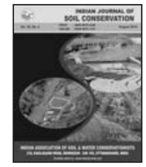
Vol. 42, No. 3, pp 249-254, 2014
Indian Journal of Soil Conservation
Online URL:http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home



Effect of varying drip irrigation levels and NPK fertigation on soil water dynamics, productivity and water use efficiency of cauliflower (*Brassica oleracea var. botrytis*) in wet temperate zone of Himachal Pradesh

Renu Kapoor, Sanjeev K. Sandal[1], Sanjay K. Sharma, Anil Kumar and Kapil Saroch

Chaudhary Sarwan Kumar Himachal Pradesh Agricultural University, Palampur-176062, Himachal Pradesh.
[1]E-mail: sksandal@rediffmail.com

ARTICLE INFO

Article history :
Received : June, 2013
Revised : January, 2014
Accepted : April, 2014

Key words :
B:C ratio,
Drip irrigation,
Fertigation,
Marketable yield,
Water use efficiency

ABSTRACT

Efficient utilization of harvested rain-water either in small or big farm ponds is being emphasized upon through micro-irrigation systems. Among the various techniques developed for application of water, drip irrigation is gaining popularity as perhaps the most efficient method of water application. Keeping it in view, the study was conducted at experimental farm of CSK HPKV, Palampur, during the years 2010-11 and 2011-12 with the objectives of evaluating the effects of drip irrigation levels applied at 1.2, 1.0 and 0.8 CPE and NPK fertigation on soil water retention, water use efficiency, growth and productivity of cauliflower. The treatments comprised of (a) Three drip irrigation levels *viz.,* $I_{1.2}$ (1.2 CPE) *i.e.* drip at 120% CPE, $I_{1.0}$ (1.0 CPE) *i.e.* drip at 100% CPE and $I_{0.8}$ (0.8 CPE) *i.e.* drip at 80% CPE, (b) Three fertigation levels v*iz.,* F_{100} *i.e.* 100% recommended dose of fertilizer, $F_{66.6}$ *i.e.* 66.6% recommended dose of fertilizer and $F_{33.3}$ *i.e.* 33.3% recommended dose of fertilizer and (c) Control (I_{Rec}) *i.e.* flood Irrigation of 4 cm at 8-10 days interval and 100% recommended dose of fertilizer. The cauliflower variety cv. PSB K-1 was transplanted on October 12, 2010 in the first year and on October 30, 2011 in the second year of experiment. The results showed significant rise in moisture content when water application depth was increased from $I_{0.8}$ to $I_{1.2}$. In both years, the results indicated that $I_{1.2}$ treatment had higher soil water content in comparison to $I_{1.0}$, $I_{0.8}$ and I_{Rec}. The $I_{1.2}$ treatment due to favorable soil moisture regimes led to higher marketable curd yield and water use efficiency in comparison to $I_{1.0}$ and $I_{0.8}$. Likewise, F_{100} treatment had higher marketable curd yield and water use efficiency in comparison to $F_{66.6}$ and $F_{33.3}$. The highest marketable curd yield, water use efficiency, gross return was obtained under $I_{1.2}F_{100}$ treatment combination. The study concluded that drip based irrigation scheduling resulted in higher water use efficiency (44.94 to 54.34%) and saving in irrigation water (35.85 to 50%) in comparison to conventional method of irrigation.

1. INTRODUCTION

In Himachal Pradesh, about 18% of the cultivated area has assured irrigation facilities, and is generally under vegetable cultivation. Since, the productivity of irrigated agriculture is more than twice the rain fed agriculture, it is very essential to bring the maximum area under irrigation with judicious and economic use of harvested rain and ground water for increasing the water productivity. Efficient utilization of harvested rain-water either in small or big farm ponds is being emphasized upon through micro-irrigation systems especially drip irrigation system. In recent years, keeping in view the limited available water resources, micro- irrigation systems comprising drip and sprinkler are being promoted in Himachal Pradesh. Also, undulating topography with poor soil water retention characteristics in hills favours drip irrigation system. Drip irrigation is the system for precise application of water to synchronize with the plant needs. It is an eco-friendly irrigation system that saves more than 60% water and increases the yield by 30-40% over conventional methods (Magar and Nandgude, 2005). The study conducted by Kumar *et al.* (2012) have indicated increased tomato yield and water use efficiency with gravity fed drip irrigation system and water saving of 40% over full irrigation method. Drip irrigation along with fertilizer (fertigation) reduces the wastage of water and chemical fertilizers and subsequently optimizes the nutrient and water use by applying them at critical stages at proper place and time, which finally increases the water and nutrient use efficiency.

In Himachal Pradesh, the cultivation of cauliflower (*Brassica oleracea* var. *botrytis* L.) has been promoted keeping in view its off-season cultivation feasibility and market demand. Cauliflower is low in fat but high in dietary fiber, foliate, water and vitamins C along with possessing a high nutritional density with anti-cancer properties. As per National Horticulture Board during 2012-13, the annual production of cauliflower was 63.24 thousand tons in Himachal Pradesh as compared to 7826.54 thousand tons at national levels.

At present, scientific information with respect to drip irrigation on soil water dynamics, productivity and water use efficiency of cauliflower under varying fertigation level is lacking in Himalayan acid Alfisol so that necessary recommendation can be made to the farmers. Hence, an initiative is taken to enhance yield and water productivity of above crop to harvest more produce using less quantity of water applied. The experiment was planned to study the "Effect of varying drip irrigation levels and NPK fertigation on soil water dynamics and productivity of cauliflower (*Brassica oleracea* var. *botrytis* L.)" with the objectives (i) to evaluate the effects of drip irrigation levels applied at 0.8 CPE, 1.0 CPE and 1.2 CPE on soil water retention and water use efficiency; and (ii) to evaluate the effects of NPK fertigation on productivity at varying drip irrigation levels.

2. MATERIALS AND METHODS

A field experiment was conducted at the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, during the years 2010-11 transplanted on 12th October and 2011-12 transplanted on 30th of October. The area lies in Palam Valley (32.6^{0}N latitude and 76.3^0 E longitude), at an elevation of 1290 m above mean sea level, of Kangra district of Himachal Pradesh and represents the mid hills sub-humid agro climatic zone of Himachal Pradesh in North Western Himalayas. The soil of the experiment field is silty clay loam and rich in clay content (26%) with accumulation of sesquioxides. Taxonomically, the soils are classified as Alfisols Typic Hapludalf (Verma 1979). The average values of physico-chemical and chemical properties of the surface soil (0-0.15 m) were pH 5.1 and organic carbon 12.68 g kg^{-1}. The soil was medium in available N (290 kg ha^{-1}), high in available P (48 kg ha^{-1}) and medium in available K (270 kg ha^{-1}). At 33 and 1500 kPa tensions, the soil retained around 0.31 and 0.16 m^3 m^{-3} moisture.

The experiment was laid out in randomized block design with ten treatments, comprising of (a) Three drip irrigation levels *viz.,* $I_{1.2}$ (1.2 CPE) *i.e.* Drip at 120% CPE, $I_{1.0}$ (1.0 CPE) *i.e.* Drip at 100% CPE and $I_{0.8}$ (0.8 CPE) *i.e.* Drip at 80% CPE, (b) Three fertigation levels *viz.,* F_{100} *i.e.* 100% recommended dose of fertilizer, $F_{66.6}$ *i.e.* 66.6% recommended dose of fertilizer and $F_{33.3}$ *i.e.* 33.3% recommended dose of fertilizer and (c) Control(I_{Rec}) *i.e.* flood Irrigation of 4 cm at 8-10 days interval along with 100% recommended dose of fertilizer. The treatments were replicated thrice. The plot size was 5m x 2m. The averaged pan evaporation data (2004-05 to 2010-11) was used to determine the amount of water to be given in the ratio of 0.8, 1.0 and 1.2 cumulative pan evaporation (CPE). The drip irrigation was given at 2-3 days interval. In fertigation treatments, the soil test based NPK fertilizer doses (125:55:70 :: N:P_2O_5:K_2O) calculated as per treatment were applied in ten equal splits at 8-10 days interval through fertigation. The water soluble fertilizers *viz.,* urea, 19:19:19 and 0:0:50 were used for fertigation. In control half of N and whole of P and K were given basal and the remaining N was given in two equal splits, at 30 and 75 DAT.

To undertake the study of discharge variation, drip laterals fitted in 27 plots were selected starting from first to last plot. In each plot, second lateral was selected and the containers were kept at dripper Nos. 2, 8 and 14. The whole system was operated for 5 minutes and water was collected in each container. The discharge variation was calculated by the following equation (El Nemr, 2012).

$$\text{Discharge variation (\%)} = \frac{Q_{max} - Q_{min}}{Q_{max}} \text{X100}$$

Where, 'Q_{max}' is the maximum discharge rate (L h^{-1}) and 'Q_{min}' is the minimum discharge rate (L h^{-1}). There was a mean discharge rate of 2.30 L h^{-1} with 7.35% variation. Depth wise soil samples were collected from three replications at four places 15 cm away from the dripper. The changes in soil water content during the season at 0-0.15, 0.15-0.30, 0.30-0.45 and 0.45-0.60 m depths were determined by thermo gravimetric method twice a month during cauliflower crop growth period one day after irrigation. Volumetric water content (Θ) for different depths was calculated by multiplying the gravimetric water content (w/w basis) with pre determined bulk density for that depth (Hillel 1982). The aeration porosity was calculated by determining relation of air to water content on a particular day by the following equation (Rattan, 2009).

$$f_a\ (\%) = (f - \Theta)$$

Where, ' f_a' is the aeration porosity, 'f' is porosity (%) and 'Θ' is volumetric wetness (%).

The consumptive water use was calculated by the following equation.

$$\text{Consumptive Water Use} = I + ER \pm \Delta S$$

Where, 'I' is the amount of irrigation water applied, 'ER' is the effective rainfall during the crop period and 'ΔS' is the profile water depletion.

The fresh marketable curd yield of cauliflower was recorded at harvest expressed in Mg ha^{-1}. Water use efficiency (kg ha^{-1}mm^{-1}) was computed from curd yield production per unit consumptive water use.

3. RESULTS AND DISCUSSION

Rainfall and Evaporation

The rainfall distribution and evaporation during growth period of cauliflower are given in Table 1 for the year 2010-11 and 2011-12. The data indicated that total monthly evaporation exceeded the total monthly rainfall during October and November, 2010-11 and of November and December in the year 2011-12 year, whereas during the rest of the crop growth periods in both the years, total monthly rainfall exceeded the total monthly evaporation.

Soil Water Content

The soil water content (Θ) determined during crop growth period of winter 2010-11 is shown in Fig 1. The 'Θ' determined at early crop growth stages *i.e.* at 30 DAT were 0.33, 0.32, 0.34, 0.32 and 0.30 m^3 m^{-3} in $I_{0.8}$; 0.36, 0.36, 0.36, 0.35 and 0.33 m^3 m^{-3} in $I_{1.0}$; 0.40, 0.37, 0.36, 0.36 and 0.37 m^3 m^{-3} in $I_{1.2}$ and 0.34, 0.35, 0.36, 0.28 and 0.27 m^3 m^{-3} in I_{Rec} at 0-0.075, 0.075-0.15, 0.15-0.30, 0.30-0.45 and 0.45-0.60 m soil depths, respectively. The soil water content in $I_{0.8}$ and I_{Rec} was higher in 0.15-0.30 m depth soil layer in comparison to surface layers (0-0.075 and 0.075-0.15 m depth) and sub-surface layer (0.30-0.45 and 0.45-0.60 m depth). The lower 'Θ' in surface layer was due to evaporation losses whereas, in sub-surface layer (0.30-0.45 and 0.45-0.60 m depth), it was due to drainage losses. Similar results were also reported by Ponnuswamy and Santhi (1989). The soil water content in $I_{1.0}$ and $I_{1.2}$ was, however, higher in surface layer (0-0.075 and 0.075-0.15 m depth) and lower in sub-surface layer (0.30-0.45 and 0.45-0.60 m depth) including 0.15-0.30m soil depth. The higher soil water content in $I_{1.0}$ and $I_{1.2}$ may be attributed due to higher drip water application rate compensating evaporation and drainage losses. Similar findings have also been observed by Kumar *et al.* (2012).

The soil water content (Θ) determined at 68 DAT were 0.33, 0.33, 0.33, 0.33 and 0.31 m^3 m^{-3} in $I_{0.8}$; 0.37, 0.37, 0.37, 0.34 and 0.33 m^3 m^{-3} in $I_{1.0}$; 0.41, 0.37, 0.38, 0.37 and 0.39 m^3 m^{-3} in $I_{1.2}$ and 0.34, 0.35, 0.34, 0.26 and 0.28 m^3 m^{-3} in I_{Rec} at 0-0.075, 0.075-0.15, 0.15-0.30, 0.30-0.45 and 0.45-0.60 m soil depths, respectively. There was uniform distribution of soil water among different soil layers in $I_{0.8}$, $I_{1.0}$ and I_{Rec} whereas, in $I_{1.2}$, the surface layer had higher soil moisture content in comparison to other depths. This may be due to the application of more quantity of irrigation water. The soil

Table :1
Week wise rainfall(mm) and evaporation (mm) during cauliflower crop growth

Week	2010-11					2011-12				
	Oct	Nov	Dec	Jan	Feb	Nov	Dec	Jan	Feb	Mar
Week I	1.8	0	0	5.8	7.6	14	0	15	35	18
(1-7 Days)	(2)	(0)	(0)	(1)	(2)	(2)	(0)	(1)	(3)	(3)
Week II	2.5	0	0	0	23	2	9	15	7	7
(8-14 Days)	(0)	(0)	(0)	(0)	(3)	(1)	(2)	(3)	(2)	(2)
Week III	0	5.2	0	58.2	98.2	0	0	54	85	2
(15-21 Days)	(0)	(2)	(0)	(2)	(2)	(0)	(0)	(4)	(4)	(1)
Week IV	28.6	0	0	0	7.6	0	0	20	0	0
(22-28 Days)	(2)	(0)	(0)	(0)	(4)	(0)	(0)	(4)	(0)	(0)
Week V	0	0	91.2	1.0	0	0	0	2	0	0
(29-30/31 Days)	(0)	(0)	(2)	(1)	(0)	(0)	(0)	(1)	(0)	(0)
Total monthly rainfall (mm)	32.9	5.2	91.2	65.0	136.4	16	9	106	117	27
	(6)	(2)	(2)	(4)	(11)	(3)	(2)	(13)	(9)	(6)
Monthly evaporation (mm)	94.9	74.8	59.8	54.6	54.4	67.7	57.4	43.5	46.9	113.1
Daily evaporation rate (mm d^{-1})	3.1	2.5	2.0	1.8	1.9	2.3	1.9	1.4	1.6	3.7

Values in parentheses indicate number of rainy days

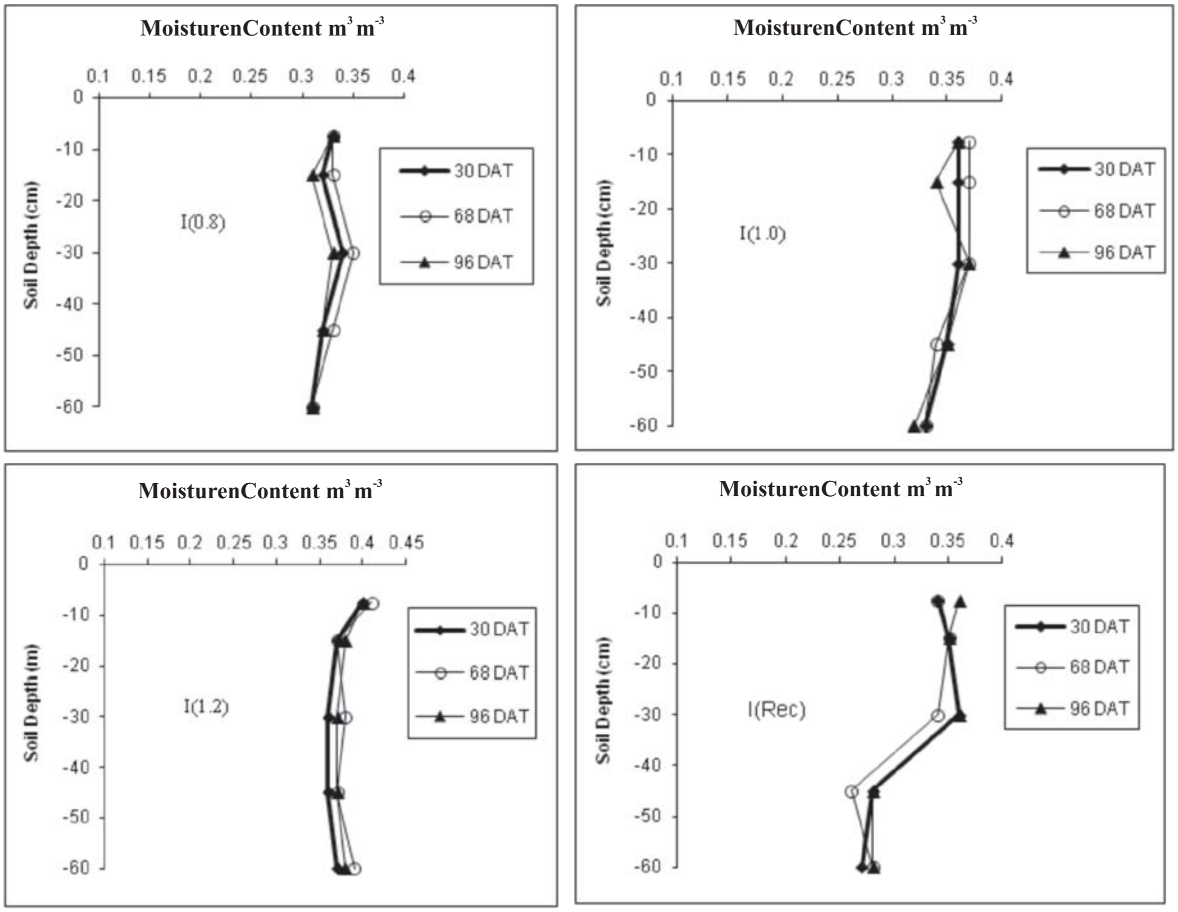


Fig. 1. Depth wise soil water content on selected days of crop growth (2010-11)

water content (Θ) determined at 96 DAT also showed the similar trend.

Soil Water Content and Aeration Porosity Distribution Studies around Dripper

The soil water content (Θ) determined around the dripper at 81 DAT during winter 2010-11 indicated that soil moisture content was higher at dripper point in comparison to other four observation points A, B, C and D 15cm away from the dripper in all drip irrigation levels (Table 2). For example, in $I_{1.0}$ at 0-0.075 m soil depth, there was higher moisture content at dripper point (0.37 m^3 m^{-3}) by 2.7, 16.2,16.2 and 5.4% in comparison to other four observation points A, B, C and D (0.36, 0.31, 0.31 and 0.35 $m^3 m^{-3}$), respectively. The aeration porosity calculated at 81 DAT, indicated that aeration porosity

Table: 2
Effect of drip based irrigation scheduling on variation in soil water content (m^3 m^{-3}) and aeration porosity (%) around the dripper at 81 days after transplanting during 2010-11

Drip based irrigation	Soil depth (m)	Soil water content (Θ)					Aeration porosity (fa)				
		O	A	B	C	D	O	A	B	C	D
I0.8	0-0.075	0.35	0.35	0.30	0.30	0.33	16.28	21.28	21.28	18.28	15.28
	0.075-0.15	0.36	0.31	0.29	0.29	0.33	20.28	22.28	22.28	18.28	16.28
	0.15-0.30	0.34	0.31	0.28	0.32	0.32	17.76	20.76	16.76	16.76	14.76
I1.0	0-0.075	0.37	0.36	0.31	0.31	0.35	15.28	20.28	20.28	16.28	13.28
	0.075-0.15	0.37	0.33	0.30	0.30	0.34	18.28	21.28	21.28	17.28	14.28
	0.15-0.30	0.35	0.32	0.30	0.34	0.30	16.76	18.76	14.76	18.76	12.76
I1.2	0-0.075	0.40	0.37	0.32	0.33	0.35	11.28	14.28	19.28	18.28	16.28
	0.075-0.15	0.38	0.35	0.31	0.33	0.35	13.28	16.28	20.28	18.28	16.28
	0.15-0.30	0.37	0.34	0.31	0.34	0.34	11.76	14.76	17.76	14.76	14.76

O = At dripper, A,B,C,D = Observation points at 15 cm away from dripper in four directions
(A = ↓ , B = → , C = ↑ , D = ←)

was lower at dripper point in comparison to other four observation points A, B, C and D 15cm away from the dripper in all drip irrigation levels (Table 2). This was primarily due to the higher moisture content at dripper point in comparison to other four observation points. For example, the aeration porosity was less at dipper (16.28%) and more at other four observation points A, B, C and D (21.28, 21.28, 18.28 and 15.28%) which was primarily due to more water content at dripper. Among drip irrigation treatments, soil water content was lower and aeration porosity was higher in $I_{0.8}$ (at dripper and other four observation points) in comparison to other drip irrigation levels primarily due to the less application of water.

Marketable Yield and Water Use Efficiency

The averaged marketable curd yield of drip based irrigation and fertigation levels obtained during 2010-11 and 2011-12 is given in Table 3. The highest curd yield was recorded with $I_{1.2}F_{100}$ (13.20 Mg ha^{-1}) which was significantly superior over all treatment combinations (Table 3) and lowest under $I_{0.8}F_{33.3}$ (8.8 Mg ha^{-1}). The highest curd yield was due to more quantity of irrigation applied with 100% recommended dose of fertilizer which resulted in increased nutrient availability. Madile *et al.* (2012) also obtained higher capsicum yield when moisture was applied at lowest soil suction values and 100% recommended doses of fertilizers were applied. The treatment combinations $I_{1.0}F_{100}$ and $I_{0.8}F_{100}$ were statistically at par with each other resulting in saving of 20 percent irrigation water. Likewise, $I_{1.0}F_{100}$ and $I_{1.0}F_{66.6}$ were also statistically at par with each other resulting in 33.3% saving of fertilizer requirement. Similar findings were also reported by Sathya *et al.* (2008).

The averaged marketable curd yield and water use efficiency of drip based irrigation and fertigation levels obtained during 2010-11 and 2011-12 years is given in Table 4. The results revealed that fertigation is a better source of fertilizer application. Application of the 100% recommended dose of water soluble fertilizer with fertigation with 1.2 CPE gave the highest yield and coupled WUE compared to control in cauliflower (Table 4). Similar results were also obtained by Mahajan *et al.* (2007), where they reported that 1.0 CPE with 100% recommended dose of nitrogen supplied through drip irrigation system increased the red hot pepper yield (277.4 q ha^{-1}) in comparison to check basin method of irrigation.

The results revealed that highest WUE was recorded under $I_{1.2}F_{100}$ (21.5 kg ha^{-1} mm^{-1}) followed by $I_{0.8}F_{100}$ (21.0 kg ha^{-1} mm^{-1}) in comparison to rest of the treatment combinations (Table 4) and lowest under control (14.5 kg ha^{-1} mm^{-1}). The highest WUE was primarily due to recommended doses of fertilizer application at $I_{0.8}$ and $I_{1.2}$ levels. The lowest WUE in control was primarily due to higher amount of water used. The results revealed that all the drip fertigation treatments resulted in higher WUE compared to recommended practices in cauliflower (Table 4). Similar results were also obtained by Tanaskovik *et al.* (2011), where they reported that drip fertigation showed almost 87% more WUE in comparison with the treatment with furrow irrigation and conventional application of fertilizer. The total consumptive water use through drip and surface system was 551.80 and 779.45 mm, resulting in 42% water saving over control.

Table: 3
Effect of drip irrigation and fertigation on curd yield (Mg ha^{-1}) (Mean of 2010-11 and 2011-12)

Drip Irrigation	Fertigation Levels			
Levels	F_{100}	$F_{66.6}$	$F_{33.3}$	Mean
$I_{0.8}$	11.30	10.20	8.80	10.10
$I_{1.0}$	11.90	11.10	9.30	10.77
$I_{1.2}$	13.20	11.50	10.30	11.77
Mean	12.13	10.93	9.46	
CD I (P=0.05)		0.58		
CD F(P=0.05)		0.58		
CD I*F(P=0.05)		1.01		

Economics

The averaged data pertaining to economic returns of drip based irrigation and fertigation levels obtained during 2010-11 and 2011-12 is given in Table 4. The results revealed that the gross return was highest under $I_{1.2}F_{100}$ (₹ 1,31,563) and lowest under $I_{0.8}F_{33.3}$ (₹ 87,969). The higher gross return in $I_{1.2}F_{100}$ may be due to higher marketable yield. The net return was highest in control *i.e.* I_{Rec} (₹ 90,685) in comparison to drip-fertigation treatments and lowest under $I_{0.8}F_{66.6}$ (₹ 52,535). Further, the B:C ratio was highest in $I_{Rec}F_{100}$ (4.40) and lowest in $I_{0.8}F_{100}$ (0.71). The results revealed that highest gross return was recorded with the treatment application of 100% NPK and irrigation at 1.2 CPE in comparison to control. The net returns and B:C ratio were recorded highest in control in comparison to other drip fertigation treatments (Table 4). Maximum net returns and B:C ratio of cauliflower was observed in control due to higher cost of cultivation in drip fertigation treatments because of higher cost of water soluble fertilizers and drip installation cost in comparison to control where conventional fertilizers were used. Also, the interest and depreciation values of drip system were included which resulted in higher cost of cultivation.

4. CONCLUSIONS

Increasing the drip irrigation quantity from 0.8 to 1.2 CPE and fertigation from 33.3 to 100 % recommended dose of fertilizer significantly increased the curd yield. Drip based irrigation scheduling resulted in higher soil water

Table: 4
Effect of drip irrigation and fertigation on water use efficiency, returns and B:C ratio of cauliflower (Mean of 2010-11 and 2011-12)

Treatment	Curd yield (Mg ha^{-1})	Consumptive water use (mm)	Water Use Efficiency (kg ha^{-1} mm^{-1})	Gross return (`)	Cost of cultivation (₹ ha^{-1})			Net Return (`)	B:C ratio
					Seedlings + spray materials + labour cost + interest & depreciation on drip system	Fertilizer cost	Total cost		
I_{Rec}	11.1	779.45	14.5	1,11,316	16,488	4,143	20,631	90,685	4.40
$I_{1.2}F_{100}$	13.2	646.26	21.5	1,31,563	17,188	48,730	65,918	65,645	1.00
$I_{1.2}F_{66.6}$	11.5	646.26	18.8	1,15,255	17,188	32,435	49,623	65,632	1.33
$I_{1.2}F_{33.3}$	10.3	646.26	16.6	1,02,334	17,188	16,292	33,480	68,854	2.06
$I_{1.0}F_{100}$	11.9	599.30	20.4	1,18,453	17,188	48,730	65,918	52,535	0.80
$I_{1.0}F_{66.6}$	11.1	599.30	19.2	1.11,300	17,188	32,435	49,623	61,677	1.24
$I_{1.0}F_{33.3}$	9.3	599.30	`16.0	93,114	17,188	16,292	33,480	59,634	1.78
$I_{0.8}F_{100}$	11.3	551.80	21.0	1,12,564	17,188	48,730	65,918	46,646	0.71
$I_{0.8}F_{66.6}$	10.2	551.80	19.1	1,01,750	17,188	32,435	49,623	52,127	1.05
$I_{0.8}F_{33.3}$	8.8	551.80	16.4	87,969	17,188	16,292	33,480	54,489	1.63
CD (P=0.05)	1.01		1.73						

Cost of cauliflower seed: @ 375 g ha^{-1} = ₹ 7988 (₹ 21,300 kg^{-1}) ; Cost of labour : ₹ 3750 (for 25 mandays) for drip irrigation and ₹ 6300 (for 42 mandays @ ₹150 manday^{-1}) for control; Cost on spray and electricity : ₹ 3200; Cost of fertilizers: Urea @ 241.50 50 kg^{-1}, SSP @ 340 50 kg^{-1}, MOP @ 222.75 50 kg^{-1}, 19:19:19 @ 150 kg^{-1}, 0:0:50 @ 150 kg^{-1}; Interest on drip irrigation system @ 8% annum^{-1} ₹ 2000, Depreciation cost on drip system ₹1250.

content, water use efficiency (44.94 to 54.34%) and saving in irrigation water (35.85-50%) in comparison to conventional method of irrigation. Drip based irrigation along with fertigation through water soluble fertilizers had comparatively lower net return and B:C ratio than flood irrigation and conventional fertilizer application. The study concluded that fertigation through water soluble fertilizers was effective in terms of yield but higher price of water soluble fertilizers in comparison to conventional fertilizers reduced the net return and B:C ratio.

ACKNOWLEDGMENTS

The authors thank Indian Council of Agricultural Research for financial support through AICRP on Water Management for conducting the present investigations.

REFERENCES

El Nemr, M.K. 2012. An interactive spreadsheet for drip irrigation system uniformity parameter evaluation. *Int. J. Agric. Sci.*, 4(4): 216-220.

Hillel, D. 1982. *Introduction to Soil Physics.* Department of Plant and Soil Science, University of Massachusetts, Amaherst, Massachusetts, 57 & 112 p.

Kumar, A., Kwatra, J., Sharma, H.C., Sharma, A.K. and Singh, A.K. 2012. Feasibility study of gravity-fed drip irrigation system on hilly terrace land in mid-Himalayan regions. *Ind. J. Soil Cons.,* 40(3): 202-206.

Madile, A.K., Singh, P.K., Sharma, H.C., Singh, R.P. and Joshi, G. 2012. Tensiometer based drip irrigation scheduling for enhancing water productivity of capsicum (*Capsicum annum L.*) under polyhouse. *Ind. J. Soil Cons.*, 40(1): 41-45.

Magar, S.S. and Nandgude, S.B. 2005. Micro-irrigation status and holistic strategy for evergreen revolution. *J. Water Mngt.,* 13(2): 106-111.

Mahajan, G., Singh, K.G., Sharda, R. and Siag, M. 2007. Response of red hot pepper (*Capsicum annum* L.) to water and nitrogen under drip and check basin method of irrigation. *Asian J. Plant Sci.,* 6(5): 815-820.

Ponnuswamy, K. and Santhi, P. 1998. Effect of drip on soil moisture distribution pattern in cassava (*Manihot exculenta* Crantz). *J. Water Mngt.,* 6(1&2): 1-2.

Rattan, R.K. 2009. *Fundamentals of Soil Science.* National Agricultural Science Centre Complex, New Delhi, 91 p.

Sathya, S., Pitchai, J.G., Indirani, R. and Kannathasan, M. 2008. Effect of fertigation on availability of nutrients (N, P & K) in soil- A Review. *Agric. Reviews,* 29(3): 214-219.

Tanaskovik, V., Cukaliev, O., Romic, D. and Ondrasek, G. 2011. The Influence of Drip Fertigation on Water Use Efficiency in Tomato Crop Production. *Agriculturae Conspectus Scientificus,* 76: 57-63.

Verma, S.D. 1979. Characterization and genesis of soils of Himachal Pradesh Ph.D. Thesis, Himachal Pradesh Krishi Vishvavidalaya, Palampur.