Available online at www.ijpab.com

DOI: http://dx.doi.org/10.18782/2320-7051.2496

ISSN: 2320 – 7051

Int. J. Pure App. Biosci. **5 (1):** 210-220 (2017)

Research Article

International Journal of Pure & Applied Bioscience

OPEN ACCESS

Effect of Varying Drip Irrigation Levels and Different Methods of NPK Fertilizer Application on Soil Water Dynamics, Water use Efficiency and Yield of Broccoli (*Brassica oleracea* L. *var*. *italica*) in Wet Temperate Zone of Himachal Pradesh

Juvaria Jeelani*, K.K. Katoch, Sanjeev K. Sandal and R.K. Gupta

Department of Soil Science, Chaudhary Sarwan Kumar Himachal Pradesh Agricultural University, Palampur – 176062, Himachal Pradesh

*Corresponding Author E-mail: juvairia23@gmail.com

Received: 24.01.2017 | Revised: 6.02.2017 | Accepted: 10.02.2017

ABSTRACT

The present study was conducted at experimental farm of CSK HPKV, Palampur, during the year 2012-2013 with the objectives of evaluating the effects of drip irrigation levels applied at CPE 0.4, 0.6 and 0.8 and different methods of fertilizer application on soil water retention and transmission, plant water and water use efficiency, productivity and nutrient uptake of broccoli. The treatments comprised of (a) three drip irrigation levels viz., $I_{0.4}$ *– Drip at 40 per cent CPE,* $I_{0.6}$ *– Drip at 60 per cent CPE and* $I_{0.8}$ *– Drip at 80 per cent CPE (b) three fertilizer application levels viz.,* F_{100}*–100 per cent recommended dose of fertilizer through fertigation,* $F_{C25+F75}$ *– 25 percent recommended dose of fertilizer through conventional method as a basal dose and 75 per cent through fertigation and* F_{CF} *–100 per cent of recommended dose of fertilizer through conventional method and fertilizers , (c) control - Flood irrigation of 4 cm at 8-10 days interval + 100 per cent recommended dose of fertilizer and (d) absolute control- No recommended dose of fertilizer and flood irrigation of 4 cm at 8-10 days interval. The broccoli cv. Palam Samridhi was transplanted on October 31, 2012. The results indicated that* $I_{0.8}$ *and* I_{Rec} *treatment had higher soil water content, soil water stock, profile water recharge in comparison to* $I_{0.4}$ *and* $I_{0.6}$*. The* $I_{0.8}$ *treatment due to favorable soil moisture regimes led to better root and shoot growth, higher relative leaf water content, marketable curd yield, NPK uptake and water use efficiency in comparison to* $I_{0.4}$*,* $I_{0.6}$ *and* I_{Rec}*. Likewise,* F_{100} *and* $F_{C25+F75}$ *treatment had higher root and shoot growth, relative leaf water content, marketable curd yield, NPK uptake and water use efficiency in comparison to* F_{CF}*. The marketable curd yield obtained under* $I_{0.4}F_{100}$ *was at par with* $I_{0.6}F_{100}$ *treatment, which resulted in saving of 20 per cent irrigation water. The study concluded that drip based irrigation scheduling resulted in higher water use efficiency (44.68% to 54.88%) and saving in irrigation water (43.25% to 48.90%) in comparison to conventional method of irrigation.*

Key words: *B:C ratio ; Drip irrigation; Fertigation; Marketable yield; RLWC; Water use efficiency*

INTRODUCTION

Water availability for agriculture is under challenge in the world as well as in India. Today, it is more important to use water resources wisely and to irrigate intelligently. With increasing population in India, food grain demand by 2030 will be 345 M mt and by 2050 will be 494 M mt[11]. To meet the increasing food grain demand, productivity is to be increased from 2.3t ha^{-1} to 4.0t ha^{-1} under irrigated conditions and 1.0t ha^{-1} to 1.5t ha^{-1} under rainfed conditions[5]. To achieve the target productivity, there is stiff competition for water from different sources. In 2025, water demand will be 1093 BCM and out of this, 910 BCM will be required for agriculture, thus other sectors will be under stress[5].

Himachal Pradesh is a hilly state and the majority of the people are engaged in farming profession. State has made major strides in horticulture and off season vegetable cultivation and has earned a niche for itself in national scenario. But the potential for off-season vegetable cultivation has not been harnessed fully owing to irrigation constraints. Moreover, conventional irrigation methods are not feasible due to mountainous terrains. Some parts of Himachal Pradesh receive annual rainfall up to 3000 mm and about 85 per cent of it occurs during June to September. Most of monsoon rainfall goes waste as runoff due to uneven terrain of the region. The months of October, November and December are generally dry, due to which *rabi* crops fail frequently and yield levels are very low. Under such circumstances rainwater harvesting and application of harvested water by micro irrigation system is the most feasible option.

In drip irrigation, water is applied drop by drop on continuous basis through closed network of plastic pipes at frequent intervals near to the root zone for consumptive use of the crop. Drip irrigation enhances profitability, increases crop yield and improves crop quality. It reduces costs from water, energy, labour, chemical inputs and run- off. It improves plant vigor by delivering water and nutrients directly to the plant roots – the effective feeding zone, avoiding wetting of leaves which results in low disease incidence. It minimizes conventional losses of water by deep percolation, evaporation and run off. This method is very suitable under situations of water scarcity. 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*. Soils with high as well as low water transmission characteristics can be irrigated by this method efficiently. Better crop establishment can be ensured under this system of irrigation since mechanical impedance for emerging seedlings is lowered by reducing the soil crusting phenomenon.

Broccoli (*Brassica oleracea var*.L. *italica*) is a member of the *Brassicaceae* family and its wild form is found along the Mediterranean region. It is a very delicious, nutritious and exotic vegetable grown. Broccoli is rich in vitamin A, C and dietary fibre and in terms of minerals; the value of broccoli includes Fe, Ca, P, Mg, Zn, K. It contains 2500 IU vitamin A in a 100 g edible portion. It also contains 103 mg calcium, 78 mg phosphorous, 382 mg potassium and 113 mg vitamin C[4]. Broccoli is the upcoming cash crop in the country. It contains multiple nutrients with anti-cancer properties such as di-indolylmethane and sulphoraphane. Broccoli can prevent Alzheimer’s disease, diabetes, Ca deficiency, colon cancer, malignant tumor, lung cancer, heart disease and arthritis.

Being a cool season crop, it requires 15-20 degree centigrade optimum temperature for head production. It prefers a well drained, sandy loam soil with optimum pH of 5.5-6.8[4].

Cite this article: Jeelani, J., Katoch, K.K., Sandal, S.K. and Gupta, R.K., Effect of Varying Drip Irrigation Levels and Different Methods of NPK Fertilizer Application on Soil Water Dynamics, Water use Efficiency and Yield of Broccoli (*Brassica oleracea* L. *var. italica*) in Wet Temperate Zone of Himachal Pradesh, *Int. J. Pure App. Biosci.* **5(1):** 210-220 (2017). doi: http://dx.doi.org/10.18782/2320-7051.2496

Keeping in mind its better nutritive character, more edible dry matter content, market price and its suitability to low temperature conditions it has a great potential in low hill conditions of Himachal Pradesh.

As such, limited information is available on the quantity of water to be applied through drip and on application of water soluble fertilizer through fertigation, which have become recently available in the market. With this background, the study was planned under Sub-Humid Zone of the State of Himachal Pradesh, to show how the test crop of Broccoli behaves under varying levels of these two inputs with the following objectives:

- To evaluate the effects of drip irrigation levels applied at 0.4 CPE, 0.6 CPE and 0.8 CPE on soil and plant water behavior
- To evaluate the effects of NPK fertigation, NPK fertilization and the combined method of fertigation and fertilization on productivity and nutrient uptake at varying drip irrigation levels.

MATERIALS AND METHODS

A field experiment was conducted at the experimental farm of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, during *rabi* season 2012-13 in an acid Alfisol. The broccoli cv. Palam Samridhi was transplanted on Oct 31, 2012 at 45 cm x 45 cm spacing in 6 m x 2 m (12 m^2) plots. The area lies in Palam Valley (32°06′ N latitude and 76°33′ 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. Taxonomically, the soil is classified as Alfisols – Typic Hapludalf[14]. The average values of physico-chemical and chemical properties of the surface soil (0-0.15 m) were determined. The soil had a pH value 5.08. The soil was low in available N (198.76 kg ha^{-1}), high in available P (46.79 kg ha^{-1}) and medium in available K (224.88 kg ha^{-1}).The mean weight diameter of the aggregates for the surface layer was 1.919 mm with infiltration rate of 1.753 x 10^{-5} m s^{-1}.

The experiment was laid out in a randomized block design with eleven treatments comprising of (a) Three drip irrigation levels viz., $I_{0.8}$ (0.8 CPE) i.e. Drip at 80 per cent CPE, $I_{0.6}$ (0.6 CPE) i.e. Drip at 60 per cent CPE and $I_{0.4}$ (0.4 CPE) i.e. Drip at 40 per cent CPE (b) Three methods of fertilizer application levels viz., (i) 100 per cent through fertigation, (ii) 25 per cent basal dose through conventional fertilization method and 75 per cent through fertigation and (iii) conventional fertilization. The RDF (Recommended dose of fertilizer) was kept same in all the treatments. Besides this there was (c) one recommended practice (RP) i.e., control (I_{Rec}) i.e. flood irrigation of 4 cm at 8-10 days interval along with 100 per cent recommended dose of fertilizer and (d) absolute control where flood irrigation of 4 cm was given at 8-10 days interval and with no recommended dose of fertilizer. The treatments were replicated thrice. The averaged pan evaporation data (2004-05 to 2011-12) was used to determine the amount of water to be given in the ratio of 0.8, 0.6 and 0.4 cumulative pan evaporation (CPE). The drip irrigation was given at 2 day interval. In NPK fertigation treatments, water soluble fertilizers *viz*., 19:19:19+12:61:0+Urea was applied in different calculated proportions injected through overhead fertilizer tank at 8-10 days interval. In fertigation treatments NPK fertilizer doses calculated as per treatment were applied in 10 equal splits at 8-10 day interval through fertigation in 100 per cent fertigation treatment and in seven equal splits at 8-10 day interval in 75 per cent fertigation treatment. In conventional fertilization treatment and control half of nitrogen fertilizer and full of phosphorous and potassium fertilizers were applied at transplanting. The remaining half of nitrogen fertilizer was applied in two splits, first after 30 days of transplanting and second at head formation stage.

To undertake the study, drip laterals fitted in 27 plots were selected starting from first to last plot. In each plot, 10 drippers were selected and the containers were kept at the respective drippers. The whole system was operated for one minute and water was collected in each container. The discharge variation was calculated by the following equation[2].

$$\textbf{Discharge variation}\ (\%) = \frac{\mathbf{Q_{max} - Q_{min}}}{\mathbf{Q_{max}}} \times \mathbf{100}$$

where,

'Q_{max}' is the maximum discharge rate (Litre h^{-1}) and 'Q_{min}' is the minimum discharge rate (Litre h^{-1})

The uniformity coefficient (U.C) was calculated by the following equation[1].

$$\mathbf{U.C}\ (\%) = \mathbf{100}\left[\mathbf{1} - \frac{\sum_{i=0}^{n}[q_i - \overline{q}]}{\overline{q}}\right]$$

Where, 'n' represents number of emitters evaluated, 'q_i' is the discharge through emitter and '$\overline{q}$' is the average discharge rate.

The overall averaged discharge rate and discharge variation was 4.05 Litre h^{-1} and 17.11 per cent respectively. Also the overall averaged uniformity coefficient was 94.57 per cent. 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 periodically during broccoli crop growth 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[3] (Hillel 1982). The aeration porosity was calculated by determining relation of air to water content on a particular day by the following equation[9].

$$\mathbf{f_a\ (\%) = (f\ -\ \Theta)}$$

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.

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

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 relative leaf water content (RLWC) was determined at 50 and 100 DAT during crop growth at 0700 h and 1400 h. RLWC was computed from the fresh weight, turgid weight and oven dry weight of leaves.

$$\mathbf{RLWC} = \frac{\textbf{Fresh weight} - \textbf{Oven dry weight}}{\textbf{Fully turgid weight} - \textbf{Oven dry weight}}\ \mathbf{x\ 100}$$

The fresh marketable curd yield of broccoli 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.

RESULTS AND DISCUSSION

Rainfall and Evaporation

The rainfall distribution and evaporation during growth period of broccoli are given in Table 1 for the year 2012-13. The data indicated that total monthly evaporation exceeded the total monthly rainfall during November and December of 2012, whereas during the rest of the crop growth period, total monthly rainfall exceeded the total monthly evaporation.

Soil water content

The soil water content (θ) determined during crop growth period of winter 2012-13 is shown in Fig 1. The 'θ' determined at early crop growth stages i.e. at 30 DAT was 0.27, 0.32, 0.27 and 0.30 $m^3\ m^{-3}$ in $I_{0.4}$; 0.29, 0.33, 0.28 and 0.31 $m^3\ m^{-3}$ in $I_{0.6}$; 0.30, 0.33, 0.31 and 0.31 $m^3\ m^{-3}$ in $I_{0.8}$ and 0.37, 0.38, 0.37 and 0.36 $m^3\ m^{-3}$ in I_{Rec} at 0-0.15, 0.15-0.30, 0.30-0.45 and 0.45-0.60 m soil depths, respectively. The soil water content showed an increasing trend from $I_{0.4}$ to $I_{0.8}$ in 0-0.15, 0.15-0.30 and 0.30-0.45 m depths. The higher soil water content in $I_{0.8}$ may be attributed to higher amount of drip irrigation compensating evaporation and drainage losses. Similar findings have also been observed by Kumar *et al*[6]. However, the soil water content was almost similar in $I_{0.4}$, $I_{0.6}$ and $I_{0.8}$ in 0.45-0.60m deep layer. The soil water content was higher both in surface (0-0.15 and 0.15-0.30) as well as subsurface (0.30-0.45 and 0.45-0.60) layers in I_{Rec}.

The soil water content (θ) determined at 63 DAT was 0.25, 0.30, 0.33 and 0.35$m^3\ m^{-3}$in $I_{0.4}$; 0.26, 0.34, 0.32 and 0.39$m^3\ m^{-3}$ in $I_{0.6}$; 0.34, 0.38, 0.37 and 0.36$m^3\ m^{-3}$ in $I_{0.8}$;0.32, 0.35,0.33 and 0.36$m^3\ m^{-3}$ in I_{Rec} at 0-0.15, 0.15-0.30, 0.30-0.45 and 0.45-0.60 m soil depths. This showed that there was less moisture content in surface layers of 0-0.15 and 0.15-0.30 m depth in $I_{0.4}$ and $I_{0.6}$ as compared to the surface layers of $1_{0.8}$ and I_{Rec}. There was an increase in soil water content with increase in depth of soil with highest subsurface – moisture content in $I_{0.8}$. The soil water content (θ) determined at 96 DAT also showed the similar trend. The soil moisture content (θ) determined during the growth stages of broccoli showed higher values for $I_{0.8}$ in comparison to $I_{0.4}$ and $I_{0.6}$. This might be due to the application of more quantity of water in $I_{0.8}$ than other treatments. Similar results were also reported by Ponnuswamy and Santhi[7] and Ueta *et al*[13].

Soil water content and aeration porosity distribution studies around dripper

The soil water content and aeration porosity distribution values are given in Table 2. The soil water content (θ) determined at 86 DAT indicated that soil moisture content at dripper point was at par in comparison to other four observation points A, B, C and D 22.5cm away from the dripper in all drip irrigation levels. Since the drippers as well as laterals were separated by an equal spacing of 45 cm, there was an overlap of moisture distribution circles formed around the dripper at points A, B, C and D which made the moisture content at the dripper at par with the moisture content around the dripper at these points. For example in $I_{0.6}$ at 0.15-0.30 m depth moisture content at dripper was 0.32 $m^3m^{-3}$and at four points around the dripper were 0.32, 0.30, 0.30 and 0.29 m^3m^{-3} around the dripper. Among drip treatments, 'θ' determined at 86 DAT indicated that soil moisture content was higher in $I_{0.8}$ (at dripper and other four observation points) in comparison to other drip irrigation levels due to the application of more quantity of water. . The soil moisture content varied from 0.22 to 0.41 $m^3\ m^{-3}$ at 86 DAT among all the soil depths and drip treatments.

The aeration porosity determined at 86 DAT, indicated that aeration porosity at the dripper point was at par to other four observation points A, B, C and D 22.5cm away from the dripper in all drip irrigation levels. This was primarily due to the uniform moisture content at dripper point in and the other four observation points. For example, the aeration porosity at dipper (27.64 %) and at other four observation points A, B, C and D were 25.40 28.76 29.88 27.64 per cent respectively. Among drip irrigation treatments, aeration porosity determined at 86 DAT indicated that aeration porosity was higher in $I_{0.4}$ (at dripper and other four observation points) in comparison to other drip irrigation levels due to the application of less quantity of water. The aeration porosity varied from 10.04-34.36 per cent at 86 DAT among all the soil depths and drip treatments.

Relative leaf water content

The relative leaf water content (RLWC) determined at 50 and 100 DAT, during broccoli growth period at 0700 h and 1400 h are shown in Table 3. A significant increase in RLWC was recorded with increasing quantity of irrigation. The RLWC at 50 DAT was significantly higher under $I_{0.8}$ (90.68 and 84.95%) and $I_{0.6}$ (88.48 and 85.58%) compared to $I_{0.4}$ (83.58 and 77.77%) at 0700 h and 1400 h, respectively. Similar pattern was recorded at 100 DAT where RLWC was higher under $I_{0.8}$ (89.32 and 82.01%) and $I_{0.6}$ (88.93 and 82.47%) compared to $I_{0.4}$ (86.11 and 78.53%) at 0700 h and 1400 h, respectively. The RLWC decreased with decrease in irrigation amount from $I_{0.8}$ to $I_{0.4}$ leading to proportional decrease in quantity of available water in soil.

The RLWC values at 50 DAT under methods of fertilizer application were, 89.57 per cent in F_{100} followed by 87.07 per cent in $F_{C25+F75}$ both of them however were statistically at par with each other. The RLWC value in F_{100} was significantly higher over F_{CF} (86.10%) primarily due to better root growth. The RLWC values at 100 DAT were higher in $F_{C25+F75}$ (90.37 and 83.35%) followed by F_{100} (87.92 and 80.32%) and F_{CF} (86.07 and 79.35%), during 0700h and 1400 h respectively. The RLWC under 'others' treatment (88.12 and 81.00%) was significantly higher over 'control' (84.34 and 74.57%) during 0700 h and 1400 h at 100 DAT. The higher RLWC in 'others' treatments may be due to frequent application of irrigation water at 2-3 days interval, maintaining higher root zone moisture in comparison to 'control' where irrigation was applied at 8-10 days interval.

Marketable Yield and Water use efficiency

The effect of drip irrigation and different methods of fertigation on biological yield of broccoli is given in Table 4.

The highest curd yield was recorded with $I_{0.8}F_{C25+F75}$ (6.59 Mg ha^{-1}) and lowest under $I_{0.4}F_{CF}$ (5.46 Mg ha^{-1}). The highest curd yield was due to more quantity of irrigation applied with a fertilizer method in which 25 per cent was applied as basal dose and 75 per cent through fertigation, resulting in better root and shoot growth due to increased nutrient availability. Also, the treatment combinations $I_{0.4}F_{100}$ and $I_{0.6}F_{100}$ were statistically at par with each other resulting in saving of 20 per cent irrigation water. Similar findings were also reported by Sathya *et al*[10].

By producing broccoli curd yield of 6.35 Mg ha^{-1}, $I_{0.4}F_{C25+F75}$ was found to be the best treatment as it produced yield at par with the $I_{0.6}F_{C25+F75}$ and $I_{0.8}F_{C25+F75}$ and superior to all other treatment combinations, thereby saving water as well as fertilizer.

The highest WUE was recorded under $I_{0.4}F_{C25+F75}$ (21.21 kg ha^{-1} mm^{-1}) and $I_{0.6}F_{C25+F75}$ (20.38 kg ha^{-1} mm^{-1}) followed by $I_{0.8}F_{C25+F75}$ (19.82 kg ha^{-1} mm^{-1}) in comparison to rest of the treatment combinations and lowest was recorded under control (9.57 kg ha^{-1} mm^{-1}) shown in Table 7. The highest WUE in $I_{0.4}F_{C25+F75}$ was primarily due to higher curd yield produced with lesser quantity of water applied. The lowest WUE in control was primarily due to higher amount of water used which however produced lesser yield in comparison to other drip treatments. This shows that water application beyond 0.8CPE was not utilized by the crop. Similar results were reported by Rathore *et al*[8]. Similarly, Tanaskovik *et al*[12]., reported that drip fertigation showed almost 87 percent 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 299.30 and 585.80 mm, resulting in 49 percent water saving over control.

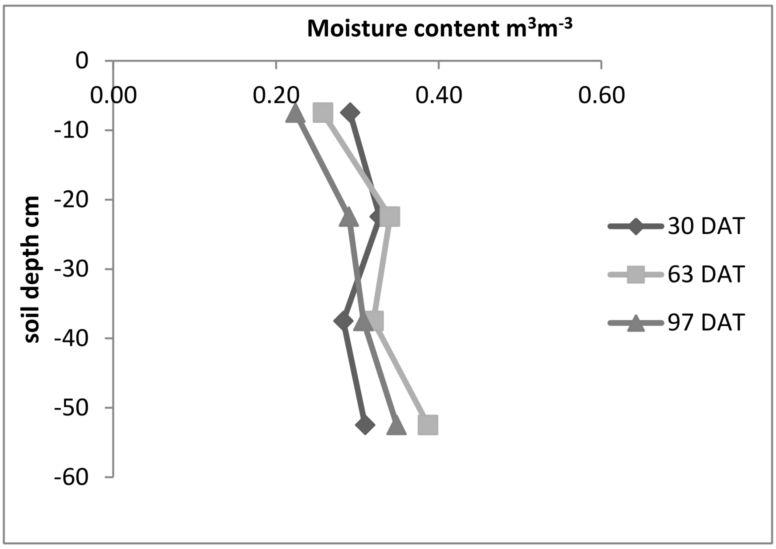
Economics

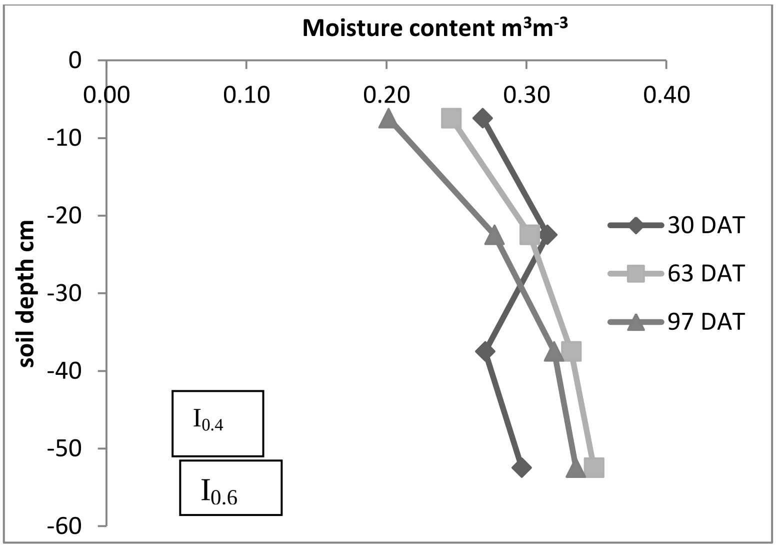
The gross return was highest under $I_{0.8}F_{C25+F75}$ (Rs. 1,97,600) followed by $I_{0.8}F_{100}$ (Rs. 1,93,790) and lowest under $I_{Rec.}$ (Rs. 1,68,110). The higher gross return in $I_{0.8}F_{C25+F75}$ and $I_{0.8}F_{100}$ may be due to higher marketable yield. The B: C ratio was highest in control i.e. I_{Rec} (4.17) in comparison to drip-fertigation treatments and lowest under $I_{0.4}F_{100}$ (1.35).The higher B: C ratio in $I_{Rec}F_{100}$ was due to less cost of cultivation primarily due to less cost of conventional fertilizers in comparison to drip irrigation treatments where cost of soluble fertilizers was much higher. Also, the interest and depreciation values of drip system were included which resulted in higher cost of cultivation. The data also revealed that the labour requirement was higher under 'control' in comparison to drip irrigated treatments. Similar results were also reported by Woltering *et al*[15].

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

Week	Nov	Dec	Jan	Feb	Mar
Week I (1-7 days)	0 (0)	0 (0)	0 (0)	86.6 (4)	0 (0)
Week II (8-14 days)	0 (0)	20.0 (2)	1.8 (1)	0 (0)	0 (0)
Week III (15-21 days)	0 (0)	8.2 (1)	73.6 (3)	15.4 (4)	
Week IV (22-28 days)	0 (0)	0 (0)	0 (0)	63.2 (4)	
Week V (29-30/31 days)	4.0 (2)	0 (0)	0 (0)	0 (0)	
Total monthly rainfall (mm)	**4.0 (2)**	**28.2 (3)**	**75.4 (4)**	**165.2 (12)**	
Total monthly evaporation (mm)	**74.7**	**58.9**	**53.4**	**53.7**	
Daily evaporation rate (mmd^{-1})	**2.5**	**1.9**	**1.7**	**1.9**	

Values in parentheses indicate number of rainy day





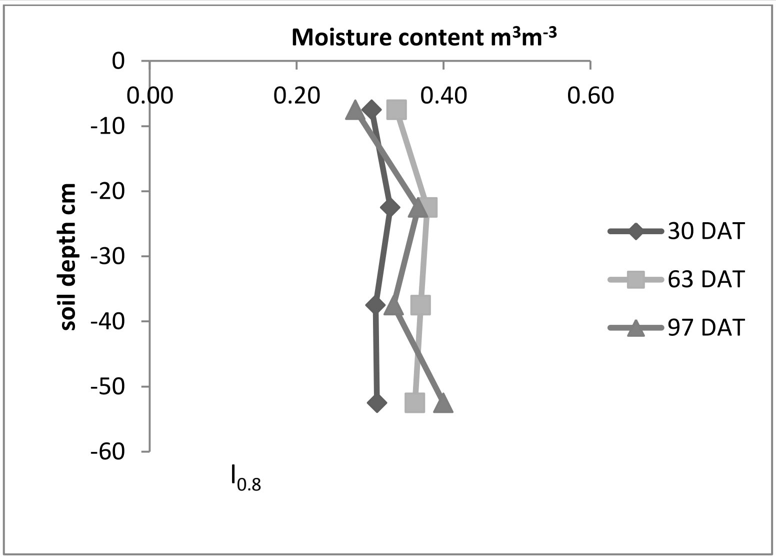


Fig. 1: Depth wise soil water content on selected days of crop growth (2012-13)

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 86 days after transplanting during 2012-13.

Drip based irrigation	Soil depth (m)	Soil moisture content					Aeration porosity				
		O	**A**	**B**	**C**	**D**	**O**	**A**	**B**	**C**	**D**
$I_{0.4}$	**0-0.15**	0.29	0.31	0.28	0.27	0.29	27.64	25.40	28.76	29.88	27.64
	0.15-0.30	0.34	0.38	0.32	0.38	0.38	18.07	14.29	20.59	14.29	14.29
	0.30-0.45	0.31	0.34	0.34	0.37	0.36	23.85	20.16	20.16	17.70	18.93
	0.45-0.60	0.36	0.37	0.36	0.40	0.39	15.20	13.91	15.20	11.33	12.62
$I_{0.6}$	**0.0-0.15**	0.29	0.25	0.24	0.27	0.22	27.64	32.12	33.24	29.88	34.36
	0.15-0.30	0.32	0.32	0.30	0.30	0.29	20.59	20.59	21.85	21.85	23.11
	0.30-0.45	0.33	0.33	0.27	0.32	0.27	21.39	21.60	27.54	22.62	27.54
	0.45-0.60	0.39	0.34	0.35	0.35	0.36	12.62	17.78	16.49	16.49	15.20
$I_{0.8}$	**0.0-0.15**	0.31	0.28	0.29	0.27	0.27	25.40	28.76	27.64	29.88	29.88
	0.15-0.30	0.33	0.35	0.33	0.35	0.33	19.33	16.81	19.33	16.81	19.33
	0.30-0.45	0.37	0.33	0.34	0.37	0.36	17.70	21.39	20.16	17.70	18.93
	0.45-0.60	0.39	0.41	0.37	0.40	0.37	12.62	10.04	13.91	11.33	13.91

O = At dripper, A, B, C, D = Observation points at 22.5 cm away from dripper in four directions

(A = ↓ , B = →, C = ↑, D = ←)

Table 3: Effect of drip based irrigation and method of fertilizer application on relative leaf water content during crop growth

Treatment	Relative leaf water content (%)			
	50 DAT		100 DAT	
	0700 h	1400 h	0700 h	1400 h
Drip irrigation levels				
$I_{0.4}$	83.58	77.77	86.11	78.53
$I_{0.6}$	88.48	85.58	88.93	82.47
$I_{0.8}$	90.68	84.95	89.32	82.01
CD (P=0.05)	2.462	4.422	2.210	2.666
Different methods of fertilizer application				
F_{100}	89.57	84.14	87.92	80.32
$F_{C25+F75}$	87.07	80.97	90.37	83.35
F_{CF}	86.10	83.19	86.07	79.35
CD (P=0.05)	2.462	NS	2.210	2.666
Control vs. Others				
Control	78.64	87.33	84.34	74.57
Others	87.58	82.77	88.12	81.00
CD (P=0.05)	3.178	NS	2.854	3.441

Table 4: Effect of drip irrigation and fertigation on curd yield (Mg ha^{-1})

Drip Irrigation Levels	Fertigation Levels			
	F_{100}	$F_{C25+F75}$	F_{CF}	Mean
$I_{0.4}$	5.87	6.35	5.46	5.89
$I_{0.6}$	6.06	6.44	5.66	6.05
$I_{0.8}$	6.46	6.59	5.75	6.25
Mean	6.13	6.46	5.62	
CD I(P=0.05)	**0.178**			
CD F(P=0.05)	**0.178**			
CD I*F(P=0.05)	**0.309**			

Table 5: Effect of drip irrigation and method of fertilizer application on water use efficiency, returns and B:C ratio

Treatment	Curd yield (Mg ha^{-1})	Consumptive water use (mm)	Water use efficiency (kg ha^{-1} mm^{-1})	Gross return (Rs)	Cost of cultivation (Rs ha^{-1})			Net Return (Rs)	B: C ratio
					Seedlings + spray materials + labour cost + interest & depreciation on drip system	Fertilizer cost	Total cost		
$I_{0.4}F_{100}$	5.87	299.30	19.60	176000	28500	46,245	74745	101255	1.35
$I_{0.4}F_{C25+F75}$	6.35	299.30	21.21	190400	28500	36230	64730	125670	1.94
$I_{0.4}F_{CF}$	5.46	299.30	18.24	163800	28500	6233	34733	129067	3.72
$I_{0.6}F_{100}$	6.06	316.00	19.19	181900	28500	46,245	74745	107155	1.43
$I_{0.6}F_{C25+F75}$	6.44	316.00	20.38	193200	28500	36230	64730	128470	1.98
$I_{0.6}F_{CF}$	5.66	316.00	17.90	169720	28500	6233	34733	134987	3.89
$I_{0.8}F_{100}$	6.46	332.40	19.43	193790	28500	46,245	74745	119045	1.59
$I_{0.8}F_{C25+F75}$	6.59	332.40	19.82	197600	28500	36230	64730	132870	2.05
$I_{0.8}F_{CF}$	5.75	332.40	17.30	172480	28500	6233	34733	137747	3.97
I_{Rec}	5.60	585.80	9.57	168110	26300	6233	32533	135577	4.17
CD (P=0.05)	0.302		0.904						

Cost of broccoli seed: @50 Rs/100 seedlings ;Cost of labour : Rs. 3750 (for 25 man days) for drip irrigation and Rs 6300 (for 42 man days @ Rs. 150/ man day) for control; Cost on spray : Rs. 1500; Cost of fertilizers : Urea – @ 241.50/50 kg , SSP – @ 340/50 kg ,MOP – @ 222.75/50 kg, 19:19:19 – @ 150/kg, 12:61:0- @ 150/kg; Interest on drip irrigation system @ 8% per annum – Rs 2000, Depreciation cost on drip system – Rs 1250

CONCLUSIONS

Increasing the drip irrigation quantity IW/CPE ratio from 0.4 to 0.8 and application of fertilizer 25 per cent as basal and 75 per cent through fertigation significantly increased the curd yield and NPK uptake. Curd yield obtained in $I_{0.4}F_{100}$ and $I_{0.6}F_{100}$ was statistically at par with each other which resulted in saving of 20 per cent irrigation water. By producing broccoli curd yield of 6.35 Mg ha^{-1}, $I_{0.4}F_{C25+F75}$ was found to be the best treatment as it produced yield at par with the $I_{0.6}F_{C25+F75}$ and $I_{0.8}F_{C25+F75}$ and superior to all other treatment combinations, thereby saving water as well as fertilizer. Gravity fed drip based irrigation along with fertigation through water soluble fertilizers had comparatively lower net return and B:C ratio in comparison to flood irrigation and conventional fertilizer application. The quality parameters of broccoli increased with increase in IW/CPE from 0.4 to 0.8 and the fertilizer treatment in which 25 per cent was applied through conventional method and 75 per cent through drip showed superiority over other methods of fertilizer application. N, P and K use efficiency increased with increasing drip irrigation quantity from 0.4 to 0.8 and in different methods of fertilizer application, N, P and K use efficiency was highest in $F_{C25+F75}$ in comparison to other treatments. Drip based irrigation scheduling resulted in higher soil water content, water use efficiency and saving in irrigation water in comparison to conventional method of irrigation.

Acknowledgement

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

REFERENCES

1. Christiansen, J.E., Hydraulics of sprinkling systems for irrigation. *Trans. Amer. Soc.Civ. Eng.*, **107:** 221-239 (1942).
2. El Nemr, M.K., An interactive spreadsheet for drip irrigation system uniformity parameter evaluation. *Int. J. Agric. Sci*., **4(4):** 216-220 (2012).
3. Hillel, D., Introduction to Soil Physics. *Department of Plant and Soil Science, University of Massachusetts, Amaherst, Massachusetts*, p 57 & 112 (1982).
4. Kohli, U.K., Vikram, A. and Dohroo, N.P., Broccoli. In : Exotic vegetable production and post harvest. Centre of Advance Studies. Department of Vegetable Crops, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan, HP (2006).
5. Kumar Ashwani, *Vision 2030*. http://www.wtcer.ernet.in/pdf/Vision_2030.pdf , 41p (2011).
6. Kumar, A., Kwatra, J., Sharma, H.C., Sharma, A.K. and Singh, A.K., Feasibility study of gravity-fed drip irrigation system on hilly terrace land in mid-Himalayan regions. *Indian J. Soil Cons.*, **40(3):** 202-206 (2012).
7. Ponnuswamy, K. and Santhi, P., Effect of drip on soil moisture distribution pattern in cassava (*Manihot exculenta Crantz*). *J.Water Mngt.*, **6(1&2):** 1-2 (1998).
8. Rathore, A.C. and Singh, J.N., Optimization of nitrogen application and irrigation for improved growth and spike production of tuberose (*Polianthes tuberosa* Lin.). *Indian J. Soil Cons.*, **37(1):** 45-49 (2009).
9. Rattan, R.K., Fundamentals of Soil Science. *National Agricultural Science Centre Complex, New Delhi* p 91 (2009).
10. Sathya, S., Pitchai, J.G., Indirani, R. and Kannathasan, M., Effect of fertigation on availability of nutrients (N, P & K) in soil – A Review. *Agric. Reviews*., **29(3):** 214-219 (2008).
11. Soman, P., *Mechanising-farmoperations*. http://www.ficcifood360.in/pdfs/da2012//2.Dr%20P%20Soman%20jain%20irrigation.pdf , 17p (2012).
12. Tanaskovik, V., Cukaliev, O., Romic, D. and Ondrasek, G., The Influence of Drip Fertigation on Water Use Efficiency in Tomato Crop Production. *Agriculturae Conspectus Scientificus*, **76(1):** 57-63 (2011).

13. Ueta, T., Ikeba, T., Ahn-DongHyuk, Kato, K., Kawano, T. and Matsumoto, E., Effects of drip fertigation on yield and quality of leaf vegetables and on efficiency of nitrogen fertilization in outdoor plant. *Japanese Journal of Soil Science and Plant Nutrition culture*, **80:** 477-486 (2009).
14. Verma, S.D., Characterization and genesis of soils of Himachal Pradesh Ph.D. *Thesis submitted to Himachal Pradesh Krishi Vishvavidalaya, Palampur (*1979).
15. Woltering, L., Ibrahim, A., Pasternak, D. and Ndjeunga, J., The economics of low pressure drip irrigation and hand watering for vegetable production in the Sahel. *Agricultural Water Management*, **99(1):** 67-73 (2011).