174.11 and 10.30, 20.53, 38.71, 39.21, 47.37, 51.09, 136.72, 187.81 and 10.08, 20.19, 37.19, 37.73, 46.70, 50.79, 130.17, 180.96 kg ha^{-1} during first year, second year and pooled mean, respectively.

In control treatment, drip irrigation with no fertilizer resulted into minimum uptake of nitrogen as 9.57, 18.45, 35.03, 35.17, 44.45, 49.22, 73.80, 123.02 and 10.01, 19.03, 37.89, 38.10, 45.79, 49.82, 93.88, 143.70, and 9.79, 18.74, 36.46, 36.63, 45.12, 49.52, 83.84, 133.36 kg ha^{-1} during first year, second year and pooled mean, respectiviely.

4.7.2 Phosphorus uptake

The data regarding uptake of phosphorus by tomato plant and fruit as influenced periodically by different treatments are presented in Table 4.19 and graphically presented in Fig 4.27 and 4.28. The mean uptake of phosphorus at 30, 60, 90, 120 ,150 days after transplanting and at last harvest were 2.56, 4.32, 6.83, 6.22, 7.14 and 7.51, 27.77 and 35.29 kg ha^{-1}, respectively for the year 2014-15, while it was 2.70 , 4.10, 6.82, 6.02, 6.76 and 6.83, 31.19 and 38.02 kg ha^{-1}, respectively for the year 2015-16 and 0.29, 0.64, 0.43, 0.40, 0.62 and 0.47, 0.32 and 0.38 kg ha^{-1} repectively during pooled mean.

Among the eleven treatments, the application of fertilizers in the second tertile of the irrigation period exhibited significantly maximum uptake of phosphorus as 3.29, 5.01, 8.61, 8.08, 8.69, 9.02, 40.94, 49.95 and 3.48, 5.09, 8.55, 8.12, 8.08, 8.34, 47.17, 55.51 and 3.39, 5.05, 8.58, 8.10, 8.38, 8.68, 44.06 and 52.73 at 30, 60 90, 120, 150

Table 4.19 Phosphorus uptake influenced by different treatments

Treatment	Phosphorus uptake (kg/ha)																							
	2014-2015								2015-2016								Pooled mean							
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest			30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest			30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest		
						Plant	Fruit	Total						Plant	Fruit	Total						Plant	Fruit	Total
T_1 : 100% fertigation in first tertile of the irrigation period	2.60	4.25	7.99	6.44	7.68	7.95	35.42	43.37	2.91	4.46	7.75	6.50	6.98	7.30	39.14	46.44	2.76	4.36	7.87	6.47	7.33	7.62	37.28	44.91
T_2 : 100% fertigation in second tertile of the irrigation period	3.29	5.01	8.61	8.08	8.69	9.02	40.94	49.95	3.48	5.09	8.55	8.12	8.08	8.34	47.17	55.51	3.39	5.05	8.58	8.10	8.38	8.68	44.06	52.73
T_3 : 100% fertigation in third tertile of the irrigation period	3.00	4.69	8.40	7.40	8.40	8.60	40.51	49.11	3.24	4.85	8.33	7.47	7.75	8.00	43.77	51.77	3.12	4.77	8.37	7.44	8.07	8.30	42.14	50.44
T_4 : 100% fertigation during complete irrigation period	2.83	4.47	8.20	6.87	7.96	8.30	35.86	44.17	3.06	4.62	8.12	6.92	7.47	7.70	42.87	50.57	2.95	4.55	8.16	6.89	7.72	8.00	39.37	47.37
T_5 : 75% fertigation + 25% soil application	2.17	4.00	5.80	5.40	5.95	6.40	24.72	31.11	2.31	3.62	5.97	4.89	5.67	6.15	28.16	34.31	2.24	3.81	5.89	5.15	5.81	6.28	26.44	32.71
T_6 : 50% fertigation + 50% soil application	2.46	4.31	6.10	5.74	6.39	6.87	27.02	33.90	2.60	3.85	6.44	5.35	6.33	6.63	25.71	32.34	2.53	4.08	6.27	5.54	6.36	6.75	26.37	33.12
T_7 : 25% fertigation + 75% soil application	2.66	4.51	6.26	6.05	7.01	7.56	24.45	32.00	2.81	4.05	6.77	5.76	6.77	6.89	27.37	34.26	2.74	4.28	6.51	5.91	6.89	7.23	25.91	33.13
T_8 : DI with 100% CF	2.83	4.84	7.47	6.44	7.70	8.30	27.34	35.64	2.94	4.45	7.17	6.17	7.49	7.42	33.73	41.15	2.89	4.64	7.32	6.31	7.60	7.86	30.54	38.40
T_9 : SI with 100% CF + foliar spray	2.20	4.10	5.67	5.63	6.69	6.87	20.40	27.27	2.19	3.66	5.51	5.33	6.25	5.97	21.85	27.82	2.20	3.88	5.59	5.48	6.47	6.42	21.12	27.54
T_{10} : SI with 100% CF	2.11	3.75	5.37	5.31	6.25	6.61	18.15	24.76	2.10	3.26	5.34	4.97	6.00	5.49	19.53	25.02	2.10	3.50	5.36	5.14	6.13	6.05	18.84	24.89
T_{11} : DI with no fertilizer	2.02	3.63	5.22	5.10	5.79	6.15	10.70	16.85	2.04	3.15	5.02	4.76	5.53	5.24	13.76	19.01	2.03	3.39	5.12	4.93	5.66	5.70	12.23	17.93
SE±	0.08	0.20	0.12	0.09	0.19	0.16	0.14	0.16	0.12	0.24	0.18	0.18	0.25	0.17	0.06	0.11	2.63	4.21	6.82	6.12	6.95	7.17	29.48	36.65
C.D. at 5 %	0.24	0.60	0.34	0.27	0.55	0.48	0.42	0.46	0.34	0.72	0.52	0.52	0.73	0.50	0.19	0.31	0.10	0.22	0.15	0.14	0.22	0.17	0.11	0.13
General mean	2.56	4.32	6.83	6.22	7.14	7.51	27.77	35.29	2.70	4.10	6.82	6.02	6.76	6.83	31.19	38.02	0.29	0.64	0.43	0.40	0.62	0.47	0.32	0.38

days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively and drip irrigation with no fertilizer resulted into minimum uptake of phosphorus as 2.83, 4.84 , 7.47, 6.44, 7.70, 8.30, 27.34, 35.64 and 2.94, 4.45, 7.17, 6.17, 7.49, 7.42, 33.73, 41.15 and 2.89, 4.64, 7.32, 6.31, 7.60, 7.86, 30.54, 38.40 kg ha^{-1} at 30, 60 90, 120, 150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively.

In 100% fertigated treatmnets, the maximum phosphorus uptake observed under application of fertilizer in the second tertile of the irrigation period was 3.29, 5.01, 8.61, 8.08, 8.69, 9.02, 40.94, 49.95 and 3.48, 5.09, 8.55, 8.12, 8.08, 8.34, 47.17, 55.51 and 3.39, 5.05, 8.58, 8.10, 8.38, 8.68, 44.06 and 52.73 kg ha^{-1} at 30, 60 90, 120, 150 days after transplanting and at harvest during first year, second year and pooled mean, respectively and it was showed at par values with application of fertilizer in the third and first tertile of the irrigation period.

The application of fertilizer in the first tertile of the irrigation period noticed lowest uptake of phosphorus by tomato crop during first year, second year and pooled mean. The phosphorus uptake was increased with increase in age of the crop and maximum uptake was observed at harvesting stage. It might be due the adequate and continuous supply of nutrients throughout the crop growth period resulted in maximum dry matter production with increased nutrient concentration in fruit, leaf and stem reflected on more uptake by plant. Similar result were observed by Hebber *et al.* (2004).

Out of the split fertilized treatments, drip irrigation with 100% conventional fertilizer (NK-drip and P-soil) noticed significantly maximum uptake of phosphorus as 2.83, 4.84 , 7.47, 6.44, 7.70, 8.30, 27.34, 35.64 and 2.94, 4.45, 7.17, 6.17, 7.49, 7.42, 33.73, 41.15 and 2.89, 4.64, 7.32, 6.31, 7.60, 7.86, 30.54, 38.40 kg ha^{-1} at 30, 60 90, 120, 150 days after transplanting and at harvest during first year, second year and pooled mean, respectively and it was at par with 25% fertigation + 75% soil application and 50% fertigation + 50% soil application. The increased nutrient uptake might be due to adequate and sustained availability of nutrients throughout the growth stages of crop and mineralization of nitrogen and slow release of fixed P (Raskar, 2004).

In conventional fertilized treatments, the surface irrigation with 100% conventional fertilizer + foliar sprays exhibited significantly maximum phosphorus

uptake 2.20, 4.10, 5.67, 5.63, 6.69, 6.87, 20.40, 27.27 and 2.19, 3.66, 5.51, 5.33, 6.25, 5.97, 21.85, 27.82 and 2.20, 3.88, 5.59, 5.48, 6.47, 6.42, 21.12, 27.54 kg ha^{-1} at 30, 60 90, 120, 150 days after transplanting and at harvest during first year, second year and pooled mean, respectively as compared to surface irrigation with 100% conventional fertilizer.

In control treatment the minimum uptake of phosphorus was noticed under drip irrigation with no fertilizer as 2.02, 3.63, 5.22, 5.10, 5.79, 6.15, 10.70, 16.85 and 2.04, 3.15, 5.02, 4.76, 5.53, 5.24, 13.76, 19.01 and 2.03, 3.39, 5.12, 4.93, 5.66, 5.70, 12.23, 17.93 kg ha^{-1} at 30, 60 90, 120, 150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively.

4.7.3 Potassium uptake

The data regarding uptake of potassium by tomato plant and fruit as influenced periodically by different treatments are presented in Table 4.20 and graphically presented in Fig 4.29 and 4.30. The mean uptake of potassium at 30, 60, 90, 120 ,150 days after transplanting and at last harvest were 11.05, 20.10, 36.93, 35.99, 45.00, 44.59, 128.22 and 172.80 kg ha^{-1}, respectively for the year 2014-15, while it was 12.11, 21.63, 40.32, 38.68, 44.25, 45.75, 135.60 and 181.34 kg ha^{-1}, respectively for the year 2015-16 and 0.31, 0.28, 0.29, 0.38, 0.28, 0.28, 0.21 and 0.48 kg ha^{-1} during pooled mean.

In eleven treatments, the application of fertilizers in the second tertile of the irrigation period resulted into significantly maximum uptake of potassium as 14.10, 22.34, 38.74, 42.99, 46.49, 48.46, 163.75, 212.21 and 14.60, 23.43, 42.27, 44.58, 47.22, 48.67, 188.68, 237.35 and 14.35, 22.89, 40.51, 43.79, 46.86, 48.57, 176.22 and 224.78 kg ha^{-1} at 30, 60 90, 120, 150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively. The drip irrigation with no fertilizer observed minimum uptake of potassium at all growth stages during both the years.

Among the 100% fertigated treatments, the application of fertilizer in the second tertile of the irrigation period showed significantly higher uptake of potassium as 14.10, 22.34, 38.74, 42.99, 46.49, 48.46, 163.75, 212.21 and 14.60, 23.43, 42.27, 44.58, 47.22, 48.67, 188.68, 237.35 and 14.35,22.89, 40.51, 43.79, 46.86, 48.57, 176.22 and 224.78 kg ha^{-1} at 30, 60 90, 120, 150 days after transplanting and at harvest during first

Table 4.20 Potassium uptake influenced by different treatments

Treatment	Potassium uptake (kg/ha)																							
	2014-2015								2015-2016								Pooled mean							
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest			30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest			30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest		
						Plant	Fruit	Total						Plant	Fruit	Total						Plant	Fruit	Total
T_1 : 100% fertigation in first tertile of the irrigation period	11.68	20.58	37.27	36.39	44.48	44.90	158.93	203.82	12.83	21.77	40.74	38.67	44.75	45.56	169.62	215.18	12.26	21.18	39.01	37.53	44.62	45.23	164.27	209.50
T_2 : 100% fertigation in second tertile of the irrigation period	14.10	22.34	38.74	42.99	46.49	48.46	163.75	212.21	14.60	23.43	42.27	44.58	47.22	48.67	188.68	237.35	14.35	22.89	40.51	43.79	46.86	48.57	176.22	224.78
T_3 : 100% fertigation in third tertile of the irrigation period	12.66	21.53	38.17	39.73	45.60	47.00	167.68	214.67	13.73	22.64	41.83	41.78	46.30	47.77	178.44	226.21	13.20	22.09	40.00	40.76	45.95	47.39	173.06	220.44
T_4 : 100% fertigation during complete irrigation period	12.21	21.02	37.75	38.24	45.16	46.11	154.82	200.93	13.33	22.20	41.39	40.49	45.42	47.10	181.92	229.02	12.77	21.61	39.57	39.37	45.29	46.60	168.37	214.98
T_5 : 75% fertigation + 25% soil application	9.67	18.63	35.79	33.88	44.17	42.22	130.54	172.76	10.74	20.42	39.48	36.83	42.76	43.48	131.11	174.59	10.21	19.52	37.63	35.36	43.46	42.85	130.83	173.67
T_6 : 50% fertigation + 50% soil application	10.56	19.30	36.32	34.42	45.12	43.18	132.80	175.98	11.60	21.03	39.89	38.12	43.50	44.68	114.93	159.61	11.08	20.17	38.10	36.27	44.31	43.93	123.86	167.80
T_7 : 25% fertigation + 75% soil application	11.13	19.67	36.85	34.84	45.76	43.82	114.97	158.79	12.21	21.42	40.47	39.16	44.14	45.56	117.07	162.63	11.67	20.55	38.66	37.00	44.95	44.69	116.02	160.71
T_8 : DI with 100% CF	11.59	21.23	37.78	35.94	47.17	45.01	120.30	165.31	12.52	22.39	41.28	38.83	45.33	46.55	142.22	188.76	12.05	21.81	39.53	37.39	46.25	45.78	131.26	177.04
T_9 : SI with 100% CF + foliar spray	9.46	19.77	36.21	33.94	44.31	43.82	105.70	149.52	10.69	21.72	39.17	36.15	43.14	45.34	102.89	148.23	10.07	20.74	37.69	35.05	43.73	44.58	104.30	148.88
T_{10} : SI with 100% CF	9.31	18.67	35.82	32.98	43.76	43.29	98.93	142.21	10.52	20.61	38.61	35.75	42.60	44.57	94.40	138.97	9.92	19.64	37.21	34.37	43.18	43.93	96.67	140.59
T_{11} : DI with no fertilizer	9.15	18.31	35.57	32.47	42.96	42.65	61.99	104.64	10.40	20.30	38.35	35.08	41.64	43.92	70.29	114.21	9.78	19.30	36.96	33.78	42.30	43.29	66.14	109.42
SE±	0.08	0.09	0.12	0.17	0.10	0.12	0.08	0.20	0.13	0.10	0.07	0.07	0.10	0.06	0.06	0.13	11.58	20.86	38.62	37.33	44.63	45.17	131.91	177.07
C.D. at 5 %	0.24	0.28	0.37	0.51	0.30	0.37	0.25	0.59	0.38	0.30	0.21	0.21	0.28	0.19	0.18	0.38	0.11	0.10	0.10	0.13	0.10	0.10	0.07	0.17
General mean	11.05	20.10	36.93	35.99	45.00	44.59	128.22	172.80	12.11	21.63	40.32	38.68	44.25	45.75	135.60	181.34	0.31	0.28	0.29	0.38	0.28	0.28	0.21	0.48

year, second year and pooled mean, respectively as compared to application of fertilizer in the third tertile, first tertile and during complete irrigation period. The application of fertilizer in the first tertile of the irrigation period registered significantly lowest uptake of potassium by tomato crop during first year, second year and pooled mean. The potassium uptake was increased with increase in age of the crop and maximum uptake was observed at harvesting stage. It might be due the adequate and continuous supply of nutrients throughout the crop growth period resulted in maximum dry matter production with increased nutrient concentration in fruit, leaf and stem reflected on more uptakes by plant. Similar results were observed by Nalina *et al.* (2009) and Hebber *et al.* (2004).

In split fertilized treatments, the maximum uptake of potassium was noticed under drip irrigation with 100% conventional fertilizer (NK-drip and P-soil) as 11.59, 21.23, 37.78, 35.94, 47.17, 45.01, 120.30, 165.31 and 12.52, 22.39, 41.28, 38.83, 45.33, 46.55, 142.22, 188.76 and 12.05, 21.81, 39.53, 37.39, 46.25, 45.78, 131.26, 177.04 kg ha^{-1} at 30, 60 90, 120, 150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively as compared to 25% fertigation + 75% soil application and 50% fertigation + 50% soil application. The 75% fertigation + 25% soil application showed minimum uptake of potassium during at 30, 60 90, 120, 150 days after transplanting and at harvest during first year, second year and pooled mean. Similar result observed by Shaymaa *et al.* (2009) and Hebber *et al.* (2004).

In conventional fertilized treatments, the surface irrigation with 100% conventional fertilizer + foliar spray resulted significantly more potassium uptake was 9.46, 19.77, 36.21, 33.94, 44.31, 43.82, 105.70, 149.52, and 10.69, 21.72, 39.17, 36.15, 43.14, 45.34, 102.89, 148.23 and 10.07, 20.74, 37.69, 35.05, 43.73, 44.58, 104.30, 148.88 kg ha^{-1} at 30, 60 90, 120, 150 days after transplanting and at harvest during first year, second year and pooled mean as compared to surface irrigation with 100% conventional fertilizer. The potassium uptake was increased with increase in age of the crop. It might be due to adequate and better availability of nutrients at all growth stages of the crop. These result are in line with the findings of Hebber *et al.* (2004) and Pawar *et al.* (2018).

In control treatment, the minimum uptake of potassium was noticed under drip irrigationwith no fertilizer was 9.15, 18.31, 35.57, 32.47, 42.96, 42.65, 61.99, 104.64 and 10.40, 20.30, 38.35, 35.08, 41.64, 43.92, 70.29, 114.21 and 9.78, 19.30, 36.96, 33.78,

42.30, 43.29, 66.14, 109.42 kg ha^{-1} at 30, 60 90, 120, 150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean.

4.8 Dry Matter of Tomato

The data regarding periodical dry matter accumulation per plant by tomato plant as influenced periodically by different treatments is presented in Table 4.21 and graphically presented in Fig 4.31 and 4.32. The mean dry matter accumulation per plant at 30, 60, 90, 120,150 days after transplanting and at last harvest were 18.62, 33.91, 66.05, 71.20, 92.05 and 102.32 g $plant^{-1}$ respectively for the year 2014-15, while it was 20.66, 37.09, 73.04, 79.60 , 96.82 and 105.45 g $plant^{-1}$ respectively for the year 2015-16.

Among the eleven tratments, the application of fertilizer in the second tertile of the irrigation period resulted significantly maximum dry matter accumulation per plant as 22.20, 35.40, 67.80, 81.25, 95.50, 106.50 and 24.20, 39.40, 74.80, 89.25, 100.50, 109.50 and 23.20, 37.40, 71.30, 85.25, 98.00, 108.00 g $plant^{-1}$ at 30, 60, 90, 120, 150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively. The drip irrigation with no fertilizer noticed minimum dry matter accumulation per plant as 16.20, 32.40, 64.90, 67.00, 88.25, 100.25 and 18.20, 35.40, 71.90, 75.00, 93.25, 103.25 and 17.20, 33.90, 68.40, 71.00, 90.75, 101.75 g $plant^{-1}$ at 30, 60, 90, 120, 150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively.

Out of the 100% fertigated treatments, the application of fertilizer in the second tertile of the irrigation period resulted significantly maximum dry matter accumulation as 22.20, 35.40, 67.80, 81.25, 95.50, 106.50 and 24.20, 39.40, 74.80, 89.25, 100.50, 109.50 and 23.20, 37.40, 71.30, 85.25, 98.00, 108.00 g $plant^{-1}$ at 30, 60, 90, 120, 150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively. However, it showed at par values with application of fertilizer in the third tertile of the irrigation period at 30, 60, 90 and 150 days after transplanting during first year and 60, 90, 150 days after transplanting and at harvest during second year. Application of fertilizer in the first tertile of the irrigation period showed less dry matter accumulation per plant at all the crop growth stages during first year and second year. The dry matter content was increased with increase in age of the crop and higher dry matter was recorded at harvest. Similar results have been reported by Abdelraouf and Ragab (2018) and Shaymaa *et al.* (2009).

Table 4.21 Periodical dry matter content as influenced by different treatments

Treatment	Dry matter content (g plant^{-1})																	
	2014-2015						2015-2016						Pooled mean					
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT	At harvest
T_1 : 100% fertigation in first tertile of the irrigation period	19.50	34.00	66.20	70.75	93.00	101.50	21.50	37.00	73.20	78.75	97.00	104.50	20.50	35.50	69.70	74.75	95.00	103.00
T_2 : 100% fertigation in second tertile of the irrigation period	22.20	35.40	67.80	81.25	95.50	106.50	24.20	39.40	74.80	89.25	100.50	109.50	23.20	37.40	71.30	85.25	98.00	108.00
T_3 : 100% fertigation in third tertile of the irrigation period	20.85	35.20	67.30	76.00	94.50	104.25	22.85	38.20	74.30	84.00	99.00	108.00	21.85	36.70	70.80	80.00	96.75	106.12
T_4 : 100% fertigation during complete irrigation period	20.25	33.60	66.80	73.75	94.00	103.25	22.25	37.60	73.80	81.75	98.00	107.00	21.25	35.60	70.30	77.75	96.00	105.13
T_5 : 75% fertigation + 25% soil application	16.80	32.60	65.30	69.00	90.75	100.75	18.80	35.60	72.30	77.00	95.75	103.75	17.80	34.10	68.80	73.00	93.25	102.25
T_6 : 50% fertigation + 50% soil application	18.15	33.40	65.50	69.50	91.50	101.50	20.15	36.40	72.50	79.00	96.50	104.50	19.15	34.90	69.00	74.25	94.00	103.00
T_7 : 25% fertigation + 75% soil application	19.05	33.80	65.70	69.75	92.00	102.00	21.05	36.80	72.70	80.10	97.00	105.00	20.05	35.30	69.20	74.93	94.50	103.50
T_8 : DI with 100% CF	19.35	35.20	66.60	70.75	93.25	103.25	21.35	38.20	73.60	78.75	98.25	106.25	20.35	36.70	70.10	74.75	95.75	104.75
T_9 : SI with 100% CF + foliar spray	16.05	34.60	65.30	68.25	90.25	101.50	18.50	37.60	72.30	76.25	95.25	104.50	17.28	36.10	68.80	72.25	92.75	103.00
T_{10} : SI with 100% CF	16.38	32.80	65.10	67.25	89.50	100.75	18.35	35.80	72.10	75.75	94.50	103.75	17.37	34.30	68.60	71.50	92.00	102.25
T_{11} : DI with no fertilizer	16.20	32.40	64.90	67.00	88.25	100.25	18.20	35.40	71.90	75.00	93.25	103.25	17.20	33.90	68.40	71.00	90.75	101.75
SE±	0.65	0.64	0.60	0.55	0.56	1.20	0.86	0.81	0.62	0.61	0.47	0.59	0.77	0.74	0.61	0.59	0.52	0.95
C.D. at 5 %	1.94	1.90	1.77	1.64	1.65	3.55	2.56	2.40	1.85	1.81	1.39	1.75	2.20	NS	NS	1.68	1.48	2.72
General mean	18.62	33.91	66.05	71.20	92.05	102.32	20.66	37.09	73.04	79.60	96.82	105.45	19.64	35.50	69.55	75.40	94.43	103.89

In split fertilized treatments, the maximum dry matter accumulation per plant was noticed under drip irrigation with 100% conventional fertilizer (NK-drip and P-soil) as 19.35, 35.20, 66.60, 70.75, 93.25, 103.25 and 21.35, 38.20, 73.60, 78.75, 98.25, 106.25 and 20.35, 36.70, 70.10, 74.75, 95.75, 104.75 g plant^{-1} at 30, 60, 90, 120, 150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively. As compared to 25% fertigation + 75% soil application and 50% fertigation + 50% soil application during 2014-15, 2015-16 and pooled mean.

In conventional fertilized treatments, the surface irrigation with 100% conventional fertilizer + foliar spray showed significantly maximum dry matter accumulation per plant was 16.05, 34.60, 65.30, 68.25, 90.25, 101.50 and 18.50, 37.60, 72.30, 76.25, 95.25, 104.50 and 17.28, 36.10, 68.80, 72.25, 92.75, 103.00 g plant^{-1} at 30, 60, 90, 120, 150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively as compared to surface irrigation with 100% conventional fertilizer.

In control treatment of the drip irrigation with no fertilizer registered significantly minimum dry matter accumulation per plant as 16.20, 32.40, 64.90, 67.00, 88.25, 100.25 and 18.20, 35.40, 71.90, 75.00, 93.25, 103.25 and 17.20, 33.90, 68.40, 71.00, 90.75, 101.75 g plant^{-1} at 30, 60, 90, 120, 150 days after transplanting and at harvest during 2014-15, 2015-16 and pooled mean, respectively.

4.9 Water Use by Tomato

Data regarding water applied, water use efficiency, water saving, and per cent increase in yield during 2014-2015, 2015-2016 and pooled mean are presented in Table 4.22 and Appendix-I.

The drip method of irrigation resulted into lowest water use (432.72 mm) as compared to surface method of irrigation (868.22 mm) and thus resulted into 50.60 % water saving in drip irrigation system over surface irrigation (Table 4.22). The water requirement in drip was very less as compared with water requirement under surface method of irrigation, because water was applied directly in root zone which increased water application efficiency and water loss through percolation, infiltration and evaporation etc. was avoided.

Among all the eleven treatments, the application of fertilizer in the third tertile of the irrigation period resulted into significantly maximum water use efficiency

(165.37 kg ha^{-1} mm^{-1}) and per cent increase in yield (71.47 %) during 2014-15 and application of fertilizer in the second tertile of the irrigation period resulted into maximum water use efficiency (165.73 and 163.05 kg ha^{-1} mm^{-1}) and per cent increase in yield (81.14 and 74.01 %) during 2015-16 and pooled mean.The drip irrigation with no fertilizer resulted into minimum water use efficiency (64.78, 69.08 and 67.17 kg ha^{-1} mm^{-1}) and per cent increase in yield (-32.83, -24.50 and -28.32 %) during 2014-15, 2015-16 and pooled mean.

In 100% fertigated treatments, the application of fertilizer in the third tertile of the irrigation period resulted into significantly higher water use efficiency (165.37 kg ha^{-1} mm^{-1}) and per cent increase in yield (71.47 %) during first year and application of fertilizer in the second tertile of the irrigation period resulted into maximum water use efficiency (165.73 kg ha^{-1} mm^{-1}) and per cent increase in yield (81.14 %) during second year. The application of fertilizer during complete irrigation period exhibited minimum water use efficiency (153.55 kg ha^{-1} mm^{-1}) and per cent increase in yield (59.22 %) during first year and the application of fertilizer in the first tertile of the irrigation period resulted into minimum water use efficiency (152.81 kg ha^{-1} mm^{-1}) and per cent increase in yield (67.02 %) during second year.

Out of the split fertilized treatments, the application of 75% fertigation + 25% soil application observed significantly maximum water use efficiency (135.60, 123.67 and 128.98 kg ha^{-1} mm^{-1}) and per cent increase in yield (40.61, 37.17 and 37.64%) during 2014-15, 2015-16 and pooled mean as compared to application of 50% fertigation + 50% soil application and drip irrigation with 100% conventional fertilizer (NK-drip and P-soil). The application of 25% fertigation + 75% soil application showed lesser water use efficiency (115.99 106.84 and 110.91 kg ha^{-1} mm^{-1}) and per cent increase in yield (20.27 16.77 and 18.36%) during 2014-15, 2015-16 and pooled mean.

Out of the conventional fertilized treatments the surface irrigation with 100% conventional fertilizer + foliar spray exhibited higher water use efficiency (53.61, 52.79 and 53.17 kg ha^{-1} mm^{-1}) and per cent increase in yield (12.52, 8.26 and 10.20%) during 2014-15, 2015-16 and pooled mean as compared to surface irrigation with 100% conventional fertilizer. Similar results were reported by Tanaskovik *et al.* (2011) and Singandhupe *et al.* (2003).

Table 4.22 Water use by tomato as influenced by different treatments

Treatment	2014-2015				2015-2016				Pooled mean			
	Water Applied mm	WUE kg/ha-mm	Water saving (%)	% Increase in yield	Water Applied mm	WUE kg/ha-mm	Water saving (%)	% Increase in yield	Water Applied mm	WUE kg/ha-mm	Water saving (%)	% Increase in yield
T_1 : 100% fertigation in first tertile of the irrigation period	432.72	159.43	50.60	65.31	592.94	152.81	46.70	67.02	512.83	155.76	48.51	66.22
T_2 : 100% fertigation in second tertile of the irrigation period	432.72	159.70	50.60	65.60	592.94	165.73	46.70	81.14	512.83	163.05	48.51	74.01
T_3 : 100% fertigation in third tertile of the irrigation period	432.72	165.37	50.60	71.47	592.94	162.85	46.70	72.39	512.83	161.12	48.51	71.95
T_4 : 100% fertigation during complete irrigation period	432.72	153.55	50.60	59.22	592.94	157.72	46.70	77.99	512.83	158.72	48.51	69.38
T_5 : 75% fertigation + 25% soil application	432.72	135.60	50.60	40.61	592.94	123.67	46.70	35.17	512.83	128.98	48.51	37.64
T_6 : 50% fertigation + 50% soil application	432.72	118.73	50.60	23.11	592.94	106.27	46.70	16.15	512.83	111.80	48.51	19.31
T_7 : 25% fertigation + 75% soil application	432.72	115.99	50.60	20.27	592.94	106.84	46.70	16.77	512.83	110.91	48.51	18.36
T_8 : DI with 100% CF	432.72	119.99	50.60	24.42	592.94	111.26	46.70	21.60	512.83	115.14	48.51	22.88
T_9 : SI with 100% CF + foliar spray	868.22	53.61	0.00	12.52	1112.49	52.79	0.00	8.26	990.355	53.17	0.00	10.20
T_{10} : SI with 100% CF	868.22	47.65	0.00	0.00	1112.49	48.76	0.00	0.00	990.355	48.25	0.00	0.00
T_{11} : DI with no fertilizer	432.72	64.78	50.60	-32.83	592.94	69.08	46.70	-24.50	512.83	67.17	48.51	-28.32

In control treatment of drip irrigation with no fertilizer exhibited minimum water use efficiency (64.78, 69.08 and 67.17 kg $ha^{-1}mm^{-1}$) and per cent increase in yield (-32.83, -24.50 and -28.32%) during 2014-15, 2015-16 and pooled mean.

4.10 Economics

The data regarding the cost of cultivation, net seasonal income, total net income B:C ratio and net extra income over control and water productivity (Appendix-IV) of tomato as influenced by different fertigation treatments during 2014-15, 2015-16 and pooled mean are presented in Table 4.23 and graphically presented in Fig 4.33, 4.34 4.35 and 4.36.

The annalised cost of drip irrigation systems comprising of depreciation, intrest on capit and repairs and maintainance cost towards irrigation system was include into the cost of cultivation of all treatment under drip. Due to this the cost of cultivation of drip irrigation treatments observed to be higher than surface irrigated treatment due to higher fixed cost of drip systems (Table 4.23 and Appendix-IV). Similarly the cost of cultivation in all the treatments with application of 0 to 100% of water soluble fertilizers varied considerably due to very high (3 to 5 times) costs of water soluble fertilizers as compared to conventional fertilizers.The cost of cultivation of 100% fertigated treatments observed to be higher than the application of 75% fertigation + 25% soil application, application of 50% fertigation + 50% soil application, and surface irrigation with 100% Conventional fertilizer + foliar spray during first, second year and pooled mean. Minimum cost of cultivation was observed in drip irrigation with no fertilizer during first, second year and pooled mean.

The cost of cultivation of the application of 100% water soluble fertilizers was observed higher (₹ 131241 ha^{-1} during both the years) than the application of 75% fertigation + 25% soil application, application of 50% fertigation + 50% soil application, and surface irrigation with 100% Conventional fertilizer + foliar spray (₹ 122790, ₹ 122790 and ₹ 122790 ha^{-1}) during first, second year and pooled mean. Minimum cost of cultivation was observed in drip irrigation with no fertilizer (₹ 100348 ha^{-1}) during first, second year and pooled mean.

Table 4.23 Economics of tomato as influenced by different treatments

Treatment	2014-2015						2015-2016						Pooled mean					
	Cost of cultivation (₹/ha)	Net seasonal income (₹/ha)	Total net income (₹/ha)	B:C ratio	Net extra income over control (₹)	Water productivity (₹/ha mm)	Cost of cultivation (₹/ha)	Net seasonal income (₹/ha)	Total net income (₹/ha)	B:C ratio	Net extra income over control (₹)	Water productivity (₹/ha mm)	Cost of cultivation (₹/ha)	Net seasonal income (₹/ha)	Total net income (₹/ha)	B:C ratio	Net extra income over control (₹)	Water productivity (₹/ha mm)
T_1 : 100% fertigation in first tertile of the irrigation period	131241	613261	1436443	5.77	274496	966	131241	762561	1700049	6.90	339296	1286	131241	687961	1569452	6.34	306796	1121
T_2 : 100% fertigation in second tertile of the irrigation period	131241	614561	1438911	5.78	275796	968	131241	839161	1843768	7.49	415896	1415	131241	726861	1642876	6.63	345696	1184
T_3 : 100% fertigation in third tertile of the irrigation period	131241	641461	1489968	5.98	302696	1010	131241	822061	1811685	7.36	398796	1386	131241	731761	1652125	6.67	350596	1192
T_4 : 100% fertigation during complete irrigation period	131241	585361	1383488	5.55	246596	922	131241	791661	1754647	7.13	368396	1335	131241	688461	1570396	6.34	307296	1121
T_5 : 75% fertigation + 25% soil application	122790	508612	1221774	5.24	169847	801	122790	598212	1375837	5.97	174947	1009	122790	553412	1299541	5.61	172247	901
T_6 : 50% fertigation + 50% soil application	115622	435680	1069740	4.87	96915	686	115622	502180	1182211	5.45	78915	847	115622	468980	1126646	5.16	87815	764
T_7 : 25% fertigation + 75% soil application	108555	429747	1045066	5.07	90982	677	108555	512647	1188590	5.84	89382	865	108555	471247	1117586	5.45	90082	768
T_8 : DI with 100% CF	118655	438647	1081128	4.80	99882	691	118655	528747	1237747	5.56	105482	892	118655	483747	1160243	5.18	102582	788
T_9 : SI with 100% CF + foliar spray	119337	394283	515100	4.32	55518	327	119337	466483	587300	4.92	43218	419	119337	430383	551200	4.62	49218	371
T_{10} : SI with 100% CF	117555	338765	457800	3.89	0	281	117555	423265	542300	4.61	0	380	117555	381165	500200	4.26	0	329
T_{11} : DI with no fertilizer	100348	194854	583650	3.06	-143911	307	100348	296954	768503	4.08	-126311	501	100348	245954	676856	3.57	-135211	401

The higher net seasonal income was observed under the application of fertilizer in the second tertile of the irrigation period (₹ 641461 and ₹ 839161 ha^{-1}) due to higher fruit yield during first and second year and in the third tertile of the irrigation period (₹ 731761 ha^{-1}) during pooled mean. The application of fertilizer during complete irrigation period gave lowest yield of fruit hence the net seasonal income was also lowest (₹ 585361 ha^{-1}) during first year and application of fertilizer in the first tertile of the irrigation period (₹ 762561 and ₹ 687961 ha^{-1}) during second year and pooled mean. The application of 75% fertigation + 25% soil application resulted into maximum net seasonal income (₹ 508612, ₹ 598212 and ₹ 553412 ha^{-1}) as compared to application of 50% fertigation + 50% soil application during first, second year and pooled mean. The application of 25% fertigation + 75% soil application observed minimum value of net seasonal income (₹ 429747, ₹ 512647 and ₹ 471247 ha^{-1}) due to lowest yield of fruit during first, second year and pooled mean. Among the control treatment, surface irrigation with 100% Conventional fertilizer + foliar spray exhibited higher value of net seasonal income (₹ 394283, ₹ 466483 and ₹ 430383 ha^{-1}) as compared to drip irrigation with no fertilizer during first, second year and pooled mean.

Total net income was estimated taking into consideration the additional area that can be brought under irrigation due to water saving into drip as compared to conventional method. The application of fertilizer in the third tertile of the irrigation period resulted into maximum total net income (₹ 1489968 and ₹ 1652125 ha^{-1}) during first year and pooled mean second tertile of the irrigation period (₹ 1843768 ha^{-1}) during second year. The lowest value of total net income (₹ 1383488 ha^{-1}) was observed under application of fertilizer during complete irrigation period during first year and application of fertilizer in first tertile of the irrigation period (₹ 1700049 and ₹ 1569452 ha^{-1}) during second year and pooled mean. The application of 75% fertigation + 25% soil application observed maximum total net income (₹ 1221774, ₹ 1375837 and ₹ 1299541 ha^{-1}) as compared to application of 50% fertigation + 50% soil application during first, second year and pooled mean. Drip irrigation with 100%Conventional fertilizer resulted higher value of total net income (₹ 1081128, ₹ 1237747 and ₹ 1160243 ha^{-1}) as compared to drip irrigation with no fertilizer during first, second year and pooled mean.

The treatment is said to be profitable when the B:C ratio is more than 1 and if it is less than 1, then treatment showed more expenditure than income i.e. not

profitable and if its value is 1 then there is no loss or profit. The B:C ratio was improved under fertigation treatments as compared to surface irrigation with conventional fertilizers.

Out of 4 treatments of 100% fertigation, highest value of B:C ratio was observed under the application of fertilizer in the third tertile of the irrigation period (5.98 and 6.67) during first year and pooled mean and second tertile of the irrigation period (7.49) during second year. The lowest value of B:C ratio was observed under application of fertilizer during complete irrigation period (5.55) during first year and application of fertilizer in first tertile of the irrigation period (6.90 and 6.34) during second year and pooled mean. Among split fertilization, the application of 75% fertigation + 25% soil application recorded maximum higher value of B:C ratio (5.24, 5.97 and 5.61) as compared to application of 50% fertigation + 50% soil application during first, second year and pooled mean. Drip irrigation with 100% Conventional fertilizer observed higher value of B:C ratio (4.80, 5.56 and 5.18) as compared to surface irrigation with 100% conventional fertilizer + foliar spray during first, second year and pooled mean. The drip irrigation with no fertilizer resulted lowest value of B:C ratio (3.06, 4.08 and 3.57) during first, second year and pooled mean among all eleven treatments.

The application of fertilizer in the third tertile of the irrigation period exhibited highest net extra income over control (₹ 302696 and ₹ 350596) during first year and pooled mean and second tertile of the irrigation period (₹ 415896) during second year. The application of fertilizer during complete irrigation period observed significantly lower net extra income over control (₹ 246596) during first year and application of fertilizer in the first tertile of the irrigation period (₹ 339296 and ₹ 306796) during second year and pooled mean.. The application of 75% + 25% soil application recorded maximum net extra income over control (₹ 169847, ₹ 174947 and ₹ 172247) followed by application of 50% fertigation + 50% soil application during first, second year and pooled mean. The net extra income over control (₹ 99882, ₹ 105482 and ₹ 102582) was highest in drip irrigation with 100% conventional fertilizer as compared to surface irrigation with 100% Conventional fertilizer + foliar spray during first, second year and pooled mean. The lowest value of net extra income over control aamong all eleven treatments was recorded in drip irrigation with no fertilizer (₹ -143911, ₹ -126311 and ₹ -135211) during first, second year and pooled mean. All fertigation treatments gave more income than conventional fertilizer application treatments.

The highest water productivity was observed in application of fertilizer in the third tertile of the irrigation period (₹1010 and 1192 ha^{-1} mm) during first year and pooled mean and second tertile of the irrigation period (₹1415 ha^{-1} mm) during second year. The application of fertilizer during complete irrigation period ₹ (922 ha^{-1} mm) during first year and application of fertilizer in the first tertile of the irrigation period (₹ 1286 ha^{-1} mm and 1121 ha^{-1} mm) during second year and pooled mean resulted lowest values of water productivity. The application of 75% fertigation + 25% soil application exhibited higher water productivity (₹ 801ha^{-1} mm 1009 ha^{-1} mm and 901 ha^{-1} mm) as compared to application of 50% fertigation + 50% soil application during first, second year and pooled mean. Drip irrigation with 100% conventional fertilizer observed maximum water productivity (6₹91 ha^{-1} mm, 8₹92 ha^{-1} mm and ₹788 ha^{-1} mm) as compared to surface irrigation with 100% Conventional fertilizer + foliar spray during first, second year and pooled mean. Similar results were reported by Jha *et al.* (2017), Amala and Syriac (2016), Pawar *et al.* (2013) and Kale *et al.* (2018) reported that the B:C ratio was improved under fertigation treatments as compared to surface irrigation with CF.

4.11 Nutrient distribution

The recommended doses of nutrients in the soil depends on the quantity and kinds of fertilizer applied, form of nutrient ions, moisture content of the soil and other reacting ions present in soil solution. The availability and mobility of nutrients at root zone influences the uptake and yield of the crop. Leaching, volatilization and fixation of nutrients in the soil are some of the factors that affect the availability of soil nutrients (Fanish and Muthukrishnan 2013).

4.11.1 Nitrogen distribution

The data regarding nitrogen distribution by tomato plants as influenced periodically by different treatments are graphically presented in Fig 4.37 to 4.42 and presented in Appendix II and V.

The available nitrogen was decreased steadily with distance from the dripper along and between the laterals up to a distance of 45 cm. Along the distance, the higher available nitrogen as 266.86, 270.66, 263.86 and 259.63 kg ha^{-1} during 60 DAT at a spacing of 0, 15, 30 and 45 cm, respectively was recorded under application of fertilizer in the second half of the irrigation period as compared to application of fertilizer in the first tertile of the irrigation period, third tertile of the irrigation period and during

complete irrigation period. The nitrogen availability steadily decreased with increased depth up to 45 cm. The peak available soil nitrogen (207 kg ha^{-1}) was recorded at a point of application. The similar trend was observed under 75% fertigation + 25% soil application, 50% fertigation + 50% soil application and 25% fertigation + 75% soil application. The peak available nitrogen of 253.71, 258.69, 248.75 and 243.63 kg ha^{-1} at 60 DAT at a depth of 0, 15, 30 and 45 cm, respectively was recorded under 50% fertigation + 50% soil application.

The contour maps of nitrogen distribution in root zone soils at 60, 120 DAT and at harvest during first and second crop years are plotted and attached as Fig. 4.37 and 4.42.

4.11.2 Phosphorus distribution

Among all the elements required by a plant, phosphorus is one of the most important nutrients for crop production. The data regarding phosphorus distribution by tomato plant as influenced periodically by different treatments are presented in Appendix-III and VI and graphically depicted in Fig. 4.43 to 4.48.

The highest available phosphorus in soil was confined to 0-15 cm of soil layer under all fertigation levels. The available phosphorus decreased with increase in distance and soil depth. Higher availability of phosphorus of 42.96 kg ha^{-1} was observed under application of fertilizer during complete irrigation period during first year at 60 DAT. The application of fertilizer in the second tertile of the irrigation period recorded highest availability of phosphorus of 30.55 and 17.00 kg ha^{-1} at 120 DAT and at harvest during first year. The application of fertilizer in the second tertile of the irrigation period recorded highest availability of phosphorus of 36.59, 28.61 and 15.71 at 60, 120 DAT and at harvest during second year. Among the split fertilized treatments, the higher available phosphorus 35.63, 26.87, 16.20 and 35.65, 24.42, 13.71 kg ha^{-1} at 60, 120 DAT and at harvest at 0, 15, 30 and 45 cm, respectively during first and second year was recorded under 75% fertigation + 25% soil application. In conventional fertilized treatments the surface irrigation with 100% conventional fertilizer + foliar spray recorded highest availability of phosphorus as 30.50, 21.75, 14.75 and 31.52, 21.57, 12.70 kg ha^{-1} at 60, 120 DAT and at harvest during first and second year, respectively.

The contour maps of phosphorus distribution in root zone soils at 60, 120 DAT and at harvest during first and second crop years are plotted and attached as Fig. 4.43 and 4.48.

4.11.3 Potassium distribution

The data regarding potassium mobility by tomato plant as influenced periodically by different treatments are presented in Appendix-IV and VII and graphically presented in Fig 4.49 to 4.54.

The highest available potassium in soil was confined to 0-15 cm of soil layer under all fertigation levels. The available potassium decreased with increase in distance and soil depth. The peak availability of potassium as 370.22, 339.56, 327.68 and 358.40, 332.56, 323.52 kg ha^{-1} at 60, 120 DAT and at harvest during first and second year was observed under the application of fertilizer in the second tertile of the irrigation period.

In split applications, higher available potassium of 356.60, 330.34, 322.44 and 353.50, 327.56, 316.45 kg ha^{-1} at 60, 120 DAT and at harvest during first and second year was recorded under 75% fertigation + 25% soil application. In conventional fertilized treatmentsThe surface irrigation with 100% conventional fertilizer + foliar spray recorded highest availability of potassium 348.45, 323.45, 318.64 and 349.59, 322.55, 314.50 kg^{-1} ha at 60, 120 DAT and at harvest during first and second year, respectively.

The contour maps of potassium distribution in root zone soils at 60, 120 DAT and at harvest during first and second crop years are plotted and attached as Fig. 4.49 and 4.54.

Similar results were observed by Mmolawa and Or (2000) who also reported similar findings as that potassium (K) distribution in the soil profile is characterized by decreasing soil K content with depth and K content increased significantly throughout the 0-15 cm soil profile even though movement of surface applied K in the soil profile was slow (Fanish and Muthukrishnan, 2013).

4.12 Nutrient mobility

The movement of nutrient and its availability studied at 0-45 cm laterally and 0-45 cm vertically in soil. The initial nutrient availability in root zone depth is given in Table 4.24 and Table 4.25, which was taken into consideration while determining the nutrient mobility in vertical and horizontal direction.

4.12.1 Nitrogen mobility

The available N content in soil was maximum just beneath the dripper in all the treatments (Table 4.26). The N mobility was found to be varied considerably with

period in all the treatments. It was maximum at 60 DAT (45 cm lateral and 45 cm vertical) in 100% fertigated treatments (T_1 to T_3) and 30 cm lateral and 30 cm vertical in split fertilized treatments (T_5 to T_3) . The N mobility increased at 60 DAT in almost all the treatments and there after they decreased. These results are in conformity with the results reported by Bangar *et al.* (1998) and Jadhav (2012).

The source of fertilizer also resulted into moderate change in 'N' availability in the root zone soil of tomato at all the stages. The water soluble fertilizers resulted into more availability of N in soil as compared to conventional fertilizers. As more quantum of water was available just beneath the dripper, there was corresponding increase in available N in the soil. It has been inferred a direct association between N availability and presence of in situ irrigation water. These results are in close conformity with those reported by Bangar *et al*. (1998) and Bangar and Chaudhary (2000).

4.12.2 Phosphorus mobility

The available P content in soil was maximum just beneath the dripper in all the treatment and the P mobility was found to be varied considerably with period in all the treatments (Table 4.27). The maximum movement of P_2O_5 was observed at 60 DAT (30 cm lateral and 30 cm vertical).

The 100% fertigated treatments and split fertilized treatments showed slight effect on the mobility of phosphorus in almost all the treatments. The higher fertilizer doses showed marginally increased P mobility. The P mobility was varied significantly due to source of fertilizers also. The 100% fertigated treatments resulted into more P mobility as compared to split fertilized treatments. It may be due to large quantity of fertilizer was applied during each split in 100% fertigated treatments as compared to split fertilized treatments.

The phosphorus mobility in the soil was due to the concentration of gradient created on account of mass flow which has rendered nutrient to move from higher concentration to lower one. The water available in root zone played a crucial role in transporting nutrients towards roots. The results are in close conformity with those reported by Kafkafi and Bar Yosef (1980) in tomato.

Table 4.24 Initial nutrient availability (kg ha^{-1}) in soil during first crop year

Depth	Nitrogen					Phosphorus					Potassium				
	0	15	30	45	Average	0	15	30	45	Average	0	15	30	45	Average
0	332.94	312.45	258.63	223.45	281.87	33.23	29.52	25.13	20.36	27.06	436.80	422.36	386.41	341.32	396.72
15	320.56	286.52	263.47	212.56	270.78	28.36	24.36	19.24	15.36	21.83	428.63	369.24	341.56	320.41	364.96
30	286.45	255.46	224.36	196.48	240.69	24.53	22.36	17.42	14.30	19.65	365.24	345.63	331.25	316.52	339.66
45	225.88	191.23	188.10	185.74	197.74	20.36	16.36	12.45	9.36	14.63	352.36	320.45	311.45	278.52	315.70
Average	291.46	261.42	233.64	204.56	247.77	26.62	23.15	18.56	14.85	20.79	395.76	364.42	342.67	314.19	354.26

Table 4.25 Initial nutrient availability (kg ha^{-1}) in soil during second crop year

Depth	Nitrogen					Phosphorus					Potassium				
	0	15	30	45	Average	0	15	30	45	Average	0	15	30	45	Average
0	240.36	235.21	231.40	225.31	233.07	28.52	24.52	18.42	14.52	21.50	352.25	349.52	345.14	342.16	347.27
15	238.56	233.48	224.51	220.36	229.23	24.45	21.30	16.20	13.47	18.86	349.52	344.47	340.53	335.24	342.44
30	229.52	223.52	218.47	212.24	220.94	20.47	18.23	15.40	12.25	16.59	344.26	340.36	337.51	332.38	338.63
45	222.25	216.42	210.45	206.54	213.92	16.54	12.36	10.48	9.52	12.23	340.26	336.52	331.58	326.31	333.67
Average	232.67	227.16	221.21	216.11	224.29	22.50	19.10	15.13	12.44	17.29	346.57	342.72	338.69	334.02	340.50

Table 4.26 Nitrogen mobility as influenced by different treatments

Treatment	N mobility (cm)											
	2014-2015						2015-2016					
	60 DAT		120 DAT		At harvest		60 DAT		120 DAT		At harvest	
	Horizantal	Vertical	Horizantal	Vertical	Horizantal	Vertical	Horizantal	Vertical	Horizantal	Vertical	Horizantal	Vertical
T_1 : 100% fertigation in first tertile of the irrigation period	45	45	30	30	30	30	40	40	30	30	30	30
T_2 : 100% fertigation in second tertile of the irrigation period	45	45	30	30	30	30	40	40	30	30	30	30
T_3 : 100% fertigation in third tertile of the irrigation period	45	45	30	30	30	30	40	30	30	30	30	30
T_4 : 100% fertigation during complete irrigation period	40	40	30	30	30	30	30	30	30	30	30	30
T_5 : 75% fertigation + 25% soil application	30	30	30	30	15	15	30	30	30	15	15	15
T_6 : 50% fertigation + 50% soil application	30	30	15	15	15	15	30	30	15	15	15	15
T_7 : 25% fertigation + 75% soil application	15	15	15	15	15	15	15	15	15	15	15	15
T_8 : DI with 100% CF	15	15	15	15	15	15	15	15	15	15	15	15
T_9 : SI with 100% CF + foliar spray	-	-	-	-	-	-	-	-	-	-	-	-
T_{10} : SI with 100% CF	-	-	-	-	-	-	-	-	-	-	-	-
T_{11} : DI with no fertilizer	-	-	-	-	-	-	-	-	-	-	-	-

Table 4.27 Phosphorus mobility as influenced by different treatments

Treatment	P mobility (cm)											
	2014-2015						2015-2016					
	60 DAT		120 DAT		At harvest		60 DAT		120 DAT		At harvest	
	Horizantal	Vertical	Horizantal	Vertical	Horizantal	Vertical	Horizantal	Vertical	Horizantal	Vertical	Horizantal	Vertical
T_1 : 100% fertigation in first tertile of the irrigation period	15	30	15	30	15	30	15	30	15	30	15	30
T_2 : 100% fertigation in second tertile of the irrigation period	30	30	15	30	15	30	30	30	15	30	15	30
T_3 : 100% fertigation in third tertile of the irrigation period	30	30	15	30	15	30	15	30	15	30	15	30
T_4 : 100% fertigation during complete irrigation period	15	30	15	30	15	30	15	30	15	30	15	30
T_5 : 75% fertigation + 25% soil application	15	30	15	15	15	15	15	30	15	15	15	15
T_6 : 50% fertigation + 50% soil application	15	30	15	15	15	15	15	15	15	15	15	15
T_7 : 25% fertigation + 75% soil application	15	15	15	15	15	15	15	15	15	15	15	15
T_8 : DI with 100% CF	15	15	15	15	15	15	15	15	15	15	15	15
T_9 : SI with 100% CF + foliar spray	-	-	-	-	-	-	-	-	-	-	-	-
T_{10} : SI with 100% CF	-	-	-	-	-	-	-	-	-	-	-	-
T_{11} : DI with no fertilizer	-	-	-	-	-	-	-	-	-	-	-	-

4.12.3 Potassium mobility

The available K content in soil was maximum just beneath the dripper in all the treatments (Table 4.28). The K mobility was found to be varied considerably with period in all the treatments. It was maximum at 60 DAT (15 to 30 cm horizontal and 30 cm vertical). These results of findings are in close conformity to those of Rauschkolb *et al*. (1978). The 100% fertigated treatments and split fertilized treatments showed slight effect on the mobility of potassium in almost all the treatments. The higher fertilizer doses showed marginally increased K mobility. Less mobility in split fertilized treatments was observed. The K mobility was varied significantly due to source of fertilizers also.

As more quantum of water was available just beneath the dripper, there was corresponding increase in available potassium in the soil. It has been inferred direct association between potassium availability and presence of in-situ irrigation water. These results are in conformity with those reported by Bangar *et al*. (1998) and Bangar and Chaudhari (2006).

4.13 Moisture distribution pattern

The data regarding moisture distribution in drip irrigation treatments pattern as influenced periodically by different treatments are presented in Appendix-VIII and graphically depicated in Fig 4.55 and 4.56.

Higher available soil moisture was observed at 30 cm depth from the dipper. The availability of moisture increased vertically upto the 30 cm depth thereafter they decreased and horizontally it decreased with increase in distance from emitter. The similar trend was observed under all the drip irrigated treatments. Similar results are reported by Li *et al.* (2004), Amin *et al.* (2006) and Ahluwalia *et al.* (1993).

Large spatial and temporal variability in soil moisture is generally influenced by soil texture, soil profile, topography, crop cover and irrigation practices (Western and Grayson, 1998). To study the soil moisture distribution pattern within root zone, the soil moisture was determined periodically during both the crop years on gravimetric basis at the location of 0, 15, 30 and 45 cm horizontally and vertically from selected one dripper in each treatment. The moisture content was measured in each treatment 24 hrs after irrigation. The moisture content at respective positions are presented in Appendix-VIII.

Table 4.28 Potassium mobility as influenced by different treatments

Treatment	K mobility (cm)											
	2014-2015						2015-2016					
	60 DAT		120 DAT		At harvest		60 DAT		120 DAT		At harvest	
	Horizantal	Vertical	Horizantal	Vertical	Horizantal	Vertical	Horizantal	Vertical	Horizantal	Vertical	Horizantal	Vertical
T_1 : 100% fertigation in first tertile of the irrigation period	30	30	15	30	15	15	15	30	15	30	15	15
T_2 : 100% fertigation in second tertile of the irrigation period	30	30	15	30	15	30	30	15	15	30	15	30
T_3 : 100% fertigation in third tertile of the irrigation period	30	30	15	30	15	30	30	15	15	30	15	30
T_4 : 100% fertigation during complete irrigation period	30	15	15	30	15	15	30	15	15	30	15	15
T_5 : 75% fertigation + 25% soil application	15	15	15	15	15	15	15	15	15	15	15	15
T_6 : 50% fertigation + 50% soil application	15	15	15	15	15	15	15	15	15	15	15	15
T_7 : 25% fertigation + 75% soil application	15	15	15	15	15	15	15	15	15	15	15	15
T_8 : DI with 100% CF	15	15	15	15	15	15	15	15	15	15	15	15
T_9 : SI with 100% CF + foliar spray	-	-	-	-	-	-	-	-	-	-	-	-
T_{10} : SI with 100% CF	-	-	-	-	-	-	-	-	-	-	-	-
T_{11} : DI with no fertilizer	-	-	-	-	-	-	-	-	-	-	-	-

The limitations of soil moisture measurements using gravimetric method are highlighted in the results obtained in this investigation also. The trends are not consistent and many times contours at surface and deeper layers found to be behaving in unexplained manner, may be due to recording errors. However, in absence of any other sensors, the indicative conclusions are drawn from the analysis of observed data.

The data presented in Fig. 4.55 to 4.56 indicated that the soil moisture distribution and its uniformity within the soil profile under drip irrigation was to great extent affected by quantum of irrigation water applied during each event. Generally, the soil moisture was increased upto a depth of 30 cm and thereafter reduced. In horizontal direction, uniform distribution was seen upto a distance of 30 cm from lateral; however it decreased progressively with distance from the lateral.

The following observations could be outlined;

1. Across laterals, the values of moisture content and its distribution for all the treatments under drip were slightly different.
2. There was gradual increment in soil moisture content with increased soil depth and higher soil moisture content was found in the middle soil layer (15-30 cm) under all treatments.
3. Under drip irrigation in almost all treatments the lowest values of moisture contents were observed at soil surface may be due to evaporation.

5. SUMMARY AND CONCLUSIONS

The field investigation entitled, “Effect of fertigation timing on growth, yield and nutrient mobility for tomato in Inceptisol” was conducted during the *Rabi* season of the year 2014-15 and 2015-16 at research farm of the Inter Faculty Department of Irrigation Water Management, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar.

The soil of experimental site was uniform and leveled. It was well drained, silty clay loam in texture with low in available nitrogen (164.47 kg ha^{-1}), medium in phosphorus (18.79 kg ha^{-1}) and high in potassium (334.26 kg ha^{-1}) with slightly alkaline in reaction (pH 7.90). The electrical conductivity was 0.28 dSm^{-1} and organic carbon content of 0.5 per cent.

The present experiment was laid out in randomized block design (RBD) with three replications. There were eleven treatment combinations including 100 % fertigated treatments, spilt fertilization viz., 100% fertigation in first tertile of the irrigation period, 100% fertigation in second tertile of the irrigation period, 100% fertigation in third tertile of the irrigation period, 100% Fertigation during complete irrigation period, 75% fertigation + 25% soil application, 50% fertigation + 50% soil application, 25% fertigation + 75% soil application, drip irrigation with 100% conventional fertilizer, surface irrigation with 100% conventional fertilizer + foliar spray, surface irrigation with 100% conventional fertilizer, drip irrigation with no fertilizer.

The rainfall was not received during the entire crop growth period. The mean maximum temperature was ranged from 24.9 to 38.7^{0}C and minimum from 6.8 to 21.6^{0}C, relative humidity was ranged from 26 to 74 per cent at morning hours and 17 to 55 per cent at evening hours was favourable for the crop.

The periodical observations on growth, yield attributes, physiological parameters were recorded in tomato during both the years of investigation. Apart from this, chemical analysis for estimation of N, P and K in soil and plant was carried out during experimentation. Simultaneously nutrient uptake, fruit quality and economics were also studied. In irrigation studies, water requirement, water use efficiency and water

productivity were worked out. The important findings emerged from this investigation are summarized below.

1. Growth attributes

Among the 100% fertigated treatments the application of fertilizer in the third tertile of the irrigation period produced significantly maximum plant height (117.23, 115.22 and 116.23 cm), number of branches plant^{-1} (12.70, 12.37 and 12.53) at last harvesting stage, whereas the number of leaves plant^{-1} (75.87, 74.43 and 75.15) and leaf area plant^{-1} (179.70, 177.73 and 178.72 dm^2) were significantly higher at 120 days after transplanting during both the year and pooled mean. However application of fertilizer in the second tertile of the irrigation period found second in rank in respect of above growth attributes during both the years and pooled mean. The application of fertilizer during complete irrigation period resulted minimum values in respect of above growth attributes during both the years and pooled mean. The application of fertilizer in the second tertile of the irrigation period resulted into significantly maximum dry matter (106.50, 109.50 and 108.00g plant^{-1}) during both the years and pooled mean.

In the split fertigated treatments the 75 % fertigation (as per schedule B) + 25 % soil application produced significantly maximum plant height (110.56, 108.62 and 109.59 cm), number of branches plant^{-1} (11.57, 11.30 and 11.43) at last harvesting stage, whereas the number of leaves plant^{-1} (73.20, 72.30 and 72.75) and leaf area plant^{-1} (177.33, 176.10 and 176.72 dm^2) were also significantly higher at 120 days after transplanting during both the year and pooled mean. However 50% fertigation + 50% soil application found second in rank in respect of above growth attributes during both the years and pooled mean. The drip irrigation with 100% conventional fertilizer resulted maximum dry matter (103.25, 106.25 and 104.75 g plant^{-1}) during both the years and pooled mean.

Among the conventional fertilized treatments the surface irrigation with 100% conventional fertilizers + foliar spray produced significantly higher plant height (108.62, 105.53 and 107.07cm), number of branches plant^{-1} (10.73, 10.53 and 10.63) and dry matter (101.50, 104.50 and 103.00 g plant^{-1}) at last harvesting stage, whereas the number of leaves plant^{-1} (71.47, 71.47 and 71.47), leaf area plant^{-1} (176.60, 175.13 and 175.87 dm^2) were significantly higher at 120 days after transplanting during both the

years and pooled mean. However surface irrigation with 100 % conventional fertilizer found second in rank in respect of above growth attributes during both the year and pooled mean.

In control treatment drip irrigation with no fertilizers observed minimum values in respect of above growth attributes during both the years and pooled mean.

2. Yield attributes

In 100 % fertilized treatments the application of fertilizer in the third tertile of the irrigation period produced significantly maximum fruit yield of 78.50 t ha^{-1} during 2014-2015 and the application of fertilizer in the second tertile of the irrigation period registered higher fruit yield of 98.27 and 87.04 t ha^{-1} during 2015-2016 and pooled mean. The application of fertilizer in the third tertile of the irrigation period produced significantly higher number of fruits $plant^{-1}$ (73.35, 73.22 and 73.29) as well as fruit weight $plant^{-1}$ (2.72, 2.71 and 2.72) during both the years and pooled mean. Whereas, minimum fruit yield were observed under application of fertilizer during complete irrigation period.

Among the split fertilized treatments the application of 75% fertigation + 25 % soil application produced significantly higher fruit yield (64.37, 73.33 and 68.85 t ha^{-1}), number of fruits $plant^{-1}$ (65.57, 64.54 and 65.06) as well as fruit weight $plant^{-1}$ (2.41, 2.40 and 2.41 kg) during 2014-15, 2015-16 and pooled mean. The drip irrigation with 100% conventional fertilizer found second in rank in respect of fruit yield (56.96, 65.97 and 61.47 t ha^{-1}) and the application of 50% fertigation + 50% soil application found second in rank in respect of number of fruits $plant^{-1}$ (62.24, 62.10 and 62.17) as well as fruit weight $plant^{-1}$ (2.36, 2.34 and 2.35 kg) during both the years and pooled mean.

In conventional fertilized treatments surface irrigation with 100% conventional fertilizer + foliar spray produced significantly maximum fruit yield, number of fruits $plant^{-1}$ as well as fruit weight $plant^{-1}$ (51.51, 58.73 and 55.12 t ha^{-1}, 55.23, 55.17 and 55.20 and 1.80, 1.79 and 1.80 kg) during 2014-15, 2015-16 and pooled mean. However surface irrigation with 100% conventional fertilizer found second in rank in respect fruit yield, number of fruits $plant^{-1}$ as well as fruit weight $plant^{-1}$ during both the years and pooled mean.

In control treatment drip irrigation with no fertilizers observed minimum values in respect of above growth attributes during both the years and pooled mean.

3. Micrometeorological studies

Among the 100 % fertilized treatments the application of fertilizer in the third tertile of the irrigation period produced significantly higher CO_2 concentration (385.21, 383.47 and 384.34) at 90 days after transplanting, photosynthetic rate (27.76, 26.81 and 27.29) at 90 days after transplanting, stomatal conductance (0.72, 0.70 and 0.71) at 90 days after transplanting, stomatal resistance (13.53, 12.48 and 13.01) at harvest and transpiration rate (12.77, 12.45 and 12.61) at 90 days after transplanting during both the years and pooled mean followed by the application of fertilizer in the second tertile of the irrigation period. Application of fertilizer during complete irrigation period produced minimum CO_2 concentration, photosynthetic rate, stomatal conductance, stomatal resistance and transpiration rate during both the years and pooled mean.

In split fertilized treatments the 75% fertigation + 25% soil application produced significantly maximum CO_2 concentration (381.60, 378.89 and 380.24) at 90 days after transplanting, photosynthetic rate (23.71, 22.51 and 23.11) at 90 days after transplanting, stomatal conductance (0.64, 0.62 and 0.63) at 90 days after transplanting, stomatal resistance (10.18, 10.07 and 10.12) at harvest and transpiration rate (11.40, 11.18 and 11.29) at 90 days after transplanting during both the year and pooled mean. However 50% fertigation + 50% soil application soil application observed second rank in respect of CO_2 concentration, photosynthetic rate, stomatal conductance, stomatal resistance and transpiration rate during both the year and pooled mean. The 25% fertigation + 75% soil application produced lower values of CO_2 concentration, photosynthetic rate, stomatal conductance, stomatal resistance and transpiration rate during both the years and pooled mean.

Among conventional fertilized treatments the surface irrigation with 100% conventional fertilizer + foliar produced significantly maximum CO_2 concentration (376.18, 373.44 and 374.81) at 90 days after transplanting, photosynthetic rate (20.52, 17.49 and 19.01) at 90 days after transplanting, stomatal conductance (0.57, 0.47 and 0.56) at 90 days after transplanting, stomatal resistance (8.58, 8.13 and 8.36) at harvest

and transpiration rate (9.72, 9.42 and 9.57) at 90 days after transplanting during both the years and pooled mean followed by surface irrigation with 100% conventional fertilizers.

In control treatment drip irrigation with no fertilizers observed minimum CO_2 concentration, photosynthetic rate, stomatal conductance, stomatal resistance and transpiration rate during both the years, respeactively.

4. Fruit quality

The fruit quality parameters viz., total soluble solids (4.88 and 4.81^0) and lycopene content (4.12 and 4.11 mg 100 g^{-1} fruit juice) in tomato fruit were improved due to application of fertilizer in the third tertile of the irrigation period, where as pH of juice and titrable acidity were almost identical in all the fertigation treatments. The application of fertilizer in the second tertile of the irrigation period found second best treatment in respect of fruit quality during both the years. Application of fertilizer during complete irrigation period produced minimum value of fruit quality parameters during both the years, respectively.

Among all split fertilized treatments the fruit quality parameters viz., total soluble solids (4.58 and 4.54^0) and lycopene content (4.08 and 4.07 mg 100 g^{-1} fruit juice) in tomato fruit were improved due to 75% fertigation + 25% soil application, where as pH of juice and titrable acidity were almost identical in all the fertigation schedule. The 50% fertigation + 50% soil application observed second best treatment in respect of fruit quality during both the years.

The drip irrigation with 100% conventional fertilizer produced significantly higher fruit quality parameters viz., total soluble solids (4.49 and 4.44^0) and lycopene content (4.04 and 4.05 mg 100 g^{-1} fruit juice) in tomato fruit, where as pH of juice and titrable acidity were almost identical in all the fertigation schedule. The surface irrigation with 100% conventional fertilizer + foliar spray ranked second in fruit quality parameters during both the years. Drip irrigation with no fertilizer resulted inferior fruit quality parameters viz., total soluble and lycopene content as compared to fertigation treatments.

5. Nutrient uptake and availability

The application of fertilizer in second tertile of the irrigation period resulted significantly maximum uptake and availability of nitrogen **(**246.26, 299.72,

272.99 kg ha^{-1} and 258.03, 252.49, 255.26 kg ha^{-1}), phosphorus (49.95, 55.51, 52.73 kg ha^{-1} and 39.32, 39.52, 39.42 kg ha^{-1}) and potassium (212.21, 237.35, 224.78 kg ha^{-1} and 370.22, 358.40, 364.31 kg ha^{-1}) at harvest and 60 DAT during first year, second year and pooled mean. While application of fertilizer in the third tertile of the irrigation period found second in order in respect of uptake and availability of nitrogen, phosphorus and potassium during both the year and pooled mean. Application of fertilizer in the first tertile of the irrigation period resulted minimum uptake and availability of nitrogen, phosphorus and potassium during both the year and pooled mean

The 75% fertigation + 25% soil application observed significantly maximum uptake of nitrogen 205.16, 223.64 and 214.40 kg ha^{-1} during first year, second year and pooled mean. The 50% fertigation + 50% soil application soil application resulted maximum availability of phosphorus (33.88, 34.63, 34.26 kg ha^{-1}) and potassium (355.42, 352.46, 353.94 kg ha^{-1}) at harvest during first, second year and pooled mean. The 75% fertigation + 25% soil application observed significantly maximum availability of nitrogen (240.73, 235.51, 238.12 kg ha^{-1}), phosphorus (16.20, 13.71, 14.96 kg ha^{-1}) and potassium (322.44, 316.45, 319.45 kg ha^{-1}) at 60 DAT during first, second year and pooled mean.

The surface irrigation with 100% conventional fertilizers + foliar spray produced significantly maximum uptake and availability of nitrogen (174.11, 187.81, 180.96 kg ha^{-1} and 233.36, 230.73, 232.05 kg ha^{-1}), phosphorus (27.27, 27.82, 27.54 kg ha^{-1} and 30.50, 31.52, 31.01 kg ha^{-1}) and potassium (149.52, 148.23, 148.88 kg ha^{-1} and 348.45, 353.72, 349.02 kg ha^{-1}) during first, second year and pooled mean. While surface irrigation with 100% conventional fertilizer + foliar spray found second in order in respect of uptake and availability of nitrogen, phosphorus and potassium during both the year and pooled mean. Drip irrigation with no fertilizer resulted minimum uptake and availability of nitrogen, phosphorus and potassium during both the years and pooled mean.

6. Water use

The seasonal water requirement of tomato crop was observed to be 432.72 mm under drip method of irrigation as compared to 868.22 mm under conventional

method of irrigation and drip resulted into water saving to the extent of 50% over conventional method.

The application of fertilizer in the third tertile of the irrigation period found superior in water use efficiency and per cent increase in yield (123.64 ha-mm and 71.47%) during first year and the application of fertilizer in second tertile of the irrigation period resulted into significantly maximum water use efficiency and per cent increase in yield (165.73 ha-mm and 81.1%) during second year. The application of fertilizer in first tertile of the irrigation period resulted into minimum water use efficiency and per cent increase in yield.

The 75% fertigation + 25% soil application observed significantly maximum water use efficiency and per cent increase in yield (101.38 and 123.67 ha-mm and 35.17 and 40.61 %) during both the years as compared to other split fertilized treatments.

The drip irrigation with 100% conventional fertilizer observed significantly higher water use efficiency and per cent increase in yield (89.71 and 111.26 ha-mm and 24.42 and 21.60%) during both the year followed by surface irrigation with 100% conventional fertilizer + foliar spray. Surface irrigation with 100% conventional fertilizer found inferior in water use efficiency and per cent increase in yield among all eleven treatments during both the years.

7. Economics

The application of fertilizer in the third tertile of the irrigation period found superior in net seasonal income, total net income, B:C ratio, net extra income over control and water productivity (₹ 641461 ha^{-1}, ₹ 1489968 ha^{-1}, 5.98, ₹ 302696 and 1010 ha-mm) during first year and application of fertilizer in second tertile of the irrigation period (₹ 839161 ha^{-1}, ₹ 1843768 ha^{-1}, 7.49, ₹ 415896, 1415 ha-mm and ₹ 726861 ha^{-1}, ₹ 1642876 ha^{-1}, 6.63, ₹ 345696, 1184 ha-mm) during second year and pooled mean.

The 75% fertigation + 25% soil application resulted into higher values of net seasonal income, total net income, B:C ratio, net extra income over control and water productivity (₹ 508612 ha^{-1}, ₹ 1221774 ha^{-1}, 5.24, ₹ 169847, 801 ha-mm and ₹ 598212 ha^{-1}, ₹ 1375837 ha^{-1}, 5.97, ₹ 174947, 1009 ha-mm and ₹ 553412 ha^{-1}, ₹ 1299541

ha^{-1}, 5.61, ₹ 172247, 901 ha-mm) during first, second year and pooled mean followed by 50% fertigation + 50% soil application soil application.

The drip irrigation with 100% conventional fertilizer resulted into significantly higher values of net seasonal income, total net income, B:C ratio, net extra income over control and water productivity (₹ 438647 ha^{-1}, ₹ 1081128 ha^{-1}, 4.80, ₹ 99882, 691 ha-mm and ₹ 528747 ha^{-1}, ₹ 1237747 ha^{-1}, 5.56, ₹ 105482, 892 ha-mm and ₹ 483747 ha^{-1}, ₹ 1160243 ha^{-1}, 5.18, ₹ 102582, 788 ha-mm) during first, second year and pooled mean followed by surface irrigation with 100 % conventional fertilizer + foliar spray. The drip irrigation with no fertilizer obtained less net seasonal income, total net income, B:C ratio, net extra income over control and water productivity during first, second year and pooled mean.

8. Nutrient mobility

The mobility of nutrients was observed to be function of quantum of nutrients applied, source of nutrients, irrigation system and crop growth stage. The fertigation using 100% water soluble fertilizers resulted into maximum N (45 cm vertically and horizontally), P (15 cm vertically and 30 cm horizontally) and K (30 cm vertically and horizontally) movement at 60 days after transplantation. The nutrient movement in split fertilizer treatments and in case of conventional fertilizers was less.

Conclusions

1. The application of fertilizer in the third of the irrigation period exhibited higher plant height, branches, leaves and leaf area at all the crop growth stages; however, it was at par with fertigation in second tertile of irrigation period. The 75% fertigation + 25% soil application produced higher growth attributes as compared to other split fertilizer application treatments.
2. The application of fertilizers in the third tertile of the irrigation period produced significantly better yield attributes and thereby produced significantly maximum fruit yield of 87.53 t ha^{-1} in pooled means, which was at par with fertigation in second tertile of the irrigation period. The 75% fertigation + 25% soil application produced higher fruit yield (68.85 t ha^{-1}) as compared to other split fertilized treatments; but, it was sizably lower than 100% fertigated treatments.

3. The values of all microclimatic parameters were found to be significantly higher in treatments of water soluble fertiliser application in third and second tertile of irrigation period; these treatments also registered improved fruit quality parameters.
4. The drip method of irrigation used lowest water (432.72 mm) as compared to surface method of irrigation (868.22 mm) and thus resulted into 50.60 per cent water saving. The drip fertigation treatments (T_1 to T_8) produced 22 to 74 per cent more tomato yield as compared conventional irrigation with conventional fertilization treatment (T_{10}) in addition to water saving. The 100 % fertigated treatments resulted into average water use efficiency of 155.76 to 163.05 kg $ha^{-1}mm^{-1}$ which was higher than all other treatments.
5. The availability of nutrients in root zone soil as well as uptake of nutrients by tomato crop was found maximum in 100 % fertigated treatments as compared to all other treatments.
6. The mobility of nutrients in soil was observed to be influenced by quantum of nutrients applied, source of nutrients, irrigation system and crop growth stage. The fertigation using 100 % water soluble fertilizers resulted into maximum N (45 cm vertically and horizontally), P (15 cm vertically and 30 cm horizontally) and K (30 cm vertically and horizontally) movement at 60 days after transplantation..
7. The application of fertilizers in the third tertile of the irrigation period obtained maximum total seasonal income (₹ 726861 and ₹ 1489968 $ha^{-1)}$ and there by registered maximum net extra income of ₹ 302696 ha^{-1} over conventional irrigation and fertilization system (T_{10}). The application of fertilizers in second tertile closely followed these results.
8. The maximum B:C ratio of 5.98 was also recorded in application of fertilizers in the third tertile of the irrigation period treatment (T_3) and 5.78 in T_2 as compared to 4.32 in conventional irrigation treatment (T_{10}). The in application of fertilizers in the third and second tertile of the irrigation period resulted into maximum economic water productivity as 1010 and 968 Rs $ha^{-1}mm^{-1}$ as compared to lowest value of ₹ 327 $ha^{-1}mm^{-1}$ in conventional irrigation (T_{10}).

Recommendation

Based on the results of the two years of experimentation, the 100% application of water soluble fertilizers through drip in the third and second tertile of the irrigation period (following irrigation – irrigation - fertigation or irrigation – fertigation – irrigation cycle within irrigation period) is recommended for tomato crop for maximum growth and yield attributes, fruit yield of tomato crop and net seasonal income, B:C ratio and water productivity.

Future Implications

Future implications of the results of this investigation in respect of research, agricultural production and Indian economy are described below.

Research:

1. The fertigation timing within the irrigation period, which was a long time dilemma amongst fertigation users, is answered first time.
2. The economical feasibility of combination of fertigation and basal conventional fertilization is also studied first time.

Indian Agricultural Production and Economy:

- Fertigation applied through drip irrigation systems improved nutrient use efficiency by supplying nutrient at low rate and high frequency, improved plant nutrient uptake and nutrient availability in the root zone, in addition to the reduced nutrient loss and thereby enhanced productivity to the extent of 72 per cent.
- Thus, the technology has the potential to improve tomato production and net revenues on national level from tomato cultivation as tabulated below;

Sr. No	Item	Present	On adoption of this technology
1.	Tomato area, Mha	1.256	1.256
2.	Productivity, t/ha	14.92	25.65
3.	Total production, Mt	18.74	32.16
4.	Total revenues, Rs. in crores	18735.90	32161.25
5.	Additional revenues generated, Rs. in crores	-	13425.00

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7. APPENDICES

APPENDIX-I

A. Water requirement of tomato

Date	DAT	PE (mm)	CPE	KC	WR (mm)	Rainfall (mm)	Rainfall (mm)	
							IR (mm)	ER (mm)
2014								
Nov.								
28	0	5.00						
29	1	4.60						
30	2	5.40	10.00	0.60	4.20	0.00	4.20	0.00
Dec.								
1	3	4.50		0.60	0.00	0.00	0.00	0.00
2	4	4.10	8.60	0.60	3.61	0.00	3.61	0.00
3	5	4.20		0.60	0.00	0.00	0.00	0.00
4	6	4.60	8.80	0.60	3.70	0.00	3.70	0.00
5	7	5.40		0.60	0.00	0.00	0.00	0.00
6	8	5.20	10.60	0.60	4.45	0.00	4.45	0.00
7	9	4.80		0.60	0.00	0.00	0.00	0.00
8	10	4.60	9.40	0.60	3.95	0.00	3.95	0.00
9	11	4.70		0.60	0.00	0.00	0.00	0.00
10	12	5.00	9.70	0.60	4.07	0.00	4.07	0.00
11	13	4.50		0.60	0.00	0.00	0.00	0.00
12	14	4.80	9.30	0.60	3.91	0.00	3.91	0.00
13	15	4.60		0.70	0.00	0.00	0.00	0.00
14	16	4.40	9.00	0.70	4.41	0.00	4.41	0.00
15	17	5.20		0.70	0.00	0.00	0.00	0.00
16	18	4.70	9.90	0.70	4.85	0.00	4.85	0.00
17	19	4.50		0.70	0.00	0.00	0.00	0.00
18	20	4.20	8.70	0.70	4.26	0.00	4.26	0.00
19	21	4.00		0.70	0.00	0.00	0.00	0.00
20	22	4.40	8.40	0.80	4.70	0.00	4.70	0.00
21	23	4.50		0.80	0.00	0.00	0.00	0.00
22	24	5.00	9.50	0.80	5.32	0.00	5.32	0.00
23	25	5.20		0.80	0.00	0.00	0.00	0.00
24	26	5.60	10.80	0.80	6.05	0.00	6.05	0.00
25	27	4.80		0.80	0.00	0.00	0.00	0.00
26	28	4.60	9.40	0.80	5.26	0.00	5.26	0.00
27	29	4.20		0.90	0.00	0.00	0.00	0.00
28	30	4.40	8.60	0.90	5.42	0.00	5.42	0.00
29	31	4.00		0.90	0.00	0.00	0.00	0.00
30	32	4.60	8.60	0.90	6.04	0.00	6.04	0.00
31	33	5.20		0.90	0.00	0.00	0.00	0.00
Jan.								
1	34	3.80	9.00	0.90	5.67	1.20	4.47	1.20
2	35	3.60		0.90	0.00	0.00	0.00	0.00
3	36	3.40	7.00	1.00	4.90	0.00	4.90	0.00
4	37	3.00		1.00	0.00	0.00	0.00	0.00
5	38	3.60	6.60	1.00	4.62	0.00	4.62	0.00
6	39	4.40		1.00	0.00	0.00	0.00	0.00
7	40	4.60	9.00	1.00	6.30	0.00	6.30	0.00
8	41	5.00		1.00	0.00	0.00	0.00	0.00

Appendix contd….

Date	DAT	PE (mm)	CPE	KC	WR (mm)	Rainfall (mm)	Rainfall (mm)	
							IR (mm)	ER (mm)
9	42	5.80	10.80	1.00	7.56	0.00	7.56	0.00
10	43	5.60		1.15	0.00	0.00	0.00	0.00
11	44	4.70	10.30	1.15	8.29	0.00	8.29	0.00
12	45	4.50		1.15	0.00	0.00	0.00	0.00
13	46	4.80	9.30	1.15	7.49	0.00	7.49	0.00
14	47	5.20		1.15	0.00	0.00	0.00	0.00
15	48	4.90	10.10	1.15	8.13	0.00	8.13	0.00
16	49	4.90		1.15	0.00	0.00	0.00	0.00
17	50	4.50	9.40	1.15	7.57	0.00	7.57	0.00
18	51	4.30		1.15	0.00	0.00	0.00	0.00
19	52	4.60	8.90	1.15	7.16	0.00	7.16	0.00
20	53	4.20		1.15	0.00	0.00	0.00	0.00
21	54	4.40	8.60	1.15	6.92	0.00	6.92	0.00
22	55	4.90		1.15	0.00	0.00	0.00	0.00
23	56	4.00	8.90	1.15	7.16	0.00	7.16	0.00
24	57	4.60		1.15	0.00	0.00	0.00	0.00
25	58	4.50	9.10	1.15	7.33	0.00	7.33	0.00
26	59	4.20		1.15	0.00	0.00	0.00	0.00
27	60	4.80	9.00	1.15	7.25	0.00	7.25	0.00
28	61	4.50		1.15	0.00	0.00	0.00	0.00
29	62	5.20	9.70	1.15	7.81	0.00	7.81	0.00
30	63	4.70		1.15	0.00	0.00	0.00	0.00
31	64	5.60	10.30	1.15	8.29	0.00	8.29	0.00
Feb.								
1	65	4.90		1.15	0.00	0.00	0.00	0.00
2	66	5.80	10.70	1.15	8.61	0.00	8.61	0.00
3	67	5.60		1.15	0.00	0.00	0.00	0.00
4	68	5.20	10.80	1.15	8.69	0.00	8.69	0.00
5	69	5.80		1.15	0.00	0.00	0.00	0.00
6	70	6.00	11.80	1.15	9.50	0.00	9.50	0.00
7	71	5.60		1.15	0.00	0.00	0.00	0.00
8	72	5.40	11.00	1.15	8.86	0.00	8.86	0.00
9	73	6.20		1.15	0.00	0.00	0.00	0.00
10	74	5.90	12.10	1.15	9.74	0.00	9.74	0.00
11	75	5.60		1.15	0.00	0.00	0.00	0.00
12	76	5.20	10.80	1.15	8.69	0.00	8.69	0.00
13	77	5.90		1.15	0.00	0.00	0.00	0.00
14	78	6.30	12.20	1.15	9.82	0.00	9.82	0.00
15	79	6.50		1.15	0.00	0.00	0.00	0.00
16	80	6.60	13.10	1.15	10.55	0.00	10.55	0.00
17	81	6.80		1.15	0.00	0.00	0.00	0.00
18	82	7.10	13.90	1.15	11.19	0.00	11.19	0.00
19	83	6.50		1.15	0.00	0.00	0.00	0.00
20	84	7.40	13.90	1.15	11.19	0.00	11.19	0.00
21	85	6.80		1.15	0.00	0.00	0.00	0.00
22	86	7.00	13.80	1.15	11.11	0.00	11.11	0.00
23	87	6.90		1.15	0.00	0.00	0.00	0.00
24	88	7.20	14.10	1.15	11.35	0.00	11.35	0.00
25	89	6.80		1.15	0.00	0.00	0.00	0.00

Appendix contd….

Date	DAT	PE (mm)	CPE	KC	WR (mm)	Rainfall (mm)	Rainfall (mm)	
							IR (mm)	ER (mm)
26	90	7.60	14.40	1.15	11.59	0.00	11.59	0.00
27	91	7.00		1.15	0.00	0.00	0.00	0.00
38	92	6.60	13.60	1.15	10.95	0.00	10.95	0.00
March								
1	93	5.80		1.15	0.00	30.00	0.00	0.00
2	94	1.90	7.70	1.15	6.20	12.40	0.00	6.20
3	95	5.20		1.15	0.00	0.00	0.00	0.00
4	96	5.60	10.80	1.15	8.69	0.00	8.69	0.00
5	97	5.40		1.15	0.00	0.00	0.00	0.00
6	98	5.90	11.30	1.15	9.10	0.00	9.10	0.00
7	99	6.40		1.15	0.00	0.00	0.00	0.00
8	100	6.00	12.40	1.15	9.98	0.00	9.98	0.00
9	101	5.80		1.15	0.00	0.00	0.00	0.00
10	102	6.20	12.00	1.15	9.66	0.00	9.66	0.00
11	103	4.80		1.15	0.00	22.80	0.00	0.00
12	104	5.60	10.40	1.15	8.37	0.00	0.00	8.37
13	105	6.40		1.15	0.00	0.00	0.00	0.00
14	106	5.40	11.80	1.15	9.50	3.00	6.50	3.00
15	107	5.90		1.15	0.00	8.00	0.00	0.00
16	108	6.50	12.40	1.15	9.98	0.00	1.98	8.00
17	109	5.60		1.15	0.00	0.00	0.00	0.00
18	110	6.00	11.60	1.15	9.34	0.00	9.34	0.00
19	111	6.40		1.15	0.00	0.00	0.00	0.00
20	112	6.20	12.60	1.15	10.14	0.00	10.14	0.00
21	113	6.80		1.15	0.00	0.00	0.00	0.00
22	114	6.50	13.30	1.15	10.71	0.00	10.71	0.00
23	115	6.60		1.15	0.00	0.00	0.00	0.00
24	116	7.00	13.60	1.15	10.95	0.00	10.95	0.00
25	117	7.40		1.15	0.00	0.00	0.00	0.00
26	118	7.80	15.20	1.15	12.24	0.00	12.24	0.00
27	119	7.50		1.15	0.00	0.00	0.00	0.00
28	120	7.90	15.40	1.15	12.40	0.00	12.40	0.00
29	121	7.40		1.15	0.00	0.00	0.00	0.00
30	122	7.20	14.60	1.15	11.75	0.00	11.75	0.00
31	123	6.80		1.15	0.00	0.00	0.00	0.00
April								
1	124	7.60	14.40	1.15	11.59	0.00	11.59	0.00
2	125	8.00		1.15	0.00	0.00	0.00	0.00
3	126	8.40	16.40	1.15	13.20	0.00	13.20	0.00
4	127	7.80		1.15	0.00	0.00	0.00	0.00
5	128	4.50	12.30	1.15	9.90	0.00	9.90	0.00
6	129	8.20		1.15	0.00	0.00	0.00	0.00
7	130	7.40	15.60	1.15	12.56	0.00	12.56	0.00
8	131	7.20		1.15	0.00	0.00	0.00	0.00
9	132	7.00	14.20	1.15	11.43	0.00	11.43	0.00
10	133	7.60		1.15	0.00	0.00	0.00	0.00
11	134	6.40	14.00	0.90	8.82	0.00	8.82	0.00
12	135	6.00		0.90	0.00	5.00	0.00	0.00
13	136	6.80	12.80	0.90	8.06	0.00	3.06	5.00
14	137	5.90		0.90	0.00	2.20	0.00	0.00

Appendix contd….

Date	DAT	PE (mm)	CPE	KC	WR (mm)	Rainfall (mm)	Rainfall (mm)	
							IR (mm)	ER (mm)
15	138	6.50	12.40	0.90	7.81	0.00	5.61	2.20
16	139	6.80		0.90	0.00	0.00	0.00	0.00
17	140	5.80	12.60	0.90	7.94	0.00	7.94	0.00
18	141	6.60		0.90	0.00	0.00	0.00	0.00
19	142	7.40	14.00	0.90	8.82	0.00	8.82	0.00
20	143	7.80		0.90	0.00	0.00	0.00	0.00
21	144	8.00	15.80	0.90	9.95	0.00	9.95	0.00
22	145	7.60		0.90	0.00	0.00	0.00	0.00
23	146	7.60	15.20	0.90	9.58	0.00	9.58	0.00
24	147	8.00		0.90	0.00	0.00	0.00	0.00
25	148	8.40	16.40	0.80	9.18	0.00	9.18	0.00
26	149	8.50		0.80	0.00	0.00	0.00	0.00
27	150	8.80	17.30	0.80	9.69	0.00	9.69	0.00
28	151	8.00		0.80	0.00	0.00	0.00	0.00
29	152	8.60	16.60	0.80	9.30	0.00	9.30	0.00
30	153	8.20		0.80	0.00	0.00	0.00	0.00
May								
1	154	8.60	16.80	0.80	9.41	0.00	9.41	0.00
2	155	8.50		0.80	0.00	0.00	0.00	0.00
3	156	9.80	18.30	0.80	10.25	0.00	10.25	0.00
4	157	9.60		0.80	0.00	0.00	0.00	0.00
5	158	9.20	18.80	0.80	10.53	0.00	10.53	0.00
6	159	8.80		0.80	0.00	0.00	0.00	0.00
7	160	9.40	18.20	0.80	10.19	0.00	10.19	0.00
8	161	9.00		0.80	0.00	0.00	0.00	0.00
9	162	9.60	18.60	0.80	10.42	0.00	10.42	0.00
10	163	9.20		0.80	0.00	0.00	0.00	0.00
11	164	8.60	17.80	0.80	9.97	0.00	9.97	0.00
12	165	10.40		0.80	0.00	0.00	0.00	0.00
13	166	9.00	19.40	0.80	10.86	0.00	10.86	0.00
14	167	8.20		0.80	0.00	8.00	0.00	0.00
15	168	7.50	15.70	0.80	8.79	0.00	0.79	8.00
16	169	8.20		0.70	0.00	0.00	0.00	0.00
17	170	9.60	17.80	0.70	8.72	0.00	8.72	0.00
18	171	9.00		0.70	0.00	0.00	0.00	0.00
19	172	9.60	18.60	0.70	9.11	0.00	9.11	0.00
20	173	9.40		0.70	0.00	0.00	0.00	0.00
21	174	11.20	20.60	0.70	10.09	0.00	10.09	0.00
22	175	11.80		0.70	0.00	0.00	0.00	0.00
23	176	7.40	19.20	0.70	9.41	0.00	9.41	0.00
24	177	11.60		0.70	0.00	0.00	0.00	0.00
25	178	7.00	18.60	0.70	9.11	0.00	9.11	0.00
26	179	11.00		0.70	0.00	0.00	0.00	0.00
27	180	11.40	22.40	0.70	10.98	0.00	10.98	0.00
		1142.40	**1137.40**	**174.05**	**763.18**	**92.60**	**721.20**	**41.97**

B. Water requirement of tomato

Date	DAT	PE (mm)	CPE	KC	WR (mm)	Rainfall (mm)	
						IR (mm)	ER (mm)
2015							
Dec.							
20	0	5.20					
21	1	4.80					
22	2	5.60	10.40	0.60	4.37		
23	3	6.20		0.60	0.00	0.00	0.00
24	4	5.20	11.40	0.60	4.79	4.79	0.00
25	5	4.60		0.60	0.00	0.00	0.00
26	6	4.20	8.80	0.60	3.70	3.70	0.00
27	7	4.40		0.60	0.00	0.00	0.00
28	8	5.60	10.00	0.60	4.20	4.20	0.00
29	9	5.20		0.60	0.00	0.00	0.00
30	10	5.80	11.00	0.60	4.62	4.62	0.00
331	11	5.40		0.60	0.00	0.00	0.00
2Jan.							
1	12	6.20	11.60	0.60	4.87	4.87	0.00
2	13	6.60		0.60	0.00	0.00	0.00
3	14	5.40	12.00	0.60	5.04	5.04	0.00
4	15	5.80		0.60	0.00	0.00	0.00
5	16	5.60	11.40	0.70	5.59	5.59	0.00
6	17	5.50		0.70	0.00	0.00	0.00
7	18	5.80	11.30	0.70	5.54	5.54	0.00
8	19	5.00		0.70	0.00	0.00	0.00
9	20	4.80	9.80	0.70	4.80	4.80	0.00
10	21	5.60		0.70	0.00	0.00	0.00
11	22	5.40	11.00	0.70	5.39	5.39	0.00
12	23	5.80		0.80	0.00	0.00	0.00
13	24	6.00	11.80	0.80	6.61	6.61	0.00
14	25	5.50		0.80	0.00	0.00	0.00
15	26	5.80	11.30	0.80	6.33	6.33	0.00
16	27	6.20		0.80	0.00	0.00	0.00
17	28	6.60	12.80	0.80	7.17	7.17	0.00
18	29	5.60		0.90	0.00	0.00	0.00
19	30	6.80	12.40	0.90	7.81	7.81	0.00
20	31	6.50		0.90	0.00	0.00	0.00
21	32	5.40	11.90	0.90	7.50	7.50	0.00
22	33	5.00		0.90	0.00	0.00	0.00
23	34	5.60	10.60	0.90	6.68	6.68	0.00
24	35	5.20		0.90	0.00	0.00	0.00
25	36	5.80	11.00	1.00	7.70	7.70	0.00
26	37	5.50		1.00	0.00	0.00	0.00
27	38	6.00	11.50	1.00	8.05	8.05	0.00
28	39	6.40		1.00	0.00	0.00	0.00
29	40	5.60	12.00	1.00	8.40	8.40	0.00
30	41	6.00		1.00	0.00	0.00	0.00
31	42	5.40	11.40	1.00	7.98	7.98	0.00
Feb.							
1	43	6.60		1.15	0.00	0.00	0.00
2	44	6.80	13.40	1.15	10.79	10.79	0.00
3	45	6.00		1.15	0.00	0.00	0.00

Appendix contd…

Date	DAT	PE (mm)	CPE	KC	WR (mm)	Rainfall (mm)	
						IR (mm)	ER (mm)
4	46	6.40	12.40	1.15	9.98	9.98	0.00
5	47	6.50		1.15	0.00	0.00	0.00
6	48	6.20	12.70	1.15	10.22	10.22	0.00
7	49	6.80		1.15	0.00	0.00	0.00
8	50	5.40	12.20	1.15	9.82	9.82	0.00
9	51	4.60		1.15	0.00	0.00	0.00
10	52	5.00	9.60	1.15	7.73	7.73	0.00
11	53	5.80		1.15	0.00	0.00	0.00
12	54	6.40	12.20	1.15	9.82	9.82	0.00
13	55	6.00		1.15	0.00	0.00	0.00
14	56	5.60	11.60	1.15	9.34	9.34	0.00
15	57	5.50		1.15	0.00	0.00	0.00
16	58	5.80	11.30	1.15	9.10	9.10	0.00
17	59	5.40		1.15	0.00	0.00	0.00
18	60	6.20	11.60	1.15	9.34	9.34	0.00
19	61	6.80		1.15	0.00	0.00	0.00
20	62	7.20	14.00	1.15	11.27	11.27	0.00
21	63	6.60		1.15	0.00	0.00	0.00
22	64	7.40	14.00	1.15	11.27	11.27	0.00
23	65	7.00		1.15	0.00	0.00	0.00
24	66	7.60	14.60	1.15	11.75	11.75	0.00
25	67	8.20		1.15	0.00	0.00	0.00
26	68	7.80	16.00	1.15	12.88	12.88	0.00
27	69	8.40		1.15	0.00	0.00	0.00
28	70	7.60	16.00	1.15	12.88	12.88	0.00
29	71	6.80		1.15	0.00	0.00	0.00
March							
1	72	7.40	14.20	1.15	11.43	11.43	0.00
2	73	6.60		1.15	0.00	0.00	0.00
3	74	5.20	11.80	1.15	9.50	9.50	0.00
4	75	5.80		1.15	0.00	0.00	0.00
5	76	5.60	11.40	1.15	9.18	9.18	0.00
6	77	6.20		1.15	0.00	0.00	0.00
7	78	6.60	12.80	1.15	10.30	10.30	0.00
8	79	7.00		1.15	0.00	0.00	0.00
9	80	7.40	14.40	1.15	11.59	11.59	0.00
10	81	7.80		1.15	0.00	0.00	0.00
11	82	8.00	15.80	1.15	12.72	12.72	0.00
12	83	7.60		1.15	0.00	0.00	0.00
13	84	7.20	14.80	1.15	11.91	11.91	0.00
14	85	7.50		1.15	0.00	0.00	0.00
15	86	8.00	15.50	1.15	12.48	12.48	0.00
16	87	7.20		1.15	0.00	0.00	0.00
15	57	5.50		1.15	0.00	0.00	0.00
16	58	5.80	11.30	1.15	9.10	9.10	0.00
17	88	6.80	14.00	1.15	11.27	11.27	0.00
18	89	7.00		1.15	0.00	0.00	0.00
19	90	7.60	14.60	1.15	11.75	11.75	0.00
20	91	7.80		1.15	0.00	0.00	0.00
21	92	8.60	16.40	1.15	13.20	13.20	0.00

Appendix contd…

Date	DAT	PE (mm)	CPE	KC	WR (mm)	Rainfall (mm)	
						IR (mm)	ER (mm)
22	93	8.80		1.15	0.00	0.00	0.00
23	94	8.00	16.80	1.15	13.52	13.52	0.00
24	95	8.60		1.15	0.00	0.00	0.00
25	96	9.00	17.60	1.15	14.17	14.17	0.00
26	97	9.60		1.15	0.00	0.00	0.00
27	98	9.40	19.00	1.15	15.30	15.30	0.00
28	99	9.20		1.15	0.00	0.00	0.00
29	100	8.80	18.00	1.15	14.49	14.49	0.00
30	101	8.50		1.15	0.00	0.00	0.00
31	102	9.40	17.90	1.15	14.41	14.41	0.00
April							
1	103	9.60		1.15	0.00	0.00	0.00
2	104	8.80	18.40	1.15	14.81	14.81	0.00
3	105	9.20		1.15	0.00	0.00	0.00
4	106	9.80	19.00	1.15	15.30	15.30	0.00
5	107	8.20		1.15	0.00	0.00	0.00
6	108	8.60	16.80	1.15	13.52	13.52	0.00
7	109	8.00		1.15	0.00	0.00	0.00
8	110	8.40	16.40	1.15	13.20	13.20	0.00
9	111	9.00		1.15	0.00	0.00	0.00
10	112	9.40	18.40	1.15	14.81	14.81	0.00
11	113	8.60		1.15	0.00	0.00	0.00
12	114	8.80	17.40	1.15	14.01	14.01	0.00
13	115	9.60		1.15	0.00	0.00	0.00
14	116	9.40	19.00	1.15	15.30	15.30	0.00
15	117	10.00		1.15	0.00	0.00	0.00
16	118	10.60	20.60	1.15	16.58	16.58	0.00
17	119	10.20		1.15	0.00	0.00	0.00
18	120	10.60	20.80	1.15	16.74	16.74	0.00
19	121	11.20		1.15	0.00	0.00	0.00
20	122	10.80	22.00	1.15	17.71	17.71	0.00
21	123	9.40		1.15	0.00	0.00	0.00
22	124	8.80	18.20	1.15	14.65	14.65	0.00
23	125	10.80		1.15	0.00	0.00	0.00
24	126	10.40	21.20	1.15	17.07	17.07	0.00
25	127	8.40		1.15	0.00	0.00	0.00
26	128	10.60	19.00	1.15	15.30	15.30	0.00
27	129	10.40		1.15	0.00	0.00	0.00
28	130	11.40	21.80	1.15	17.55	17.55	0.00
29	131	10.80		1.15	0.00	0.00	0.00
30	132	10.60	21.40	1.15	17.23	17.23	0.00
May							
1	133	10.50		1.15	0.00	0.00	0.00
2	134	10.80	21.30	0.90	13.42	13.42	0.00
3	135	10.20		0.90	0.00	0.00	0.00
4	136	10.80	21.00	0.90	13.23	13.23	0.00
5	137	11.20		0.90	0.00	0.00	0.00
6	138	9.60	20.80	0.90	13.10	13.10	0.00
7	139	10.80		0.90	0.00	0.00	0.00
8	140	11.60	22.40	0.90	14.11	14.11	0.00

Appendix contd…

Date	DAT	PE (mm)	CPE	KC	WR (mm)	Rainfall (mm)	
						IR (mm)	ER (mm)
9	141	9.40		0.90	0.00	0.00	0.00
10	142	8.20	17.60	0.90	11.09	11.09	0.00
11	143	9.80		0.90	0.00	0.00	0.00
12	144	10.40	20.20	0.90	12.73	12.73	0.00
13	145	11.00		0.90	0.00	0.00	0.00
14	146	11.60	22.60	0.90	14.24	14.24	0.00
16	147	11.20		0.90	0.00	0.00	0.00
17	148	11.40	22.60	0.80	12.66	12.66	0.00
18	149	10.80		0.80	0.00	0.00	0.00
19	151	11.60		0.80	0.00	0.00	0.00
20	152	10.40	22.00	0.80	12.32	12.32	0.00
21	153	11.50		0.80	0.00	0.00	0.00
22	154	11.00	22.50	0.80	12.60	12.60	0.00
23	155	11.60		0.80	0.00	0.00	0.00
24	156	12.00	23.60	0.80	13.22	13.22	0.00
25	157	12.40		0.80	0.00	0.00	0.00
26	158	11.80	24.20	0.80	13.55	13.55	0.00
27	159	10.20		0.80	0.00	0.00	0.00
28	160	10.80	21.00	0.80	11.76	11.76	0.00
29	161	11.60		0.80	0.00	0.00	0.00
30	162	10.40	22.00	0.80	12.32	12.32	0.00
31	163	10.20		0.80	0.00	0.00	0.00
June							
1	164	11.80	22.00	0.80	12.32	12.32	0.00
2	165	12.20		0.80	0.00	0.00	0.00
3	166	11.60	23.80	0.80	13.33	13.33	0.00
4	167	10.40		0.80	0.00	0.00	0.00
5	168	9.60	20.00	0.80	11.20	11.20	0.00
6	169	10.80		0.70	0.00	0.00	0.00
7	170	9.60	20.40	0.70	10.00	10.00	0.00
8	171	10.00		0.70	0.00	0.00	0.00
9	172	10.80	20.80	0.70	10.19	10.19	0.00
10	173	10.20		0.70	0.00	0.00	0.00
11	174	7.80	18.00	0.70	8.82	8.82	0.00
12	175	9.40		0.70	0.00	0.00	0.00
13	176	10.40	19.80	0.70	9.70	9.70	0.00
14	177	10.80		0.70	0.00	0.00	0.00
15	178	9.60	20.40	0.70	10.00	10.00	0.00
16	179	10.60		0.70	0.00	0.00	0.00
17	180	9.00	19.60	0.70	9.60	9.60	0.00
		1463.80	**1463.80**	**173.85**	**992.57**	**988.24**	**0.00**

Appendix-II : Nitrogen distribution at 30 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	223.41	220.63	214.71	212.40	217.79
	15	219.75	214.52	210.68	205.53	212.62
	30	215.54	210.49	205.32	201.55	208.23
	45	211.46	206.51	202.53	197.51	204.50
	Average	217.54	213.04	208.31	204.25	210.78
T_2	0	227.42	222.41	218.24	213.41	220.37
	15	223.24	220.47	215.41	210.33	217.36
	30	220.34	213.37	209.38	201.36	211.11
	45	214.43	210.39	205.26	201.42	207.88
	Average	221.36	216.66	212.07	206.63	214.18
T_3	0	225.63	222.57	218.45	214.50	220.29
	15	221.48	217.53	212.48	208.63	215.03
	30	217.59	212.58	208.40	204.25	210.71
	45	213.71	209.63	205.34	201.41	207.52
	Average	219.60	215.58	211.17	207.20	213.39
T_4	0	223.25	220.36	216.40	212.51	218.13
	15	218.37	215.41	211.31	207.32	213.10
	30	214.30	210.42	207.26	203.33	208.83
	45	210.37	206.52	202.43	198.36	204.42
	Average	216.57	213.18	209.35	205.38	211.12
T_5	0	232.34	229.74	225.78	220.56	227.11
	15	228.40	225.58	221.47	216.46	222.98
	30	223.95	219.48	215.52	211.56	217.63
	45	218.36	215.25	211.28	207.42	213.08
	Average	225.76	222.51	218.51	214.00	220.20
T_6	0	243.59	238.47	233.57	229.81	236.36
	15	239.68	235.76	231.61	228.71	233.94
	30	234.63	229.56	225.61	221.47	227.82
	45	230.36	225.64	221.74	217.58	223.83
	Average	237.07	232.36	228.13	224.39	230.49
T_7	0	246.52	241.43	237.36	233.45	239.69
	15	242.63	236.41	231.25	225.69	234.00
	30	236.42	234.65	230.41	226.51	232.00
	45	231.43	226.30	221.43	217.63	224.20
	Average	239.25	234.70	230.11	225.82	232.47
T_8	0	250.95	246.55	242.84	238.58	244.73
	15	245.55	241.48	236.78	232.53	239.09
	30	241.58	237.79	232.67	228.36	235.10
	45	237.78	232.69	227.58	223.68	230.43
	Average	243.97	239.63	234.97	230.79	237.34
T_9	0	243.58	-	-	-	-
	15	237.65	-	-	-	-
	30	232.71	-	-	-	-
	45	228.67	-	-	-	-
	Average	235.65	-	-	-	-
T_{10}	0	241.68	-	-	-	-
	15	236.47	-	-	-	-
	30	232.52	-	-	-	-
	45	227.60	-	-	-	-
	Average	234.57	-	-	-	-
T_{11}	0	170.36	165.34	160.32	155.36	162.85
	15	167.38	164.38	158.43	154.63	161.21
	30	163.48	160.65	156.58	152.74	158.36
	45	159.47	154.36	151.47	146.53	152.96
	Average	165.17	161.18	156.70	152.32	158.84

Nitrogen distribution at 60 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	259.55	254.48	248.60	244.41	251.76
	15	253.53	247.81	243.53	239.47	246.09
	30	251.47	247.33	242.50	239.58	245.22
	45	247.71	242.43	239.60	234.52	241.07
	Average	253.07	248.01	243.56	239.50	246.03
T_2	0	270.66	266.71	260.65	258.79	264.20
	15	266.86	262.69	258.46	252.53	260.14
	30	263.86	258.67	253.50	249.68	256.43
	45	259.63	253.46	248.77	243.58	251.36
	Average	265.25	260.38	255.35	251.15	258.03
T_3	0	262.70	258.80	253.41	248.56	255.87
	15	255.66	251.71	247.50	244.49	249.84
	30	252.63	247.63	244.59	241.73	246.65
	45	249.53	244.83	241.63	239.49	243.87
	Average	255.13	250.74	246.78	243.57	249.06
T_4	0	261.36	258.47	252.66	248.32	255.20
	15	256.63	251.51	246.73	240.43	248.83
	30	252.43	245.31	241.70	237.51	244.24
	45	246.35	242.51	238.58	233.48	240.23
	Average	254.19	249.45	244.92	239.94	247.12
T_5	0	255.48	251.23	246.52	238.39	247.91
	15	250.63	244.46	240.56	236.44	243.02
	30	245.53	240.37	236.82	231.50	238.56
	45	239.48	235.63	231.27	227.35	233.43
	Average	247.78	242.92	238.79	233.42	240.73
T_6	0	258.69	253.83	248.69	245.72	251.73
	15	253.71	249.79	244.68	242.76	247.74
	30	248.75	242.76	238.65	234.71	241.22
	45	243.63	240.66	236.78	232.83	238.48
	Average	251.20	246.76	242.20	239.01	244.79
T_7	0	243.48	237.39	232.34	229.26	235.62
	15	239.26	235.30	231.38	224.23	232.54
	30	234.23	229.26	226.42	221.43	227.84
	45	231.29	227.45	223.28	219.34	225.34
	Average	237.07	232.35	228.36	223.57	230.33
T_8	0	246.32	242.56	238.56	233.25	240.17
	15	243.38	239.41	235.32	231.42	237.38
	30	240.34	236.28	232.52	228.37	234.38
	45	236.33	231.37	228.53	224.23	230.12
	Average	241.59	237.41	233.73	229.32	235.51
T_9	0	239.48	-	-	-	-
	15	234.32	-	-	-	-
	30	231.36	-	-	-	-
	45	228.29	-	-	-	-
	Average	233.36	-	-	-	-
T_{10}	0	236.61	-	-	-	-
	15	232.45	-	-	-	-
	30	228.52	-	-	-	-
	45	224.30	-	-	-	-
	Average	230.47	-	-	-	-
T_{11}	0	166.62	163.65	160.51	156.53	161.83
	15	162.53	159.73	155.48	151.72	157.37
	30	158.42	153.45	149.82	145.62	151.83
	45	154.67	151.55	148.63	143.58	149.61
	Average	160.56	157.10	153.61	149.36	155.16

Nitrogen distribution at 90 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	235.63	231.56	227.69	222.48	229.34
	15	229.48	225.86	219.71	215.39	222.61
	30	223.75	220.58	216.49	211.49	218.08
	45	218.57	213.85	210.56	206.55	212.38
	Average	226.86	222.96	218.61	213.98	220.60
T_2	0	246.12	242.08	238.816	234.408	240.36
	15	242.832	238.56	233.312	229.768	236.12
	30	237.472	233.392	228.624	223.592	230.77
	45	233.976	229.824	225.88	221.408	227.77
	Average	240.10	235.96	231.66	227.29	233.75
T_3	0	242.36	237.80	233.50	229.77	235.86
	15	238.12	234.28	230.70	226.31	232.35
	30	234.57	230.26	226.03	222.49	228.34
	45	230.41	226.03	222.63	218.41	224.37
	Average	236.36	232.09	228.22	224.24	230.23
T_4	0	241.54	236.53	232.76	228.43	234.81
	15	237.75	233.98	229.82	225.41	231.74
	30	232.79	228.69	224.41	220.41	226.57
	45	228.75	224.98	220.68	216.63	222.76
	Average	235.21	231.05	226.92	222.72	228.97
T_5	0	232.18	228.18	223.10	219.21	225.67
	15	228.75	224.08	220.63	215.22	222.17
	30	224.31	219.18	214.18	210.40	217.02
	45	220.06	215.26	210.32	206.54	213.05
	Average	226.33	221.68	217.06	212.84	219.48
T_6	0	233.14	229.18	224.24	221.41	226.99
	15	229.05	225.08	221.63	216.22	223.00
	30	226.26	222.24	218.38	214.40	220.32
	45	221.06	217.16	213.22	209.14	215.15
	Average	227.38	223.42	219.37	215.29	221.36
T_7	0	230.24	226.18	222.90	218.41	224.43
	15	226.75	222.08	218.63	214.12	220.40
	30	222.91	218.04	214.14	209.40	216.12
	45	218.06	214.26	210.03	205.54	211.97
	Average	224.49	220.14	216.43	211.87	218.23
T_8	0	210.63	206.66	202.63	198.82	204.69
	15	206.04	202.63	198.59	196.32	200.90
	30	202.80	198.54	196.41	192.63	197.60
	45	198.11	194.43	190.55	186.87	192.49
	Average	204.40	200.57	197.05	193.66	198.92
T_9	0	198.12	-	-	-	-
	15	194.62	-	-	-	-
	30	189.26	-	-	-	-
	45	185.49	-	-	-	-
	Average	191.87	-	-	-	-
T_{10}	0	196.32	-	-	-	-
	15	192.20	-	-	-	-
	30	187.35	-	-	-	-
	45	183.40	-	-	-	-
	Average	189.82	-	-	-	-
T_{11}	0	166.11	162.12	158.50	154.40	160.28
	15	162.03	158.20	154.18	150.20	156.15
	30	158.20	154.30	150.24	145.61	152.09
	45	154.05	150.30	145.02	141.22	147.65
	Average	160.10	156.23	151.98	147.86	154.04

Nitrogen distribution at 120 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	202.83	197.36	192.22	188.48	195.22
	15	198.28	194.62	190.03	186.38	192.33
	30	193.11	189.18	185.18	182.88	187.59
	45	190.12	187.80	183.63	178.54	185.02
	Average	196.09	192.24	187.76	184.07	190.04
T_2	0	206.42	203.03	199.23	195.04	200.93
	15	202.11	197.72	194.18	190.02	196.01
	30	197.28	194.62	190.03	185.18	191.78
	45	194.23	190.26	186.22	183.13	188.46
	Average	200.01	196.41	192.41	188.34	194.29
T_3	0	205.32	201.26	197.28	194.48	199.58
	15	201.88	197.12	194.03	190.18	195.80
	30	197.11	193.28	188.18	183.20	190.44
	45	193.12	189.03	185.63	180.54	187.08
	Average	199.36	195.17	191.28	187.10	193.23
T_4	0	204.79	200.76	197.98	193.88	199.35
	15	199.88	196.87	191.63	187.89	194.07
	30	195.68	191.99	186.88	183.95	189.63
	45	192.22	188.66	184.63	183.84	187.34
	Average	198.14	194.57	190.28	187.39	192.60
T_5	0	199.98	195.58	192.90	187.41	193.97
	15	194.15	190.38	187.63	184.82	189.25
	30	190.28	185.98	182.98	178.86	184.53
	45	187.66	184.66	181.82	177.54	182.92
	Average	193.02	189.15	186.33	182.16	187.67
T_6	0	191.40	187.18	183.10	179.41	185.27
	15	187.75	183.08	179.63	175.82	181.57
	30	183.58	178.38	173.91	170.40	176.57
	45	179.06	175.26	170.16	166.54	172.76
	Average	185.45	180.98	176.70	173.04	179.04
T_7	0	188.98	184.98	181.48	177.40	183.21
	15	184.18	181.08	177.93	172.12	178.83
	30	179.98	175.38	172.18	169.40	174.24
	45	176.06	173.26	169.82	165.54	171.17
	Average	182.30	178.68	175.35	171.12	176.86
T_8	0	184.00	179.53	175.36	171.58	177.62
	15	180.34	177.38	172.53	167.48	174.43
	30	175.23	171.52	166.72	162.40	168.97
	45	171.23	166.52	162.37	159.47	164.90
	Average	177.70	173.74	169.25	165.23	171.48
T_9	0	165.12	-	-	-	-
	15	161.11	-	-	-	-
	30	157.76	-	-	-	-
	45	153.49	-	-	-	-
	Average	159.37	-	-	-	-
T_{10}	0	163.82	-	-	-	-
	15	158.46	-	-	-	-
	30	155.54	-	-	-	-
	45	151.46	-	-	-	-
	Average	157.32	-	-	-	-
T_{11}	0	165.12	160.36	166.40	162.40	163.57
	15	161.06	156.26	152.18	147.30	154.20
	30	157.55	152.48	148.40	144.63	150.77
	45	153.75	149.20	145.19	140.26	147.10
	Average	159.37	154.58	153.04	148.65	153.91

Nitrogen distribution at 150 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	196.29	193.26	189.22	186.13	191.22
	15	192.04	189.16	185.03	183.38	187.40
	30	189.20	186.20	182.18	177.52	183.77
	45	185.12	182.03	178.32	175.54	180.25
	Average	190.66	187.66	183.69	180.64	185.66
T_2	0	202.82	198.86	194.63	191.56	196.97
	15	197.72	193.52	189.48	185.89	191.65
	30	194.88	189.16	184.66	180.18	187.22
	45	189.83	185.60	181.60	178.13	183.79
	Average	196.31	191.79	187.59	183.94	189.91
T_3	0	198.83	194.56	190.22	186.80	192.60
	15	193.88	189.62	186.82	182.76	188.27
	30	190.69	184.99	181.76	177.89	183.83
	45	185.62	180.83	176.69	171.59	178.68
	Average	192.26	187.50	183.87	179.76	185.85
T_4	0	198.32	194.26	191.22	187.13	192.73
	15	196.19	191.62	188.03	185.18	190.25
	30	191.42	187.20	185.18	180.52	186.08
	45	186.12	182.03	178.63	173.54	180.08
	Average	193.01	188.78	185.76	181.59	187.29
T_5	0	194.97	189.76	184.94	180.80	187.62
	15	189.75	185.68	181.68	177.82	183.73
	30	184.76	179.98	175.84	172.98	178.39
	45	180.56	176.74	172.82	169.58	174.93
	Average	187.51	183.04	178.82	175.30	181.17
T_6	0	181.98	177.18	174.90	170.41	176.12
	15	176.75	172.03	168.60	165.82	170.80
	30	174.36	171.20	167.40	163.40	169.09
	45	170.06	167.26	163.82	159.54	165.17
	Average	175.79	171.92	168.68	164.79	170.29
T_7	0	180.98	177.69	173.90	169.41	175.50
	15	177.75	172.59	167.83	163.82	170.50
	30	172.84	169.84	165.84	160.74	167.32
	45	169.96	164.69	161.82	158.54	163.75
	Average	175.38	171.20	167.35	163.13	169.27
T_8	0	181.82	177.86	174.98	169.88	176.14
	15	176.80	172.78	169.59	164.92	171.02
	30	172.84	167.84	164.48	159.52	166.17
	45	169.92	165.93	162.55	159.87	164.57
	Average	175.35	171.10	160.91	163.55	167.73
T_9	0	162.12	-	-	-	-
	15	158.32	-	-	-	-
	30	155.61	-	-	-	-
	45	152.43	-	-	-	-
	Average	157.12	-	-	-	-
T_{10}	0	156.68	-	-	-	-
	15	152.30	-	-	-	-
	30	149.59	-	-	-	-
	45	146.70	-	-	-	-
	Average	151.32	-	-	-	-
T_{11}	0	162.32	159.20	154.57	150.45	156.64
	15	158.26	155.26	151.18	146.82	152.88
	30	154.58	149.98	145.90	141.67	148.03
	45	150.75	145.90	141.49	137.26	143.85
	Average	156.48	152.59	148.28	144.05	150.35

Nitrogen distribution at harvest during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	172.83	169.59	166.68	160.88	167.50
	15	168.88	164.62	161.03	157.18	162.93
	30	163.67	160.99	156.76	152.95	158.59
	45	159.82	156.53	153.63	150.54	155.13
	Average	166.30	162.93	159.53	155.39	161.04
T_2	0	176.12	173.03	168.63	164.14	170.48
	15	172.11	167.30	163.18	159.52	165.53
	30	168.48	164.16	161.03	157.18	162.71
	45	165.32	160.06	157.22	153.13	158.93
	Average	170.51	166.14	162.51	158.49	164.41
T_3	0	174.32	171.26	166.22	162.13	168.48
	15	170.88	167.62	165.03	161.18	166.18
	30	167.11	162.20	159.18	159.20	161.92
	45	163.12	158.03	154.63	150.54	156.58
	Average	168.86	164.78	161.26	158.26	163.29
T_4	0	174.83	171.26	167.22	163.13	169.11
	15	170.28	167.62	164.03	160.18	165.53
	30	166.11	161.49	157.18	153.31	159.52
	45	162.12	158.03	154.32	150.54	156.25
	Average	168.34	164.60	160.69	156.79	162.60
T_5	0	196.11	171.99	152.18	154.54	168.71
	15	180.12	168.03	149.63	130.95	157.18
	30	171.88	186.62	118.03	152.18	157.18
	45	154.83	180.26	149.22	144.13	157.11
	Average	175.74	176.72	142.26	145.45	160.04
T_6	0	171.68	167.76	163.90	160.41	165.94
	15	166.75	163.08	159.63	154.82	161.07
	30	162.76	158.98	154.98	151.64	157.09
	45	159.36	155.64	151.82	147.54	153.59
	Average	165.14	161.37	157.58	153.60	159.42
T_7	0	170.93	167.18	163.90	159.41	165.35
	15	166.75	162.08	158.63	154.82	160.57
	30	163.51	158.40	154.24	150.14	156.57
	45	159.06	155.26	150.82	145.54	152.67
	Average	165.06	160.73	156.90	152.48	158.79
T_8	0	167.24	163.18	158.90	155.21	161.13
	15	164.24	160.20	157.63	153.82	158.97
	30	161.36	156.98	152.32	148.21	154.72
	45	157.20	154.36	150.79	145.10	151.86
	Average	162.51	158.68	154.91	150.58	156.67
T_9	0	158.41	-	-	-	-
	15	154.10	-	-	-	-
	30	150.36	-	-	-	-
	45	147.46	-	-	-	-
	Average	152.58	-	-	-	-
T_{10}	0	155.48	-	-	-	-
	15	152.53	-	-	-	-
	30	147.20	-	-	-	-
	45	145.10	-	-	-	-
	Average	150.08	-	-	-	-
T_{11}	0	161.55	157.31	154.89	150.48	156.06
	15	156.63	152.45	147.69	144.82	150.40
	30	153.59	149.60	145.84	141.40	147.61
	45	149.49	146.63	142.82	138.54	144.37
	Average	155.32	151.50	147.81	143.81	149.61

Appendix-III : Phosphorus distribution at 30 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	37.42	35.36	33.34	32.24	34.59
	15	31.65	28.71	26.50	24.68	27.89
	30	26.47	24.16	22.85	21.77	23.81
	45	24.77	23.60	21.64	18.74	22.19
	Average	30.08	27.96	26.08	24.36	27.12
T_2	0	39.61	36.24	32.41	23.57	32.96
	15	36.48	33.51	30.46	25.31	31.44
	30	35.52	33.18	29.54	21.36	29.90
	45	32.31	29.34	26.56	18.62	26.71
	Average	35.98	33.07	29.74	22.22	30.25
T_3	0	37.63	35.54	33.52	28.31	33.75
	15	34.79	32.89	28.46	24.63	30.19
	30	32.51	29.65	27.77	23.42	28.34
	45	30.56	26.48	21.54	18.78	24.34
	Average	33.87	31.14	27.82	24.66	29.15
T_4	0	35.42	32.82	29.66	27.49	31.35
	15	33.58	29.78	26.83	24.78	28.74
	30	31.80	28.73	25.49	22.51	27.13
	45	29.67	26.47	24.70	21.69	25.63
	Average	32.62	31.70	26.67	24.12	28.21
T_5	0	31.81	28.63	26.46	23.80	27.68
	15	28.61	25.46	23.61	21.73	24.85
	30	26.71	24.59	22.82	20.55	23.67
	45	24.58	23.47	21.78	19.68	22.38
	Average	27.93	31.70	23.67	21.44	24.64
T_6	0	30.58	28.73	25.64	22.45	26.85
	15	32.69	29.54	26.71	24.86	28.45
	30	28.71	26.80	23.59	20.68	24.95
	45	26.81	24.67	21.48	19.75	23.18
	Average	29.20	31.70	24.36	21.94	25.86
T_7	0	34.53	32.47	28.36	26.51	30.47
	15	32.39	30.47	26.43	24.36	28.41
	30	31.40	28.37	25.50	22.48	26.94
	45	28.37	26.56	23.41	20.35	24.67
	Average	31.67	31.70	29.36	23.43	27.62
T_8	0	43.36	41.71	38.52	35.36	39.74
	15	40.43	36.63	33.82	31.30	35.55
	30	38.62	35.71	32.63	29.55	34.13
	45	35.47	33.69	30.48	26.59	31.56
	Average	39.47	31.70	33.86	30.70	35.24
T_9	0	37.83	-	-	-	-
	15	35.66	-	-	-	-
	30	31.82	-	-	-	-
	45	28.67	-	-	-	-
	Average	33.50	-	-	-	-
T_{10}	0	33.30	-	-	-	-
	15	35.40	-	-	-	-
	30	31.56	-	-	-	-
	45	29.81	-	-	-	-
	Average	32.52	-	-	-	-
T_{11}	0	22.63	20.43	18.63	15.34	19.26
	15	20.48	18.52	16.30	14.34	17.41
	30	18.40	16.36	14.46	12.42	15.41
	45	17.42	15.30	12.41	10.47	13.90
	Average	19.73	17.65	15.45	13.14	16.49

Phosphorus distribution at 60 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	49.58	44.36	40.52	36.68	42.79
	15	45.68	41.71	37.62	33.40	26.58
	30	42.76	37.53	32.45	29.58	35.58
	45	37.49	33.36	28.63	24.43	30.98
	Average	43.88	39.24	34.81	31.02	37.24
T_2	0	52.64	47.82	41.63	36.48	44.64
	15	47.63	42.79	37.58	32.61	40.15
	30	43.58	41.52	35.65	31.61	38.09
	45	40.36	36.39	32.40	28.48	34.41
	Average	46.05	47.77	36.82	35.29	39.32
T_3	0	54.63	51.57	47.75	43.57	49.38
	15	50.69	45.56	42.81	37.49	44.14
	30	46.39	43.69	37.40	33.48	40.24
	45	42.58	36.29	32.67	28.75	35.07
	Average	48.57	44.28	40.16	35.82	42.21
T_4	0	56.72	52.63	46.39	42.53	49.57
	15	52.82	47.82	42.59	36.48	44.93
	30	47.63	41.52	37.52	33.72	40.10
	45	43.86	39.58	34.71	30.82	37.24
	Average	50.26	45.39	40.30	35.89	42.96
T_5	0	45.36	42.59	38.38	34.75	40.27
	15	41.57	37.60	33.69	30.48	35.84
	30	37.58	34.61	31.58	31.45	33.80
	45	32.49	36.77	33.44	27.76	32.61
	Average	39.25	37.89	34.27	31.11	35.63
T_6	0	44.76	41.82	38.68	35.47	40.18
	15	40.58	37.56	32.49	29.53	35.04
	30	36.68	33.85	30.79	27.86	32.30
	45	33.81	28.79	25.69	23.79	28.02
	Average	38.96	35.51	31.91	29.16	33.88
T_7	0	46.27	43.67	40.34	35.20	41.37
	15	42.31	37.52	33.40	30.71	35.99
	30	36.41	34.44	30.37	27.51	32.18
	45	32.54	28.57	24.38	22.49	27.00
	Average	39.38	36.05	32.12	28.98	34.13
T_8	0	42.59	38.71	35.55	30.48	36.83
	15	39.57	34.40	31.63	28.86	33.62
	30	35.73	32.57	29.69	25.43	30.86
	45	30.59	27.46	24.82	21.85	26.18
	Average	37.12	33.29	30.42	26.66	31.87
T_9	0	36.56	-	-	-	-
	15	32.43	-	-	-	-
	30	28.63	-	-	-	-
	45	24.37	-	-	-	-
	Average	30.50	-	-	-	-
T_{10}	0	35.48	-	-	-	-
	15	30.28	-	-	-	-
	30	26.34	-	-	-	-
	45	24.33	-	-	-	-
	Average	29.11	-	-	-	-
T_{11}	0	25.69	22.49	18.63	15.63	20.61
	15	22.63	18.53	14.49	11.56	16.80
	30	18.56	15.72	12.75	10.59	14.41
	45	15.56	12.57	10.55	8.69	11.84
	Average	20.61	17.33	14.11	11.62	15.92

Phosphorus distribution at 90 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	44.16	38.85	34.77	30.40	37.04
	15	40.17	36.60	31.20	27.27	33.81
	30	36.47	32.44	28.85	23.45	30.30
	45	32.24	28.02	26.44	22.64	27.33
	Average	38.26	33.98	30.31	25.94	32.12
T_2	0	50.57	46.41	41.00	36.71	43.67
	15	46.98	42.27	38.74	33.56	40.39
	30	42.70	38.20	34.66	30.41	36.49
	45	38.44	34.70	30.64	26.84	32.66
	Average	44.67	40.39	36.26	31.88	38.30
T_3	0	49.62	45.23	41.41	36.87	43.28
	15	45.51	41.11	37.27	33.09	39.24
	30	41.46	37.42	33.56	29.24	35.42
	45	37.77	33.50	29.17	24.64	31.27
	Average	43.59	39.32	35.35	30.96	37.30
T_4	0	46.84	42.85	38.77	34.45	40.73
	15	42.77	38.60	34.95	30.27	36.65
	30	38.47	34.44	30.93	27.45	32.82
	45	34.24	30.77	26.84	22.78	28.66
	Average	40.58	36.66	32.87	28.74	34.71
T_5	0	41.96	38.95	34.77	29.77	36.36
	15	38.27	33.87	28.85	24.77	31.44
	30	34.47	30.44	26.87	22.95	28.68
	45	30.74	26.77	22.44	19.34	24.82
	Average	36.36	32.51	28.23	24.20	30.33
T_6	0	39.17	35.26	31.42	27.70	33.39
	15	35.70	31.85	27.70	23.75	29.75
	30	31.68	27.27	23.60	19.58	25.53
	45	27.41	23.34	19.47	15.64	21.47
	Average	33.49	29.43	25.55	21.67	27.54
T_7	0	41.17	37.02	33.42	29.70	35.33
	15	37.70	33.85	29.70	24.20	31.36
	30	33.68	29.49	25.22	20.66	27.27
	45	28.41	24.44	20.47	16.64	22.49
	Average	35.24	31.20	27.20	22.80	29.11
T_8	0	38.26	34.27	30.28	26.57	32.35
	15	34.48	30.74	26.09	24.37	28.92
	30	30.18	26.16	22.41	17.44	24.05
	45	26.12	22.31	18.00	14.16	20.15
	Average	32.26	28.37	24.20	20.64	26.37
T_9	0	29.16	-	-	-	-
	15	26.45	-	-	-	-
	30	22.35	-	-	-	-
	45	19.02	-	-	-	-
	Average	24.25	-	-	-	-
T_{10}	0	28.71	-	-	-	-
	15	24.92	-	-	-	-
	30	21.44	-	-	-	-
	45	19.37	-	-	-	-
	Average	23.61	-	-	-	-
T_{11}	0	25.20	22.43	18.48	14.58	20.17
	15	22.09	18.52	14.56	10.42	16.40
	30	18.31	14.11	10.10	6.20	12.18
	45	14.45	10.33	7.40	3.67	8.96
	Average	20.01	16.35	12.64	8.72	14.43

Phosphorus distribution at 120 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	34.86	31.85	28.77	25.00	30.12
	15	31.77	27.60	24.70	20.27	26.08
	30	27.87	24.84	21.83	18.41	23.24
	45	24.54	21.77	18.90	15.92	20.28
	Average	29.76	26.51	23.55	19.90	24.93
T_2	0	40.57	37.93	34.96	31.76	36.30
	15	37.98	33.66	30.90	26.64	32.29
	30	33.64	29.95	26.66	22.49	28.19
	45	30.44	26.70	23.64	20.82	25.40
	Average	35.66	32.06	29.04	25.43	30.55
T_3	0	37.23	34.18	30.41	27.66	32.37
	15	34.81	30.09	27.27	24.22	29.10
	30	30.46	26.92	22.64	19.92	24.98
	45	27.47	24.54	21.20	18.46	22.92
	Average	32.49	28.93	25.38	22.56	27.34
T_4	0	37.98	34.44	30.23	27.59	32.56
	15	33.76	30.60	27.52	23.67	28.89
	30	30.47	26.84	23.88	19.89	25.27
	45	26.84	22.77	18.44	15.34	20.85
	Average	32.26	28.66	25.02	21.62	26.89
T_5	0	37.64	33.47	31.77	27.87	32.69
	15	33.77	30.60	27.95	24.26	29.14
	30	29.57	26.77	23.88	20.45	25.17
	45	25.84	22.26	18.44	15.34	20.47
	Average	31.70	28.28	25.51	21.98	26.87
T_6	0	33.59	30.27	26.38	23.57	28.45
	15	29.02	26.74	22.22	18.37	24.08
	30	26.18	22.54	18.31	15.44	20.62
	45	22.12	18.07	14.00	11.16	16.34
	Average	27.73	24.40	20.23	17.14	22.37
T_7	0	35.47	32.02	29.42	25.46	30.59
	15	31.70	27.85	23.70	19.20	25.61
	30	28.38	25.49	21.22	17.51	23.15
	45	24.41	20.44	17.27	13.14	18.82
	Average	29.99	26.45	22.90	18.83	24.54
T_8	0	32.27	29.48	25.53	22.13	27.35
	15	28.98	25.74	21.09	17.37	23.29
	30	24.68	21.16	17.41	14.41	19.42
	45	21.12	18.31	14.00	11.16	16.15
	Average	26.76	23.67	19.51	16.27	21.55
T_9	0	25.64	-	-	-	-
	15	23.72	-	-	-	-
	30	20.37	-	-	-	-
	45	17.28	-	-	-	-
	Average	21.75	-	-	-	-
T_{10}	0	24.41	-	-	-	-
	15	21.92	-	-	-	-
	30	18.44	-	-	-	-
	45	15.68	-	-	-	-
	Average	20.11	-	-	-	-
T_{11}	0	21.20	19.36	17.19	13.27	17.76
	15	20.10	17.12	14.05	11.17	15.61
	30	17.51	14.30	11.25	8.15	12.80
	45	14.28	12.35	9.42	6.49	10.64
	Average	18.27	15.78	12.98	9.77	14.20

Phosphorus distribution at 150 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	28.16	26.50	23.27	21.25	24.80
	15	25.87	23.03	20.20	16.27	21.34
	30	22.47	19.14	17.23	13.15	18.00
	45	19.24	16.47	12.44	9.34	14.37
	Average	23.93	21.28	18.28	15.00	19.63
T_2	0	37.85	34.64	29.77	27.80	32.51
	15	32.60	28.77	25.20	21.27	26.96
	30	29.74	27.47	24.88	21.99	26.02
	45	26.77	23.24	20.44	17.34	21.94
	Average	31.74	28.53	25.07	22.10	26.86
T_3	0	27.51	24.91	22.27	21.09	23.94
	15	22.46	23.42	25.16	21.02	23.02
	30	21.62	23.23	31.41	22.27	24.63
	45	20.77	21.54	18.20	16.64	19.29
	Average	23.09	23.28	24.26	20.26	22.72
T_4	0	31.16	28.78	25.77	22.62	27.08
	15	27.97	25.60	22.65	19.50	23.93
	30	24.47	21.54	17.23	14.35	19.40
	45	21.74	17.77	14.44	12.24	16.55
	Average	26.33	23.42	20.02	17.18	21.74
T_5	0	29.16	27.47	25.27	21.00	25.73
	15	27.57	24.60	22.20	18.27	23.16
	30	25.50	22.44	18.23	15.85	20.51
	45	22.24	19.37	16.44	12.34	17.59
	Average	26.12	23.47	20.53	16.86	21.75
T_6	0	25.59	23.27	20.68	18.17	21.93
	15	22.18	20.74	17.09	15.37	18.84
	30	19.68	16.46	14.41	13.44	16.00
	45	18.12	15.47	12.61	9.64	13.96
	Average	21.40	18.98	16.20	14.15	17.68
T_7	0	27.17	24.02	21.42	18.15	22.69
	15	25.70	22.85	19.05	16.20	20.95
	30	22.28	19.06	17.22	15.24	18.45
	45	19.09	16.44	13.17	10.64	14.84
	Average	23.56	20.59	17.72	15.06	19.23
T_8	0	25.17	23.02	20.42	18.52	21.78
	15	22.05	20.17	17.16	14.52	18.48
	30	20.18	17.19	15.22	11.40	16.00
	45	17.41	15.04	12.47	9.64	13.64
	Average	21.20	18.86	16.32	13.52	17.48
T_9	0	20.38				
	15	18.50				
	30	15.36				
	45	12.76				
	Average	16.75				
T_{10}	0	19.71				
	15	16.92				
	30	14.44				
	45	11.37				
	Average	15.61				
T_{11}	0	21.96	19.27	16.68	14.57	18.12
	15	18.98	16.74	13.16	11.37	15.06
	30	15.68	13.64	11.83	9.32	12.62
	45	12.84	10.31	8.96	6.64	9.69
	Average	17.37	14.99	12.66	10.47	13.87

Phosphorus distribution at harvest during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	25.16	22.85	19.62	16.50	21.03
	15	22.69	19.36	16.40	13.46	17.98
	30	19.36	16.68	13.39	11.61	15.26
	45	17.73	14.34	11.78	9.51	13.34
	Average	21.24	18.31	15.30	12.77	16.90
T_2	0	24.28	21.85	18.29	15.91	20.08
	15	22.36	19.26	17.63	14.67	18.48
	30	20.39	16.90	14.46	12.60	16.09
	45	17.88	14.59	11.26	9.69	13.36
	Average	21.23	18.15	15.41	13.22	17.00
T_3	0	25.85	22.48	19.84	16.24	21.10
	15	22.69	19.56	16.46	14.96	18.42
	30	20.24	17.65	14.94	11.56	16.10
	45	18.24	15.77	13.44	10.34	14.44
	Average	21.75	18.86	16.17	13.28	17.52
T_4	0	27.53	25.64	22.77	19.45	23.85
	15	24.36	22.43	18.20	15.27	20.06
	30	21.40	18.47	16.48	13.29	17.41
	45	17.53	15.24	12.83	8.34	13.48
	Average	22.71	20.44	17.57	14.09	18.70
T_5	0	24.16	21.59	19.47	16.60	20.46
	15	21.63	19.20	16.24	13.20	17.57
	30	18.29	15.40	12.39	10.50	14.15
	45	16.47	14.24	11.44	8.34	12.62
	Average	20.14	17.61	14.88	12.16	16.20
T_6	0	24.64	21.83	18.92	15.48	20.22
	15	19.63	17.23	14.49	12.29	15.91
	30	17.97	14.46	12.84	10.63	13.98
	45	15.69	14.31	11.96	9.52	12.87
	Average	19.30	16.96	14.55	11.98	15.74
T_7	0	23.74	19.42	17.55	14.96	18.92
	15	20.65	17.56	15.32	12.21	16.44
	30	17.86	15.43	12.69	10.41	14.10
	45	16.36	14.31	11.56	9.16	12.85
	Average	19.65	16.68	14.28	11.69	15.57
T_8	0	23.91	20.42	18.64	16.21	19.80
	15	21.13	19.80	16.26	14.82	18.00
	30	18.46	16.49	13.62	11.53	15.03
	45	15.10	13.88	11.78	10.33	12.77
	Average	19.65	17.65	15.08	13.22	16.40
T_9	0	18.11	-	-	-	-
	15	16.53	-	-	-	-
	30	13.56	-	-	-	-
	45	10.78	-	-	-	-
	Average	14.75	-	-	-	-
T_{10}	0	17.84	-	-	-	-
	15	15.23	-	-	-	-
	30	13.16	-	-	-	-
	45	11.25	-	-	-	-
	Average	14.37	-	-	-	-
T_{11}	0	15.36	14.27	13.18	11.36	13.54
	15	14.02	12.64	11.09	9.26	11.75
	30	13.28	11.16	9.41	7.44	10.32
	45	11.12	10.31	8.00	6.16	8.90
	Average	13.45	12.09	10.42	8.56	11.13

Appendix-IV : Potassium distribution at 30 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	354.52	351.10	346.10	342.71	348.61
	15	350.43	346.18	343.73	337.38	344.43
	30	347.19	342.20	338.50	333.26	340.29
	45	342.76	337.54	333.68	328.26	335.56
	Average	348.73	344.26	340.50	335.40	342.22
T_2	0	362.53	359.01	354.43	349.60	356.39
	15	358.30	354.34	349.28	344.36	351.57
	30	353.52	351.38	347.80	342.71	348.85
	45	350.46	345.71	344.53	339.47	345.04
	Average	356.20	352.61	376.36	333.56	350.46
T_3	0	359.45	355.64	352.63	347.74	353.87
	15	356.71	352.89	348.41	344.63	350.66
	30	352.63	347.93	343.91	339.56	346.01
	45	348.59	344.78	341.76	336.60	342.93
	Average	354.35	350.31	346.68	342.13	348.37
T_4	0	360.76	354.61	349.77	345.63	352.69
	15	354.37	351.34	346.55	343.50	348.94
	30	351.66	346.57	341.44	336.76	344.11
	45	347.33	341.71	336.76	331.55	339.34
	Average	353.53	348.56	343.63	339.36	346.27
T_5	0	352.63	349.71	345.53	340.21	347.02
	15	348.45	344.10	340.71	336.56	342.46
	30	346.24	341.03	337.30	332.40	339.24
	45	342.30	336.56	331.12	326.73	334.18
	Average	347.40	342.85	338.66	333.98	340.72
T_6	0	368.56	365.61	360.49	356.36	362.76
	15	363.43	357.64	351.34	346.55	354.74
	30	356.53	351.73	345.59	340.33	348.55
	45	352.73	346.36	341.73	336.56	344.35
	Average	360.31	355.34	349.79	273.50	352.60
T_7	0	367.68	363.71	359.81	354.61	361.45
	15	362.73	357.67	352.76	349.85	355.75
	30	357.86	354.87	351.58	347.77	353.02
	45	353.64	350.70	346.59	342.88	348.45
	Average	360.48	356.74	352.69	348.78	354.67
T_8	0	374.59	371.59	366.10	361.43	368.43
	15	369.63	364.79	358.39	353.10	361.48
	30	364.48	358.58	353.66	347.53	356.06
	45	358.69	353.26	349.54	343.21	351.18
	Average	366.85	362.06	356.92	351.32	359.29
T_9	0	364.49	-	-	-	-
	15	364.49	-	-	-	-
	30	355.60	-	-	-	-
	45	350.30	-	-	-	-
	Average	358.72	-	-	-	-
T_{10}	0	361.75	-	-	-	-
	15	357.67	-	-	-	-
	30	353.86	-	-	-	-
	45	348.58	-	-	-	-
	Average	355.47	-	-	-	-
T_{11}	0	338.25	333.69	330.51	325.31	331.94
	15	334.69	330.55	326.31	323.41	328.74
	30	329.61	322.36	320.63	318.50	322.78
	45	323.54	319.43	314.38	311.47	317.21
	Average	331.52	326.51	322.96	319.67	325.17

Potassium distribution at 60 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	373.68	369.51	365.49	361.65	367.58
	15	368.73	362.78	358.69	354.72	361.23
	30	363.56	357.73	353.69	350.46	356.36
	45	358.47	354.69	351.67	347.58	353.10
	Average	366.11	361.18	357.39	353.60	359.57
T_2	0	382.63	377.72	372.58	368.43	375.34
	15	378.53	372.49	369.57	365.75	371.59
	30	374.61	371.59	367.82	363.82	369.46
	45	370.58	366.48	362.53	358.43	364.51
	Average	376.59	372.07	368.13	364.11	370.22
T_3	0	379.63	374.69	370.48	366.81	372.90
	15	375.86	372.56	367.73	363.49	369.91
	30	371.68	367.82	363.66	359.71	365.72
	45	367.59	363.43	359.48	355.34	361.46
	Average	373.69	369.63	365.34	361.34	367.50
T_4	0	372.29	368.46	364.35	360.24	366.34
	15	369.48	365.55	362.49	358.39	363.98
	30	365.43	361.44	357.52	353.42	359.45
	45	361.59	358.33	353.24	349.45	355.65
	Average	367.20	363.45	359.31	326.20	361.35
T_5	0	367.58	363.31	359.41	354.23	361.13
	15	363.47	360.55	358.47	352.33	358.71
	30	361.82	357.30	354.83	350.67	356.16
	45	357.43	352.46	347.50	344.30	350.42
	Average	362.58	358.41	355.05	350.38	356.60
T_6	0	366.58	362.81	359.71	356.81	361.48
	15	362.59	358.76	353.79	349.57	356.18
	30	359.48	355.79	350.64	347.67	353.40
	45	355.72	352.61	348.47	345.79	350.65
	Average	361.09	357.49	353.15	349.96	355.42
T_7	0	362.49	359.64	354.79	350.82	356.94
	15	358.64	355.46	349.78	346.58	352.62
	30	352.69	347.41	343.83	339.69	345.91
	45	348.86	343.61	340.68	335.81	342.24
	Average	355.67	351.53	347.27	343.23	349.42
T_8	0	365.49	362.57	359.62	355.63	360.83
	15	361.78	357.46	353.42	349.82	355.62
	30	358.71	354.67	351.43	347.55	353.09
	45	354.76	351.72	347.69	343.82	349.50
	Average	360.19	356.61	353.04	349.21	354.76
T_9	0	354.53	-	-	-	-
	15	350.69	-	-	-	-
	30	346.73	-	-	-	-
	45	341.83	-	-	-	-
	Average	348.45	-	-	-	-
T_{10}	0	353.48	-	-	-	-
	15	348.52	-	-	-	-
	30	343.57	-	-	-	-
	45	339.41	-	-	-	-
	Average	346.25	-	-	-	-
T_{11}	0	330.24	327.23	323.36	319.27	325.03
	15	327.32	324.31	320.48	316.33	322.11
	30	323.44	320.41	316.24	312.41	318.13
	45	320.34	317.34	314.73	311.25	315.92
	Average	325.34	322.32	318.70	314.82	320.29

Potassium distribution at 90 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	352.90	348.77	343.84	339.83	346.34
	15	348.69	343.88	337.96	334.45	341.25
	30	344.45	340.86	336.80	333.47	338.90
	45	340.87	336.92	333.86	329.90	335.39
	Average	346.73	342.61	338.12	334.41	340.47
T_2	0	363.83	359.56	355.69	351.90	357.75
	15	359.90	355.40	351.80	347.90	353.75
	30	354.41	350.76	347.89	343.78	349.21
	45	350.80	347.46	342.80	339.60	345.17
	Average	357.24	353.30	349.55	345.80	351.47
T_3	0	361.12	357.10	353.70	350.10	355.51
	15	356.96	352.20	348.50	342.20	349.97
	30	352.21	348.03	343.80	339.40	345.86
	45	348.20	345.14	341.20	337.80	343.08
	Average	354.62	350.62	346.80	342.38	348.60
T_4	0	359.12	355.10	352.20	346.20	353.16
	15	355.53	351.20	347.50	342.20	349.11
	30	350.21	346.01	342.20	338.40	344.21
	45	345.94	341.12	337.20	333.40	339.42
	Average	352.70	348.36	344.78	326.20	346.47
T_5	0	349.20	345.20	341.06	336.15	342.90
	15	344.16	339.40	336.10	332.26	337.98
	30	341.21	336.10	334.10	330.20	335.40
	45	336.10	332.10	327.20	323.20	329.65
	Average	342.67	338.20	334.62	330.45	336.48
T_6	0	344.36	340.12	335.48	331.60	337.89
	15	341.20	337.10	333.76	329.80	335.47
	30	338.40	334.16	329.56	325.31	331.86
	45	334.12	330.40	325.10	321.20	327.71
	Average	339.52	335.45	330.98	326.98	333.23
T_7	0	341.40	337.26	333.40	328.48	335.14
	15	337.20	334.06	330.10	326.86	332.06
	30	333.20	329.30	325.40	321.31	327.30
	45	329.20	325.40	321.50	317.26	323.34
	Average	335.25	331.51	327.60	323.48	329.46
T_8	0	346.10	341.98	338.86	334.50	340.36
	15	342.21	337.76	334.80	330.50	336.32
	30	338.62	335.40	331.69	327.70	333.35
	45	333.47	329.18	326.80	323.30	328.19
	Average	340.10	336.08	333.04	329.00	334.55
T_9	0	332.43	-	-	-	-
	15	328.50	-	-	-	-
	30	324.32	-	-	-	-
	45	320.51	-	-	-	-
	Average	326.44	-	-	-	-
T_{10}	0	331.46	-	-	-	-
	15	327.64	-	-	-	-
	30	322.86	-	-	-	-
	45	319.54	-	-	-	-
	Average	325.38	-	-	-	-
T_{11}	0	329.60	325.60	321.60	318.80	323.90
	15	324.98	321.90	317.45	313.46	319.45
	30	320.74	316.70	311.98	308.81	314.56
	45	316.80	312.76	308.80	304.66	310.76
	Average	323.03	319.24	314.96	311.43	317.17

Potassium distribution at 120 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	344.30	340.34	337.14	333.20	338.75
	15	341.23	337.10	334.31	330.25	335.72
	30	336.25	332.03	328.14	324.36	330.20
	45	332.25	327.29	323.13	319.21	325.47
	Average	338.51	334.19	330.68	326.75	332.53
T_2	0	351.12	347.14	344.09	339.65	345.50
	15	347.44	343.40	339.80	335.80	341.61
	30	343.61	339.65	335.56	331.26	337.52
	45	339.80	335.40	331.80	327.40	333.60
	Average	345.49	341.40	337.81	333.53	339.56
T_3	0	351.14	347.20	343.10	337.06	344.63
	15	347.10	343.08	338.28	333.25	340.43
	30	343.62	339.22	335.42	330.06	337.08
	45	338.10	334.40	329.16	325.26	331.73
	Average	344.99	340.98	321.86	331.41	338.47
T_4	0	350.38	346.66	342.47	338.77	344.57
	15	344.95	341.84	337.80	333.94	339.63
	30	340.59	336.79	332.58	329.87	334.96
	45	337.70	333.40	328.80	325.94	331.46
	Average	343.41	339.67	335.41	326.20	337.66
T_5	0	342.78	338.68	333.69	333.86	337.25
	15	338.52	334.40	329.89	325.59	332.10
	30	333.64	329.83	324.82	320.84	327.28
	45	330.82	326.71	322.92	318.46	324.73
	Average	336.44	332.41	327.83	324.69	330.34
T_6	0	340.84	335.60	330.60	326.95	333.50
	15	335.94	331.81	327.82	323.54	329.78
	30	331.71	327.76	323.68	320.59	325.94
	45	325.72	321.50	317.81	314.61	319.91
	Average	333.55	329.17	324.98	321.42	327.28
T_7	0	336.90	331.84	328.64	325.58	330.74
	15	332.61	328.23	323.94	318.31	325.77
	30	329.40	324.77	319.77	314.99	322.23
	45	324.63	321.86	317.50	313.60	319.40
	Average	330.89	326.68	322.46	318.12	324.54
T_8	0	338.46	334.76	329.48	326.50	332.30
	15	333.92	330.52	326.80	322.50	328.44
	30	330.93	325.46	322.80	318.93	324.53
	45	326.84	322.60	318.80	315.30	320.89
	Average	332.54	328.34	324.47	320.81	326.54
T_9	0	329.49	-	-	-	-
	15	324.65	-	-	-	-
	30	321.38	-	-	-	-
	45	318.26	-	-	-	-
	Average	323.45	-	-	-	-
T_{10}	0	328.91	-	-	-	-
	15	324.44	-	-	-	-
	30	320.71	-	-	-	-
	45	316.56	-	-	-	-
	Average	322.65	-	-	-	-
T_{11}	0	327.76	324.30	319.49	315.49	321.76
	15	324.60	320.80	315.59	311.10	318.02
	30	319.68	315.70	310.78	306.39	313.14
	45	314.80	310.45	306.76	303.52	308.88
	Average	321.71	317.81	313.16	309.13	315.45

Potassium distribution at 150 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	339.26	335.61	330.69	326.90	333.12
	15	336.10	333.61	329.46	324.15	330.83
	30	333.62	328.63	324.50	320.49	326.81
	45	329.50	325.12	322.20	317.41	323.56
	Average	334.62	330.74	326.71	322.24	328.58
T_2	0	347.30	343.08	339.52	335.84	341.44
	15	343.27	339.40	334.80	329.96	336.86
	30	338.60	334.59	329.67	324.69	331.89
	45	333.51	329.40	326.45	323.64	328.25
	Average	340.67	336.62	332.61	328.53	334.61
T_3	0	345.40	341.42	338.43	334.32	339.89
	15	340.52	337.81	333.80	329.30	335.36
	30	337.10	334.06	330.22	325.45	331.71
	45	333.14	329.40	324.58	320.14	326.82
	Average	339.04	335.67	331.76	327.30	333.44
T_4	0	344.40	340.85	337.75	333.89	339.22
	15	339.20	335.36	332.80	328.69	334.01
	30	336.14	332.58	328.55	325.90	330.79
	45	331.61	328.34	324.85	320.80	326.40
	Average	337.84	334.28	330.99	321.30	332.61
T_5	0	336.62	333.36	329.66	325.93	331.39
	15	332.72	328.40	324.92	320.94	326.75
	30	329.81	324.94	319.46	315.74	322.49
	45	323.71	318.74	314.53	311.50	317.12
	Average	330.72	326.36	322.14	318.53	324.44
T_6	0	335.57	330.76	327.86	322.41	329.15
	15	329.76	326.66	322.86	318.48	324.44
	30	325.54	321.49	318.68	314.97	320.17
	45	322.62	317.64	313.25	310.60	316.03
	Average	328.37	324.14	320.66	316.62	322.45
T_7	0	332.40	329.56	325.60	320.24	326.95
	15	328.20	325.86	322.12	316.56	323.19
	30	326.14	322.78	318.36	313.36	320.16
	45	321.20	317.36	314.49	310.60	315.91
	Average	326.99	323.89	320.14	315.19	321.55
T_8	0	335.14	332.21	328.40	323.50	329.81
	15	331.21	327.23	324.28	318.35	325.27
	30	328.20	323.16	319.61	314.23	321.30
	45	323.40	319.06	316.13	312.30	317.72
	Average	329.49	325.42	322.11	317.10	323.53
T_9	0	325.48	-	-	-	-
	15	322.26	-	-	-	-
	30	318.27	-	-	-	-
	45	315.81	-	-	-	-
	Average	320.46	-	-	-	-
T_{10}	0	323.14	-	-	-	-
	15	320.35	-	-	-	-
	30	318.56	-	-	-	-
	45	315.30	-	-	-	-
	Average	319.34	-	-	-	-
T_{11}	0	321.26	317.62	313.65	310.30	315.71
	15	317.14	314.56	310.46	306.60	312.19
	30	314.25	311.37	307.24	303.60	309.12
	45	310.24	307.56	303.36	299.34	305.13
	Average	315.72	312.78	308.68	304.96	310.53

Potassium distribution at harvest during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	336.20	333.36	328.36	323.26	330.30
	15	331.45	328.32	324.30	320.54	326.15
	30	328.21	325.19	321.06	317.09	322.89
	45	324.29	320.10	316.30	312.69	318.35
	Average	330.04	326.74	322.51	318.40	324.42
T_2	0	341.36	336.89	333.70	329.36	335.33
	15	335.31	331.48	326.86	323.61	329.32
	30	331.50	327.20	322.80	318.50	325.00
	45	326.60	322.52	319.80	315.36	321.07
	Average	333.69	329.52	325.79	321.71	327.68
T_3	0	338.20	334.40	329.25	326.04	331.97
	15	335.20	330.40	326.80	322.36	328.69
	30	331.50	327.10	324.34	319.70	325.66
	45	326.10	322.40	317.42	313.49	319.85
	Average	332.75	328.58	324.45	320.40	326.54
T_4	0	336.26	332.14	329.45	325.30	330.79
	15	333.16	329.40	325.34	321.30	327.30
	30	329.50	325.59	322.67	317.36	323.78
	45	325.32	321.40	317.21	313.60	319.38
	Average	331.06	327.13	323.67	321.30	325.31
T_5	0	334.70	330.82	325.78	322.57	328.47
	15	329.63	326.40	322.56	318.69	324.32
	30	325.36	321.45	318.97	314.84	320.16
	45	322.56	318.61	314.55	311.50	316.80
	Average	328.06	324.32	320.47	316.90	322.44
T_6	0	331.41	327.60	324.10	320.29	325.85
	15	328.40	324.60	319.35	315.36	321.93
	30	324.89	319.52	315.30	311.26	317.74
	45	321.56	318.31	315.10	311.10	316.52
	Average	326.57	322.51	318.46	314.50	320.51
T_7	0	330.23	327.16	323.34	318.06	324.70
	15	327.20	323.48	320.23	316.64	321.89
	30	323.48	319.23	315.14	310.69	317.14
	45	320.21	316.19	312.52	307.14	314.02
	Average	325.28	321.52	317.81	313.13	319.43
T_8	0	333.34	330.20	325.36	321.05	327.49
	15	329.36	325.30	321.50	317.50	323.42
	30	325.20	322.46	317.19	313.73	319.65
	45	322.40	318.10	314.60	309.12	316.06
	Average	327.58	324.02	319.66	315.35	321.65
T_9	0	325.25	-	-	-	-
	15	321.24	-	-	-	-
	30	316.46	-	-	-	-
	45	311.61	-	-	-	-
	Average	318.64	-	-	-	-
T_{10}	0	324.31	-	-	-	-
	15	319.40	-	-	-	-
	30	315.14	-	-	-	-
	45	311.36	-	-	-	-
	Average	317.55	-	-	-	-
T_{11}	0	322.20	317.20	315.43	312.30	316.78
	15	318.30	315.28	311.34	306.36	312.82
	30	316.31	311.37	307.31	303.16	309.54
	45	312.20	307.40	303.16	299.80	305.64
	Average	317.25	312.81	309.31	305.41	311.20

Appendix-V : Nitrogen distribution at 30 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	218.41	215.30	209.41	207.10	212.56
	15	214.55	209.52	205.28	200.53	207.47
	30	210.04	205.09	200.32	196.55	203.00
	45	206.46	201.10	197.53	191.51	199.15
	Average	212.37	207.75	203.14	198.92	205.54
T_2	0	223.42	217.41	213.24	208.41	215.62
	15	218.24	215.47	210.41	205.33	212.36
	30	215.9	208.37	204.38	200.36	207.25
	45	209.43	205.79	201.26	197.42	203.48
	Average	216.75	211.76	207.32	202.88	209.68
T_3	0	220.63	217.57	213.05	209.50	215.19
	15	216.80	212.83	207.48	203.63	210.19
	30	212.90	203.80	198.40	195.75	202.71
	45	208.71	209.63	205.34	201.41	206.27
	Average	214.76	210.96	206.07	202.57	208.59
T_4	0	220.50	216.76	212.64	208.51	214.60
	15	214.37	210.41	206.31	203.32	208.60
	30	211.73	207.84	203.60	199.93	205.78
	45	207.37	203.52	198.83	195.60	201.33
	Average	213.49	209.63	205.35	201.84	207.58
T_5	0	230.94	226.40	222.68	219.86	224.97
	15	225.40	221.58	217.47	214.46	219.73
	30	221.65	217.80	212.42	208.56	215.11
	45	216.36	213.50	208.28	204.82	210.74
	Average	223.59	219.82	215.21	211.93	217.64
T_6	0	238.59	234.57	229.97	224.81	231.99
	15	234.68	230.76	226.61	223.71	228.94
	30	229.63	224.66	220.61	216.47	222.84
	45	225.36	220.64	216.74	212.58	218.83
	Average	232.07	227.66	223.48	219.39	225.65
T_7	0	241.52	236.43	231.36	227.49	234.20
	15	235.63	231.91	227.25	224.69	229.87
	30	231.42	226.65	222.85	219.81	225.18
	45	227.93	223.30	219.48	214.63	221.34
	Average	234.13	229.57	225.24	221.66	227.65
T_8	0	245.53	241.53	237.81	233.53	239.60
	15	240.55	236.48	231.78	227.53	234.09
	30	237.51	232.05	227.67	222.60	229.96
	45	233.78	229.69	224.18	218.28	226.48
	Average	239.34	234.94	230.36	225.48	232.53
T_9	0	238.58	-	-	-	-
	15	232.65	-	-	-	-
	30	227.71	-	-	-	-
	45	223.67	-	-	-	-
	Average	230.65	-	-	-	-
T_{10}	0	236.68	-	-	-	-
	15	231.97	-	-	-	-
	30	227.57	-	-	-	-
	45	222.60	-	-	-	-
	Average	229.71	-	-	-	-
T_{11}	0	162.36	158.98	155.82	150.36	156.88
	15	158.38	155.38	149.43	144.63	151.96
	30	154.48	151.65	147.58	143.74	149.36
	45	150.47	146.36	141.47	137.53	143.96
	Average	156.42	153.09	148.58	144.07	150.54

Nitrogen distribution at 60 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	255.55	251.48	246.46	241.41	248.73
	15	250.93	244.81	239.53	235.47	242.69
	30	247.47	243.83	238.50	235.58	241.35
	45	243.71	238.43	235.60	231.52	237.32
	Average	249.42	244.64	240.02	236.00	242.52
T_2	0	264.66	260.71	256.65	252.79	258.70
	15	260.86	256.69	252.46	246.63	254.16
	30	257.86	253.67	249.75	245.68	251.74
	45	253.63	247.46	242.77	237.58	245.36
	Average	259.25	254.63	250.41	245.67	252.49
T_3	0	261.70	257.80	252.41	247.60	254.88
	15	256.66	251.71	246.50	243.49	249.59
	30	251.63	246.53	243.59	240.73	245.62
	45	248.53	243.83	240.63	238.49	242.87
	Average	254.63	249.97	245.78	242.58	248.24
T_4	0	258.36	254.47	248.56	244.92	251.58
	15	253.43	248.51	243.73	237.43	245.78
	30	248.43	241.31	237.67	233.51	240.23
	45	242.35	238.51	234.58	229.48	236.23
	Average	250.64	245.70	241.14	236.34	243.45
T_5	0	248.48	245.30	241.52	237.39	243.17
	15	243.63	239.46	235.56	230.44	237.27
	30	239.53	236.37	232.20	227.50	233.90
	45	234.48	230.63	224.27	221.35	227.68
	Average	241.53	237.94	233.39	229.17	235.51
T_6	0	253.29	248.33	243.29	239.42	246.08
	15	248.71	244.79	239.68	235.76	242.24
	30	242.75	237.76	232.50	228.71	235.43
	45	238.30	234.66	231.48	227.30	232.94
	Average	245.76	241.39	236.74	232.80	239.17
T_7	0	238.48	232.39	227.34	224.46	230.67
	15	234.26	230.30	226.38	219.23	227.54
	30	229.73	224.26	221.52	216.43	222.99
	45	226.90	222.45	218.28	214.74	220.59
	Average	232.34	227.35	223.38	218.72	225.45
T_8	0	243.82	239.69	235.56	230.59	237.42
	15	240.38	236.41	232.82	228.42	234.51
	30	237.74	233.28	229.92	225.37	231.58
	45	233.33	228.79	225.53	221.23	227.22
	Average	238.82	234.54	230.96	226.40	232.68
T_9	0	236.46	-	-	-	-
	15	232.32	-	-	-	-
	30	227.86	-	-	-	-
	45	226.29	-	-	-	-
	Average	230.73	-	-	-	-
T_{10}	0	235.41	-	-	-	-
	15	231.61	-	-	-	-
	30	227.52	-	-	-	-
	45	224.13	-	-	-	-
	Average	229.67	-	-	-	-
T_{11}	0	158.62	155.65	152.51	149.53	154.08
	15	154.53	151.73	147.48	143.72	149.37
	30	150.62	145.85	141.82	137.62	143.98
	45	146.67	143.55	140.63	135.58	141.61
	Average	152.61	149.20	145.61	141.61	147.26

Nitrogen distribution at 90 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	229.63	225.56	221.69	216.48	223.34
	15	223.48	219.86	213.71	209.39	216.61
	30	217.85	214.80	210.59	205.99	212.31
	45	212.57	207.85	204.56	200.55	206.38
	Average	220.88	217.02	212.64	208.10	214.66
T_2	0	241.12	237.08	233.6	229.08	235.22
	15	237.32	233.56	229.312	224.68	231.22
	30	232.2	227.2	223.4	218.2	225.25
	45	228.76	224.24	220.38	216.08	222.37
	Average	234.85	230.52	226.67	222.01	228.51
T_3	0	237.60	232.97	228.44	223.68	230.67
	15	232.12	228.28	224.80	220.31	226.38
	30	228.57	224.56	220.03	216.49	222.41
	45	225.41	220.03	216.63	212.41	218.62
	Average	230.92	226.46	222.48	218.22	224.52
T_4	0	234.56	229.53	224.76	220.83	227.42
	15	230.75	225.98	221.82	217.41	223.99
	30	225.79	220.69	216.88	212.41	218.94
	45	221.77	217.98	213.68	209.63	215.77
	Average	228.22	223.55	219.28	215.07	221.53
T_5	0	226.18	222.18	217.10	213.21	219.67
	15	222.75	218.08	214.63	209.22	216.17
	30	218.31	213.84	208.18	204.40	211.18
	45	214.06	209.26	204.32	200.54	207.05
	Average	220.33	215.84	211.06	206.84	213.52
T_6	0	224.64	220.76	215.47	212.80	218.42
	15	220.05	216.08	212.63	207.22	214.00
	30	217.66	213.94	209.49	205.49	211.65
	45	212.56	208.16	203.22	200.44	206.10
	Average	218.73	214.74	210.20	206.49	212.54
T_7	0	215.44	210.76	206.90	203.41	209.13
	15	210.75	206.08	202.63	198.12	204.40
	30	206.96	203.40	198.48	193.84	200.67
	45	202.56	198.66	194.60	189.58	196.35
	Average	208.93	204.73	200.65	196.24	202.64
T_8	0	227.63	222.66	218.32	213.82	220.61
	15	223.04	218.63	214.59	209.32	216.40
	30	219.80	215.54	212.41	207.63	213.85
	45	214.11	209.43	205.55	201.87	207.74
	Average	221.15	216.57	212.72	208.16	214.65
T_9	0	205.86	-	-	-	-
	15	201.39	-	-	-	-
	30	196.62	-	-	-	-
	45	194.59	-	-	-	-
	Average	199.61	-	-	-	-
T_{10}	0	199.82	-	-	-	-
	15	195.53	-	-	-	-
	30	190.72	-	-	-	-
	45	187.94	-	-	-	-
	Average	193.50	-	-	-	-
T_{11}	0	159.11	154.52	150.50	146.40	152.63
	15	153.03	149.20	145.18	141.20	147.15
	30	149.62	145.93	141.84	136.61	143.50
	45	145.05	141.30	136.02	132.22	138.65
	Average	151.70	147.74	143.38	139.11	145.48

Nitrogen distribution at 120 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	195.83	191.36	187.60	183.58	189.59
	15	191.28	187.62	183.32	179.38	185.40
	30	186.30	182.98	178.76	175.88	180.98
	45	183.42	180.80	176.63	171.54	178.10
	Average	189.21	185.69	181.58	177.59	183.52
T_2	0	199.42	196.03	192.23	188.04	193.93
	15	195.11	190.72	187.16	183.02	189.00
	30	190.20	187.62	183.32	178.15	184.82
	45	187.23	183.24	179.22	176.13	181.45
	Average	192.99	189.40	185.48	181.34	187.30
T_3	0	197.32	193.46	189.28	186.48	191.64
	15	193.88	189.56	186.43	182.48	188.09
	30	189.62	185.80	180.76	175.20	182.85
	45	185.12	181.32	178.63	172.54	179.40
	Average	191.49	187.54	183.78	179.18	185.49
T_4	0	196.79	192.76	189.48	185.28	191.08
	15	191.88	188.87	183.63	178.89	185.82
	30	187.18	183.49	178.38	175.95	181.25
	45	184.22	180.66	176.63	175.84	179.34
	Average	190.02	186.44	182.03	178.99	184.37
T_5	0	194.34	190.58	187.90	182.41	188.81
	15	189.15	185.38	182.63	179.82	184.25
	30	185.28	180.54	177.40	173.60	179.20
	45	182.66	179.66	176.16	172.54	177.76
	Average	187.86	184.04	181.02	177.09	182.50
T_6	0	189.40	185.18	181.10	178.41	183.52
	15	184.75	180.08	176.63	172.82	178.57
	30	180.58	176.38	172.91	168.54	174.60
	45	176.06	172.26	167.16	163.64	169.78
	Average	182.70	178.48	174.45	170.85	176.62
T_7	0	186.98	182.98	179.48	175.34	181.20
	15	182.18	179.08	175.93	170.12	176.83
	30	177.98	173.38	170.18	166.40	171.99
	45	174.06	170.26	165.82	161.54	167.92
	Average	180.30	176.43	172.85	168.35	174.48
T_8	0	191.00	186.53	182.36	178.18	184.52
	15	187.34	184.38	179.53	174.48	181.43
	30	182.03	179.20	173.72	169.40	176.09
	45	179.23	173.52	169.37	166.47	172.15
	Average	184.90	180.91	176.25	172.13	178.55
T_9	0	176.52	-	-	-	-
	15	172.62	-	-	-	-
	30	168.75	-	-	-	-
	45	164.49	-	-	-	-
	Average	170.59	-	-	-	-
T_{10}	0	165.56	-	-	-	-
	15	168.48	-	-	-	-
	30	173.84	-	-	-	-
	45	161.64	-	-	-	-
	Average	167.38	-	-	-	-
T_{11}	0	156.12	152.36	149.24	145.24	150.74
	15	153.06	149.26	145.18	141.30	147.20
	30	148.55	143.48	139.40	135.63	141.77
	45	144.75	140.20	136.19	133.26	138.60
	Average	150.62	146.33	142.50	138.86	144.58

Nitrogen distribution at 150 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	189.29	186.26	183.22	180.13	184.72
	15	186.14	183.16	179.03	177.38	181.43
	30	183.32	180.32	176.18	171.52	177.83
	45	179.12	176.03	172.32	169.24	174.18
	Average	184.47	181.44	177.69	174.57	179.54
T_2	0	195.82	191.86	187.63	184.56	189.97
	15	190.72	186.52	182.48	179.89	184.90
	30	186.88	182.16	177.66	173.28	179.99
	45	181.83	176.60	172.60	169.33	175.09
	Average	188.81	184.29	180.09	176.76	182.49
T_3	0	194.32	190.06	186.22	182.18	188.19
	15	189.38	185.62	181.20	178.76	183.74
	30	186.42	182.39	177.06	173.19	179.77
	45	181.32	176.83	171.69	166.59	174.11
	Average	187.86	183.73	179.04	175.18	181.45
T_4	0	191.72	186.56	183.32	179.89	185.37
	15	188.19	183.62	180.32	177.18	182.33
	30	183.42	179.62	177.76	172.52	178.33
	45	178.92	174.03	170.63	165.54	172.28
	Average	185.56	180.96	178.01	173.78	179.58
T_5	0	189.97	185.76	181.94	176.80	183.62
	15	184.75	180.68	176.68	172.82	178.73
	30	179.76	175.98	171.84	168.78	174.09
	45	175.56	171.74	167.82	164.58	169.93
	Average	182.51	178.54	174.57	170.75	176.59
T_6	0	182.98	178.18	174.54	170.41	176.53
	15	176.75	172.03	168.60	165.82	170.80
	30	175.36	171.20	167.54	163.40	169.38
	45	171.06	167.26	163.82	160.54	165.67
	Average	176.54	172.17	168.62	165.04	170.59
T_7	0	184.98	180.69	175.90	171.41	178.25
	15	179.75	174.59	169.83	165.82	172.50
	30	174.84	171.84	167.84	162.40	169.23
	45	171.96	166.69	163.82	160.54	165.75
	Average	177.88	173.45	169.35	165.04	171.43
T_8	0	182.82	178.86	175.58	170.88	177.04
	15	177.80	173.78	170.59	165.32	171.87
	30	173.84	168.84	165.80	160.52	167.25
	45	170.92	166.93	163.55	160.87	165.57
	Average	176.35	172.10	160.91	164.40	168.44
T_9	0	168.42	-	-	-	-
	15	163.32	-	-	-	-
	30	160.61	-	-	-	-
	45	157.70	-	-	-	-
	Average	162.51	-	-	-	-
T_{10}	0	163.64	-	-	-	-
	15	159.94	-	-	-	-
	30	157.59	-	-	-	-
	45	153.70	-	-	-	-
	Average	158.72	-	-	-	-
T_{11}	0	154.32	150.20	145.57	141.45	147.89
	15	150.26	146.26	142.18	138.82	144.38
	30	145.58	141.98	136.90	132.67	139.28
	45	141.75	136.90	132.88	128.26	134.95
	Average	147.98	143.84	139.38	135.30	141.62

Nitrogen distribution at harvest during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	169.17	165.23	165.47	160.75	165.16
	15	164.23	161.23	169.23	157.18	162.97
	30	160.36	158.28	154.27	152.88	156.45
	45	156.28	154.21	153.12	150.23	153.46
	Average	162.51	159.74	160.52	155.26	159.51
T_2	0	176.24	173.03	168.53	164.14	170.49
	15	172.11	167.30	163.18	159.32	165.48
	30	168.21	164.12	161.02	157.41	162.69
	45	165.32	160.06	157.22	153.13	158.93
	Average	170.47	166.13	162.49	158.50	164.40
T_3	0	173.25	169.52	165.24	162.13	167.53
	15	169.48	166.25	164.35	161.18	165.31
	30	165.23	161.85	158.23	156.25	160.39
	45	161.23	158.03	154.63	150.36	156.06
	Average	167.30	163.91	160.61	157.48	162.33
T_4	0	173.86	170.96	168.39	164.97	169.55
	15	169.86	164.75	160.59	157.27	163.12
	30	163.85	160.39	155.87	150.56	157.67
	45	159.63	156.23	154.32	150.44	155.16
	Average	166.80	163.08	159.79	155.81	161.37
T_5	0	168.23	165.28	161.25	158.23	163.25
	15	164.28	161.03	158.27	155.36	159.74
	30	160.28	157.23	154.25	150.56	155.58
	45	159.63	156.23	154.32	150.44	155.16
	Average	163.11	159.94	157.02	153.65	158.43
T_6	0	168.23	165.20	163.45	160.25	164.28
	15	164.15	160.55	159.21	154.12	159.51
	30	158.02	154.26	150.24	148.36	152.72
	45	154.23	150.63	147.53	145.28	149.42
	Average	161.16	157.66	155.11	152.00	156.48
T_7	0	165.78	162.87	160.78	157.68	161.78
	15	161.39	158.63	155.64	151.61	156.82
	30	156.87	153.68	151.96	149.63	153.04
	45	153.74	151.87	149.62	145.54	150.19
	Average	159.45	156.76	154.50	151.12	155.46
T_8	0	169.53	164.23	158.90	155.45	162.03
	15	165.28	161.23	157.63	154.86	159.75
	30	161.86	158.39	154.36	151.96	156.64
	45	156.89	154.46	150.79	145.68	151.96
	Average	163.39	159.58	155.42	151.99	157.59
T_9	0	160.58	-	-	-	-
	15	155.45	-	-	-	-
	30	152.39	-	-	-	-
	45	149.66	-	-	-	-
	Average	154.52	-	-	-	-
T_{10}	0	158.63	-	-	-	-
	15	155.56	-	-	-	-
	30	151.27	-	-	-	-
	45	148.21	-	-	-	-
	Average	153.42	-	-	-	-
T_{11}	0	151.45	149.63	145.69	141.95	147.18
	15	145.32	141.52	138.42	134.59	139.96
	30	140.35	138.47	134.75	131.45	136.26
	45	137.56	131.58	128.69	124.69	130.63
	Average	143.67	140.30	136.89	133.17	138.51

Appendix-VI : Phosphorus distribution at 30 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	35.42	32.36	30.34	27.24	31.34
	15	32.65	28.71	26.50	23.68	27.89
	30	28.47	25.16	22.85	19.77	24.06
	45	26.77	23.60	21.64	18.74	22.69
	Average	30.83	27.46	25.33	22.36	26.49
T_2	0	38.10	35.24	31.41	22.57	31.83
	15	35.48	32.10	29.26	24.31	30.29
	30	33.52	30.18	28.24	25.36	29.33
	45	30.31	27.34	24.56	22.62	26.21
	Average	34.35	31.22	28.37	23.72	29.41
T_3	0	37.30	34.42	32.52	28.31	33.14
	15	34.79	31.89	27.46	24.30	29.61
	30	31.51	28.65	26.26	22.42	27.21
	45	30.06	26.48	21.54	18.78	24.22
	Average	33.42	30.36	26.95	24.66	28.54
T_4	0	34.68	32.82	29.66	26.69	30.96
	15	32.58	29.78	26.83	23.78	28.24
	30	30.80	27.73	24.90	21.91	26.34
	45	28.67	25.47	23.70	21.69	24.88
	Average	31.68	31.70	26.27	23.52	27.61
T_5	0	30.81	26.63	24.46	22.80	26.18
	15	28.61	25.46	22.61	19.73	24.10
	30	26.71	24.59	22.42	20.55	23.57
	45	23.58	21.47	19.78	15.68	20.13
	Average	27.43	31.70	22.32	19.69	23.49
T_6	0	31.69	29.54	26.71	24.86	28.20
	15	28.80	26.63	23.64	20.45	24.88
	30	26.71	24.48	22.59	19.68	23.37
	45	24.81	22.67	20.80	18.75	21.76
	Average	29.20	31.70	23.44	20.94	24.55
T_7	0	33.30	31.17	27.36	25.10	29.23
	15	31.39	29.47	25.43	23.36	27.41
	30	30.40	27.37	24.50	21.48	25.94
	45	27.37	25.56	22.41	19.35	23.67
	Average	30.62	31.70	29.36	22.32	26.56
T_8	0	41.36	38.10	35.52	33.36	37.09
	15	38.43	36.63	33.82	30.30	34.80
	30	35.62	33.71	30.30	27.55	31.80
	45	34.47	31.69	28.48	25.59	30.06
	Average	37.47	31.70	32.03	29.20	33.43
T_9	0	36.83	-	-	-	-
	15	34.66	-	-	-	-
	30	30.42	-	-	-	-
	45	28.67	-	-	-	-
	Average	32.65	-	-	-	-
T_{10}	0	34.40	-	-	-	-
	15	32.30	-	-	-	-
	30	30.46	-	-	-	-
	45	28.81	-	-	-	-
	Average	31.49	-	-	-	-
T_{11}	0	19.30	17.33	15.43	13.04	16.28
	15	18.48	16.52	13.30	10.34	14.66
	30	16.24	14.06	12.46	9.02	12.95
	45	14.42	12.30	9.41	6.47	10.65
	Average	17.11	15.05	12.65	9.72	13.63

Phosphorus distribution at 60 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	49.58	45.36	41.22	36.68	43.21
	15	44.68	40.76	36.62	32.40	26.58
	30	41.47	36.53	31.45	28.80	34.56
	45	36.49	32.36	27.63	23.43	29.98
	Average	43.05	38.75	34.23	30.33	36.59
T_2	0	52.40	47.62	43.63	38.48	45.53
	15	47.63	42.79	37.58	32.61	40.15
	30	43.58	41.52	35.65	31.21	37.99
	45	40.36	36.39	32.40	28.48	34.41
	Average	45.99	47.77	37.32	35.29	39.52
T_3	0	52.63	46.57	43.75	39.57	45.63
	15	47.69	42.56	38.81	33.49	40.64
	30	42.39	39.69	34.60	30.48	36.79
	45	38.58	33.29	28.67	24.75	31.32
	Average	45.32	40.53	36.46	32.07	38.60
T_4	0	50.72	46.63	42.39	37.53	44.32
	15	46.32	41.82	36.19	31.48	38.95
	30	41.30	36.20	32.52	28.72	34.69
	45	38.86	34.58	29.71	25.32	32.12
	Average	44.30	39.81	35.20	30.76	37.52
T_5	0	45.66	42.59	38.48	34.75	40.37
	15	41.57	37.60	33.69	30.48	35.84
	30	37.54	34.61	31.58	31.45	33.79
	45	32.49	36.77	33.44	27.76	32.61
	Average	39.32	37.89	34.30	31.11	35.65
T_6	0	45.76	42.62	39.25	36.43	41.01
	15	41.53	38.36	33.49	30.53	35.98
	30	37.65	34.15	31.21	28.36	32.84
	45	34.10	29.53	26.45	24.71	28.70
	Average	39.76	36.17	32.60	30.01	34.63
T_7	0	43.27	40.67	37.34	32.42	38.43
	15	39.31	36.52	33.40	28.10	34.33
	30	35.41	32.04	28.57	25.51	30.38
	45	32.54	28.57	24.38	21.49	26.75
	Average	37.63	34.45	30.92	26.88	32.47
T_8	0	46.12	42.21	39.05	34.14	40.38
	15	43.57	38.40	35.63	30.60	37.05
	30	39.73	36.54	33.29	28.43	34.50
	45	34.59	31.46	28.82	24.85	29.93
	Average	41.00	37.15	34.20	29.51	35.46
T_9	0	37.58	-	-	-	-
	15	33.45	-	-	-	-
	30	29.66	-	-	-	-
	45	25.37	-	-	-	-
	Average	31.52	-	-	-	-
T_{10}	0	35.24	-	-	-	-
	15	31.25	-	-	-	-
	30	27.34	-	-	-	-
	45	24.13	-	-	-	-
	Average	29.49	-	-	-	-
T_{11}	0	19.29	17.49	14.30	11.63	15.68
	15	16.63	14.53	12.49	9.16	13.20
	30	13.06	11.42	9.50	5.29	9.82
	45	10.56	8.37	6.05	4.69	7.42
	Average	14.89	12.95	10.59	7.69	11.53

Phosphorus distribution at 90 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	44.16	38.85	34.77	30.40	37.04
	15	40.17	36.60	31.20	28.27	34.06
	30	37.47	33.44	29.85	26.59	31.84
	45	33.24	29.02	26.44	22.64	27.83
	Average	38.76	34.48	30.56	26.97	32.69
T_2	0	47.57	43.41	40.00	36.71	41.92
	15	43.98	39.27	34.74	30.56	37.14
	30	39.70	35.40	31.66	27.56	33.58
	45	35.44	31.70	27.64	23.84	29.66
	Average	41.67	37.44	33.51	29.67	35.57
T_3	0	46.62	42.49	38.41	33.87	40.35
	15	42.51	38.11	34.67	30.22	36.38
	30	38.60	34.42	30.56	26.24	32.45
	45	34.77	30.50	26.17	21.64	28.27
	Average	40.62	36.38	32.45	27.99	34.36
T_4	0	44.52	41.47	37.77	33.45	39.30
	15	41.77	37.60	35.95	29.27	36.15
	30	37.47	33.44	29.93	26.20	31.76
	45	33.24	28.66	24.84	21.78	27.13
	Average	39.25	35.29	32.12	27.67	33.58
T_5	0	38.96	35.95	31.80	26.77	33.37
	15	35.27	30.87	25.85	22.77	28.69
	30	32.70	29.54	23.87	19.95	26.52
	45	27.64	23.77	19.44	16.34	21.79
	Average	33.64	30.03	25.24	21.45	27.59
T_6	0	38.17	34.26	30.42	26.70	32.39
	15	34.70	30.85	26.70	22.75	28.75
	30	30.38	26.27	22.60	18.58	24.46
	45	26.41	22.34	18.47	14.64	20.47
	Average	32.42	28.43	24.55	20.67	26.52
T_7	0	37.17	33.02	30.42	26.70	31.83
	15	33.70	29.85	26.70	22.20	28.11
	30	29.68	25.49	21.22	17.66	23.52
	45	24.41	20.44	16.47	12.64	18.49
	Average	31.24	27.20	23.70	19.80	25.49
T_8	0	39.26	35.77	31.84	27.57	33.61
	15	35.48	31.74	27.09	25.37	29.92
	30	31.18	27.16	23.41	18.44	25.05
	45	27.12	23.31	19.00	16.16	21.40
	Average	33.26	29.49	25.33	21.89	27.49
T_9	0	29.64				
	15	26.42				
	30	22.24				
	45	19.73				
	Average	24.51				
T_{10}	0	28.51				
	15	24.92				
	30	21.42				
	45	19.37				
	Average	23.55				
T_{11}	0	20.20	17.43	13.38	10.48	15.37
	15	16.09	12.52	9.56	5.42	10.90
	30	14.31	10.11	6.10	2.20	8.18
	45	11.45	8.33	7.40	3.67	7.71
	Average	15.51	12.10	9.11	5.44	10.54

Phosphorus distribution at 120 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	35.86	31.85	28.77	25.20	30.42
	15	32.77	28.60	25.78	21.27	27.10
	30	28.87	24.84	21.83	18.41	23.49
	45	24.54	21.77	18.90	15.92	20.28
	Average	30.51	26.76	23.82	20.20	25.32
T_2	0	38.72	35.93	32.96	29.76	34.34
	15	35.98	31.66	28.90	24.84	30.34
	30	31.64	27.95	24.66	20.59	26.21
	45	28.74	24.95	21.64	18.82	23.54
	Average	33.77	30.12	27.04	23.50	28.61
T_3	0	37.23	34.80	30.41	27.66	32.52
	15	34.81	31.49	27.67	24.22	29.55
	30	30.46	27.92	23.64	19.92	25.48
	45	27.47	24.54	21.20	18.46	22.92
	Average	32.49	29.69	25.73	22.56	27.62
T_4	0	36.98	34.44	30.23	27.59	32.31
	15	33.76	30.60	27.52	23.67	28.89
	30	30.47	26.54	22.48	18.89	24.60
	45	26.84	22.77	18.44	15.34	20.85
	Average	32.01	28.59	24.67	21.37	26.66
T_5	0	35.64	31.44	28.77	24.87	30.18
	15	31.77	27.60	24.95	21.26	26.39
	30	27.57	24.75	20.86	17.43	22.65
	45	23.84	20.26	16.44	13.34	18.47
	Average	29.70	26.01	22.75	19.22	24.42
T_6	0	34.59	31.27	27.38	24.57	29.45
	15	30.02	27.74	23.22	19.37	25.08
	30	27.18	23.54	19.31	16.44	21.62
	45	23.12	19.07	15.60	12.16	17.49
	Average	28.73	25.40	21.38	18.14	23.41
T_7	0	33.47	30.98	27.42	23.46	28.83
	15	30.75	25.85	21.70	17.20	23.87
	30	26.38	23.49	19.96	15.51	21.34
	45	22.41	18.44	15.27	11.14	16.82
	Average	28.25	24.69	21.09	16.83	22.71
T_8	0	34.37	31.48	27.53	24.23	29.40
	15	30.98	27.74	23.59	19.37	25.42
	30	26.68	23.64	19.83	16.41	21.64
	45	23.38	20.31	16.96	13.16	18.45
	Average	28.85	25.79	21.98	18.29	23.73
T_9	0	25.31	-	-	-	-
	15	23.32	-	-	-	-
	30	20.37	-	-	-	-
	45	17.28	-	-	-	-
	Average	21.57	-	-	-	-
T_{10}	0	25.87	-	-	-	-
	15	21.99	-	-	-	-
	30	18.79	-	-	-	-
	45	15.68	-	-	-	-
	Average	20.58	-	-	-	-
T_{11}	0	17.20	15.34	13.17	9.70	13.85
	15	16.10	12.11	8.05	5.70	10.49
	30	13.51	10.30	7.24	4.13	8.80
	45	10.26	8.35	5.42	3.49	6.88
	Average	14.27	11.53	8.47	5.76	10.00

Phosphorus distribution at 150 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	34.86	29.48	25.47	22.45	28.07
	15	28.15	25.36	22.63	18.58	23.68
	30	24.50	21.45	17.34	15.47	19.69
	45	20.12	16.23	13.56	11.36	15.32
	Average	26.91	23.13	19.75	16.97	21.69
T_2	0	35.26	31.45	29.14	25.86	30.43
	15	31.65	28.57	25.68	21.27	26.79
	30	27.45	24.12	21.47	17.36	22.60
	45	23.47	19.24	15.44	11.85	17.50
	Average	29.46	25.85	22.93	19.08	24.33
T_3	0	34.12	30.15	26.39	22.48	28.29
	15	30.47	26.25	22.27	19.63	24.65
	30	25.46	23.42	25.16	21.02	23.77
	45	20.77	18.25	16.38	13.85	17.31
	Average	27.70	24.52	22.55	19.25	23.50
T_4	0	34.58	30.78	27.48	24.98	29.46
	15	29.85	26.78	22.16	19.50	24.57
	30	25.46	21.54	17.23	13.58	19.45
	45	21.74	17.77	14.44	12.24	16.55
	Average	27.91	24.22	20.33	17.57	22.51
T_5	0	33.54	29.47	25.35	21.00	27.34
	15	28.35	24.86	20.36	18.27	22.96
	30	23.47	19.24	15.23	11.85	17.45
	45	20.31	16.52	12.56	8.23	14.41
	Average	26.42	22.52	18.38	14.84	20.54
T_6	0	29.63	24.58	20.45	18.52	23.30
	15	25.84	21.74	17.25	15.37	20.05
	30	20.65	16.46	14.41	13.44	16.24
	45	18.12	15.47	12.61	9.64	13.96
	Average	23.56	19.56	16.18	14.24	18.39
T_7	0	29.56	26.35	22.45	19.63	24.50
	15	25.68	21.68	19.86	15.23	20.61
	30	20.84	15.56	11.22	9.45	14.27
	45	15.23	12.36	9.12	7.85	11.14
	Average	22.83	18.99	15.66	13.04	17.63
T_8	0	31.56	28.63	24.56	20.59	26.34
	15	26.36	22.14	19.86	16.52	21.22
	30	21.56	17.19	15.22	11.40	16.34
	45	18.56	15.04	12.47	9.64	13.93
	Average	24.51	20.75	18.03	14.54	19.46
T_9	0	22.60	-	-	-	-
	15	19.23	-	-	-	-
	30	15.56	-	-	-	-
	45	12.41	-	-	-	-
	Average	17.45	-	-	-	-
T_{10}	0	22.15	-	-	-	-
	15	18.23	-	-	-	-
	30	15.23	-	-	-	-
	45	11.40	-	-	-	-
	Average	16.75	-	-	-	-
T_{11}	0	20.56	16.23	13.54	11.23	15.39
	15	15.42	11.23	9.58	6.21	10.61
	30	11.65	8.45	5.41	3.47	7.25
	45	9.45	6.41	4.58	2.24	5.67
	Average	14.27	10.58	8.28	5.79	9.73

Phosphorus distribution at harvest during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	25.36	21.74	18.36	15.23	20.17
	15	21.39	19.37	15.47	10.85	16.77
	30	15.34	11.77	9.34	5.75	10.55
	45	11.74	9.37	6.14	3.17	7.61
	Average	18.46	15.56	12.33	8.75	13.77
T_2	0	27.45	24.86	20.56	18.69	22.89
	15	24.76	20.69	16.74	12.78	18.74
	30	19.35	14.78	10.96	8.75	13.46
	45	12.63	9.63	5.87	2.87	7.75
	Average	21.05	17.49	13.53	10.77	15.71
T_3	0	28.94	24.78	18.47	14.67	21.72
	15	22.97	18.77	13.98	10.39	16.53
	30	18.96	13.74	9.39	5.89	12.00
	45	14.39	10.95	6.25	3.78	8.84
	Average	21.32	17.06	12.02	8.68	14.77
T_4	0	26.35	23.15	21.74	19.45	22.67
	15	22.39	18.47	14.36	10.39	16.40
	30	18.64	12.28	9.25	5.45	11.41
	45	12.18	9.38	5.17	3.05	7.45
	Average	19.89	15.82	12.63	9.59	14.48
T_5	0	24.53	21.39	18.68	14.78	19.85
	15	20.96	18.23	16.24	13.20	17.16
	30	15.23	13.56	10.23	5.12	11.04
	45	11.23	8.36	5.36	2.31	6.82
	Average	17.99	15.39	12.63	8.85	13.71
T_6	0	24.13	21.35	18.12	15.23	19.71
	15	20.15	17.23	14.20	11.29	15.72
	30	15.29	11.96	9.35	5.17	10.44
	45	11.23	9.23	6.15	3.70	7.58
	Average	19.30	14.94	11.96	8.85	13.36
T_7	0	24.55	19.86	17.69	14.96	19.27
	15	19.87	16.84	15.94	12.87	16.38
	30	15.69	11.85	9.60	5.87	10.75
	45	10.85	8.54	4.68	2.88	6.74
	Average	17.74	14.27	11.98	9.15	13.28
T_8	0	24.35	20.17	17.39	13.28	18.80
	15	20.51	13.28	11.36	9.75	13.73
	30	16.23	13.56	10.39	9.14	12.33
	45	13.98	10.69	8.75	4.69	9.53
	Average	18.77	14.43	11.97	9.22	13.60
T_9	0	16.45	-	-	-	-
	15	14.36	-	-	-	-
	30	11.36	-	-	-	-
	45	8.63	-	-	-	-
	Average	12.70	-	-	-	-
T_{10}	0	16.02	-	-	-	-
	15	14.15	-	-	-	-
	30	11.46	-	-	-	-
	45	7.15	-	-	-	-
	Average	12.20	-	-	-	-
T_{11}	0	15.36	13.25	10.46	8.39	11.87
	15	11.97	9.58	6.38	3.47	7.85
	30	10.87	8.93	9.41	7.44	9.16
	45	7.48	5.39	4.39	2.79	5.01
	Average	11.42	9.29	7.66	5.52	8.47

Appendix-VII : Potassium distribution at 30 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	356.52	353.10	348.10	344.71	350.61
	15	352.43	348.18	345.73	339.38	346.43
	30	349.19	344.20	340.50	335.26	342.29
	45	344.76	339.54	335.68	330.26	337.56
	Average	350.73	346.26	342.50	337.40	344.22
T_2	0	360.53	357.01	352.43	347.26	354.31
	15	356.30	352.34	347.28	342.36	349.57
	30	353.52	349.38	345.18	340.10	347.05
	45	349.46	344.71	341.53	337.47	343.29
	Average	354.95	350.86	376.36	333.56	348.55
T_3	0	358.45	355.64	351.63	347.04	353.19
	15	353.11	349.39	345.41	341.63	347.39
	30	351.63	347.13	343.31	338.16	345.06
	45	347.19	342.78	338.76	334.60	340.83
	Average	352.60	348.74	344.78	340.36	346.62
T_4	0	359.76	353.61	348.77	344.63	351.69
	15	353.37	350.34	345.55	344.50	348.44
	30	350.66	345.77	340.64	336.76	343.46
	45	346.33	340.71	335.76	331.55	338.59
	Average	352.53	347.61	342.68	339.36	345.54
T_5	0	358.66	352.75	346.59	341.71	349.93
	15	354.75	350.91	344.73	337.56	346.99
	30	349.80	342.87	337.78	332.99	340.86
	45	345.83	339.56	334.66	329.73	337.45
	Average	352.26	346.52	340.94	335.50	343.81
T_6	0	368.56	365.61	360.49	356.36	362.76
	15	363.43	357.64	351.34	346.55	354.74
	30	356.53	351.73	345.59	340.63	348.62
	45	352.73	346.60	341.73	336.56	344.41
	Average	360.31	355.40	349.79	273.50	352.63
T_7	0	366.58	362.71	358.10	353.61	360.25
	15	361.73	356.67	351.76	348.85	354.75
	30	356.36	353.27	350.58	346.77	351.75
	45	352.54	349.47	345.59	341.88	347.37
	Average	359.30	355.53	351.51	347.78	353.53
T_8	0	372.59	368.59	363.86	358.77	365.95
	15	365.63	361.79	355.39	350.81	358.41
	30	359.78	355.58	350.66	345.56	352.90
	45	354.69	350.76	346.54	341.81	348.45
	Average	363.17	359.18	354.11	349.24	356.43
T_9	0	363.59	-	-	-	-
	15	357.69	-	-	-	-
	30	352.86	-	-	-	-
	45	347.73	-	-	-	-
	Average	355.47	-	-	-	-
T_{10}	0	360.75	-	-	-	-
	15	356.95	-	-	-	-
	30	352.86	-	-	-	-
	45	347.64	-	-	-	-
	Average	354.55	-	-	-	-
T_{11}	0	326.24	322.29	319.01	315.31	320.71
	15	323.34	319.55	315.31	311.41	317.40
	30	320.61	315.33	313.63	309.50	314.77
	45	316.54	312.43	307.38	302.44	309.70
	Average	321.68	317.40	313.83	309.66	315.64

Potassium distribution at 60 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	369.58	365.51	361.45	357.45	363.50
	15	364.73	358.78	354.39	350.72	357.16
	30	359.56	353.03	349.24	346.16	352.00
	45	354.47	350.69	347.07	343.58	348.95
	Average	362.09	357.00	353.04	349.48	355.40
T_2	0	371.63	366.72	361.58	357.43	364.34
	15	366.53	360.49	357.57	353.75	359.59
	30	362.61	359.39	355.42	351.20	357.16
	45	358.58	354.48	350.53	346.43	352.51
	Average	364.84	360.27	356.28	352.20	358.40
T_3	0	369.73	364.69	360.48	356.89	362.95
	15	365.86	362.56	357.73	353.49	359.91
	30	362.58	357.48	353.69	349.71	355.87
	45	357.59	353.43	349.48	345.34	351.46
	Average	363.94	359.54	355.35	351.36	357.55
T_4	0	366.24	363.66	359.35	354.24	360.87
	15	363.48	360.55	357.42	353.39	358.71
	30	360.43	356.44	352.52	348.42	354.45
	45	356.59	353.63	348.24	344.50	350.74
	Average	361.68	358.57	359.31	326.20	356.19
T_5	0	364.58	360.31	356.47	351.23	358.15
	15	360.47	357.55	353.57	349.33	355.23
	30	358.82	354.43	351.83	347.67	353.19
	45	354.43	349.46	344.50	341.30	347.42
	Average	359.58	355.44	351.59	347.38	353.50
T_6	0	363.28	359.81	356.61	353.11	358.20
	15	359.59	355.76	351.74	347.57	353.66
	30	356.48	352.79	347.44	344.67	350.35
	45	352.72	349.61	345.47	342.79	347.65
	Average	358.02	354.49	350.31	347.04	352.46
T_7	0	363.49	360.64	355.79	351.42	357.84
	15	359.64	356.46	350.78	347.58	353.62
	30	353.69	348.51	344.83	340.69	346.93
	45	349.86	344.61	340.68	335.81	342.74
	Average	356.67	352.56	348.02	343.88	350.28
T_8	0	364.49	361.57	358.32	354.63	359.75
	15	360.78	356.46	352.42	348.42	354.52
	30	357.71	353.67	350.43	346.55	352.09
	45	353.76	350.72	346.69	342.82	348.50
	Average	359.19	355.61	351.97	348.11	353.72
T_9	0	355.35	-	-	-	-
	15	351.69	-	-	-	-
	30	347.43	-	-	-	-
	45	343.88	-	-	-	-
	Average	349.59	-	-	-	-
T_{10}	0	353.84	-	-	-	-
	15	349.55	-	-	-	-
	30	345.78	-	-	-	-
	45	340.68	-	-	-	-
	Average	347.46	-	-	-	-
T_{11}	0	318.24	315.83	311.36	307.70	313.28
	15	315.32	312.31	310.48	304.33	310.61
	30	311.44	308.47	304.24	300.41	306.14
	45	308.38	305.64	302.73	299.55	304.08
	Average	313.35	310.56	307.20	303.00	308.53

Potassium distribution at 90 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	352.90	348.77	343.40	339.83	346.23
	15	348.69	343.88	337.96	334.45	341.25
	30	344.45	340.86	336.80	333.47	338.90
	45	340.87	336.92	333.86	329.90	335.39
	Average	346.73	342.61	338.01	334.41	340.44
T_2	0	355.83	351.56	347.69	343.90	349.75
	15	351.90	347.44	343.87	339.90	345.78
	30	346.41	342.76	339.89	336.78	341.46
	45	342.80	339.46	334.80	331.60	337.17
	Average	349.24	345.31	341.56	338.05	343.54
T_3	0	354.12	351.10	347.47	344.10	349.20
	15	350.96	346.20	342.35	336.20	343.93
	30	346.21	342.38	337.80	333.40	339.95
	45	342.20	339.14	335.20	331.80	337.08
	Average	348.37	344.70	340.71	336.38	342.54
T_4	0	354.52	350.91	347.72	341.72	348.72
	15	350.53	346.20	342.50	337.32	344.14
	30	345.21	341.31	337.92	333.40	339.46
	45	340.94	336.12	332.20	328.84	334.53
	Average	347.80	343.64	340.09	326.20	341.71
T_5	0	351.20	347.52	343.46	338.15	345.08
	15	346.16	341.40	338.10	334.26	339.98
	30	343.21	338.34	336.36	332.20	337.53
	45	338.10	334.10	329.20	325.20	331.65
	Average	344.67	340.34	336.78	332.45	338.56
T_6	0	348.36	344.12	339.48	335.60	341.89
	15	345.20	341.10	337.76	333.80	339.47
	30	343.24	338.16	333.56	329.41	336.09
	45	338.62	334.40	329.10	325.20	331.83
	Average	343.86	339.45	334.98	331.00	337.32
T_7	0	347.40	343.26	339.64	334.48	341.20
	15	343.20	340.06	336.23	332.86	338.09
	30	339.20	335.30	331.46	327.31	333.32
	45	335.20	331.40	327.50	323.26	329.34
	Average	341.25	337.51	333.71	329.48	335.49
T_8	0	351.10	346.98	343.46	339.45	345.25
	15	351.10	346.98	343.46	339.45	345.25
	30	347.21	342.76	339.80	335.15	341.23
	45	338.47	334.18	331.80	328.30	333.19
	Average	346.97	342.73	339.63	335.59	341.23
T_9	0	339.43	-	-	-	-
	15	335.55	-	-	-	-
	30	331.54	-	-	-	-
	45	326.84	-	-	-	-
	Average	333.34	-	-	-	-
T_{10}	0	337.46	-	-	-	-
	15	333.64	-	-	-	-
	30	328.86	-	-	-	-
	45	325.54	-	-	-	-
	Average	331.38	-	-	-	-
T_{11}	0	305.86	301.60	297.76	293.80	299.76
	15	301.98	297.90	294.45	290.46	296.20
	30	297.74	294.70	289.98	286.86	292.32
	45	294.80	291.76	288.87	285.68	290.28
	Average	300.10	296.49	292.77	289.20	294.64

Potassium distribution at 120 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	341.30	337.34	334.14	330.20	335.75
	15	338.23	334.10	331.31	327.25	332.72
	30	333.25	329.03	325.14	321.06	327.12
	45	329.25	324.29	319.13	315.21	321.97
	Average	335.51	331.19	327.43	323.43	329.39
T_2	0	344.12	340.14	337.09	332.50	338.46
	15	340.44	337.40	332.80	328.80	334.86
	30	336.61	332.25	328.56	324.26	330.42
	45	332.80	328.40	324.38	320.40	326.50
	Average	338.49	334.55	330.71	326.49	332.56
T_3	0	344.14	340.20	336.17	330.06	337.64
	15	340.10	336.08	331.28	326.25	333.43
	30	336.22	332.22	328.42	323.56	330.11
	45	331.10	327.40	322.16	317.26	324.48
	Average	337.89	333.98	321.86	324.28	331.41
T_4	0	343.38	339.66	335.47	331.77	337.57
	15	338.50	334.84	330.80	326.94	332.77
	30	333.59	329.19	325.58	322.27	327.66
	45	330.70	326.40	321.80	318.34	324.31
	Average	336.54	332.52	328.41	326.20	330.58
T_5	0	340.78	335.68	330.69	327.36	333.63
	15	336.52	332.40	327.89	323.59	330.10
	30	330.64	326.83	322.82	318.84	324.78
	45	327.82	323.71	319.92	315.46	321.73
	Average	333.94	329.66	325.33	321.31	327.56
T_6	0	339.84	334.60	329.60	325.95	332.50
	15	334.94	330.81	326.82	322.54	328.78
	30	330.71	326.86	322.68	319.90	325.04
	45	324.72	321.50	317.81	313.61	319.41
	Average	332.55	328.44	324.23	320.50	326.43
T_7	0	336.90	331.84	328.64	325.58	330.74
	15	332.61	328.23	323.94	318.31	325.77
	30	329.40	324.41	319.20	314.10	321.78
	45	324.63	321.86	317.50	313.36	319.34
	Average	330.89	326.59	322.32	317.84	324.41
T_8	0	338.46	334.76	329.48	326.79	332.37
	15	333.92	330.52	326.80	322.50	328.44
	30	330.93	325.56	322.98	318.83	324.58
	45	326.84	322.60	318.80	315.30	320.89
	Average	332.54	328.36	324.52	320.86	326.57
T_9	0	328.49	-	-	-	-
	15	323.65	-	-	-	-
	30	320.48	-	-	-	-
	45	317.56	-	-	-	-
	Average	322.55	-	-	-	-
T_{10}	0	326.71	-	-	-	-
	15	322.44	-	-	-	-
	30	318.71	-	-	-	-
	45	314.56	-	-	-	-
	Average	320.60	-	-	-	-
T_{11}	0	296.30	293.49	288.49	284.34	290.66
	15	292.60	288.68	283.59	280.10	286.24
	30	287.28	284.07	280.48	276.39	282.06
	45	283.80	279.45	276.76	271.52	277.88
	Average	290.00	286.42	282.33	278.09	284.21

Potassium distribution at 150 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	338.25	334.12	330.14	325.13	331.91
	15	334.18	331.25	328.45	324.15	329.51
	30	329.12	326.17	323.17	318.25	324.18
	45	325.50	321.47	318.27	316.21	320.36
	Average	331.76	328.25	325.01	320.94	326.49
T_2	0	340.87	338.27	334.29	330.96	336.10
	15	335.69	330.98	328.67	324.16	329.88
	30	330.96	325.69	320.16	315.26	323.02
	45	335.86	330.58	326.45	324.56	329.36
	Average	335.85	331.38	327.39	323.74	329.59
T_3	0	341.26	336.28	330.55	324.58	333.17
	15	337.48	335.26	330.18	328.75	332.92
	30	331.61	329.55	324.19	319.45	326.20
	45	328.69	324.18	319.27	314.25	321.60
	Average	334.76	331.32	326.05	321.76	328.47
T_4	0	340.12	336.28	330.12	324.45	332.74
	15	336.28	333.19	329.69	325.57	331.18
	30	330.86	328.61	323.17	319.45	325.52
	45	326.12	324.18	319.27	314.25	320.96
	Average	333.35	330.57	325.56	320.93	327.60
T_5	0	334.12	330.58	325.15	323.17	328.26
	15	330.48	326.18	322.69	319.69	324.76
	30	325.69	322.35	319.46	315.74	320.81
	45	321.85	318.74	314.53	311.50	316.66
	Average	328.04	324.46	320.46	317.53	322.62
T_6	0	338.96	334.58	330.89	326.84	332.82
	15	333.84	328.69	322.86	318.74	326.03
	30	328.69	324.69	320.86	318.96	323.30
	45	322.62	317.64	313.25	310.60	316.03
	Average	331.03	326.40	321.97	318.79	324.54
T_7	0	335.48	330.76	327.86	322.41	329.13
	15	329.14	326.66	322.41	318.48	324.17
	30	325.54	321.49	318.25	314.97	320.06
	45	322.62	317.64	313.63	310.60	316.12
	Average	328.20	324.14	320.54	316.62	322.37
T_8	0	335.16	332.21	328.40	323.50	329.82
	15	331.89	327.88	324.69	318.45	325.73
	30	328.20	323.16	319.61	314.56	321.38
	45	323.40	319.06	316.25	312.45	317.79
	Average	329.66	325.58	322.24	317.24	323.68
T_9	0	325.35	-	-	-	-
	15	323.55	-	-	-	-
	30	318.25	-	-	-	-
	45	315.26	-	-	-	-
	Average	320.60	-	-	-	-
T_{10}	0	323.65	-	-	-	-
	15	320.55	-	-	-	-
	30	316.80	-	-	-	-
	45	313.25	-	-	-	-
	Average	318.56	-	-	-	-
T_{11}	0	290.13	288.39	284.15	281.23	285.98
	15	287.12	284.15	280.17	275.13	281.64
	30	283.09	280.12	277.31	272.13	278.16
	45	279.15	275.39	270.19	265.31	272.51
	Average	284.87	282.01	277.96	273.45	279.57

Potassium distribution at harvest during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	334.66	330.58	328.36	323.26	329.22
	15	328.41	324.56	318.26	314.68	321.48
	30	323.45	319.36	314.26	310.55	316.91
	45	319.55	315.45	311.48	309.67	314.04
	Average	326.52	322.49	318.09	314.54	320.41
T_2	0	338.16	334.85	330.18	325.69	332.22
	15	333.26	330.28	317.86	314.68	324.02
	30	329.68	321.47	315.26	311.70	319.53
	45	323.15	319.68	316.23	314.21	318.32
	Average	331.06	326.57	319.88	316.57	323.52
T_3	0	336.25	333.89	329.74	326.98	331.72
	15	331.29	328.69	323.16	318.69	325.46
	30	324.84	319.26	315.26	311.58	317.74
	45	320.69	318.62	313.64	309.69	315.66
	Average	328.27	325.12	320.45	316.74	322.64
T_4	0	335.26	332.14	329.45	325.30	330.54
	15	329.64	325.61	322.69	319.69	324.41
	30	323.16	320.18	316.50	313.69	318.38
	45	319.63	314.77	310.25	307.65	313.08
	Average	326.92	323.18	319.72	321.30	321.60
T_5	0	330.77	324.78	320.69	316.28	323.13
	15	324.69	319.48	314.68	311.28	317.53
	30	320.58	314.26	309.65	304.18	312.17
	45	315.26	313.25	312.69	310.69	312.97
	Average	322.83	317.94	314.43	310.61	316.45
T_6	0	331.62	329.72	324.69	320.98	326.75
	15	325.78	319.62	316.94	313.74	319.02
	30	321.45	319.52	315.30	311.26	316.88
	45	318.26	314.35	309.45	305.96	312.01
	Average	324.28	320.80	316.60	312.99	318.67
T_7	0	330.56	326.85	320.78	314.87	323.27
	15	324.69	318.64	313.58	309.48	316.60
	30	320.96	315.87	309.65	305.56	313.01
	45	318.26	315.23	312.52	307.14	313.29
	Average	323.62	319.15	314.13	309.26	316.54
T_8	0	331.26	326.15	321.48	317.26	324.04
	15	326.19	321.58	316.29	313.48	319.39
	30	322.18	318.26	312.16	309.69	315.57
	45	317.26	313.16	308.36	305.48	311.07
	Average	324.22	319.79	314.57	311.48	317.52
T_9	0	320.15	-	-	-	-
	15	316.19	-	-	-	-
	30	312.35	-	-	-	-
	45	309.30	-	-	-	-
	Average	314.50	-	-	-	-
T_{10}	0	319.26	-	-	-	-
	15	314.30	-	-	-	-
	30	311.55	-	-	-	-
	45	305.35	-	-	-	-
	Average	312.62	-	-	-	-
T_{11}	0	288.39	285.66	279.12	275.16	282.08
	15	284.69	279.34	275.48	270.45	277.49
	30	278.69	274.69	270.13	265.39	272.23
	45	270.39	265.41	259.48	254.78	262.52
	Average	280.54	276.28	271.05	266.45	273.58

APPENDIX-VIII

Moisture distribution at 30 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	33.82	32.46	31.59	30.28	32.04
	15	34.68	32.55	31.56	30.74	32.38
	30	36.56	34.26	32.38	31.69	33.72
	45	32.56	30.56	29.92	27.56	30.15
	Average	34.41	32.46	31.36	30.25	32.07
T_2	0	34.51	33.41	32.45	30.82	32.80
	15	37.30	36.41	35.62	33.21	35.64
	30	39.26	37.25	34.52	33.82	36.21
	45	33.56	32.14	30.74	29.33	31.44
	Average	36.16	34.80	33.33	31.80	34.65
T_3	0	36.84	34.86	32.28	31.84	33.96
	15	40.85	38.71	37.66	35.88	38.28
	30	44.86	42.56	40.86	39.78	42.02
	45	33.55	31.56	29.64	27.56	30.58
	Average	33.89	36.92	35.11	33.77	36.21
T_4	0	34.87	33.65	31.89	30.21	32.66
	15	36.56	33.89	32.99	31.40	33.71
	30	40.56	37.56	35.56	33.99	36.92
	45	31.98	29.56	28.33	27.56	29.36
	Average	35.99	33.67	32.19	30.79	33.16
T_5	0	28.69	27.89	26.45	24.56	26.90
	15	31.56	29.47	28.93	26.56	29.13
	30	35.46	34.96	33.21	30.45	33.52
	45	27.45	26.41	25.59	24.70	26.04
	Average	30.79	29.68	28.55	26.57	28.90
T_6	0	35.74	34.82	32.45	31.84	33.71
	15	40.89	38.39	37.68	36.24	38.30
	30	45.96	44.98	42.69	41.78	43.85
	45	33.45	32.89	31.66	30.98	32.25
	Average	39.01	37.77	36.12	35.21	37.03
T_7	0	35.84	33.45	32.61	31.96	33.47
	15	39.56	38.65	36.94	35.76	37.73
	30	43.96	41.75	40.63	39.84	41.55
	45	32.45	30.34	28.31	26.94	29.51
	Average	32.02	36.05	34.62	33.63	35.56
T_8	0	30.86	29.64	28.46	27.94	29.64
	15	35.45	33.61	31.54	29.75	32.59
	30	39.64	37.89	36.94	34.75	37.31
	45	27.54	26.94	25.61	24.59	26.17
	Average	33.37	32.02	30.64	29.26	31.43
T_9	0	26.32	-	-	-	-
	15	29.97	-	-	-	-
	30	35.64	-	-	-	-
	45	24.88	-	-	-	-
	Average	29.64	-	-	-	-
T_{10}	0	29.64	-	-	-	-
	15	30.70	-	-	-	-
	30	36.20	-	-	-	-
	45	26.17	-	-	-	-
	Average	30.68	-	-	-	-
T_{11}	0	31.87	30.63	29.37	28.97	30.21
	15	36.45	34.65	33.84	31.89	34.21
	30	42.98	40.96	38.64	37.94	40.13
	45	29.67	28.76	26.83	25.44	27.68
	Average	35.24	33.75	32.17	31.06	33.06

Moisture distribution at 60 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	32.45	31.75	30.87	28.94	31.00
	15	35.94	34.61	32.79	31.45	33.70
	30	42.96	40.88	38.76	37.69	40.07
	45	30.87	28.79	27.45	26.94	28.51
	Average	32.02	34.01	32.47	31.26	33.32
T_2	0	34.54	33.47	32.59	31.58	33.05
	15	39.56	37.62	36.48	35.38	37.26
	30	44.53	42.87	41.38	40.97	42.44
	45	31.63	32.26	30.45	29.65	31.00
	Average	37.57	36.56	35.23	34.40	35.94
T_3	0	36.45	34.21	33.78	31.82	34.07
	15	41.56	39.45	37.64	36.75	38.85
	30	46.85	44.56	43.78	42.68	44.47
	45	33.45	31.61	30.96	28.64	31.17
	Average	39.58	37.46	36.54	34.97	37.14
T_4	0	34.77	33.76	31.86	30.87	32.82
	15	38.97	36.74	35.76	34.57	36.51
	30	42.97	41.78	39.87	37.84	40.62
	45	30.98	29.74	28.91	26.97	29.15
	Average	36.92	35.51	34.10	32.56	34.77
T_5	0	30.65	28.74	27.45	26.51	28.34
	15	32.78	31.54	29.41	27.38	30.28
	30	36.74	35.45	34.87	32.84	34.98
	45	28.17	26.43	25.84	24.78	26.31
	Average	32.09	30.54	29.39	27.88	29.97
T_6	0	38.74	36.47	35.45	34.84	36.38
	15	41.57	39.42	38.94	37.98	39.48
	30	45.87	44.75	42.61	40.87	43.53
	45	36.89	35.46	33.78	31.78	34.48
	Average	40.77	39.03	37.70	36.37	38.46
T_7	0	35.68	33.75	32.46	31.79	33.42
	15	40.87	38.96	37.65	36.74	38.56
	30	44.95	43.78	41.79	40.93	42.86
	45	31.58	30.79	29.47	28.66	30.13
	Average	38.27	36.82	35.34	34.53	36.24
T_8	0	29.86	27.82	25.74	24.45	26.97
	15	34.68	32.94	31.75	30.84	32.55
	30	39.54	37.86	36.94	34.67	37.25
	45	26.75	24.61	23.76	21.74	24.22
	Average	32.71	30.81	29.55	27.93	30.25
T_9	0	27.97	-	-	-	-
	15	32.45	-	-	-	-
	30	37.98	-	-	-	-
	45	26.97	-	-	-	-
	Average	31.34	-	-	-	-
T_{10}	0	27.84	-	-	-	-
	15	33.51	-	-	-	-
	30	36.94	-	-	-	-
	45	27.64	-	-	-	-
	Average	31.48	-	-	-	-
T_{11}	0	34.54	33.47	31.94	30.76	32.68
	15	38.64	36.47	34.85	33.89	35.96
	30	44.51	43.87	42.81	40.68	42.97
	45	30.86	28.64	27.98	25.67	28.29
	Average	37.14	35.61	34.40	32.75	34.97

Moisture distribution at 90 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	34.28	33.47	32.71	31.57	33.01
	15	36.40	35.60	34.39	33.71	35.03
	30	39.78	38.74	36.74	35.68	37.74
	45	32.73	31.63	30.55	29.42	31.08
	Average	31.80	30.86	33.60	32.60	34.21
T_2	0	36.87	35.45	33.84	31.47	34.41
	15	40.97	37.48	36.78	35.78	37.75
	30	45.89	42.78	40.87	39.54	42.27
	45	32.86	30.94	28.78	26.87	29.86
	Average	39.15	36.66	35.07	33.42	36.07
T_3	0	38.45	37.23	36.59	35.43	36.93
	15	41.58	39.49	38.29	36.78	39.04
	30	45.65	43.86	42.48	41.97	43.49
	45	36.27	35.60	34.47	32.87	34.80
	Average	40.49	39.05	37.96	36.76	38.56
T_4	0	35.86	34.58	33.74	32.68	34.22
	15	38.74	36.94	35.74	34.69	36.53
	30	43.89	41.74	40.87	39.74	41.56
	45	31.97	29.73	27.55	25.87	28.78
	Average	37.62	35.75	34.48	33.25	35.27
T_5	0	30.88	28.75	26.84	25.87	28.09
	15	34.45	33.87	31.54	30.75	32.65
	30	38.86	37.48	35.78	34.61	36.68
	45	28.64	27.84	26.87	24.78	27.03
	Average	33.21	31.99	30.26	29.00	31.11
T_6	0	38.74	36.87	35.56	34.89	36.52
	15	42.76	40.68	39.52	38.67	40.41
	30	45.86	44.89	43.27	41.76	43.95
	45	36.54	35.68	34.89	33.98	35.27
	Average	32.02	39.53	38.31	37.33	39.04
T_7	0	35.78	34.97	33.47	31.74	37.86
	15	39.45	38.78	36.64	35.97	37.71
	30	44.71	42.98	40.61	39.87	42.04
	45	32.74	30.58	29.84	28.48	30.41
	Average	38.17	36.83	35.14	34.02	37.01
T_8	0	32.68	30.75	29.56	27.78	30.19
	15	36.86	35.86	33.68	32.97	34.84
	30	40.68	38.67	37.77	35.69	38.20
	45	30.74	29.87	28.97	26.55	29.03
	Average	35.24	33.79	32.50	30.75	33.07
T_9	0	29.54	-	-	-	-
	15	33.48	-	-	-	-
	30	37.86	-	-	-	-
	45	27.71	-	-	-	-
	Average	32.15	-	-	-	-
T_{10}	0	31.86	-	-	-	-
	15	35.85	-	-	-	-
	30	39.71	-	-	-	-
	45	28.94	-	-	-	-
	Average	34.09	-	-	-	-
T_{11}	0	33.86	32.69	31.86	30.96	32.34
	15	38.48	37.95	36.99	35.76	37.30
	30	42.83	40.86	39.67	37.56	40.23
	45	31.78	30.87	29.51	28.97	30.28
	Average	36.74	35.59	34.51	33.31	35.04

Moisture distribution at 120 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	36.73	34.87	32.94	31.56	34.03
	15	40.87	38.86	36.84	35.54	38.03
	30	44.78	42.69	40.87	38.66	41.75
	45	34.84	32.54	31.78	30.75	32.48
	Average	30.87	28.64	27.22	26.97	36.57
T_2	0	37.62	36.24	35.51	34.19	35.89
	15	40.31	39.53	38.49	37.35	38.92
	30	44.71	43.86	42.38	41.23	43.05
	45	35.79	34.61	33.43	32.37	34.05
	Average	39.61	38.56	37.45	36.29	37.98
T_3	0	39.53	38.63	37.41	36.24	37.95
	15	43.71	42.56	41.30	40.61	42.05
	30	47.65	45.68	44.51	43.74	45.40
	45	35.67	34.50	33.51	32.46	34.04
	Average	41.64	40.34	39.18	38.26	39.86
T_4	0	38.67	36.53	35.29	34.46	36.24
	15	41.68	39.84	37.89	36.75	39.04
	30	45.67	43.87	41.96	40.89	43.10
	45	35.58	33.60	31.72	30.45	32.84
	Average	40.40	38.46	36.72	35.64	37.80
T_5	0	32.86	30.76	29.64	27.71	30.24
	15	37.54	35.46	33.89	31.86	34.69
	30	41.86	39.76	38.64	36.87	39.28
	45	29.71	28.68	27.47	25.68	27.89
	Average	35.49	33.67	32.41	30.53	33.02
T_6	0	40.58	39.71	38.43	36.84	38.89
	15	44.96	42.81	41.56	40.75	42.52
	30	48.67	46.43	45.29	44.71	46.28
	45	38.46	36.58	35.42	33.84	36.08
	Average	32.02	41.38	40.18	39.04	40.94
T_7	0	37.86	36.54	35.78	33.70	35.97
	15	41.85	39.64	38.37	36.48	39.09
	30	46.87	45.56	44.71	43.98	45.28
	45	34.57	32.89	31.64	30.47	32.39
	Average	40.29	38.66	37.63	36.16	38.18
T_8	0	33.77	32.71	31.89	30.56	32.23
	15	37.58	36.81	34.57	33.58	35.64
	30	42.94	40.89	39.56	36.56	39.99
	45	30.96	29.47	27.59	25.69	28.43
	Average	36.31	34.97	33.40	31.60	34.07
T_9	0	31.89	-	-	-	-
	15	35.78	-	-	-	-
	30	38.54	-	-	-	-
	45	28.56	-	-	-	-
	Average	33.69	-	-	-	-
T_{10}	0	33.84	-	-	-	-
	15	36.74	-	-	-	-
	30	41.98	-	-	-	-
	45	30.87	-	-	-	-
	Average	35.86	-	-	-	-
T_{11}	0	36.25	34.51	33.61	32.81	34.30
	15	39.53	37.46	36.70	35.32	37.25
	30	43.82	42.87	41.96	40.96	42.40
	45	32.86	31.56	29.27	28.94	30.66
	Average	38.12	36.60	35.39	34.51	36.15

Moisture distribution at 150 DAT during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	37.36	36.58	35.46	34.72	36.03
	15	41.75	38.62	37.38	36.59	38.59
	30	45.96	44.86	43.75	41.75	44.08
	45	34.41	33.39	32.58	31.89	33.07
	Average	39.87	38.36	37.29	36.24	37.94
T_2	0	38.94	37.53	36.45	35.70	37.16
	15	42.75	40.67	39.41	38.42	40.31
	30	45.86	44.68	42.74	41.75	43.76
	45	35.97	34.21	33.17	32.97	34.08
	Average	40.88	39.27	37.94	37.21	38.83
T_3	0	41.28	39.46	38.50	37.61	39.21
	15	43.87	42.75	41.53	39.86	42.00
	30	47.86	46.74	45.31	44.39	46.08
	45	38.45	37.53	35.27	34.30	36.39
	Average	42.87	41.62	40.15	39.04	40.92
T_4	0	38.49	37.62	36.40	35.39	36.98
	15	40.58	39.36	38.71	37.62	39.07
	30	45.86	43.74	42.65	41.28	43.38
	45	36.51	35.38	34.71	33.62	35.06
	Average	40.36	39.03	38.12	36.98	38.62
T_5	0	34.62	32.97	30.61	29.78	32.00
	15	37.89	35.57	34.68	32.61	35.19
	30	42.74	40.87	39.52	38.74	40.47
	45	31.57	30.97	28.67	26.74	29.49
	Average	36.71	35.10	33.37	31.97	34.28
T_6	0	35.48	34.62	33.89	32.71	34.18
	15	38.53	37.46	36.58	35.24	36.95
	30	41.78	40.56	39.68	38.67	40.17
	45	33.50	32.61	31.46	30.87	32.11
	Average	32.02	36.31	35.40	34.37	35.85
T_7	0	39.23	38.46	37.63	36.52	37.96
	15	42.87	40.87	38.74	36.71	39.80
	30	47.95	45.64	44.49	43.68	45.44
	45	37.84	35.74	33.68	31.57	34.71
	Average	41.97	40.18	38.64	37.12	39.48
T_8	0	35.61	34.28	33.47	32.71	34.02
	15	37.59	36.40	35.60	34.39	36.00
	30	41.78	40.49	38.59	36.74	39.40
	45	34.72	33.41	32.57	31.40	33.03
	Average	37.43	36.15	35.06	33.81	35.61
T_9	0	28.96	-	-	-	-
	15	31.58	-	-	-	-
	30	35.46	-	-	-	-
	45	25.46	-	-	-	-
	Average	30.37	-	-	-	-
T_{10}	0	29.38	-	-	-	-
	15	33.87	-	-	-	-
	30	38.67	-	-	-	-
	45	26.53	-	-	-	-
	Average	32.11	-	-	-	-
T_{11}	0	33.75	32.45	31.87	30.28	32.09
	15	36.84	35.61	32.47	31.85	34.19
	30	40.76	38.53	36.39	35.30	37.75
	45	30.35	29.86	28.94	26.84	29.00
	Average	35.43	34.11	32.42	31.07	33.26

Moisture distribution at harvest during first crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	33.61	31.97	30.61	29.78	31.49
	15	36.56	34.57	33.68	31.87	34.17
	30	40.87	38.71	37.52	36.84	38.49
	45	30.57	28.97	26.63	25.88	28.01
	Average	35.40	33.56	32.11	31.09	33.04
T_2	0	35.94	35.66	34.87	32.71	34.80
	15	37.89	36.84	35.74	34.78	36.31
	30	42.28	41.38	40.74	39.86	41.07
	45	32.56	31.86	30.86	29.86	31.29
	Average	37.17	36.44	35.55	34.30	35.86
T_3	0	35.94	34.54	33.28	32.74	34.13
	15	38.74	37.89	36.84	35.74	37.30
	30	43.87	42.28	41.98	40.74	42.22
	45	33.47	31.54	30.87	29.86	31.44
	Average	38.01	36.56	35.74	34.77	36.27
T_4	0	38.67	36.69	35.68	33.70	36.19
	15	41.58	40.86	38.67	36.48	39.40
	30	46.87	44.56	42.28	41.98	43.92
	45	35.86	32.48	31.50	30.60	32.61
	Average	40.75	38.65	37.03	35.69	38.03
T_5	0	31.24	30.45	28.34	27.41	29.36
	15	35.41	33.43	32.78	31.75	33.34
	30	39.23	37.54	35.67	34.41	36.71
	45	29.34	28.61	27.64	25.34	27.73
	Average	33.81	32.51	31.11	29.73	31.79
T_6	0	31.79	29.75	27.84	26.89	29.07
	15	36.78	34.63	33.51	32.47	34.35
	30	40.87	38.76	36.94	35.47	38.01
	45	28.64	27.64	25.96	24.87	26.78
	Average	34.52	32.70	31.06	29.93	32.05
T_7	0	34.85	33.78	31.89	30.17	32.67
	15	38.87	36.56	35.84	34.71	36.50
	30	42.56	40.89	39.78	38.74	40.49
	45	30.58	29.68	28.90	27.68	29.21
	Average	36.72	35.23	34.10	32.83	34.72
T_8	0	30.61	29.97	28.76	27.45	29.20
	15	34.56	32.57	31.38	30.87	32.35
	30	38.87	35.71	34.52	33.36	35.62
	45	28.57	27.58	25.68	24.88	26.68
	Average	33.15	31.46	30.09	29.14	30.96
T_9	0	26.54	-	-	-	-
	15	30.46	-	-	-	-
	30	35.94	-	-	-	-
	45	23.78	-	-	-	-
	Average	29.18	-	-	-	-
T_{10}	0	31.58	-	-	-	-
	15	33.51	-	-	-	-
	30	37.64	-	-	-	-
	45	29.97	-	-	-	-
	Average	33.18	-	-	-	-
T_{11}	0	34.46	33.72	32.47	31.87	33.13
	15	37.53	37.86	35.61	34.28	36.32
	30	41.87	42.79	40.58	39.64	41.22
	45	31.51	30.50	29.86	28.50	30.09
	Average	36.34	36.22	34.63	33.57	35.19

Moisture distribution at 30 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	30.86	28.67	27.48	26.89	28.48
	15	33.84	31.45	30.76	29.67	31.43
	30	37.88	35.64	34.96	33.78	35.57
	45	27.49	25.68	24.67	23.66	25.38
	Average	32.52	30.36	29.47	30.25	30.21
T_2	0	32.14	31.54	30.84	31.82	31.59
	15	36.75	35.47	33.25	31.58	34.26
	30	40.56	39.64	37.54	36.54	38.57
	45	29.57	27.84	26.33	26.26	27.50
	Average	34.76	33.62	31.99	31.55	32.98
T_3	0	35.98	33.64	31.54	30.84	33.00
	15	39.78	37.64	35.24	34.68	36.84
	30	43.56	41.66	40.27	39.68	41.29
	45	31.44	27.56	26.55	25.38	27.73
	Average	33.89	35.13	33.40	32.65	34.72
T_4	0	32.58	31.67	30.21	28.55	30.75
	15	35.56	33.89	32.78	31.40	33.41
	30	38.69	36.55	35.56	34.75	36.39
	45	28.64	26.54	25.33	23.47	26.00
	Average	33.87	32.16	30.97	29.54	31.64
T_5	0	27.66	26.45	25.86	24.56	26.13
	15	30.68	28.97	27.86	25.86	28.34
	30	34.56	32.45	30.45	29.68	31.79
	45	25.45	26.41	25.59	24.70	25.54
	Average	29.59	28.57	27.44	26.20	27.95
T_6	0	36.74	35.68	33.45	31.84	34.43
	15	39.64	38.66	37.24	35.68	37.81
	30	42.98	41.35	40.38	38.47	40.80
	45	33.85	32.58	30.98	39.47	34.22
	Average	38.30	37.07	35.51	36.37	36.81
T_7	0	33.87	31.58	30.56	29.64	31.41
	15	37.77	35.45	34.86	32.98	35.27
	30	41.68	40.88	39.68	38.87	40.28
	45	30.56	29.31	28.69	26.99	28.89
	Average	32.02	34.31	33.45	32.12	33.96
T_8	0	28.86	27.66	26.88	25.78	29.64
	15	31.45	30.55	28.65	27.96	29.65
	30	35.69	33.99	32.65	31.58	33.48
	45	25.65	23.65	22.86	21.68	23.46
	Average	30.41	28.96	27.76	26.75	29.06
T_9	0	34.87	-	-	-	-
	15	38.86	-	-	-	-
	30	42.69	-	-	-	-
	45	32.54	-	-	-	-
	Average	28.64	-	-	-	-
T_{10}	0	25.86	-	-	-	-
	15	29.97	-	-	-	-
	30	33.56	-	-	-	-
	45	22.36	-	-	-	-
	Average	27.94	-	-	-	-
T_{11}	0	33.96	31.64	29.67	28.84	31.03
	15	35.68	34.85	32.64	30.74	33.48
	30	41.69	38.64	37.89	35.68	38.48
	45	28.44	27.56	26.55	25.38	26.98
	Average	33.89	33.17	31.69	30.16	32.49

Moisture distribution at 60 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	31.58	30.87	28.64	27.33	29.61
	15	34.55	33.47	31.87	29.44	32.33
	30	39.47	38.24	37.66	35.21	37.65
	45	28.64	27.58	26.33	25.47	27.01
	Average	32.02	32.54	31.13	29.36	31.65
T_2	0	33.42	32.24	30.78	29.88	31.58
	15	38.47	36.54	35.21	34.15	36.09
	30	43.35	41.58	40.38	39.84	41.29
	45	30.47	28.14	27.12	26.54	28.07
	Average	33.54	34.63	33.37	32.60	34.26
T_3	0	35.84	33.35	31.65	30.45	32.82
	15	39.68	38.41	37.86	35.11	37.77
	30	43.12	41.23	40.54	38.42	40.83
	45	32.51	31.24	30.65	29.54	30.99
	Average	37.79	36.06	35.18	33.38	35.60
T_4	0	32.64	31.68	30.45	28.63	30.85
	15	36.54	34.54	33.64	31.78	34.13
	30	39.56	37.28	36.57	35.66	37.27
	45	29.65	28.44	26.34	25.74	27.54
	Average	34.60	32.99	31.75	30.45	32.45
T_5	0	28.67	27.54	26.48	25.38	27.02
	15	30.68	29.45	28.76	27.64	29.13
	30	34.87	33.27	31.87	30.77	32.70
	45	26.74	24.68	23.41	22.35	24.30
	Average	30.24	28.74	27.63	30.25	28.29
T_6	0	36.58	34.23	32.47	30.59	33.47
	15	39.45	37.63	35.44	33.65	36.54
	30	42.58	41.66	40.87	39.64	41.19
	45	33.26	31.45	29.98	27.56	30.56
	Average	37.97	36.24	34.69	32.86	35.44
T_7	0	34.68	33.56	32.64	31.79	33.17
	15	37.86	36.55	35.24	33.56	35.80
	30	41.58	40.65	38.64	37.66	39.63
	45	31.75	29.41	28.36	27.68	29.30
	Average	36.47	35.04	33.72	32.67	34.48
T_8	0	31.86	29.83	28.66	26.54	29.22
	15	33.96	32.94	31.75	30.84	32.37
	30	37.54	35.74	33.54	31.58	34.60
	45	26.75	24.61	23.76	21.74	24.22
	Average	32.53	30.78	29.43	27.68	30.10
T_9	0	26.75	-	-	-	-
	15	31.45	-	-	-	-
	30	35.64	-	-	-	-
	45	23.74	-	-	-	-
	Average	29.40	-	-	-	-
T_{10}	0	28.66	-	-	-	-
	15	31.75	-	-	-	-
	30	34.44	-	-	-	-
	45	26.87	-	-	-	-
	Average	30.43	-	-	-	-
T_{11}	0	34.65	33.47	31.94	30.76	32.71
	15	37.55	36.47	34.85	33.89	35.69
	30	40.58	39.54	37.56	35.68	38.34
	45	30.56	29.56	27.98	25.67	28.44
	Average	35.84	34.76	33.08	31.50	33.79

Moisture distribution at 90 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	31.25	30.28	29.48	28.36	29.84
	15	34.86	32.84	31.75	30.52	32.49
	30	36.58	35.76	34.68	33.75	35.19
	45	29.66	27.64	26.55	25.47	27.33
	Average	31.80	30.86	30.62	29.53	31.21
T_2	0	34.87	33.25	31.47	30.56	32.54
	15	38.66	36.55	35.45	34.58	36.31
	30	43.56	42.87	40.66	39.48	41.64
	45	31.54	30.94	28.78	26.87	29.53
	Average	37.16	35.90	34.09	32.87	35.01
T_3	0	37.45	36.54	35.47	33.68	35.79
	15	40.65	38.69	37.68	36.78	38.45
	30	44.36	42.65	41.67	40.33	42.25
	45	35.63	33.47	32.52	31.25	33.22
	Average	39.52	37.84	36.84	35.51	37.43
T_4	0	32.63	30.86	29.86	28.47	30.46
	15	36.45	35.66	34.25	31.69	34.51
	30	42.86	39.64	37.86	36.54	39.23
	45	29.54	28.63	27.55	25.87	27.90
	Average	35.37	33.70	32.38	30.64	33.02
T_5	0	30.88	28.35	26.42	25.87	27.88
	15	33.65	31.45	30.69	29.88	31.42
	30	37.56	35.16	34.12	33.86	35.18
	45	28.64	27.84	26.87	24.78	27.03
	Average	32.68	30.70	29.53	28.60	30.38
T_6	0	36.66	35.86	33.62	31.36	34.38
	15	40.89	39.47	38.66	37.63	39.16
	30	45.36	44.56	42.58	40.96	43.37
	45	32.64	31.75	30.64	29.39	31.11
	Average	32.02	37.91	36.38	34.84	37.00
T_7	0	33.46	31.54	30.47	29.55	37.86
	15	37.68	35.42	34.72	33.57	35.35
	30	42.58	40.64	39.45	38.66	40.33
	45	30.87	28.69	26.33	24.57	27.62
	Average	36.15	34.07	32.74	31.59	35.29
T_8	0	31.68	30.75	29.56	27.78	29.94
	15	34.55	33.54	31.25	29.83	32.29
	30	38.66	36.12	37.77	35.69	37.06
	45	27.84	25.44	24.58	23.68	25.39
	Average	33.18	31.46	30.79	29.25	31.17
T_9	0	28.66	-	-	-	-
	15	31.75	-	-	-	-
	30	35.76	-	-	-	-
	45	25.41	-	-	-	-
	Average	30.40	-	-	-	-
T_{10}	0	30.87	-	-	-	-
	15	33.58	-	-	-	-
	30	37.71	-	-	-	-
	45	26.94	-	-	-	-
	Average	32.28	-	-	-	-
T_{11}	0	32.74	32.69	31.86	30.96	32.06
	15	37.86	36.35	35.64	34.86	36.18
	30	41.52	39.45	38.24	36.56	38.94
	45	30.45	29.54	28.45	27.69	29.03
	Average	35.64	34.51	33.55	32.52	34.05

Moisture distribution at 120 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	34.28	32.54	31.25	29.87	31.99
	15	38.69	37.42	36.84	35.54	37.12
	30	42.35	40.52	39.68	38.64	40.30
	45	31.95	30.75	28.45	27.86	29.75
	Average	30.87	28.64	27.22	26.97	34.79
T_2	0	36.54	34.85	33.47	31.53	34.10
	15	39.47	38.63	37.66	35.78	37.89
	30	43.58	41.56	40.98	38.25	41.09
	45	33.25	32.66	31.26	29.37	31.64
	Average	38.21	36.93	35.84	33.73	36.18
T_3	0	39.56	37.42	35.24	33.52	36.44
	15	42.63	40.87	39.45	38.52	40.37
	30	46.85	44.23	42.33	41.69	43.78
	45	35.66	33.25	31.52	29.84	32.57
	Average	41.18	38.94	37.14	35.89	38.29
T_4	0	37.86	36.53	35.29	34.46	36.04
	15	40.35	39.84	37.89	35.25	38.33
	30	43.56	41.48	39.68	38.74	40.87
	45	34.56	31.58	30.72	28.69	31.39
	Average	39.08	37.36	35.90	34.29	36.66
T_5	0	32.86	30.54	29.36	27.34	30.03
	15	37.54	35.12	33.52	31.45	34.41
	30	40.58	39.66	37.25	36.87	38.59
	45	30.56	28.68	27.47	25.68	28.10
	Average	35.39	33.50	31.90	30.34	32.78
T_6	0	39.68	38.97	36.55	35.28	37.62
	15	43.58	41.64	40.36	38.68	41.07
	30	47.56	45.26	44.36	42.71	44.97
	45	36.58	35.42	33.68	31.74	34.36
	Average	32.02	40.32	38.74	37.10	39.50
T_7	0	35.47	34.58	33.68	31.74	33.87
	15	39.87	37.44	35.28	36.48	37.27
	30	44.53	43.56	42.87	40.69	42.91
	45	34.57	32.89	31.64	30.47	32.39
	Average	38.61	37.12	35.87	34.85	36.61
T_8	0	32.96	31.25	30.87	29.69	31.19
	15	36.54	34.71	33.58	31.87	34.18
	30	41.36	40.63	39.56	37.68	39.81
	45	29.66	27.12	26..33	25.69	27.49
	Average	35.13	33.43	34.67	31.23	33.17
T_9	0	28.47	-	-	-	-
	15	33.58	-	-	-	-
	30	37.52	-	-	-	-
	45	25.36	-	-	-	-
	Average	31.23	-	-	-	-
T_{10}	0	32.54	-	-	-	-
	15	35.41	-	-	-	-
	30	40.35	-	-	-	-
	45	29.36	-	-	-	-
	Average	34.42	-	-	-	-
T_{11}	0	36.25	34.51	33.61	32.81	34.30
	15	39.53	37.46	36.70	35.32	37.25
	30	41.35	39.56	38.24	37.45	39.15
	45	32.86	31.56	29.27	28.94	30.66
	Average	37.50	35.77	34.46	33.63	35.34

Moisture distribution at 150 DAT during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	36.58	34.58	33.47	31.84	34.12
	15	40.86	38.62	37.38	36.59	38.36
	30	44.56	42.36	41.68	40.84	42.36
	45	33.69	31.74	30.42	28.39	31.06
	Average	38.92	36.83	35.74	34.42	36.48
T_2	0	38.94	37.53	35.42	33.97	36.47
	15	42.75	40.67	38.69	36.52	39.66
	30	44.25	42.36	40.86	39.65	41.78
	45	35.97	33.45	31.56	30.86	32.96
	Average	40.48	38.50	36.63	35.25	37.72
T_3	0	39.25	38.53	37.52	36.25	37.89
	15	42.63	40.98	39.54	38.47	40.41
	30	46.58	44.36	42.63	41.54	43.78
	45	35.66	34.56	33.86	32.58	34.17
	Average	41.03	39.61	38.39	37.21	39.06
T_4	0	37.45	35.24	33.86	31.89	34.61
	15	40.58	39.36	38.71	37.62	39.07
	30	44.86	42.14	40.25	39.68	41.73
	45	35.62	33.54	31.74	29.56	32.62
	Average	39.63	37.57	36.14	34.69	37.01
T_5	0	33.56	31.86	29.55	27.66	30.66
	15	36.52	35.41	33.77	32.61	34.58
	30	41.35	39.56	38.46	36.25	38.91
	45	31.57	30.97	28.67	26.74	29.49
	Average	35.75	34.45	32.61	30.82	33.41
T_6	0	34.56	33.14	31.75	30.89	32.59
	15	37.85	35.66	34.74	33.24	35.37
	30	40.56	39.47	38.25	37.69	38.99
	45	31.25	30.54	28.64	27.41	29.46
	Average	32.02	34.70	33.35	32.31	34.10
T_7	0	37.58	36.55	34.45	33.25	35.46
	15	40.74	38.56	36.45	34.87	37.66
	30	45.66	44.56	42.15	41.96	43.58
	45	34.25	31.64	30.54	29.66	31.52
	Average	39.56	37.83	35.90	34.94	37.05
T_8	0	35.61	34.28	33.47	32.71	34.02
	15	36.54	35.25	34.56	33.56	34.98
	30	40.56	39.47	34.14	33.66	36.96
	45	34.72	33.41	32.57	31.40	33.03
	Average	36.86	35.60	33.69	32.83	34.74
T_9	0	30.94	-	-	-	-
	15	34.28	-	-	-	-
	30	39.56	-	-	-	-
	45	26.33	-	-	-	-
	Average	32.78	-	-	-	-
T_{10}	0	33.86	-	-	-	-
	15	35.68	-	-	-	-
	30	40.86	-	-	-	-
	45	30.56	-	-	-	-
	Average	35.24	-	-	-	-
T_{11}	0	36.47	34.56	32.78	30.28	33.52
	15	40.25	38.54	36.55	34.21	37.39
	30	44.56	43.87	41.85	39.45	42.43
	45	33.25	31.58	29.84	28.84	30.88
	Average	38.63	37.14	35.26	33.20	36.06

Moisture distribution at harvest during second crop year

Treatment	Soil depth	Radial Distance (cm)				
		0	15	30	45	Average
T_1	0	33.52	31.25	30.61	29.78	31.29
	15	36.41	35.24	33.12	31.78	34.14
	30	39.56	38.47	36.55	35.47	37.51
	45	30.57	28.97	26.63	25.88	28.01
	Average	35.02	33.48	31.73	30.73	32.74
T_2	0	35.94	33.52	32.41	30.71	33.15
	15	37.89	36.84	35.74	34.78	36.31
	30	41.32	39.62	38.45	36.54	38.98
	45	32.56	31.86	30.86	29.86	31.29
	Average	36.93	35.46	34.37	32.97	34.93
T_3	0	35.94	34.54	32.47	30.58	33.38
	15	38.74	36.52	35.24	33.47	35.99
	30	42.56	41.33	40.68	39.85	41.11
	45	33.47	31.54	30.87	29.86	31.44
	Average	37.68	35.98	34.82	33.44	35.48
T_4	0	32.68	30.74	28.45	26.36	29.56
	15	37.25	36.84	35.25	33.87	35.80
	30	41.87	39.56	37.88	36.52	38.96
	45	29.85	28.47	27.45	26.51	28.07
	Average	35.41	33.90	32.26	30.82	33.10
T_5	0	31.24	28.69	27.41	25.78	28.28
	15	34.75	32.58	31.95	29.68	32.24
	30	38.24	36.52	34.41	33.47	35.66
	45	28.67	26.54	24.35	23.98	25.89
	Average	33.23	31.08	29.53	28.23	30.52
T_6	0	31.79	29.63	27.84	26.89	29.04
	15	36.42	34.25	33.25	31.69	33.90
	30	39.56	38.74	36.25	34.12	37.17
	45	28.46	27.41	25.31	24.87	26.51
	Average	34.06	32.51	30.66	29.39	31.66
T_7	0	31.85	30.96	29.65	28.47	30.23
	15	35.26	33.56	31.84	30.65	32.83
	30	40.56	38.74	37.45	36.52	38.32
	45	28.69	27.56	26.33	25.69	27.07
	Average	34.09	32.71	31.32	30.33	32.11
T_8	0	28.64	26.35	24.71	22.45	25.54
	15	30.89	32.57	31.38	30.87	31.43
	30	34.56	32.65	31.45	29.66	32.08
	45	26.33	24.15	22.57	20.99	23.51
	Average	30.11	28.93	27.53	25.99	28.14
T_9	0	26.54	-	-	-	-
	15	30.69	-	-	-	-
	30	35.21	-	-	-	-
	45	23.78	-	-	-	-
	Average	29.06	-	-	-	-
T_{10}	0	29.66	-	-	-	-
	15	32.87	-	-	-	-
	30	36.58	-	-	-	-
	45	25.64	-	-	-	-
	Average	31.19	-	-	-	-
T_{11}	0	33.45	31.45	30.58	29.74	31.31
	15	37.53	35.78	34.28	31.47	34.77
	30	41.87	40.56	38.47	37.96	39.72
	45	30.56	28.69	27.96	25.63	28.21
	Average	35.85	40.56	32.82	31.20	33.50

APPENDIX-IX : ECONOMICS OF SURFACE AND DRIP IRRIGATION FOR TOMATO CROP

Sr. No.	Items	Items Cost (₹)	Life year	Depreciation =OC- JV/L	Interest@ 12% p.a. ₹	Repair and maintenance @ 2 % p.a.(₹)
I.	**Drip irrigation**					
1.	Centrifugal pump set (5 HP) and accessories	8000	20	360	960	160
	Total annual cost	1480				
II.	Drip Irrigation					
2	Centrifugal pump set (5HP) & accessories	8000	20	360.00	960	160
3	Screen Filter	3000	10	270.00	360	60
4	Bypass	1000	10	90.00	120	20
5	Fertilizer tank	5000	10	450.00	600	100
6	PVP pipe, 90 mm (main-50 m/ha) @ 70 ₹/m	3500	10	315.00	420	70
7	PVP pipe, 63 mm (submain- 51m/ha) @ 45 ₹/m	2295	10	206.55	275.4	45.9
8	PVP pipe, 40 mm (manifold-200 m) @3 ₹/m	7200	10	648.00	864	144
9	LDPE lateral 16 mm (8333 m) @ 10.60 ₹/m	88330	7	11356.71	10599.6	1766.6
10	GTO for LDPE lateral 16 mm @ 3 ₹/unit (for 180 laterals)	540	7	69.43	64.8	10.8
11	LDPE end caps @ 2 ₹/unit (for 180 laterals)	360	7	46.29	43.2	7.2
12	PVC fittings	1000	7	128.57	120	20
13	Pressure gauge	1662	7	213.69	199.44	33.24
14	Valves	1000	7	128.57	120	20
15	Total fixed cost	130887		14642.81	15706.44	2617.74
16	Installation @ 3% of total cost	3926.61				
	Total annual cost	36893.60				
	Total seasonal cost	12297.87				

A. Cost of cultivation of tomato crop

Sr. No.	Items	T_1		T_2		T_3		T_4		T_5		T6	
		Qty	Amount	Qty	Amount	Qty	Amount	Qty	Amount	Qty	Amount	Qty	Amount
1	Ploughing @ 3000 ₹/ha		3000		3000		3000		3000		3000		3000
2	Harrowing @ 1500 ₹/ha		1500		1500		1500		1500		1500		1500
3	Seedlings 0.9/seedlings		19048		19048		19048		19048		19048		19048
4	pesticide charges		8000		8000		8000		8000		8000		8000
5	Electricity charges		750		750		750		750		750		750
6	water charges		200		200		200		200		200		200
7	Labour charges 200 ₹/day	210	42000	210	42000	210	42000	210	42000	205	41000	205	41000
8	Fertilizer charges												
	Urea @ ₹ 6/kg	591.1	3546.54	591.09	3546.54	591.09	3546.54	591.09	3546.54	393.58	2361.48	262.66	1575.96
	17:44:00 ₹ 54/kg	339	18305.46	338.99	18305.46	338.99	18305.46	338.99	18305.46	256.51	13851.54	170.25	9193.5
	MOP ₹ 17/kg	249	4233	249	4233	249	4233	249	4233	187.58	3188.86	124.5	2116.5
	SSP ₹ 8/kg												
	Spray 2 % 17:44:00												
	FYM		4000		4000		4000		4000		4000		4000
	Total fertilizer cost		26085		26085		26085		26085		19401.88		12886
9	Staking		12000		12000		12000		12000		12000		12000
10	Working capital.		116583		116583		116583		116583		108899.9		102384
11	interest on working capital @10 %		11658.3		11658.3		11658.3		11658.3		10889.99		10238.4
12	Rental value of land		3000		3000		3000		3000		3000		3000
13	Total cost		131241.3		131241.3		131241.3		131241.3		122789.9		115622

Appendix-III contd…..

Sr. No.	Items	T_1		T_2		T_3		T_4		T_5	
		Qty	**Amount**	**Qty**	**Amount**	**Qty**	**Amount**	**Qty**	**Amount**	**Qty**	**Amount**
1	Ploughing @ 3000 ₹/ha		3000		3000		3000		3000		3000
2	Harrowing @ 1500 ₹/ha		1500		1500		1500		1500		1500
3	Seedlings 0.9/seedlings		19048		19048		19048		19048		19048
4	pesticide charges		8000		8000		8000		8000		8000
5	Electricity charges		750		750		750		750		750
6	water charges		200		200		200		200		200
7	Labour charges 200 ₹/day	205	41000	205	41000	200	40000	200	40000	200	40000
8	Fertilizer charges										
	Urea @ ₹ 6/kg	134.34	806.04	651	3906	651	3906	651	3906	0	0
	17:44:00 ₹ 54/kg	85.12	4596.48							0	0
	MOP ₹ 17/kg	62.25	1058.25	249	4233	249	4233	249	4233	0	0
	SSP ₹ 8/kg			938	7504	938	7504	938	7504		
	Spray 2 % 17:44:00								1620		
	FYM		4000		4000		4000		4000		4000
	Total fertilizer cost		6460.77		15643		15643		17263		
9	Staking		12000		12000		12000		12000		12000
10	Working capital.		95958.77		105141		104141		105761		88498
11	interest on working capital @10 %		9595.877		10514.1		10414.1		105761.1		8849.8
12	Rental value of land		3000		3000		3000		3000		3000
13	Total cost		108554.6		118655.1		117555.1		119337.1		100348

B. Economics of tomato crop for first year

Sr. No.	Items	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
1	Fixed cost irrigation system (Rs/Season/ha)	12298	12298	12298	12298	12298	12298	12298	12298	1480	1480	12298
2	2 Operational cost	131241	131241	131241	131241	122790	115622	108555	118655	119337	117555	100348
3	Seasonal cost (Rs ha^{-1})	143539	143539	143539	143539	135088	127920	120853	130953	120817	119035	112646
4	Water used (mm)	613.93	613.93	613.93	613.93	613.93	613.93	613.93	613.93	1158.79	1158.79	613.93
5	Yield of tomato (t ha^{-1})	83.15	87.04	87.53	83.20	68.85	59.69	59.21	61.47	55.12	50.02	35.86
6	Selling price (₹ t^{-1})	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
7	Income from produce (₹ ha)	831500	870400	875300	832000	688500	596900	592100	614700	551200	500200	358600
8	Net seasonal income (₹ ha^{-1})	687961	726861	731761	688461	553412	468980	471247	483747	430383	381165	245954
9	Additional area (ha)	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.00	0.00	0.89
10	Additional expenditure (₹)	127390	127390	127390	127390	119890	113529	107256	116220	0	0	99973
11	Additional income (₹)	737952	772476	776825	738396	611041	529746	525486	545543	0	0	318256
12	Gross cost (₹)	270930	270930	270930	270930	254978	241449	228109	247173	120817	119035	212618
13	Water productivity (₹/ ha- mm)	1121	1184	1192	1121	901	764	768	788	371	329	401
14	Total net income (₹ ha^{-1})	1569452	1642876	1652125	1570396	1299541	1126646	1117586	1160243	551200	500200	676856
15	B:C Ratio	6.34	6.63	6.67	6.34	5.61	5.16	5.45	5.18	4.62	4.26	3.57
16	Net extra income over control (₹)	306796	345696	350596	307296	172247	87815	90082	102582	49218	0	-135211
17	Net profit ₹ per mm water used	1121	1184	1192	1121	901	764	768	788	371	329	401
18	WUE kg/ha-mm	135.44	141.78	142.57	135.52	112.15	97.23	96.44	100.13	47.57	43.17	58.41

C. Economics of tomato crop for second year

Sr. No.	Items	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
1	Fixed cost irrigation system (₹/Season/ha)	12298	12298	12298	12298	12298	12298	12298	12298	1480	1480	12298
2	2 Operational cost	131241	131241	131241	131241	122790	115622	108555	118655	119337	117555	100348
3	Seasonal cost (₹ ha^{-1})	143539	143539	143539	143539	135088	127920	120853	130953	120817	119035	112646
4	Water used (mm)	592.94	592.94	592.94	592.94	592.94	592.94	592.94	592.94	1112.49	1112.49	592.94
5	Yield of tomato (t ha^{-1})	90.61	98.27	96.56	93.52	73.33	63.01	63.35	65.97	58.73	54.23	40.96
6	Selling price (₹ t^{-1})	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
7	Income from produce (₹ ha)	906100	982700	965600	935200	733300	630100	633500	659700	587300	542300	409600
8	Net seasonal income (₹ ha^{-1})	762561	839161	822061	791661	598212	502180	512647	528747	466483	423265	296954
9	Additional area (ha)	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.00	0.00	0.88
10	Additional expenditure (₹)	125773	125773	125773	125773	118368	112087	105894	114745	0	0	98703
11	Additional income (₹)	793949	861068	846085	819447	642537	552111	555090	578047	0	0	358903
12	Gross cost (₹)	269312	269312	269312	269312	253455	240008	226747	245698	120817	119035	211349
13	Water productivity (₹/ ha- mm)	1286	1415	1386	1335	1009	847	865	892	419	380	501
14	Total net income (₹ ha^{-1})	1700049	1843768	1811685	1754647	1375837	1182211	1188590	1237747	587300	542300	768503
15	B:C Ratio	6.90	7.49	7.36	7.13	5.97	5.45	5.84	5.56	4.92	4.61	4.08
16	Net extra income over control (₹)	339296	415896	398796	368396	174947	78915	89382	105482	43218	0	-126311
17	Net profit ₹ per mm water used	1286	1415	1386	1335	1009	847	865	892	419	380	501
18	WUE kg/ha-mm	152.81	165.73	162.85	157.72	123.67	106.27	106.84	111.26	52.79	48.75	69.08

D. Economics of tomato crop for Pooled mean

Sr. No.	Items	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}
1	Fixed cost irrigation system (₹/Season/ha)	12298	12298	12298	12298	12298	12298	12298	12298	1480	1480	12298
2	2 Operational cost	131241	131241	131241	131241	122790	115622	108555	118655	119337	117555	100348
3	Seasonal cost (₹ ha^{-1})	143539	143539	143539	143539	135088	127920	120853	130953	120817	119035	112646
4	Water used (mm)	613.93	613.93	613.93	613.93	613.93	613.93	613.93	613.93	1158.79	1158.79	613.93
5	Yield of tomato (t ha^{-1})	83.15	87.04	87.53	83.20	68.85	59.69	59.21	61.47	55.12	50.02	35.86
6	Selling price (₹ t^{-1})	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
7	Income from produce (₹ ha)	831500	870400	875300	832000	688500	596900	592100	614700	551200	500200	358600
8	Net seasonal income (₹ ha^{-1})	687961	726861	731761	688461	553412	468980	471247	483747	430383	381165	245954
9	Additional area (ha)	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.00	0.00	0.89
10	Additional expenditure (₹)	127390	127390	127390	127390	119890	113529	107256	116220	0	0	99973
11	Additional income (₹)	737952	772476	776825	738396	611041	529746	525486	545543	0	0	318256
12	Gross cost (₹)	270930	270930	270930	270930	254978	241449	228109	247173	120817	119035	212618
13	Water productivity (₹/ ha- mm)	1121	1184	1192	1121	901	764	768	788	371	329	401
14	Total net income (₹ ha^{-1})	1569452	1642876	1652125	1570396	1299541	1126646	1117586	1160243	551200	500200	676856
15	B:C Ratio	6.34	6.63	6.67	6.34	5.61	5.16	5.45	5.18	4.62	4.26	3.57
16	Net extra income over control (₹)	306796	345696	350596	307296	172247	87815	90082	102582	49218	0	-135211
17	Net profit ₹ per mm water used	1121	1184	1192	1121	901	764	768	788	371	329	401
18	WUE kg/ha-mm	135.44	141.78	142.57	135.52	112.15	97.23	96.44	100.13	47.57	43.17	58.41

8. VITAE

BHOI SANGITA PRATAP

A candidate for the degree

of

DOCTOR OF PHILOSOPHY (AGRICULTURE)

in

IRRIGATION WATER MANAGEMENT

2021

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