Effect of drip irrigation and fertigation on plant growth parameters, productivity and nutrient use efficiency of capsicum in wet temperate zone of Himachal Pradesh

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ABSTRACT

The study was conducted during 2013 and 2014 at experimental farm of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh to evaluate the effect of drip irrigation and NPK fertigation levels on nutrient use efficiency and productivity of capsicum. The treatments comprised two drip irrigation levels viz $I_{0.4}$ [Drip at 40% cumulative pan evaporation (CPE)] and $I_{0.8}$ (Drip at 80% CPE); four fertigation levels viz F_{50} [50% recommended dose of fertilizer (RDF)], F_{100} (100% RDF), F_{150} (150 RDF) and F_{200} (200% RDF); farmers' practice [FYM @ 1 kg/m^2 + 10 g/m^2 IFFCO (basal) + 2 g/l of 19:19:19 at 15 days interval and drip irrigation applied at the rate of 2 l/m^2 daily] and control [100% NPK (by conventional method) + drip irrigation at 100% CPE]. Results indicated that under fertigation treatments the plant height, number of leaves, root length, volume and weight were significantly higher with F_{200} over other treatments leading to higher marketable yields. Irrigation treatments did not vary significantly because of frequent occurrence of monsoon rains during crop growth period making the effects of drip irrigation treatments negligible. The study concluded that drip fertigation treatments significantly increased the growth parameters, marketable yield and nutrient use efficiency as compared to conventional method of fertilizer application.

Keywords: Drip irrigation; fertigation; RDF; marketable yield; nutrient use efficiency

INTRODUCTION

Efficient use of available irrigation water is essential for increasing agricultural production per unit volume of water and per unit area of crop land for the alarming Indian population. The competition for limited water resources for domestic, industrial and agricultural needs is increasing considerably due to increase in population. The judicious use of the available water resources through more efficient methods of water application like drip irrigation becomes necessary to enhance the yield and water use efficiency. High-frequency water management by drip irrigation provides daily requirement of water to a portion of the root zone of each plant and sometimes maintains a high soil matric potential in the rhizosphere to reduce plant water stress (Nakayama and Bucks 1986). The added advantage of drip system is that water soluble fertilizers can also be applied through this system and the process is known as fertigation.

Capsicum is day-neutral plant belonging to the Solanaceae family which requires mild climate for its growth and development. The fruits are harvested either at green mature stage or at colouring stage and are a very good source of vitamin A and C. The plant grows at soil temperature between 18 to 35^{o}C (Kumari and Kaushal 2014). The crop requires day temperature of 25-30^{o}C and night temperature of 18-20^{o}C with relative humidity of 50- 60 per cent. It is an important crop in low and mid-hills of Himachal Pradesh. The present study was conducted under sub-humid zone of the state of the state at experimental farm of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh to evaluate the effect of drip irrigation applied at 40 and 80 per cent cumulative pan evaporation (CPE) and 50, 100, 150 and 200 per cent NPK fertigation levels on plant growth parameters, crop productivity and nutrient use efficiency of capsicum.

MATERIAL and METHODS

The field experiment was conducted at the experimental farm of Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh (32º6' N latitude and 76º3' E longitude, 1250 m amsl) during the years 2013 and 2014. Research farm lies in wet temperature zone according to Thorn waite's classification (Aggarwal et al 1978). The average annual rainfall of the place is about 2500 mm. The monsoon starts from the June end and ends in mid-September with more than 80 per cent of annual rainfall received during this period only. The soil of the experimental field was silty clay loam and rich in clay content with accumulation of sesquioxides. Taxonomically the soils were classified as alfisols – typic hapludalf (Verma 1979). The surface soil (0-0.15 m) of the experimental field was acidic in nature (5.0), low in available N (156.8 kg/ha), high in available P (50.2 kg/ha) and medium in available K (228.8 kg/ha).

The drip lines spaced at 45 cm (laterals) x 45 cm (drippers) were laid with control valves provided on each lateral. A total of 48 online drippers were available for irrigation in 12 m^2 plot. The water source for drip irrigation was from a polylined farm pond located near the experimental site and water was applied through gravity with about 8-10 m hydraulic head. The average discharge rate from each dripper was 4.05 l/h. In NPK fertigation treatments water soluble fertilizers viz 19:19:19 + 12:61:0 + urea were applied in different calculated proportions injected through overhead fertilizer tank at 8-10 days interval. The treatments comprised two irrigation levels (0.4 and 0.8 CPE), four fertigation levels (50, 100, 150 and 200% RDF), one farmers' practice and one recommended practice (control). The ten treatment combinations were imposed in a factorial randomized block design replicated three times. The details of treatments applied are given in Table 1.

The scheduling of irrigation was done according to treatments commencing from 20 days after transplanting. The daily evaporation data recorded for the crop growth period for the period 2008-2012 (five years) were averaged and irrigation requirement was calculated by multiplying the averaged values with corresponding CPE ratios. The drip irrigation was applied daily. In all fertigation treatments 25 per cent of the RDF (100:75:55) was applied as basal through conventional fertilizers viz urea, SSP and MoP and remaining 75 per cent was applied through drip line using water soluble fertilizers viz 19:19:19, 12:61:0 and urea in different splits. In farmers' practice FYM @ 1 kg/m^2 and 10 g/m^2 IFFCO were applied as basal and 2 g/l of 19:19:19 at 15 days intervals with drip irrigation operated at the rate of 2 l/m^2 daily. In control 50 per cent N and full P and K were applied as basal and remaining 25 per cent N after one month of transplanting and 25 per cent at fruit setting stage.

For analyzing the plant growth pattern of the crop five plants were selected randomly from the net plot area in each treatment. Root growth parameters viz root volume, root length and root mass per plant were determined at fruit setting stage. Infiltrometer rings (30 cm height) were excavated from randomly selected plants. The cores were kept in water overnight and then roots were made free from soil by washing with fine jet of water. The roots were collected on fine sieve for final washing with a micro-jet tap. Root length was measured in a glass bottom shallow dish of 40 x 20 cm dimension. Graph paper ruled in mm was placed below the dish. The wet roots were cut from the root-shoot joint and spread randomly in the dish containing some water with the help of forceps and needle so that they did not overlap. The long-branched roots were cut into smaller pieces. The counts for inter-sections of roots (N) with vertical and horizontal lines of 1 cm grid from the graph paper were recorded. Root length was computed using the modified version of Newman (1966) as:

$$\text{Root length} = \frac{11}{14} \times \text{Number of intersections (N)} \times \text{Grid unit}$$

The volume of roots was determined by volume displacement method. Roots were transferred to a filter paper and pressed gently in its folds to remove imbibed water. The roots were then oven-dried at 65ºC to a constant weight and the dry weight was taken.The fresh marketable fruit yield of capsicum and fresh straw

Table 1. Details of treatments applied

Parameter	Treatment details
Irrigation level (I)	
$I_{0.4}$	Drip irrigation at 40% cumulative pan evaporation (0.4 CPE)
$I_{0.8}$	Drip irrigation at 80% cumulative pan evaporation (0.8 CPE)
Fertigation level (F)	
F_{50}	50% RDF applied in 5 splits at 15 days interval
F_{100}	100% RDF applied in 7 splits at 10 days interval
F_{150}	150% RDF applied in 10 splits at 7 days interval
F_{200}	200% RDF applied in 20 splits at 3 to 4 days interval
Farmers' practice	
	FYM @ 1 kg/m^2 + 10 g/m^2 IFFCO (basal) + 2 g/l of 19:19:19 at 15 days interval and drip irrigation applied at the rate 2/l m^2 daily
Control	100% NPK (by conventional method) + drip irrigation at 100% CPE

Total number of treatment combinations= 4 x 2 + 1 + 1= 10
RDF= Recommended dose of fertilizer

weight were recorded at harvest and expressed in g/m^2. Fertilizer use efficiency (FUE) (N, P and K) was calculated by the formula given as (Pomares and Pratt 1987):

$$\text{FUE} = \frac{\text{Total uptake in treated plots} - \text{Total uptake in absolute control}}{\text{Total amount of nutrient applied}} \times 100$$

RESULTS and DISCUSSION

Rainfall and evaporation

The rainfall distribution, evaporation and maximum and minimum temperature during the crop growth period of capsicum are presented in Figs 1 and 2. The week number 17 to 34 indicating the rainfall distribution pattern for capsicum crop growth period during first year indicates that during whole growth period except first three weeks there was occurrence of heavy monsoon rains (2068.6 mm). During second year crop growth period started from week 19 to 35 that received 1204.4 mm of rainfall. During both the seasons of capsicum drip irrigation treatments were imposed during first month only. The evaporation rate during both the years ranged from 1 to 4 mm for first four weeks and thereafter it ranged from 5 to 10 mm.

Plant growth parameters

Number of leaves per plant: The number of leaves per plant recorded at fruit setting stage indicated non-significant effects of drip irrigation treatments whereas under fertigation treatments the highest number of leaves per plant was recorded with F_{200} (49.50) followed by F_{150} (47.92) both of them being statistically at par (Table 2). However number of leaves per plant recorded in F_{200} was significantly higher over F_{100} and F_{50} (44.80 and 42.17 respectively). The number of leaves per plant was higher under F_{150} and F_{200} may be due to application of 50 to 100 per cent more amount of recommended dose of fertilizer. El-Bassiony et al (2010) reported that highest potassium fertilization rate (200 kg/fed) gave the tallest capsicum plants and the highest number of leaves and branches per plant. The number of leaves per plant under farmers' practice vs fertigation was not significant. The number of leaves per plant was significantly superior under others (fertigation including farmers' practice) over control. During second year also similar trend was obtained. In case of fertigation treatments the highest number of leaves per plant was recorded under F_{200} (49.50) followed by F_{150} (47.92) both being statistically at par. In control vs others the number of leaves per plant was significantly superior under others (fertigation including farmers' practice) over control.

Plant height: The plant height recorded at fruit setting stage indicated that drip irrigation treatments were non-significant. However under fertigation treatments the

Table 2. Effect of drip-based irrigation scheduling and fertigation on plant growth parameters at fruit setting stage in capsicum

Treatment	Plant growth parameters			
	2013		2014	
	Number of leaves	Plant height (cm)	Number of leaves	Plant height (cm)
Drip irrigation				
$I_{0.4}$	45.94	47.68	44.40	42.01
$I_{0.8}$	46.25	47.40	44.64	42.18
$CD_{0.05}$	NS	NS	NS	NS
Fertigation				
F_{50}	42.17	43.14	40.83	39.52
F_{100}	44.80	46.38	44.38	41.78
F_{150}	47.92	49.18	45.60	42.64
F_{200}	49.50	51.46	47.25	44.45
$CD_{0.05}$	2.61	1.78	2.78	1.816
Farmers' practice vs fertigation				
Farmers practice	45.00	47.55	44.00	42.07
Fertigation	46.10	47.54	44.52	42.10
$CD_{0.05}$	NS	NS	NS	NS
Control vs others				
Control	43.00	43.98	41.17	39.60
Others	45.97	47.54	44.46	42.09
$CD_{0.05}$	2.75	1.88	2.93	1.91

highest plant height was recorded with F_{200} (51.46) which was significantly superior over other fertigation treatments (Table 2). The higher plant height under F_{200} could be due to application of 100 per cent more amount of recommended dose of fertilizer with more number of splits.

Khan et al (2010) observed that plant height and number of branches at first and final harvest increased significantly up to 150 kg N/ha. The plant height under farmers' practice vs fertigation was not significant. The plant height under control vs others was significantly superior under others (fertigation including farmers' practice) over control. This may be due to the use of water soluble fertilizer in fertigation as compared to control where soil application was done. Similar findings were also reported by Sadarunnisa et al (2010) and Mahajan et al (2007).

Root parameters: The data on the effect of drip irrigation and fertigation on root growth parameters at fruit setting stage are presented in Table 3. The data indicate that during first year root length, volume and mass were non-significant under drip irrigation levels. Among the fertigation treatments the highest root length was recorded under F_{200} (2.58 m) followed by F_{150} (2.38 m) which were at par with each other and significantly superior over F_{100} and F_{50} (1.91 and 1.27 m).

Similarly root volume and root mass were significantly higher under F_{200} (14.85 x 10^{-6}/m^3 and 2.74 g respectively) over other fertigation treatments. The higher root length, volume and weight under F_{200} may be attributed to the application of double quantity of recommended doses of fertilizers. The root length and volume were higher under fertigation treatments in comparison to farmers' practice whereas root mass was non-significant. The root length, volume and mass were significantly higher in others in comparison to control. Hebbar et al (2004) observed that root growth was increased by water soluble fertilizer fertigation.

During second year also under drip irrigation treatments root length and root mass were non-significant while root volume was at par with each other. Among the fertigation treatments the highest root length was recorded under F_{200} (2.53 m) which was significantly superior over F_{150}, F_{100} and F_{50} treatments. Similarly root volume and root mass were significantly higher under F_{200} (9.07 x 10^{-6}/m^3 and 2.33 g) over other fertigation treatments. In farmers' practice vs fertigation root length was non-significant while root volume and root mass were significantly higher under

Table 3. Effect of drip-based irrigation scheduling and fertigation on root parameters of capsicum

Treatment	Root parameters					
	2013			2014		
	Root length (m)	Root volume (x 10^6/m^3)	Root mass (g)	Root length (m)	Root volume (x 10^6/m^3)	Root mass (g)
Drip irrigation						
$I_{0.4}$	2.06	11.22	2.10	1.74	7.57	1.60
$I_{0.8}$	2.01	11.29	2.12	1.76	7.91	1.62
$CD_{0.05}$	NS	NS	NS	NS	0.34	NS
Fertigation						
F_{50}	1.27	8.82	1.32	0.99	6.20	0.94
F_{100}	1.91	9.67	2.10	1.40	7.50	1.37
F_{150}	2.38	11.68	2.28	2.10	8.18	1.80
F_{200}	2.58	14.85	2.74	2.53	9.07	2.33
$CD_{0.05}$	0.22	0.83	0.26	0.18	0.48	0.25
Farmers' practice vs fertigation						
Farmers' practice	1.77	9.73	1.92	1.59	7.00	1.02
Fertigation	2.03	11.25	2.11	1.75	7.74	1.61
$CD_{0.05}$	0.23	0.88	NS	NS	0.51	0.27
Control vs others						
Control	1.73	9.07	1.75	1.45	5.07	1.03
Others	2.00	11.09	2.09	1.74	7.66	1.54
$CD_{0.05}$	0.23	0.87	0.27	0.19	0.50	0.27

Table 4. Effect of drip-based irrigation scheduling and fertigation on biological yield (kg/m^2) of capsicum

Treatment	Biological yield (kg/m^2)			
	2013		2014	
	Fruit	Straw	Fruit	Straw
Drip irrigation				
$I_{0.4}$	1.19	1.41	0.71	1.06
$I_{0.8}$	1.25	1.39	0.74	1.04
$CD_{0.05}$	NS	NS	NS	NS
Fertigation				
F_{50}	0.83	1.27	0.61	0.95
F_{100}	1.10	1.28	0.73	0.96
F_{150}	1.43	1.44	0.76	1.08
F_{200}	1.52	1.61	0.82	1.21
CD(P=0.05)	0.10	0.10	0.05	0.08
Farmers' practice vs fertigation				
Farmers' practice	1.09	1.22	0.61	0.91
Fertigation	1.22	1.40	0.73	1.05
$CD_{0.05}$	0.11	0.11	0.05	0.08
Control vs others				
Control	0.74	0.85	0.61	0.63
Others	1.21	1.38	0.72	1.03
$CD_{0.05}$	0.11	0.11	0.05	0.08

fertigation treatments in comparison to farmers' practice. The root length, volume and mass were significantly higher in others in comparison to control. Zotarelli et al (2009) reported that root concentration was greatest in the vicinity of the irrigation and fertigation drip lines for all irrigation treatments.

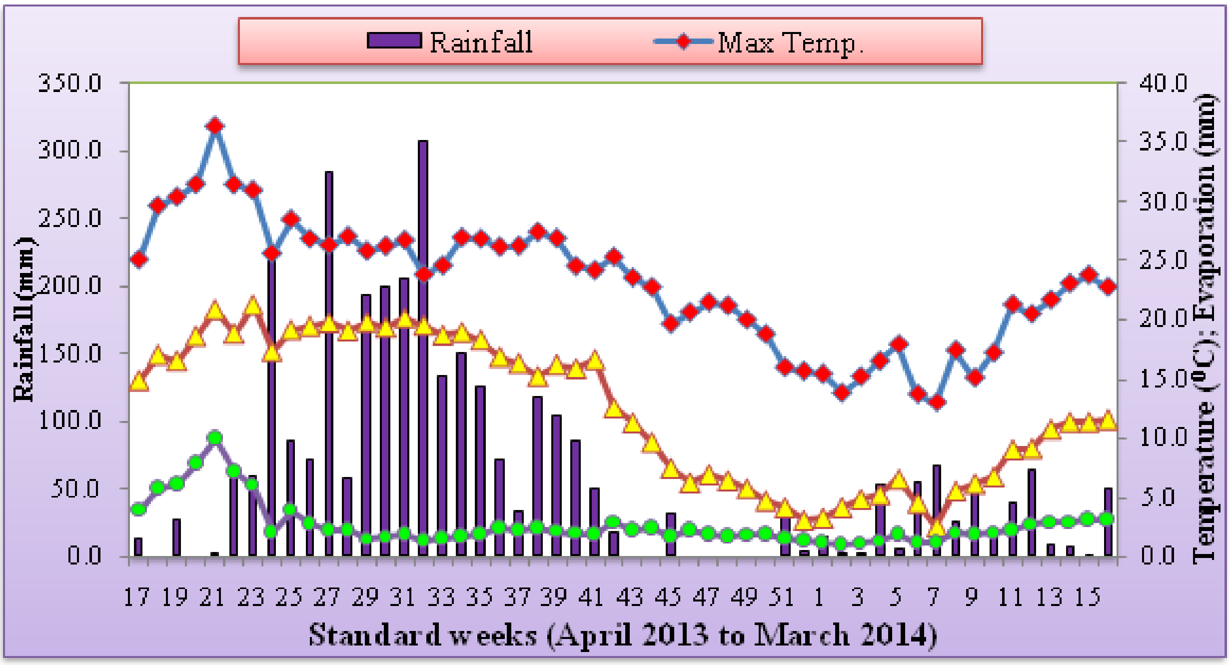

Fig 1. Mean weekly weather data at Palampur (HP) for the crop period of capsicum (April 2013 to August 2013)

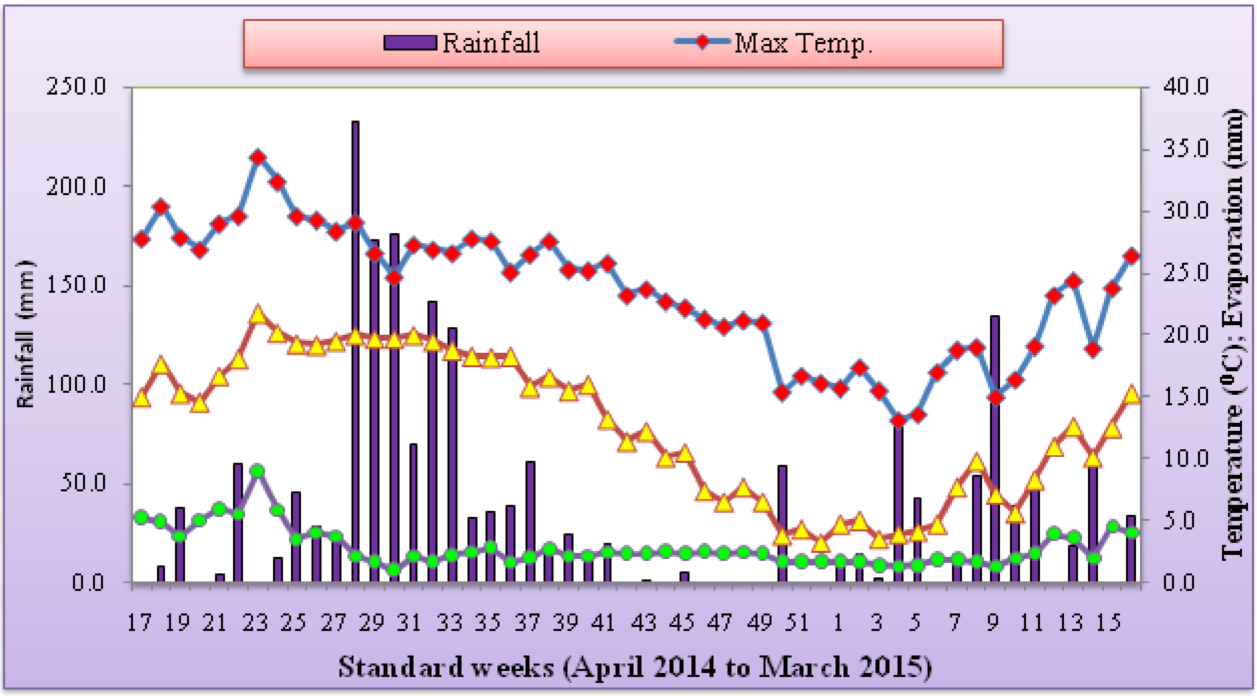

Fig 2. Mean weekly weather data at Palampur (HP) for the crop period of capsicum (April 2014 to August 2014)

Biological yield

The effect of drip irrigation and fertigation levels on biological yield of capsicum during both the years is presented in Table 4. The data indicate that the fruit and straw yield during both the years was non-significant under drip irrigation treatments. This could be because of occurrence of monsoon rains during crop growth period making the effects of drip irrigation treatments negligible.

During first year different fertigation levels significantly affected the fruit yield of capsicum. The highest fruit yield was recorded with treatment F_{200} (1.52 kg/m^2) which was at par with F_{150} (1.43 kg/m^2)

and significantly superior over F_{100} and F_{50} (1.10 and 0.83 kg/m^2 respectively). The straw yield was also significantly highest under treatment F_{200} (1.61 kg/m^2) in comparison to other fertigation treatments. Srinivas and Prabhakar (1982) observed that N fertigation increased fruit yield, plant height and number of branches. The higher biological yield under F_{200} and F_{150} may be attributed to the application of more amount of fertilizer with more number of splits.

Veeranna et al (2001) observed that crop showed a positive response to an increase of NPK concentration solution. The fruit and straw yields obtained under farmers' practice vs fertigation were significantly higher under fertigation treatments. In control vs others the highest fruit and straw yields were obtained under others (fertigation including farmers' practice) which were significantly superior (63.51 and 62.35% respectively) over control.

During second year also similar trend was observed. The highest fruit yield was recorded under treatment F_{200} (0.82 kg/m^2) followed by F_{150} (0.76 kg/m^2) which were significantly at par with each other. The fruit and straw yields obtained under farmers' practice vs fertigation were significantly higher under fertigation over farmers' practice. In control vs others the highest fruit and straw yields were obtained under others (fertigation including farmers' practice) which were significantly higher over control.

Nutrient use efficiency

Data indicate that during first year the drip irrigation treatment $I_{0.8}$ (67.24%) resulted in higher nitrogen use efficiency in comparison to the $I_{0.4}$ (63.56%) (Table 5). However phosphorus and potassium use efficiencies were not significant.

Among fertigation treatments the highest N, P and K use efficiencies were recorded in F_{50} which was significantly higher over other fertigation treatments. The higher N, P and K use efficiencies in F_{50} may be due to less application of fertilizer in comparison to other treatments. Singandhupe et al (2007) reported that application of 50 per cent recommended dose of fertilizer improved fertilizer use efficiency. In farmers' practice vs fertigation the NUE was significantly higher under farmers' practice over fertigation treatments. This may be because of less amount of nitrogen dose applied under farmers' practice. Whereas P and K use efficiencies were recorded highest under fertigation treatment. Under control vs others the N, P and K use efficiencies were recorded highest in others over control. This may be

Table 5. Effect of drip-based irrigation scheduling and fertigation on nutrient use efficiencies (%) of capsicum and broccoli crops under open field conditions

Treatment	Nutrient use efficiency (%)					
	2013			2014		
	NUE	PUE	KUE	NUE	PUE	KUE
Drip irrigation						
$I_{0.4}$	63.56	19.76	69.98	49.67	14.46	49.03
$I_{0.8}$	67.24	20.47	72.60	51.94	14.59	51.71
$CD_{0.05}$	3.22	NS	NS	NS	NS	NS
Fertigation						
F_{50}	87.61	27.48	80.54	76.75	21.34	64.21
F_{100}	64.06	20.04	70.77	50.54	13.68	46.36
F_{150}	57.90	17.36	67.93	39.69	11.64	45.09
F_{200}	52.04	15.58	65.90	36.23	11.43	45.84
$CD_{0.05}$	4.56	1.19	6.88	3.84	0.83	5.79
Farmers' practice vs fertigation						
Farmers' practice	92.80	18.02	58.50	72.91	12.46	41.55
Fertigation	65.40	20.12	71.29	50.80	14.52	50.37
$CD_{0.05}$	4.83	1.26	7.30	4.07	0.88	6.14
Control vs others						
Control	38.49	10.79	25.47	31.42	7.38	21.78
Others	68.45	19.88	69.86	53.26	14.29	49.39
$CD_{0.05}$	4.80	1.25	7.25	4.05	0.88	6.10

due to soil application of conventional fertilizers under control.

The second year data indicate that drip irrigation treatments were not significant. Among fertigation treatments the highest N, P and K use efficiencies were recorded in F_{50} which were significantly higher over other fertigation treatments. The N, P and K use efficiencies were recorded highest under others over control. This may be due to the application of twice the recommended dose of fertilizer which resulted in high uptake in comparison to control where 100 per cent recommended dose of fertilizer was applied through conventional method.

CONCLUSION

The study concluded that drip irrigation treatments did not have significant effect on plant growth parameters because of occurrence of monsoon rains during crop growth period and ultimately resulted in low yield. However the increasing fertigation levels from 50 to 200 per cent RDF significantly increased the plant growth parameters and marketable yield. The drip fertigation treatment combinations were found as best treatments as compared to conventional method of fertilizer application (control) and also resulted in saving of water and fertilizers.

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