

Research Article

EFFECT OF DIFFERENT IRRIGATION REGIMES AND FERTIGATION LEVELS ON YIELD OF TOMATO UNDER NATURALLY-VENTILATED POLYHOUSE AND OPEN FIELD

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Abstract- The experiment was conducted to evaluate the yield response of tomato (*Solanum lycopersicum* L.) to different irrigation regimes and fertigation levels under polyhouse and open field conditions. The treatment consisted of three irrigation regimes 0.95 ETc, 0.70 ETc, and 0.45 ETc. and three fertigation levels 125% RD, 100 %RD and 75% RD. The experimental design was split plot with six replications. The biometric attribute plant height was measured at harvest condition and yield attribute viz., average weight of fruit, yield in kg per plant, kg per m² and yield in t/ha. It is seen from the data pooled over two years that the plant height of tomato under polyhouse and open field was maximum (240.5cm and 133.9 cm) due to 0.95 ETc (1) irrigation level over other irrigation levels. Data on plant height was not significant. The minimum plant height (227.81 and 128.86 cm) under polyhouse and open field over other fertigation levels. The pooled data show that the average weight of a fruit of tomato under polyhouse condition. Data on effect of different irrigation levels on average weight of fruit of tomato were statistically not significant under open field. The pooled data shows that the effect of fertigation levels on yield in kg per plant, kgm⁻² and tha⁻¹ was not significant under polyhouse and open field. The pooled data shows that the effect of fertigation levels on yield in kg per plant, kgm⁻² and tha⁻¹ was not significant under polyhouse and open field. The pooled data shows that the effect of fertigation levels on yield in kg per plant, kgm⁻² and tha⁻¹ was not significant under polyhouse and open field. The average water use efficiency of tomato was in the range of 49.23 to 71.27 kg/m²-m⁻¹ and 13.55 to 31.15 kg/m²-m⁻¹ under polyhouse and open field conditions.

Keywords- drip irrigation, fertigation and water use efficiency.

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Introduction

Tomato is a warm season plant. It can withstand with severe frost conditions. Temperature and light intensity affect germination, vegetative growth, fruit set, pigmentation and nutritive value of this fruits. The minimum temperature for dermination of seeds range from 8° to 10°C. The night temperature is the critical factor in fruit setting with the optimum range of 16°C to 22°C. Fruits fail to set at 12°C or below. Under greenhouse conditions tomato crop can grow for long duration (10-12 months) by cooling during summer months (April to June or July) and by heating the greenhouse during peak winter months (December and January) in northern parts of the country [6]. Creating high values for agricultural crops by using low water inputs and high fertilizer efficiencies is one of the methods used in addressing the environmental and resources problems. Protected cultivation techniques including nethouse technology provide optimum environmental medium for better crop growth in order to gain maximum yield and high-quality products. These require comparatively less land area for agricultural production system resulting in increased land productivity and facilitate year-round production of crops. Many studies were reported on tomato cultivation under green/nethouse conditions with different advantages ref as [3].

Materials and Methods

The field experiment was conducted at the Instructional Farm of Department of Irrigation and Drainage Engineering, Dr. Annasaheb Shinde College of Agricultural

Engineering and Technology, Mahatma Phule Krishi Vidyapeeth, Rahuri during the period from November 2013 to May 2014 and November 2014 to May 2015. Geographically the farm lies at 74° 38' 00" E longitudes and 19° 20' 00" N latitude at 557 m above the mean sea levels in the central campus of Mahatma Phule Krishi Vidyapeeth, Rahuri.

Climatological data

The meteorological data on maximum and minimum temperature, minimum and maximum relative humidity, actual sunshine hour and daily wind speed etc. weather parameter during the crop growth period (30 November 2013 to 5th May 2014) and (1 December 2014 to 5th May 2015) were collected on daily basis from the meteorological observatory situated at the Instructional Farm of Department of Irrigation and Drainage Engineering, Mahatma Phule Krishi Vidyapeeth, Rahuri.

Water source The water for the experiment was pumped from an open dug well situated at the Instructional Farm of Department of Irrigation and Drainage Engineering.

Experimental Details

Two experiments were conducted under this investigation for two consecutive years. The details are given below.

Response of tomato to irrigation regimes and fertigation levels under polyhouse

condition and open field conditions. Two experiments was conducted under this investigation for two consecutive years. This experiment was carried out in split plot design with nine treatments based on different combinations of the irrigation levels and fertigation levels. Crop verity was Hy. Phule Raja. Plot size was 2.7 m X 1 m and plant spacing was 60 cm x 45 cm. Number of plants per bed was 12. The area of polyhouse and open field was 25 m x 20 m. The soil media in polyhouse consisted of red soil, farm yard manure (FYM) and sand. Irrigation was given at daily basis over the whole crop period of tomato by drip irrigation method. And fertigation was given at an alternate day. The fogger system had automatic controller to operate the system for 30 second ('ON' period) after the interval of ('OFF' period) period about 8 minutes. Fogger system was operating at 2-2.5 kg/cm².

Treatment Details

Factor A : Shading percentage	Factor	B:	Irrigation
	levels		
I ₁ = 0.95 ETc	F₁= 125%	6 RD	
l ₂ = 0.70 ETc	F ₂ = 100	% RD	
I ₃ = 0.45 ETc	F ₃ = 75%	RD	
	Factor A : Shading percentage I ₁ = 0.95 ETc I ₂ = 0.70 ETc I ₃ = 0.45 ETc	$ \begin{array}{lll} \mbox{Factor A : Shading percentage} & \mbox{Factor} & \mbox{levels} \\ \mbox{I}_1 = 0.95 \mbox{ ETc} & \mbox{F}_1 = 125\% \\ \mbox{I}_2 = 0.70 \mbox{ ETc} & \mbox{F}_2 = 100\% \\ \mbox{I}_3 = 0.45 \mbox{ ETc} & \mbox{F}_3 = 75\% \end{array} $	$\begin{tabular}{lllllllllllllllllllllllllllllllllll$

In order to study the response of tomato to irrigation regimes and fertigation levels under polyhouse and open field condition, it was necessary to collect data on the plant and yield attributes of the tomato crop. These data were collected during the experimental period and analyzed further for interpretations. The crop growth parameters including plant height were recorded at harvest condition with 5 randomly selected plants from each plot. These plants were properly labeled and growth parameters were monitored on them. The observations include average weight of tomato fruit, total yield of tomato fruit. The water use efficiency for each treatment was determined from the data on corresponding yield and volume of water applied using the following equation:

$$WUE = \frac{\sum Y}{WR}$$
[1]

Where, WUE = Water use efficiency (t/ha-cm)

Y = Yield of crop product (t/ha), WR = Total depth of water applied in the field (cm) In order to compare the treatments of different shading percentages with irrigation levels separate analysis split plot design was prepared. characteristics, water saving and water use efficiency under different irrigation levels and fertigation levels. The growth and yield characteristics of tomato were periodically monitored and recorded during the crop growth period.

Plant height: It is seen from the data pooled over two years that the plant height of tomato under polyhouse and open field was maximum (240.5cm and 133.9 cm) due to 0.95 ETc (I₁) irrigation level over other irrigation levels. Data on plant height was not significant. The minimum plant height was found in 0.45 ETc (I₃) these are presented in [Table-1]. It is seen from the data pooled over two years that the fertigation level 125% RD (F₁) recorded the maximum and not significant plant height (227.81 and 128.86 cm) under polyhouse and open field over other fertigation levels as presented in [Table-1]. Heights of plant were significantly influenced by different levels of N and K fertigation. Better growth of plant height due to increasing fertigation levels as compared to the conventional fertilization. Highest plant heights (146.10 cm) were recorded in 100% fertigation of RD of N and K, whereas conventional fertilization recorded the minimum plant height (110.63 cm). Positive effect of fertigation on plant height of tomato grown inside polyhouse. Ref as [4]. The interaction of both the factors in respect of plant height was not significant.

Yield Characteristics:

The pooled data show that the average weight of a fruit of tomato was maximum (123.83 g) due to 0.95 ETc irrigation level over other irrigation levels. It was at par with all irrigation levels. Irrigation level of 0.45 ETc recorded minimum fruit weight of tomato under polyhouse condition. Data on effect of different irrigation levels on average weight of fruit of tomato were statistically not significant under open field are presented in [Table-2]. The interaction of both the factors in respect of average weight a fruit was significantly influenced. It was found that the interactions of 0.95% ETc x 100% RD (I₁ x F₂) recorded the maximum average weight of fruit (125.68 g) which was at par of all interaction except 0.45 ETc x 75 % RD (I₃ x F₃) under polyhouse conditions these are presented in [Table-3]. Tomato plant grown under polyhouse was observed to be earlier in flowering and fruit setting by about 3 and 5 days, respectively when compared to the crop raised under open field conditions. The early and higher fruit weight and yield of tomato crops inside polyhouse was mainly because of better microclimate than the open field observed during winter months. Therefore, the polyhouse environment may provide a new scope for commercial production of high value vegetable crops like tomato. Ref as [3].

Result and Discussion

The field investigation was carried out to compare the growth and yield attributing

Table-1 Plant height of tomato at harvest as affected b	y different treatments for the yea	ar 2013-14, 2014-15 and p	ooled under polyhouse and open	field.

Plant height cm (At harvest)								
	Poly house							
2013-14	2014-15	Pooled	2013-14	2014-15	Pooled			
	,	A. Irrigation level (I)		•				
223.56	257.44	240.5	124.17	143.78	133.97			
205.06	236.22	222.64	115.00	135.78	125.39			
192.44	216.94	204.69	107.89	125.78	116.83			
2.09	2.22	1.62	1.87	3.31	1.82			
6.61	7.003	NS	5.90	10.44	NS			
	B	. Fertigation level (F)		•				
211.56	244.06	227.81	118.33	139.39	128.86			
207.78	237.11	222.44	115.39	133.83	124.61			
201.72	229.44	215.58	113.33	132.11	122.72			
1.91	1.90	1.34	1.83	1.80	1.26			
5.51	5.50	NS	NS	5.21	NS			
		C. Interaction (IxF)		•	•			
5.01	5.04	2.44	4.72	5.26	2.13			
NS	10.94	NS	NS	NS	NS			
	2013-14 223.56 205.06 192.44 2.09 6.61 211.56 207.78 201.72 1.91 5.51 5.01 NS	Poly house 2013-14 2014-15 223.56 257.44 205.06 236.22 192.44 216.94 2.09 2.22 6.61 7.003 201.72 229.44 1.91 1.90 5.51 5.50 5.01 5.04 NS 10.94	Plant height of Poly house 2013-14 2014-15 Pooled A. Irrigation level (I) 223.56 257.44 240.5 205.06 236.22 222.64 192.44 216.94 204.69 2.09 2.22 1.62 6.61 7.003 NS B. Fertigation level (F) 211.56 244.06 227.81 207.78 237.11 222.44 201.72 229.44 215.58 1.91 1.90 1.34 5.51 5.50 NS C. Interaction (IxF) 5.01 5.04 2.44 NS 10.94 NS	Plant height cm (At harvest) Poly house 2013-14 2014-15 Pooled 2013-14 2013-14 2014-15 Pooled 2013-14 A. Irrigation level (I) 223.56 257.44 240.5 124.17 205.06 236.22 222.64 115.00 192.44 216.94 204.69 107.89 2.09 2.22 1.62 1.87 6.61 7.003 NS 5.90 B. Fertigation level (F) 211.56 244.06 227.81 118.33 207.78 237.11 222.44 115.39 201.72 229.44 215.58 113.33 1.91 1.90 1.34 1.83 5.51 5.50 NS NS C. Interaction (IxF) 5.01 5.04 2.44 4.72 NS 10.94 NS NS	Plant height cm (At harvest) Poly house Open field 2013-14 2014-15 Pooled 2013-14 2014-15 A. Irrigation level (I) A. Irrigation level (I) 124.17 143.78 205.06 236.22 222.64 115.00 135.78 192.44 216.94 204.69 107.89 125.78 2.09 2.22 1.62 1.87 3.31 6.61 7.003 NS 5.90 10.44 B. Fertigation level (F) 211.56 244.06 227.81 118.33 139.39 207.78 237.11 222.44 115.39 133.83 201.72 229.44 215.58 113.33 132.11 1.91 1.90 1.34 1.83 1.80 5.51 5.50 NS NS 5.21 C. Interaction (IxF) 5.01 5.04 2.44 4.72 5.26 NS 10.94 NS NS NS NS			

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Treatments	Average weight of a fruit, (g)							
		Poly house						
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled		
	•	A	. Irrigation level (I)					
I₁=0.95 ETc	117.53	130.14	123.83	88.08	81.53	84.80		
l ₂ =0.70 ETc	111.01	94.27	102.64	72.97	64.57	68.77		
l₃=0.45 ETc	107.28	64.55	85.91	63.03	50.58	56.80		
S.E.±	2.273	3.713	13.84	1.232	1.286	0.95		
C.D. at 5%	7.163	11.69	41.52	3.881	3.99	NS		
	•	B.	Fertigation level (F)					
F1=125 % RD	114.08	104.0	109.07	78.86	72.95	75.90		
F ₂ =100 % RD	112.20	97.10	104.65	75.09	66.87	70.98		
F ₃ =75 % RD	109.54	87.80	98.67	70.13	56.86	63.49		
S.E.±	2.216	3.162	1.97	2.202	2.188	1.56		
C.D. at 5%	NS	9.131	NS	6.36	6.31	NS		
	•	C	. Interaction (IxF)					
S.E.±	5.774	8.385	12.31	5.499	5.47	2.72		
C.D. at 5%	NS	NS	40.15	NS	11.39	NS		

Table-3 Interaction effect of irrigation and fertigation levels on fruit weight (g) of tomato under polyhouse condition.

Fertigation levels (F)	Irrigation levels (I)						
	l₁=0.95 ETc	I₂=0.70 ETc	I₃= 0.45 ETc	Mean			
F₁=125 % RD	122.77	111.25	93.185	109.07			
F ₂ =100 % RD	125.68	102.43	85.83	104.65			
F3=75 % RD	123.05	94.24	78.72	98.67			
Mean	123.83	102.64	85.91	104.13			
l x F	S.E.± = 12.31, C.D. at 5% = 40.15						

The pooled data shows that the effect of irrigation levels on yield in kg per plant, kgm⁻² and tha⁻¹ was statistically not significant under polyhouse and open field. The pooled data shows that the effect of fertigation levels on yield in kg per plant, kgm⁻² and tha⁻¹ was not significant under polyhouse and open field. Different fertigation treatments 100% RD of N and K recorded the highest yield attributes and marketable fruit yield (122.59 t/ha) of tomato compared to 75% and 50% levels of fertigation and significantly superior to the conventional fertilization (control). Results revealed that marketable fruit yield between 50% fertigation levels and conventional fertilization were at par indicating that fertigation saved

fertilizers to the tune of 50% as compared to the conventional control. It was concluded from the study that drip fulfilment at 100% ER with 100% supplementation of RD of N was found to be beneficial for higher growth, yield, quality of tomato grown inside naturally ventilated polyhouse under the agroclimatic conditions. Ref as [2]. The interaction of 0.95ETc x 125 % RD (I₁ x F₁) was maximum yield in kg per plant (8.04) and significantly superior to the other interactions under polyhouse conditions. The interaction effect on yield in kgm⁻² and tha⁻¹ was not significant under polyhouse and open field as presented in [Table-4,5,6 and 7].

Table-4 Fruit yield of tomato (kgplant⁻¹) as affected by different treatments for the year 2013-14, 2014-15 and pooled means under polyhouse and open field conditions.

Treatments		Polyhouse	Open field			
	Yield, kg plant ^{.1}		Yield , kg plant ⁻¹			
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled
			A. Irrigation level (I)			
I₁=0.95 ETc	6.60	7.10	6.85	2.05	2.16	2.10
I ₂ =0.70 ETc	3.93	3.82	3.87	1.26	1.28	1.27
I ₃ = 0.45 ETc	2.48	1.91	2.19	0.86	0.81	0.83
S.E.±	0.28	0.23	0.19	0.076	0.070	5.05
C.D. at 5%	0.88	0.73	NS	0.239	0.22	NS
	I	B	. Fertigation level (F)			
F1=125 % RD	5.11	5.15	5.13	1.61	1.68	1.64
F ₂ =100 % RD	4.27	4.23	4.25	1.37	1.37	1.37
F3 =75 % RD	3.62	3.45	3.53	1.19	1.20	1.19
S.E.±	0.137	0.046	4.35	0.069	0.064	0.046
C.D. at 5%	0.396	0.133	NS	0.199	0.186	NS
			C. Interaction (IxF)		•	
S.E.±	0.414	0.231	0.24	0.181	0.169	7.82
C.D. at 5%	NS	0.556	0.73	NS	NS	NS

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Fertigation levels (F)		Irrigation level	ls (l)			
-	I₁=0.95 ETc	I₂=0.70 ETc	l₃= 0.45 ETc	Mean		
F1=125 % RD	8.04	4.76	2.58	5.13		
F ₂ =100 % RD	6.81	3.76	2.17	4.25		
F ₃ = 75 % RD	5.68	3.1	1.81	3.53		
Mean	6.85	3.87	2.19	4.30		
l x F	S.E.± =0.24 , C.D. at 5% = 0.73					

Table-6 Fruit yield of tomato (kgm⁻²) as affected by different treatments for the year 2013-14, 2014-15 and pooled means under polyhouse and open field.

		Polyhouse		Copen field kg m ⁻²				
Treatments		kg m ^{.2}						
	2013-14	2014-15	Pooled	2013-14	2014-15	Pooled		
		A	. Irrigation level (I)					
I1 = 0.95ETc	37.91	38.54	38.22	12.64	12.77	12.70		
I2=0.70 ETc	26.36	26.22	26.29	7.45	7.48	7.46		
I₃= 0.45ETc	17.54	16.83	17.18	4.10	4.04	4.07		
S.E.±	1.327	1.23	0.87	0.151	0.161	0.10		
C.D. at 5%	4.18	3.89	NS	0.475	0.48	NS		
		В.	Fertigation level (F)					
F1=125 % RD	31.19	31.23	31.21	9.60	9.69	9.64		
F2=100 % RD	27.01	26.96	26.98	7.89	7.90	7.89		
F3=75 % RD	23.62	23.40	23.51	6.70	6.71	6.70		
S.E.±	0.56	0.52	0.37	0.216	0.21	0.14		
C.D. at 5%	1.637	1.50	NS	0.625	0.61	NS		
C. Interaction (IxF)								
S.E.±	1.80	1.66	0.63	0.546	0.36	0.24		
C.D. at 5%	NS	NS	NS	1.14	1.06	NS		

Table-7 Fruit yield of tomato (t ha-1) as affected by different treatments for the year 2013-14, 2014-15 and pooled means under polyhouse and open field condition.

		Polyhouse		Open field Yield , t ha ^{.1}			
Treatments		Yield , t ha ^{.1}					
	2013-114	2014-15	Pooled	2013-14	2014-15	Pooled	
		A. Irrig	ation level (I)				
I₁=0.95 ETc	379.15	385.39	382.27	126.39	127.72	127.05	
l ₂ =0.70 ETc	263.60	262.21	262.90	74.49	74.77	74.63	
I₃=0.45 ETc	175.37	168.27	171.82	41.00	40.44	40.72	
S.E.±	13.27	12.35	8.70	1.50	1.61	1.06	
C.D. at 5%	41.82	38.91	NS	4.75	4.83	NS	
	•	B. Fertig	ation level (F)	•	•	-	
F1=125 % RD	311.87	312.31	312.09	96.02	96.86	96.44	
F ₂ =100% RD	270.08	269.58	269.83	78.89	78.95	78.92	
F3 =75 % RD	236.17	233.97	235.07	66.97	67.11	67.04	
S.E.±	5.66	5.21	3.79	2.16	2.13	1.49	
C.D. at 5%	16.37	15.06	NS	6.24	6.39	NS	
	•	C. Inte	raction (IxF)	•	•	-	
S.E.±	18.02	9.03	6.34	5.45	3.69	2.47	
C.D. at 5%	NS	NS	NS	11.45	10.65	NS	

Table-8 Average water use efficiency of tomato under different treatments of irrigation and fertigation levels under polyhouse condition.

Treatments	Yield, kg m [.] 2			WUE, kg /m ^{.2} -m ^{.1}			
	2013-14	2014-15	Average	2013-14	2014-15	Average	
I1xF1 (0.95ETc x 125 %RD)	43.43	44.17	43.80	81.86	60.67	71.27	
I1xF2 (0.95ETc x 100% RD)	37.14	37.81	37.48	69.99	51.94	60.97	
I1xF3 (0.95ETc x 75% RD)	33.17	33.64	33.41	62.52	46.21	54.37	
I ₂ xF ₁ (0.70ETc x 125 %RD)	29.53	29.58	29.56	75.52	55.15	65.34	
I ₂ xF ₂ (0.70ETc x 100 % RD)	26.51	26.39	26.45	67.81	49.21	58.51	
I ₂ xF ₃ (0.70ETc x 75% RD)	23.04	22.69	22.87	58.92	42.30	50.61	
I ₃ xF ₁ (0.45ETc x 125 %RD)	20.6	19.95	20.28	81.97	57.86	69.92	
I ₃ xF ₂ (0.45ETc x 100% RD)	17.37	16.67	17.02	69.13	48.35	58.74	
I ₃ xF ₃ (0.45ETc x 75 %RD)	14.64	13.86	14.25	58.25	40.21	49.23	

Water use efficiency under polyhouse and open field: The average water use efficiency of tomato was in the range of 49.23 to 71.27 kg/m²-m⁻¹ and 13.55 to

31.15 kg/m²-m⁻¹ under polyhouse and open field conditions as presented in [Table-8] and [Table-9].

Table-9 Average water use efficiency of tomato under different treatments of irrigation and fertigation levels under open field.

Treatments	Yield, kg m²			WUE, kg /m-2-m-1		
	2013-14	2014-15	Average	2013-14	2014-15	Average
I ₁ xF ₁ (0.95ETc x 125 %RD)	14.86	15.14	15.00	31.63	30.66	31.15
I ₁ xF ₂ (0.95ETc x 100% RD)	12.42	12.49	12.46	26.44	25.30	25.87
I ₁ xF ₃ (0.95ETc x 75% RD)	10.6	10.69	10.65	22.56	21.65	22.11
I ₂ xF ₁ (0.70ETc x 125 %RD)	8.87	8.91	8.89	25.21	24.08	24.65
I ₂ xF ₂ (0.70ETc x 100 % RD)	7.27	7.30	7.29	20.66	19.73	20.20
I ₂ xF ₃ (0.70ETc x 75% RD)	6.21	6.22	6.22	17.65	16.80	17.23
I ₃ xF ₁ (0.45ETc x 125 %RD)	5.07	5.01	5.04	21.68	20.32	21.00
I ₃ xF ₂ (0.45ETc x 100% RD)	3.95	3.89	3.92	16.89	15.79	16.34
I ₃ xF ₃ (0.45ETc x 75 %RD)	3.28	3.23	3.26	14.02	13.08	13.55

Conclusion

The experiments were conducted to know the influence of different irrigation levels, with fertigation levels on growth and yield of tomato. The results of the experiments were analyzed and following specific conclusions were derived. The yield of tomato is enhanced when cultivated in polyhouse compared to open field condition. The yield of tomato is more in polyhouse as compared to open field. The irrigations to the tomato should be scheduled daily 0.95 ETc in polyhouse. The fertigation to the tomato should be scheduled alternate day 125% RD in polyhouse.

Application of research: To study the yield response of tomato (*Solanum lycopersicum* L.) to different irrigation regimes and fertigation levels under polyhouse and open field conditions.

Research Category: Irrigation Regimes and Fertigation

Abbreviations:

RD: Recommended Dose gm: Gram Kg: Kilogram

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Conflict of Interest: None declared

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