

Original Research Article

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Effect of Varying Drip Irrigation Levels and Different Methods of NPK Fertilizer Application on Uptake, Quality Parameters and Productivity of Broccoli (*Brassica oleracea* L. var. *italica*) in Wet Temperate Zone of Himachal Pradesh, India

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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 growth, quality parameters, 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 per cent 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 in comparison to $I_{0.4}$ and $I_{0.6}$. The $I_{0.8}$ treatment due to favorable soil moisture regimes led to better marketable curd yield, TSS, ascorbic acid, chlorophyll content, NPK uptake, fertilizer use efficiency w.r.t N, P and K, fertilizer expense efficiency in comparison to $I_{0.4}$, $I_{0.6}$ and I_{Rec} . Likewise, F_{100} and $F_{C25+F75}$ treatment had higher marketable curd yield, TSS, ascorbic acid, chlorophyll content, NPK uptake 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.

Keywords

Drip irrigation;
Fertigation; Fertilizer
use efficiency;
Fertilizer expense
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Marketable yield;
TSS; Ascorbic Acid.

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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 (Soman, 2012). 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 (Kumar, 2011). 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 (Kumar, 2011). 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 (Kohli *et al.*, 2006). 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 (Kohli *et al.*, 2006). 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 productivity and quality of crop. And to evaluate the effects of NPK fertigation, NPK fertilization and the combined method of fertigation and fertilization on quality, nutrient uptake and fertilizer use efficiency 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 m²) 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 (Verma, 1979). 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 (El Nemr, 2012).

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

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 (Christiansen, 1942).

$$\text{U.C (\%)} = 100 \left[1 - \frac{\sum_{i=0}^n [q_i - \bar{q}]^2}{n \bar{q}^2} \right]$$

Where, ‘n’ represents number of emitters evaluated, ‘q_i’ is the discharge through emitter and ‘ \bar{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.

For analyzing the growth pattern of the crop, five plants were selected randomly from the net plot area in each treatment. Plant height (cm) was measured from base of the plant to the tip of the growing point at 90 DAT. Number of leaves per plant were counted in randomly selected five plants at 90 DAT. The fresh marketable curd yield and haulm of broccoli was recorded at harvest and expressed in Mg ha⁻¹.

Quality parameters like TSS, ascorbic acid and chlorophyll a, b and total chlorophyll was determined. TSS was determined by means of hand refractometer which is based on the principle of total refraction. For determining the TSS, a drop of sample juice was placed on the prism and the percentage of dry substance in it was read directly. The ascorbic acid (vitamin C) content was determined by the titration method. 10 gram of the sample was blended with 3% HPO₃ and the volume was made 100 ml. After filtration 10 ml of the filtrate was taken into conical flask and titrated with a standard dye to a pink end point. The ascorbic acid content was calculated by the following formula

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made} \times 100}{\text{Volume of filtrate taken} \times \text{Weight of sample}}$$

For estimation of chlorophyll content one gram of fresh sample was taken to which 5 ml of water added and homogenized in a blender. Volume of homogenate was made 10 ml with water from which 0.5 ml aliquot was taken to which 4.5 ml of 80% acetone was added to extract pigments. After centrifugation and removal of supernatant, its optical density (O.D) was recorded at 480, 645 and 663 nm using 80% acetone as a blank. Total chlorophyll content, chlorophyll a and

chlorophyll b were calculated by the following formula (Rangana, 2007).

$$\text{Total chlorophyll (g/litre)} = (0.0202)(\text{O.D at } 645) + (0.00802)(\text{O.D at } 663)$$

$$\text{Chlorophyll a (g/litre)} = (0.0127)(\text{O.D at } 663) - (0.00269)(\text{O.D at } 645)$$

$$\text{Chlorophyll b (g/litre)} = (0.0229)(\text{O.D at } 645) - (0.00480)(\text{O.D at } 663)$$

The fertilizer expense efficiency was computed as described by Veeranna (2001).

$$\text{FEE (kg ha}^{-1}\text{)} = \frac{\text{Oven dried fruit yield (kg ha}^{-1}\text{)}}{\text{Total quantity of nutrient applied (kg ha}^{-1}\text{)}}$$

The fertilizer use efficiency w.r.t N, P and K was calculated by the formula (Pomares and Pratt, 1987) given as:

$$\text{Per cent efficiency} = \frac{A - B}{C} \times 100$$

Where A= uptake with fertilizer; B= uptake without fertilizer; C = total amount of fertilizer that had been applied; where uptake = concentration × dry weight (kg).

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 Discussions

The effect of drip irrigation and different methods of fertilizer application on total soluble solids, ascorbic acid, chlorophyll a, chlorophyll b, and total chlorophyll in the curd of broccoli is given in Table 1. The highest value of TSS is recorded in I_{0.8} and lowest in I_{0.4}. The value of TSS was found to be significantly higher in I_{0.8} in comparison to I_{0.6} and I_{0.4}. This showed that TSS value increased with increase in the amount of water applied which further lead to the

improvement in plant root and shoot growth parameters. Similar results were reported by Shirgure *et al.*, (2004). Under different methods of fertilizer application, TSS was found to be significantly higher in $F_{C25+F75}$ and F_{100} in comparison to F_{CF} . The values for 'others' treatments was also found to be significantly higher than 'control'. In case of ascorbic acid, the value was found to be significantly high in $I_{0.8}$ and $I_{0.6}$ than $I_{0.4}$. Under different methods of fertilizer application, $F_{C25+F75}$ and F_{100} showed higher values for ascorbic acid than F_{CF} . Further, the value for 'control' was found significantly lower than 'others'. The chlorophyll a content was found significantly higher in $I_{0.8}$ than $I_{0.6}$ and $I_{0.4}$. Under different methods of fertilizer application, the value was significantly higher in $F_{C25+F75}$ than F_{100} and F_{CF} . Similarly the chlorophyll b showed significantly higher value in $I_{0.8}$ in comparison to $I_{0.6}$ and $I_{0.4}$. Under different methods of fertilizer application, $F_{C25+F75}$ and F_{100} was found to be superior over F_{CF} . The total chlorophyll content was also found to follow the same trend. The 100 per cent fertilizer application through drip in equal splits improved the quality parameters of broccoli due to 25 per cent RDF as a basal dose followed by fertigation in 7 splits than conventional method of fertilizer application. Similar results were reported by Patel *et al.*, (2011).

Plant nutrient uptake

The nutrient uptake in curd and in haulm was determined separately at harvest and is given in Table 2. The significantly higher N uptake in curd and total uptake (curd + haulm) was recorded in $I_{0.8}$ in comparison to $I_{0.6}$ and $I_{0.4}$. The highest nitrogen uptake was observed in haulm in $I_{0.8}$ followed by $I_{0.6}$ and $I_{0.4}$. There was an increase of N uptake in haulm under $I_{0.8}$ in comparison to $I_{0.4}$. The higher uptake in $I_{0.8}$ may be due to higher soil water content,

better root and shoot growth and marketable yield. Among different methods of fertilizer application, significantly higher N uptake was recorded in curd and haulm in $F_{C25+F75}$ in comparison to F_{100} and F_{CF} . The higher N uptake may be due to the better utilization of applied nitrogen through combined method of fertigation and conventional application as a basal dose leading to better root and shoot growth. Similar results were also reported by Hebbar *et al.*, (2004); Shedeed *et al.*, (2009), Sturm *et al.*, (2010) and Badr *et al.*, (2011). Phosphorus uptake in curd and total uptake was significantly higher under $I_{0.8}$ and $I_{0.6}$ in comparison to $I_{0.4}$. Among fertigation treatments, significantly higher P uptake was recorded in curd and haulm in $F_{C25+F75}$ in comparison to F_{100} and F_{CF} . Similar results were also reported by Shedeed *et al.*, (2009). A significant increase of K uptake in curd was recorded with $I_{0.6}$ and $I_{0.8}$ over $I_{0.4}$. In case of fertigation, the highest K uptake in curd and total uptake was recorded with $F_{C25+F75}$ and F_{100} and lowest in F_{CF} . This may be due to the application of 100 per cent recommended dose of fertilizer through a combined method of fertigation and conventional fertilizer application in $F_{C25+F75}$ and 100 per cent through fertigation in F_{100} as compared to F_{CF} . The K uptake recorded in haulm in F_{100} and $F_{C25+F75}$ was significantly higher than F_{CF} . Similar results were also reported by Shedeed *et al.*, (2009).

Fertilizer expense efficiency

The fertilizer expense efficiency was determined from oven dried fruit yield and total nutrient applied is given in Table 3. The data shows that fertilizer expense efficiency was significantly higher in $I_{0.4}$ in comparison to $I_{0.6}$ and $I_{0.8}$. Among different methods of fertilizer application, highest fertilizer expense efficiency was recorded under $F_{C25+F75}$ and lowest under F_{CF} . As the quantity of nutrient applied is same in all the

treatments, the difference is attributed to the difference in oven dry yield.

Fertilizer use efficiency w.r.t. N, P and K

The data presented in Table 4 indicates the significant effect of drip irrigation and fertigation levels on fertilizer use efficiency w.r.t. N, P and K. The highest N use efficiency was recorded with $I_{0.8}$ and lowest with $I_{0.4}$ among irrigation levels. Similar results were found in P and K. The reason for higher fertilizer use efficiency with respect to N, P and K in $I_{0.8}$ may be attributed to higher uptake of nutrients which in turn improved the yield and other growth parameters of the plants. Under different methods of fertilizer application, the highest N use efficiency found to be in $F_{C25+F75}$ followed by F_{100} . Similarly, the highest P and K efficiency was found to be in $F_{C25+F75}$ followed by F_{100} which was again due to higher uptake of nutrients in $F_{C25+F75}$ in comparison to F_{100} . There was significantly higher N, P and K use efficiency in 'others' as compared to 'control'. This showed that treatments other than control (where conventional method of fertilizer was applied along with the flood irrigation method) resulted in better uptake of nutrients which lead to improved root and shoot growth parameters and higher yield. Similar results were reported by Nilesh and Gulati (2004).

Biological yield

The effect of drip irrigation and different methods of fertigation on biological yield of broccoli is given in Table 5. The highest curd yield was recorded under $I_{0.8}$ which was significantly superior over $I_{0.6}$ and $I_{0.4}$. The highest fresh weight of plant without curd was recorded with $I_{0.8}$ which was statistically superior over $I_{0.6}$ and $I_{0.4}$. The higher broccoli biological yield in $I_{0.8}$ was due to more quantity of water application thereby improving the plant shoot and root growth

parameters which resulted in increase nutrient uptake in comparison to $I_{0.4}$ and $I_{0.6}$. Similar findings were also reported by Gadissa and Chemedda (2009) and Jayapiratha *et al.*, (2010).

Different fertilizer application methods significantly affected the curd yield of broccoli. The highest curd yield of broccoli was recorded under treatment $F_{C25+F75}$ which was significantly superior (5.10 and 13.00 %) over F_{100} and F_{CF} , respectively. The fresh weight of plant without curd obtained with $F_{C25+F75}$ was also significantly superior over F_{100} and F_{CF} . The higher biological yield under $F_{C25+F75}$ may be attributed to application of 25% fertilizers as a basal dose and the remaining amount of fertilizers i.e. 75% was applied through fertigation in comparison to F_{100} where entire amount of fertilizer was applied through fertigation and F_{CF} where entire amount was applied through conventional method. The application of 25 per cent NPK as a basal dose might have helped in better early establishment of seedlings. Similar findings were also reported by Sturm *et al.*, (2010); Badr *et al.*, (2011) and Tanaskovik *et al.*, (2011). The curd yield obtained under 'others' was significantly superior over 'control'. However, the haulm yield in 'control' and 'others' was at par with one another. In 'others' the highest biological yield was due better utilization of applied recommended dose of fertilizer under drip irrigation system in comparison to 'control' where recommended dose of fertilizer was applied through conventional method with water application through flooding. The highest curd yield was recorded with $I_{0.8}F_{C25+F75}$ and lowest under $I_{0.4}F_{CF}$ (Table 5). 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.

Table.1 Effect of drip irrigation and method of fertilizer application on TSS, ascorbic acid, chlorophyll a, chlorophyll b and total chlorophyll content in broccoli

Treatments	TSS	Ascorbic acid mg 100g ⁻¹	Chlorophyll a mg l ⁻¹	Chlorophyll b mg l ⁻¹	Total chlorophyll mg l ⁻¹
Irrigation levels					
I _{0.4}	7.88	61.85	0.89	0.73	1.58
I _{0.6}	8.24	69.87	1.09	0.87	1.68
I _{0.8}	8.97	74.34	1.27	0.97	1.98
CD (P=0.05)	0.627	4.029	0.131	0.081	0.250
Method of fertilizer application					
F ₁₀₀	8.49	70.22	1.13	0.81	1.83
F _{C25+F75}	8.70	72.53	1.34	0.97	1.99
F _{CF}	7.90	63.32	0.78	0.78	1.42
CD (P=0.05)	0.627	4.029	0.131	0.081	0.250
Control vs. Others					
Control	7.33	54.67	0.63	0.41	0.89
Others	8.36	68.69	1.08	0.86	1.74
CD (P=0.05)	0.809	5.201	0.170	0.105	0.322

Table.3 Effect of drip irrigation and method of fertilizer application on fertilizer expense efficiency (kg kg⁻¹)

Treatments	Fertilizer expense efficiency (Oven dried yield kg per kg of total nutrient applied)
Irrigation levels	
I _{0.4}	3.44
I _{0.6}	3.40
I _{0.8}	3.30
CD (P=0.05)	0.102
Method of fertilizer application	
F ₁₀₀	3.39
F _{C25+F75}	3.63
F _{CF}	3.12
CD (P=0.05)	0.102
Control vs. Others	
Control	3.47
Others	3.38
CD (P=0.05)	NS

Table.2 Effect of drip irrigation and method of fertilizer application on nutrient uptake of broccoli (kg ha-1)

Treatments	Nitrogen uptake			Phosphorous uptake			Potassium uptake		
	Curd	Haulm	Total	Curd	Haulm	Total	Curd	Haulm	Total
Drip irrigation levels									
I_{0.4}	37.91	137.39	175.29	10.69	19.82	30.50	29.51	29.54	59.05
I_{0.6}	38.51	138.10	176.61	12.14	20.58	32.72	31.85	29.05	60.91
I_{0.8}	39.72	138.65	178.37	12.30	21.43	33.72	31.25	33.57	64.82
CD (P=0.05)	1.065	1.058	1.283	0.447	1.009	1.117	1.243	NS	5.084
Method of fertilizer application									
F₁₀₀	38.62	138.10	176.73	12.10	20.39	32.48	31.10	31.98	63.08
F_{C25+F75}	41.44	140.56	182.00	13.00	22.58	35.58	34.72	33.92	68.74
F_{CF}	36.08	135.46	171.54	10.03	18.85	28.88	26.80	26.26	53.06
CD (P=0.05)	1.065	1.058	1.283	0.447	1.009	1.117	1.243	5.305	5.084
Control vs. Others									
Control	35.04	134.57	169.61	9.99	17.26	27.25	26.88	26.72	53.60
Others	38.71	138.04	176.76	11.71	20.61	32.32	30.87	30.72	61.59
CD (P=0.05)	1.375	1.366	1.657	0.578	1.303	1.442	1.604	NS	6.563

Table.4 Effect of drip irrigation and method of fertilizer application on fertilizer use efficiency (%) w.r.t N, P and K

Treatments	N use efficiency (NUE)	P use efficiency (PUE)	K use efficiency (KUE)
Irrigation levels			
I _{0.4}	69.64	23.24	64.82
I _{0.6}	70.52	25.46	68.20
I _{0.8}	71.70	26.46	75.31
CD (P=0.05)	0.855	1.117	9.243
Method of fertilizer application			
F ₁₀₀	70.60	25.22	72.15
F _{C25+F75}	74.12	28.32	82.25
F _{CF}	67.15	21.62	53.93
CD (P=0.05)	0.855	1.117	9.243
Control vs. Others			
Control	65.86	19.99	54.91
Others	70.62	25.05	69.44
CD (P=0.05)	1.104	1.442	11.933

Table.5 Effect of drip irrigation and method of fertilizer application on biological yield

Treatment	Marketable Curd yield (Mg ha ⁻¹)	Fresh weight of haulm (Mg ha ⁻¹)
Drip irrigation levels		
I _{0.4}	5.89	17.98
I _{0.6}	6.05	18.47
I _{0.8}	6.27	20.37
CD (P=0.05)	0.178	1.583
Method of fertilizer application		
F ₁₀₀	6.13	18.89
F _{C25+F75}	6.46	20.60
F _{CF}	5.62	17.33
CD (P=0.05)	0.178	1.583
Control vs. Others		
Control	5.60	18.33
Others	6.07	18.94
CD (P=0.05)	0.230	NS

Also, the treatment combinations I_{0.4}F₁₀₀ and I_{0.6}F₁₀₀ 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.*, (2008).

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.

In conclusion, 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}F₁₀₀ and I_{0.6}F₁₀₀ 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. 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.

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