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Comparative study of different irrigation methods on tomato crop (*Lycopersicon esculentum*) in western Uttar Pradesh, India

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Abstract
To study the effect of précised management of water through drip irrigation in tomato crop a study was conducted at Agriculture Farm, IFTM University, Moradabad in *Rabi* season (October) in 2018. The experimental results indicated that tomato crop responded very well to précised application of water through drip irrigation system. The observations taken on various parameters indicated that treatment T4 i.e. four hours irrigation at four days interval was significantly superior as compared to other drip irrigation treatments and it was far better than furrow irrigation in tomato. The data of the experiment revealed that the significantly highest average fruit yield per plant (1.001kg) was recorded in treatment T4 as compared to other treatments like T1 (0.408 kg), T2 (0.561 kg), T3 (0.817 kg), T5 (0.974 kg) and T6 (0.984 kg). The same treatment also recorded significantly highest WUE of tomato (4.139 q/ha-cm) as compared to other treatments like T1 (2.391q/ha-cm), T2 (3.098 q/ha-cm), T3 (3.510 q/ha-cm), T5 (3.977 q/ha-cm) and T6 (2.635 q/ha-cm). This clearly indicates the efficiency of drip irrigation in yield enhancement and saving of vulnerable resources like water in tomato.

Keywords: tomato, drip irrigation, irrigation interval, furrow irrigation, water use efficiency

Introduction

Tomato is a crop of *Solanaceae* family and it is believed to be originated from Mexico. Tomato is the world's largest growing vegetable crop and known as both protective and productive food, because of its special nutritive value and also because of its wide spread production. Tomato is one of the most important vegetable crops cultivated for its fleshy fruits. It is considered as important commercial and dietary vegetable crop. India ranks second in the area as well as in production of Tomato (APEDA, 2017) [11]. Productivity level of tomato in the country is 24.4 MT/ha, and production is 19696.9 thousand MT. The common method of tomato production in the India is mixed farming system and it is mainly grown on small holdings. The cultivation purely depends on irrigation from wells and rivers. Water is one of the most important constraints which significantly influence the quality and productivity of tomato crop. Use of good quality seeds and fertilizers fail to achieve their full potential if the crop doesn't receive optimum irrigation. Being a tropical plant it requires frequent supply of water and water deficit can adversely affect the crop growth and yield. Generally, in India tomato crop is irrigated by surface irrigation method. But, there are several problems associated with surface irrigation such as accumulation of salts through evaporation and leaching, difficulties in moving of farm equipment, added expenses and extra time to conduct tillage practices. It also results in increased soil erosion. Also, it may lead to accumulation of too much water near the inlet and enough water does not reach at the edges. Further, surface irrigation systems are more difficult to automate particularly with regard to regulating an equal discharge in each furrow and there is loss of considerable amount of water due to deep drainage or runoff.

Water is increasingly becoming a scarce resource in every continent of the world.. India accounts for about 17% of the world's population and only 4% of the world fresh water resources. Distribution of these water resources across the vast expanse of the country is also uneven. With 1544 m^3 per capita water availability, India is already a water-stressed country and is moving towards turning into water scarce. Indian agriculture accounts for 90% of the total water use and majority of which is lost due to fast track ground water depletion and poor irrigation systems (Dhawan, 2017) [4]. An earlier estimate for average irrigation water utilization showed that farm distribution losseconstitute 15% of irrigation water, field applicati system losses constitute 25%, irrigation system losses 15% and the water effectively used by crops constitutes only about 45% (FAO, 1993). This statistics is of particular importance, if we know that, about 97.5% of the water on Earth's surface is salt water (in the oceans or salty lakes). That leaves only 2.5% of fresh water. Out of that, about 69% is frozen fresh water in glaciers and ice caps, 30% is groundwater (water in cracks of rocks and in pore-space of sediments like sand and clay), and only about 1% is surface water in lakes, rivers, and in the atmosphere. That means that most fresh water near the surface of the earth is in glaciers and in the ground (Bell and Rossman, 1992) [2]. Keeping these statistics in mind, drip irrigation seems to be a viable option that can help in saving one of the most precious resources i.e. water. The efficient utilization of irrigation water is possible by the adoption of highly efficient irrigation system, such as, drip irrigation system. Drip irrigation system can apply frequent and small amounts of irrigation water at many points of a field surface/subsurface near the plants, that results in considerable water saving (Decroix and Malaval, 1985; Youngs *et al.*, 1999) [3, 14]. In addition, drip irrigation system has the advantage of fitting to difficult topography (Wei *et al.*, 2003) [10]. Drip irrigation also has advantages over conventional furrow irrigation as an efficient means of applying water, especially where water is limited.

Accordingly, the objectives of the study were

1. To compare drip irrigation system and the conventional surface irrigation methods for tomato production under subtropical Indian condition in terms of yield and yield components, quantities of water applied, irrigation water productivity and economic analysis.
2. To estimate the Water Efficiency (WUE) of Tomato under subtropical Indian conditions.

Materials and Methods

Experimental site

Present study on comparative performance of drip and furrow irrigated tomato during 2018 (October to April) was conducted at remotely located Agricultural Research Farm, IFTM University Moradabad, Uttar Pradesh, India. The research farm is geographically situated at 28°21´ to 28°16´ N latitude and 78°4´ to 79° E longitudes at an altitude of 193.23 m above the mean sea level. Standard materials, methods and protocols were reviewed and adopted, to analyze suitability and relative performances of drip and furrow irrigated tomato crop. The Efforts were put to create small size experimental plots with furrow and drip irrigated setups to grow a popular variety of tomato and evaluate its performance.

Soil of the experimental site

The soil of the experimental site was sandy soil with high sand content (60%) and low clay content (20%). Soil samples were collected from auger pits at 0-30 and 30-60cm soil depths. The meteorological data (average temp, humidity, sunshine duration, wind velocity, rainfall, and evaporation) of year 2018 were collected from the website: www.accuweather.com (Fig. 1). The average maximum temperature exceeded 32 ºC during hot summer in May and June and minimum temperature occasionally falls below 1ºC during winter in December and 16ºC in January. The mean annual rainfall was 904 mm. The total rainfall during the crop season was 285 mm out of which the maximum portion was received in the month of July. The relative humidity ranged from 87 % in July to 80% in December during the crop growth period.

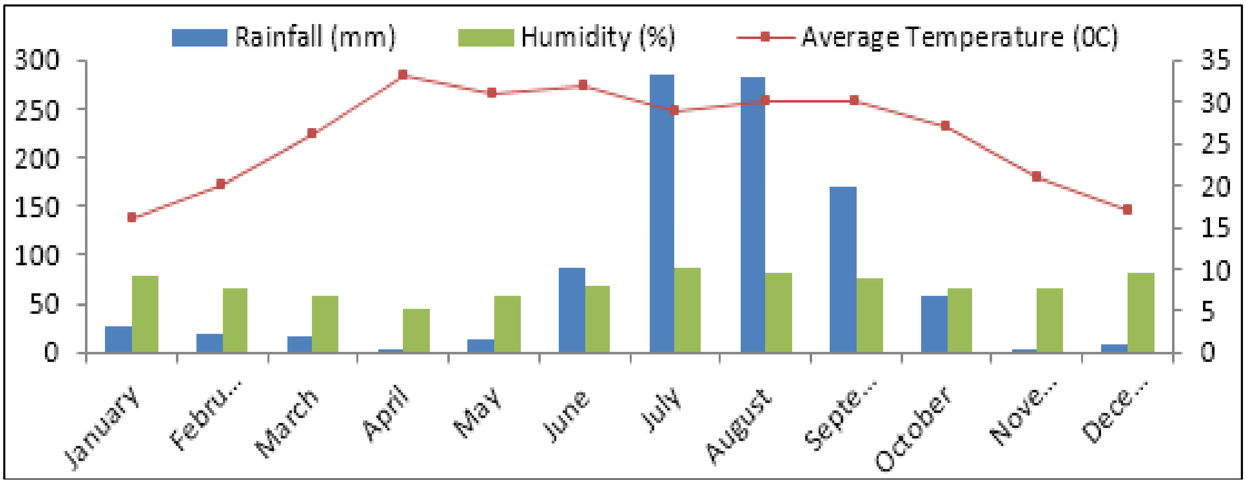

Fig 1: Graph showing the climatic data of Moradabad district in 2018

Details of treatments

There were six treatments i.e. 1, 2, 3 and 4 hours of irrigation/day at 1, 2, 3 and 4 days interval along with control.

Table 1: Detail of experimental treatments

Treatment	Irrigation Scheduling
T1	One hour irrigation at one-day interval
T2	Two hours irrigation at two-days interval
T3	Three hours irrigation at three-days interval
T4	Four hours irrigation at four-days interval
T5	Control
T6	Furrow irrigation

Planting material

21 days old planting materials of Pluto variety of tomato were transplanted in the field on 15th of October, 2017 at a spacing of 50×70 cm (1111 mother plants/ha). Holes were dug slightly wider and the planting materials were planted 4 cm deeper than their normal level in the bed.

Drip irrigation system description

The experimental setup consisted of a screen filter, main, sub mains, laterals, drippers and other accessories required for providing drip irrigation and they were fitted in the experimental plot of 0.006 ha land. The main and sub main pipelines used for drip irrigation were made of PVC pipes of

50 mm and 25 mm length and diameter, respectively. Linear Low Density Poly Ethylene (LLDPE) pipes of 12 mm diameter were used for laterals in the treatment. Drippers having flow rate of 1.46 l/h were fitted on the laterals at a spacing of 70 cm and the end plug was fixed on each lateral of the plot to control the flow rate of all taps. The experimental data was analyzed by using the completely randomized block design (RBD) with three replications.

Table 2: Experimental details of drip irrigation system

Description	Details
Crop	Tomato
Variety	Pluto
Family	*Solanacceae*
Scientific name	*Lycopersicon esculentum*
Row to Row distance	70 cm
Plant to plant distance	50 cm
Plantation time	15th October 2018
Duration of crop	150-200 days
Temperature	25-30^{o}C
Net irrigation Area	0.012 ha
Row to Row Spacing (spacing between laterals)	0.70 m
Plant to Plant Spacing (spacing between emitters)	0.50 m
Row Direction	East-West
No. of emitters in each row	16
Total No. of Plants	384
Type of irrigation System	Drip irrigation system and Furrow irrigation
Emitter Type	Online Emitter
Emitter Per Plant	1 Emitter
Emitter Discharge	1.46 l/ha
No. of Lateral Per Row	1 Lateral
Water Source	Tube well
Water Source Depth	30 m

Hydraulics of drip irrigation system (Irrigation efficiency)

The overall application efficiency of drip irrigation (Ea) is defined by Vermeiren and Gobling (1980) as follows:

$$Ea = Ks \times Eu$$

Where:

Ks = ratio between water stored and that diverted from the field. It expresses the water storage efficiency of the soil. It takes into account unavoidable deep percolation as well as other losses. Table 3 showed values of Ks for different soil types.

Eu = emission uniformity of drip irrigation system.

Table 3: Water storage efficiency of different types of soil

SI. N.	Types of soil	Water storage efficiency (Ks)
1.	Clay	100
2.	Mixed silt, clay and loamy	95
3.	Loamy	90
4.	Sandy	85

***Source*:** Vermeiren and Gobling (1980)

Irrigation treatments

Five drip irrigation treatments were used in this experiment along with furrow irrigation and one control. The water was applied as per the treatments. During the rainy season irrigation was applied only when necessary. Every drip irrigation treatment contained 12 mm valve made of black low density polyethylene (L.D.P.E) to control the entering water.

Crop water requirement

The crop water requirement was calculated according to Allen *et al*. (1998) using the following formula:

$$ETc = ETo \times Kc$$

Where,

ETc= crop evapotranspiration (cm d^{-1})

Kc= crop coefficient (dimensionless)

ETo = reference crop evapotranspiration (cm d^{-1})

Volume of Irrigation Water Applications

The volume of water applied for treatment plot was computed by the equation:

$$V = q \times n \times To = IWR \times A$$

Where,

V = Volume of water to be applied for each application (l)

To = Time of application for operation of drip irrigation unit for respective treatment (h)

q = Average discharge of emitters in respective treatments (lph).

n = No of emitters per treatment plot.

IWR = Depth of Irrigation water (cm)

A = Area of the plot (m^2)

Irrigation Scheduling

Depth and Interval of irrigation were precisely computed by assessing the irrigation needs for drip irrigation (as computed above) using the equation given below (Karmelli and Keller, 1975).

$$IT = \{L \times Kc \times KP \times CPE\} / IWR$$

Where,

IWR = Depth of irrigation water to be applied (cm)

IT = Irrigation interval, days

L = Level of irrigation (i. e. 100, 80, 60% of crop water requirements).

Kc = crop coefficient.

Kp = pan factor.

PE = pan evaporation (mm/d).

Water application rate

Water application rate of emitter/s was calculated using the following formula,

$$\text{Irrigation Rate (cm/hr)} = \frac{\text{Dripper Discharge (lph)}}{\text{Lateral Spacing (m)} \times \text{Dripper Spacing (m)}}$$

Time of actual operation of irrigation

The time of operation (hr) of drip irrigation system for each treatment plot was computed by using below given relationship,

$$\text{Irrigation time (hr)} = \frac{\text{Water requirement (cm/d)}}{\text{Irrigation rate (cm/hr)}}$$

Crop Attributes

1. Various key observations of practical significances were generated over the growing period of tomato crop, which encompasses plant height, number of fruits, fruit yields per plant, physical dimensions of fruits, weight & volume patterns and the gross marketable yields.
2. Plant height was measured from base of the plant to the tip of the growing point at 30, 45, 60, 90 DAT using measuring tape in all treatment.
3. Numbers of fruits per plant were also observed periodically at the time of pickings to judge the intensity of fruit bearing on plants across different span of time and location within the treatments.
4. Average fruit yields per plants & per rows as well as per treatment were too derived to arrive at Kg/ha yields at last.

Working out water use efficiency (WUE)

Water use efficiency (WUE) is defined as yield of plant product per unit of crop water use, and was important in all areas of plant production. WUE is the outcome of an entire suite of plant and environmental processes operating over the life of a crop to determine both the gross yield and gross amount of water used to produce it. Water use efficiency was worked out for all such combinations and expressed in q/ha-cm as well as Kg/liters of water use, and divided by the gross quantum of irrigation water used consumptively for all the respective treatments.

$$\text{WUE} = \frac{\text{Yield (q/ha)}}{\text{Total amount of water used (cm)}}$$

Economic analysis

The cost of cultivation was worked out by considering various inputs used drip irrigation system and surface irrigation during cultivation of crop. The benefit cost ratio (BCR) was worked out by using the following formula:

$$\text{BCR} = \frac{\text{Gross return (Rs.ha}^{-1}\text{)}}{\text{Total cost of cultivation (Rs.ha}^{-1}\text{)}}$$

Statistical analysis

The data were analyzed using analysis of variance (ANOVA) technique as applicable for Randomized Complete Block Design (Rangaswamy, 2006) [7]. The results were interpreted on the basis of F- test and critical difference at 5% was used for calculating the significant difference between the means of two treatments (Gomez and Gomez, 1984) [5].

Results and Discussion

The results are described in below given segments based on different objectives.

Effect of irrigation treatments on plant height: The data on the effect of irrigation treatments on plant height at 20, 40, 60, and 80 DAS is presented in Table 4. It is clear from the data that, the height of tomato plants at 20, 40, 60, and 80 DAS was significantly influenced by different irrigation treatments. The data indicated that at 20 DAS, the significantly highest plant height (5.689 cm) was recorded under treatment T4 as compared to other treatments. The similar trend was also observed at 40 DAS, 60 DAS, and 80 DAS. The significantly highest plant height, (46.514 cm) was observed at 80 DAS in T4 and the similar trend was observed at the harvesting also. The collective results indicated that the treatment T4 is significantly better than other treatments of the experiment.

Table 4: Effect of Irrigation treatments on tomato plant attributes at 20, 40, 60 and DAS.

Treatments	Plant Height (cm)			
	20 days	**40 days**	**60 days**	**80 days**
T1	5.667	12.275	23.656	36.808
T2	5.553	12.292	22.858	41.761
T3	5.469	12.889	25.017	46.117
T4	5.689	13.822	25.517	46.514
T5	5.589	13.386	25.486	46.147
T6	5.597	13.733	24.653	43.025
C.D.	N/A	N/A	1.353	3.157
SE(m)	0.065	0.422	0.424	0. 989
SE(d)	0.092	0.596	0.599	1.399

Effect of irrigation treatments on yield: The data on the effect of irrigation treatments on fruit yield per plant are presented in Table 5 and graphically depicted in Figure 2. It is clear that fruit yield per plant was influenced by different irrigation treatments and this difference was found to be significant. The data indicated that the significantly highest average fruit yield per plant (1.001kg) was recorded in treatment T4 as compared to other treatments like T1 (0.408 kg), T2 (0.561 kg), T3 (0.817 kg), T5 (0.974 kg) and T6 (0.984 kg). The overall result indicated that the treatment T4 is significantly better than other treatment. Further, the data indicated that the significantly highest average total fruit yield per plant (362.613 q/ha) was also recorded under treatment T4 as compared to other treatments like T1 (209.412 q/ha), T2 (271.427 q/ha), T3 (307.475 q/ha), T5 (348.403 q/ha) and T6 (329.354 q/ha). The overall results indicated that the treatment T4 is significantly better than other treatments.

Table 5: Effect of irrigation treatments on gross fruit yield of tomato

Treatments	Fruit Yield per Plant (Kg)				Total Yield (q/ha)	Water Use Efficiency(q/ha-cm)
	Only 4 picking fruits data					
T1	0.331	1.403	1.348	0.408	209.412	2.391
T2	0.329	1.986	1.776	0.561	271.427	3.098
T3	0.289	2.090	1.929	0.817	307.475	3.510
T4	0.359	2.366	2.318	1.001	362.613	4.139

T5	0.311	2.289	2.232	0.974	348.403	3.977
T6	0.134	2.264	2.108	0.984	329.354	2.635
C.D.	0.126	0.425	0.520	0.425	79.296	0.786
SE(m)	0.039	0.133	0.163	0.133	24.844	0.246
SE(d)	0.056	0.188	0.230	0.188	35.135	0.348

Water use efficiency (WUE)
The WUE is considered as one of the major attribute to reflect the overall effectiveness of various irrigation treatments. The data on the effect of irrigation treatments on WUE of tomato are presented in Table 5 and graphically depicted in Fig. 2. It is clear that, WUE of tomato was significantly influenced by different irrigation methods. The data indicates that the significantly highest WUE of tomato (4.139 q/ha-cm) was recorded under treatment T4 as compared to other treatments like T1 (2.391q/ha-cm), T2 (3.098 q/ha-cm), T3 (3.510 q/ha-cm), T5 (3.977 q/ha-cm) and T6 (2.635 q/ha-cm). The overall result indicated that the treatment T4 was significantly better than other treatments

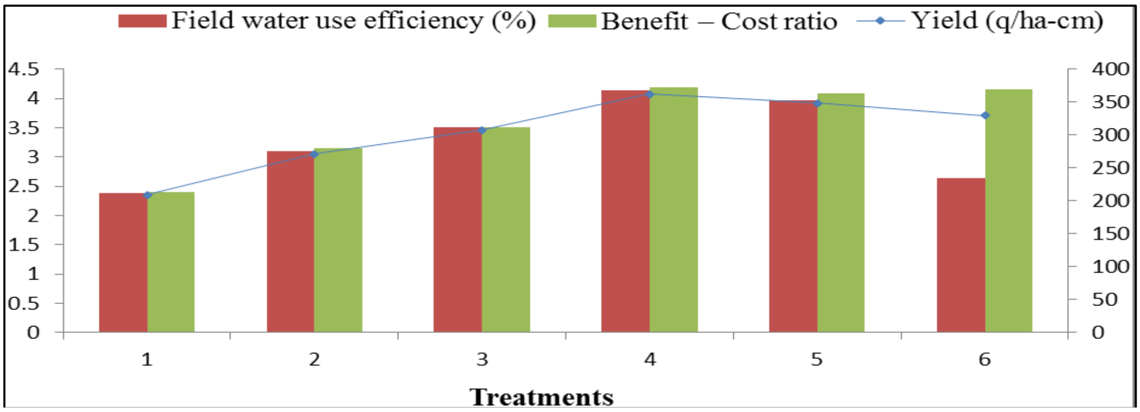

Fig 2: Variability of WUE (Kg/ha-mm) across various treatments

Benefit cost ratio (BCR)
Data from table 6 revealed that maximum B-C ratio has been obtained from the treatment T4. The differences in Benefit–Cost ratio of tomato fruit due to different treatments were found significant. The significantly highest Benefit–Cost ratio of tomato (4.194) was recorded under treatment T4 compared to other treatments likes T1 (2.405), T2 (3.154), T3 (3.516), T5 (4.086) and T6 (4.164). The overall results indicated that the treatment T4 is significantly better than other treatments.

Table 6: Benefit–Cost ratio of various treatments

Sl. No	Description	T1	T2	T3	T4	T5	T6
1	Fixed cost (Rs)	80000	80000	80000	80000	80000	-
	Life (Years)	5	5	5	5	5	-
	Annual cost (Rs)	18000	18000	18000	18000	18000	18000
	Interest @ 8% (Rs)	6400	6400	6400	6400	6400	-
	Repair and maintenance (Rs)	620	620	620	620	620	-
	Total Cost (Rs) (A)	25020	25020	25020	25020	25020	18000
2	Cost of cultivation, (Rs/ha) (B)	62050	61050	62420	61450	60250	61100
3	Seasonal total cost (Rs)C = (A+B)	87070	86070	87440	86470	85270	79100
4	Maximum production (q/ha)	209.412	271.427	307.475	362.613	348.403	329.354
5	Selling price (Rs/q)	1000	1000	1000	1000	1000	1000
6	Income from produce (Rs) (D)	209412	271427	307475	362613	348403	329354
7	Total Net seasonal benefit (Rs) E = (D – C)	122342	185357	220035	276143	263133	250254
8	Benefit – Cost ratio F = (D/C)	2.405	3.154	3.516	4.194	4.086	4.164

Conclusion
The above results indicated that T4 i.e. 4 hours irrigation at 4 days interval resulted in maximum yield, yield attributing characters and benefit cost ratio. Further, it can be concluded from the above experiment that drip irrigation is far better in tomato crop as compared to furrow irrigation, because it not only resulted in higher yield and profit, but also saved lots of irrigation water that is one of the most crucial input for agricultural production.

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