Int.J.Curr.Microbiol.App.Sci (2017) *6*(12): 2878-2889

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 6 Number 12 (2017) pp. 2878-2889**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2017.612.335

Effect of Deficit Irrigation and Plastic Mulch on Yield and Water Use Efficiency of Drip Irrigated Capsicum under Naturally Ventilated Polyhouse

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Keywords

Deficit irrigation, Drip irrigation, Naturally ventilated polyhouse, Plastic mulch, Water use efficiency and capsicum crop.

Article Info

Accepted:
21 October 2017
Available Online:
10 December 2017

A B S T R A C T

The effect of deficit irrigation on yield and water use efficiency of drip irrigated capsicum under the naturally ventilated polyhouse was studied through field experiment. In this study, six different levels of drip irrigation equivalent to 100%, 90%, 80%, 70%, 60% and 100% (control without mulch) of crop evapotranspiration with four replications were considered for their effect on crop yield and water use efficiency inside the naturally ventilated polyhouse. Capsicum (*Capsicum annuum* L. Indra Variety) plants were grown under the naturally ventilated polyhouse. The maximum crop yield was found in case of 80 % irrigation level (42.64 t/ha) and the maximum water use efficiency was also recorded in the same treatment (1296.48 kg/ha-cm). Thus, the results revealed that all the vegetative parameters, quantity parameter and water use efficiency were found maximum at drip irrigation level equal to 80 % of crop evapotranspiration under the naturally ventilated polyhouse.

Introduction

Polyhouse cultivation gives higher yield, higher productivity, better quality produce and production throughout the year (Neelam and Rajput, 2010). Capsicum, also known as sweet pepper, bell pepper or *Shimla Mirch* is one of the popular vegetables grown throughout India. It is rich in Vitamin A (8493 IU), Vitamin C (283 mg) and minerals like Calcium (13.4 mg), Magnesium (14.9 mg) Phosphorus (28.3 mg) Potassium, (263.7 mg) per 100 g fresh weight. Capsicum is a cool season crop, but it can be grown round the year using protected structures where temperature and relative humidity (RH) can be manipulated. This crop requires day temperature of 25-30˚C and night temperature of 18-20˚C with relative humidity of 50- 60 %. If temperature exceeds 35˚C or falls below 12˚C, fruit setting is affected (Shankara *et al.*, 2011).

India is the second largest producer of vegetables in the world and the concerted efforts of vegetable research and emergence of corporate sector in vegetable seeds have contributed immensely in enhancing productivity and production of vegetables in our country but still there exists a gap of 10.1% in national productivity in comparison to global scenario. Further, 62.1% (18 out of

29 states) states in the country are having lower productivity in comparison to national productivity of vegetable 17.8 t/ha (Anonymous, 2016). Mulch is a covering placed over the soil around the plants. Plastic mulch on the surface of the soil causes change in the microclimate on its vicinity.

This results in moisture conservation, less soil compaction and higher CO_2 levels around plants (Mane and Umrani, 1981). Mulching is an effective method of manipulating the crop-growing environment to increase crop yield and improve product quality by controlling soil temperature, retaining soil moisture and reducing soil evaporation (Chakraborty *et al.*, 2008).

Sharma *et al.*, (1990) found that application of maize stalk mulching increased residual soil moisture in sandy loam soil. Olasantan (1999) and Fabrizzi *et al.*, (2005) reported that soil temperature was increased during colder weather and decreased during warmer weather in mulched condition compared to in non-mulched condition. Some other benefits of mulching such as weed control, reduction of soil runoff and erosion, and improvement of plant earliness have also been recognized widely by both researchers and farmers (Dong *et al.*, 2009; Jordan *et al.*, 2010).

The drip irrigation adoption increases of water use efficiency (60-200 %), saves water (20-60 %), reduces fertilization requirement (20-30 %) through fertigation, produces better quality crop and increases yield (7-25 %) as compared with conventional irrigation (Kaushal *et al.*, 2012). Drip is an irrigation technology known to increase the control of water application and offers several advantages to growers. It reduces soil evaporation and weed population, increases plant transpiration, and when well-managed, excessive water drainage is unlikely to occur, thus allowing nutrients to be retained in the root zone for prolonged periods. Moreover, drip offers an opportunity to inject soluble fertilizers combined with irrigation, a process known as fertigation (Cabrera *et al.*, 2016).

The drip irrigation adoption increases of water use efficiency (60-200 %), saves water (20-60 %), reduces fertilization requirement (20-30 %) through fertigation, produces better quality crop and increases yield (7-25 %) as compared with conventional irrigation (Kaushal *et al.*, 2012). Capsicum yields in open field cultivation ranges between 20-40 t/ha, where as in a greenhouse the yield range is from 100-120 t/ha (Thangam *et al.*, 2013).

Water productivity (kg/m^3) is defined as crop yield (kg) per accumulated actual evapotranspiration for the growing season (m^3) (World Bank, 2003). Thereby, the objectives of current research was to assess the effect of deficit irrigation and plastic mulch on yield and water use efficiency of capsicum crop under naturally ventilated polyhouse.

Materials and Methods

A naturally ventilated polyhouse was constructed at the Plasticulture farm of College of Technology and Engineering, MPUAT Udaipur (at the elevation 582.17 m above mean sea level, 24º 35'31.5" to 24º 35'38.5" N-latitude, 73º 44'18.2" to 73º 44'21.1" E-longitude). The Udaipur comes under dry, sub-humid agro-climatic region. It receives an average annual rainfall of 654.3 mm, most of the received during the period of July to September. The maximum temperature goes as high as 46 °C during summer and minimum as below as 5 °C during winter months. The atmospheric humidity is high from June to October. The experiment was conducted during the period of March, 2017 to August, 2017 in randomized block design with four replications under the naturally ventilated polyhouse. Thereafter, six treatments were also being randomly arranged in the equally sized beds of 8 m × 1 m area. The total are of the experimental field size was 192 m^2. The deficit irrigation treatments were given below:

T_1: Drip irrigation with 100% of ET_c with mulch

T_2: Drip irrigation with 90% of ET_c with mulch

T_3: Drip irrigation with 80% of ET_c with mulch

T_4: Drip irrigation with 70% of ET_c with mulch

T_5: Drip irrigation with 60% of ET_c with mulch

T_6: Drip irrigation with 100% of ET_C without mulch (Control)

The observations were recorded on biometric observations like plant height (30, 60, 90, 120,150 DAT), no. of leaves per plant (30, 60, 90, 120,150 DAT), time required for first harvest, reproductive parameters like number of flowers per plant (60, 90, 120,150 DAT), number of fruits per plant (60, 90, 120,150 DAT), time taken for flower initiation, per cent fruit set, and quality parameters like individual fruit weight (g), fruit yield per tagged plant, etc. and water use efficiency.

Per cent fruit set

Ten unopened buds were tagged at random in each of the plant under observation. The number of fruit set from the tagged buds was recorded periodically and per cent fruit set was estimated by formula

$$\text{Percent fruit set}(\%) = \frac{\text{Number of fruits set}}{\text{Number of flowers tagged}} \times 100 \quad (2.1)$$

Crop water use efficiency is the ratio of crop yield to the amount of water depleted by the crop in the process of evaporation.

$$WUE = \frac{Y}{WR} \quad (2.2)$$

Where,

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

Results and Discussion

All the biometric and reproductive parameters differed significantly due to different irrigation treatments. The plant height, number of leaves, time required for first harvest were maximum under T_3 at all stages of crop growth viz., 30, 60, 90, 120 and 150 DAT. The number of flowers and fruits per plant was higher under T_3 at all stages of crop growth viz., 60, 90, 120 and 150 DAT (days after transplanting).

The maximum (180 cm and 57.28) plant height and no. of leaves presented and represented in Table 1, 2 and Figure 1 and 2, maximum (17.78 and 11.31) number of flowers and fruits were recorded under T_3 at 150 DAT presented and represented in Table 4, 5 and Figure 4 and 5, respectively. Similar findings were recorded by Arya *et al.*, (2017).

The maximum time taken for flower initiation (26.00) and that for first harvest (60.00) were recorded under T_3 presented and represented in Table 3 and Figure 3. The maximum (51.07%) fruit set was recorded under T_3 presented and represented in Table 5 and Figure 6. individual fruit weight (94.33 g), fruit yield per plant (1065.98 gm), fruit yield per sqm area (4263.93 gm), fruit yield (42.64 ton/ha) and water use efficiency (1296.48 kg/ha-cm) shown in Table 6 and 7 and Figure 7, 8, 9, 10 and 11. Among the different irrigation treatments maximum values were recorded in T_3 for all observations.

Table.1 Effect of deficit irrigation on plant height of capsicum crop

Treatments	Mean plant height, (cm)				
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT
T_1	68.55	92.55	104.95	121.40	169.90
T_2	70.65	95.15	108.35	134.90	174.90
T_3	73.25	97.75	115.00	152.80	180.00
T_4	68.20	90.85	101.50	117.00	167.75
T_5	65.00	86.10	96.50	100.00	157.00
T_6	66.20	89.35	98.80	112.45	164.05
$SE_m\pm$	**1.04**	**1.58**	**1.45**	**2.41**	**2.14**
CD (p = 0.05)	**3.13**	**4.77**	**4.38**	**7.28**	**6.45**

Table.2 Effect of deficit irrigation on number of leaves of capsicum crop

Treatments	Mean number of leaves per plant				
	30 DAT	60 DAT	90 DAT	120 DAT	150 DAT
T_1	16.15	22.43	31.87	41.24	51.54
T_2	17.10	24.89	33.49	42.81	54.38
T_3	19.70	28.00	36.34	47.13	57.28
T_4	16.10	22.10	28.25	35.53	45.06
T_5	15.90	20.00	25.00	31.26	40.56
T_6	15.65	21.23	26.80	33.24	41.05
$SE_m\pm$	**0.63**	**0.79**	**0.49**	**0.43**	**0.50**
CD (p = 0.05)	**1.89**	**2.39**	**1.49**	**1.29**	**1.51**

Table.3 Effect of deficit irrigation on time taken for flower initiation and on first harvest of capsicum crop

Treatments	Number of days to flowering	Number of days to harvest
T_1	28.00	64.75
T_2	27.25	62.75
T_3	26.00	60.00
T_4	28.75	67.75
T_5	31.50	71.50
T_6	30.00	69.25
SEm±	**1.05**	**1.74**
CD (p=0.05)	**3.17**	**5.25**

Table.4 Effect of deficit irrigation on number of flowers per plant of capsicum crop

Treatments	Mean number of flower per plant			
	60 DAT	90 DAT	120 DAT	150 DAT
T_1	6.77	9.88	12.08	15.28
T_2	8.23	10.48	12.58	16.08
T_3	9.21	11.98	15.18	17.78
T_4	6.45	9.48	11.68	14.48
T_5	6.00	8.68	10.78	12.98
T_6	6.35	9.08	11.28	13.88
SEm±	**0.09**	**0.07**	**0.18**	**0.15**
CD (p=0.05)	**0.27**	**0.22**	**0.55**	**0.45**

Table.5 Effect of deficit irrigation on number of fruits per plant and percent fruit set of capsicum crop

Treatments	Number of fruits per plant	Percent fruit set (%)
T_1	8.76	43.82
T_2	9.36	47.16
T_3	11.31	51.07
T_4	8.23	40.34
T_5	7.03	32.17
T_6	7.63	36.91
SEm±	**0.21**	**0.80**
CD (p=0.05)	**0.63**	**2.42**

Table.6 Effect of deficit irrigation on quantity parameters of capsicum crop

Treatments	Individual fruit weight (gm)	Fruit yield/plant (gm)	Fruit yield/sqm area (gm)	Fruit yield (ton/ha)
T_1	74.33	651.14	2604.57	26.05
T_2	83.43	780.99	3123.94	31.24
T_3	94.33	1065.98	4263.93	42.64
T_4	67.12	552.40	2209.61	22.10
T_5	42.53	298.98	1195.91	11.96
T_6	56.34	429.87	1719.47	17.19
SEm±	**4.44**	**43.28**	**173.13**	**1.73**
CD (p=0.05)	**13.38**	**130.47**	**521.87**	**5.22**

Table.7 Effect of different treatments on water use efficiency

Treatments	Water use efficiency kg/ha-cm
T_1	633.55
T_2	844.32
T_3	1296.48
T_4	767.83
T_5	484.84
T_6	327.45

Fig.1 Effect of deficit irrigation on plant height

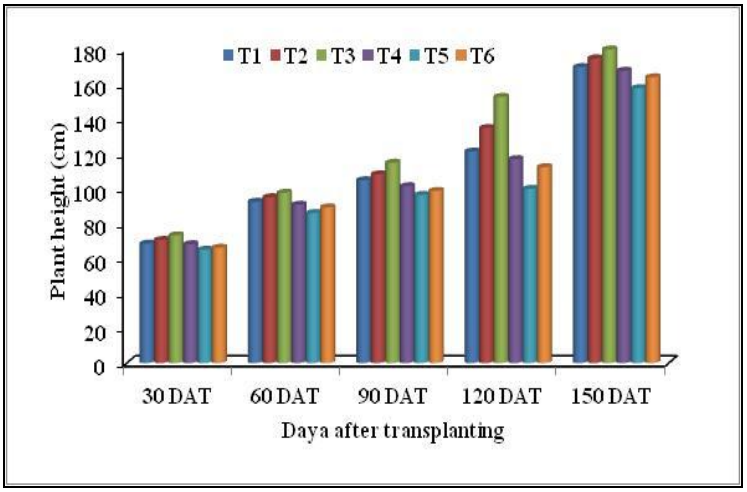


Fig.2 Effect of deficit irrigation on number of leaves

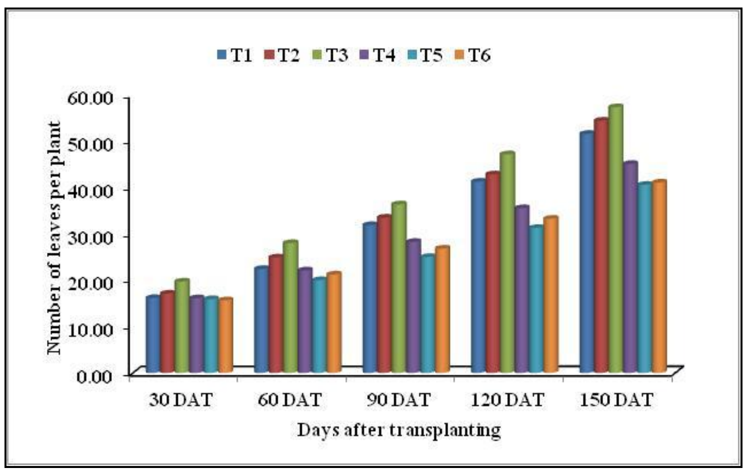


Fig.3 Effect of deficit irrigation on time taken for flower initiation and on first harvest

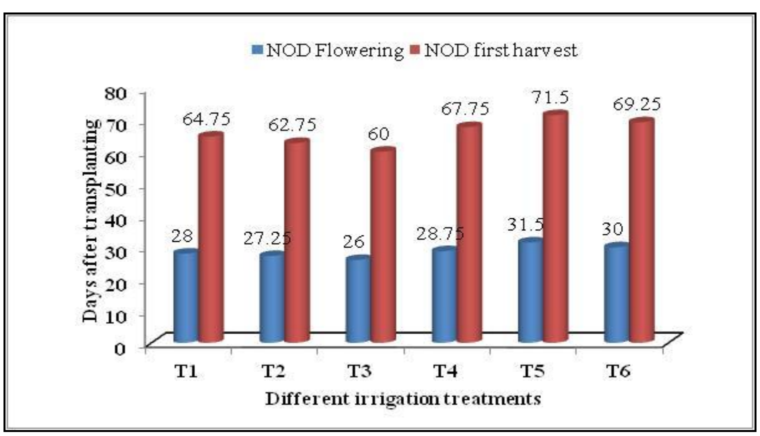


Fig.4 Effect of deficit irrigation on number of flowers per plant

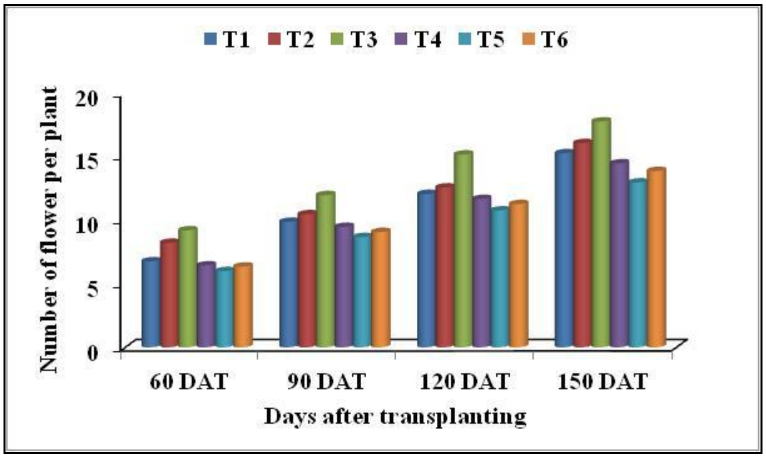


Fig.5 Effect of deficit irrigation on number of fruits per plant

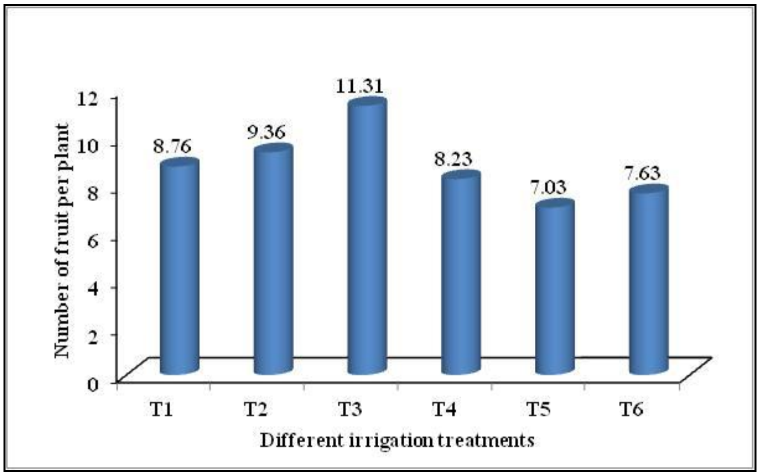


Fig.6 Effect of deficit irrigation on percent fruit set

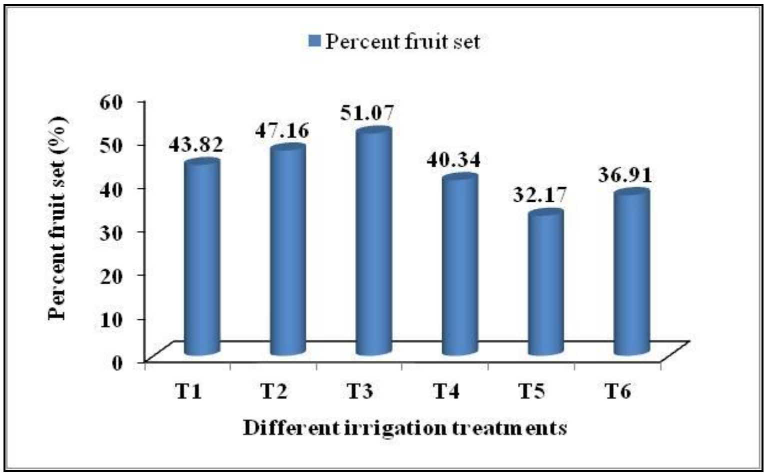


Fig.7 Effect of deficit irrigation on individual fruit weight

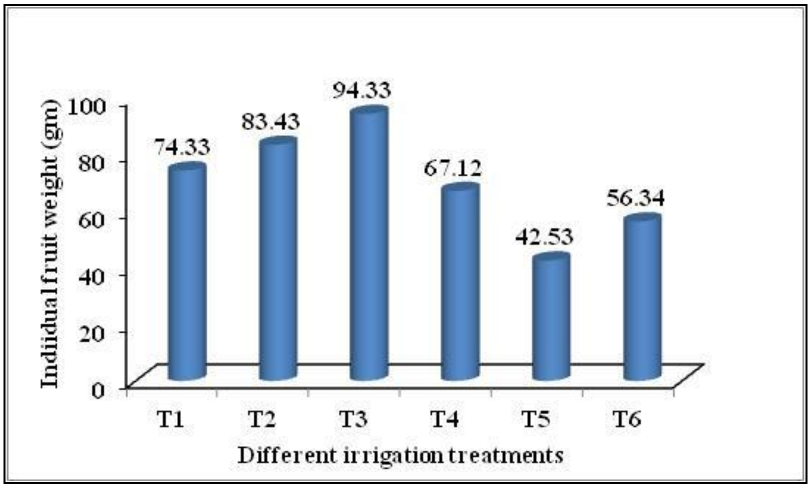


Fig.8 Effect of deficit irrigation on fruit yield per plant

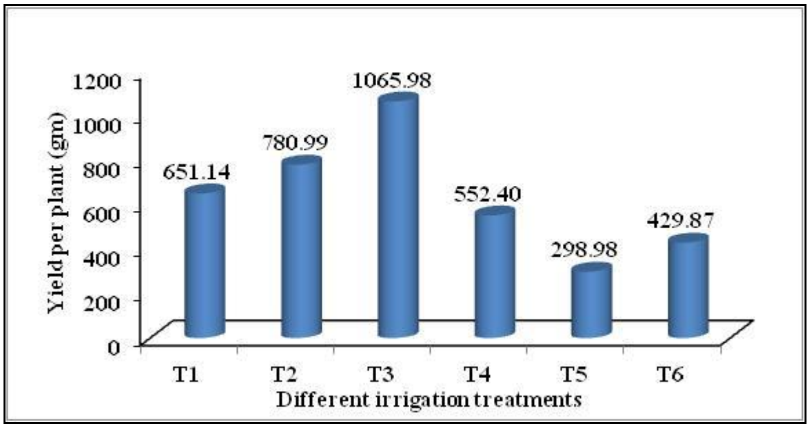


Fig.9 Effect of deficit irrigation on fruit yield per sqm area

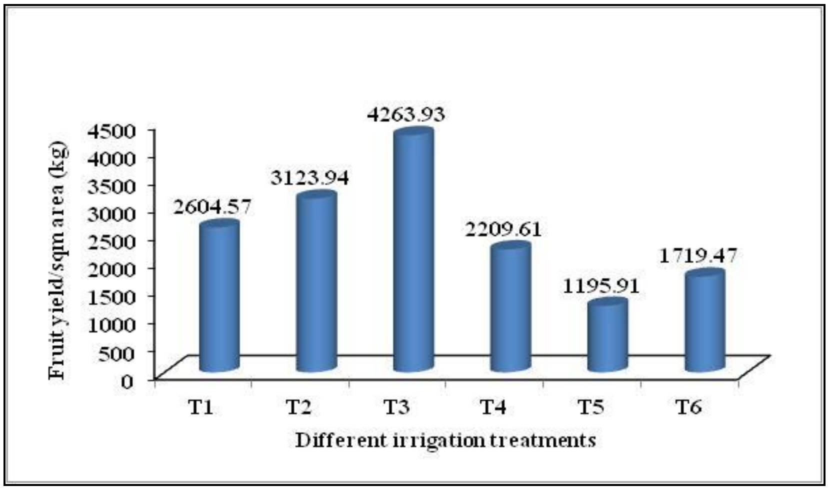


Fig.10 Effect of deficit irrigation on fruit yield

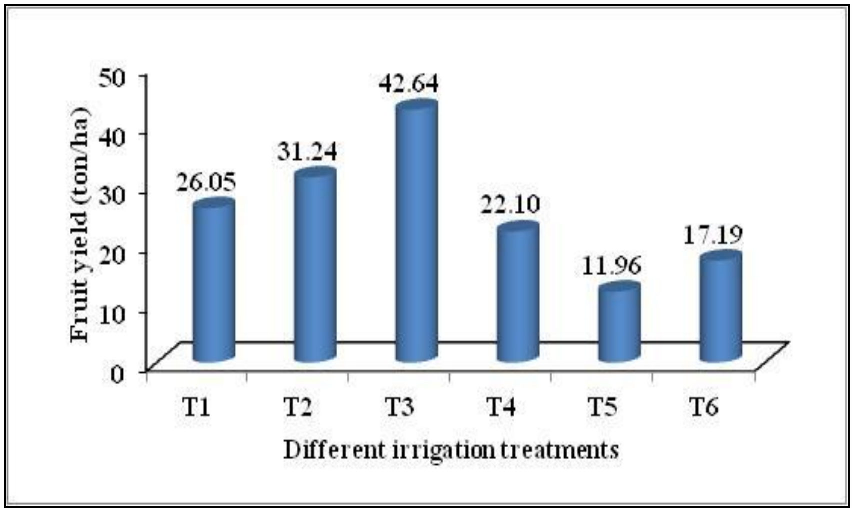
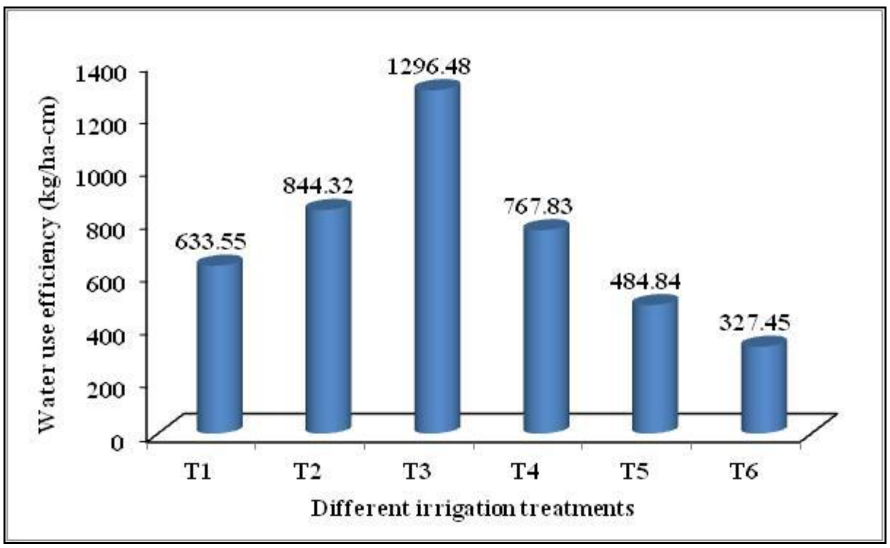


Fig.11 Effect of different treatments on water use efficiency



This might be due to better micro-climate responsible for efficient water utilization at early crop growth stages, which ultimately lead to more number of flowers and hence more number of fruits in T_3. On the other hand least values were recorded under T_5 this might be attributed to reduced number of flowers produced rather than poor fruit set (Masuda and Hayashi, 1957). It reveals that both the excess as well as less supply of water has resulted into less number of fruits plant-1. Hence, controlled irrigation is essential for having higher fruit number in capsicum as this crop is sensitive to both excess and under irrigations (Anonymous, 2009).

The results of this study showed that deficit irrigation practice can save up to 20 % of irrigation water. Statistical analysis of the observed data showed maximum average plant height (180 cm), average number of leaves per plant (57.28), early flower initiation (26 DAT), early first harvesting of plant (60 DAT), number of flower per plant (17.78), cumulative number of fruits per plant (11.31), percent fruit set (51.07 %), individual fruit weight (94.33 gm), fruit yield per plant (1065.98 gm/plant) and water use efficiency (1296.48 kg/ha-cm) in treatment T_3 at 150 DAT (i.e., irrigation with 80 % of crop evapotranspiration with mulch) under the naturally ventilated polyhouse. Among the different irrigation treatment, treatment T_3 found best and treatment T_5 least reproductive in terms of both crop growth and yield production of plant. Drip irrigation applied with 80 % of crop evapotranspiration (ET_c) was found to be the optimum irrigation amount in order to obtain the maximum capsicum yield of 42.64 ton/ha. Thus, the results revealed that all the vegetative parameters, reproductive parameter, quantity parameter and water use efficiency was found maximum in the drip irrigation applied with 80 % of crop evapotranspiration (ET_c) with mulch i.e. treatment (T_3).

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How to cite this article:

Dimple, S.R. Bhakar, S.S. Lakhawat and Kothari, M. 2017. Effect of Deficit Irrigation and Plastic Mulch on Yield and Water Use Efficiency of Drip Irrigated Capsicum under Naturally Ventilated Polyhouse. *Int.J.Curr.Microbiol.App.Sci.* 6(12): 2878-2889.
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