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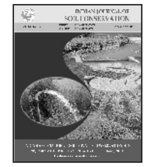

Effects of soil suction based irrigation scheduling and integrated nutrient management on crop yield and water use of broccoli

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ABSTRACT

For efficient utilization of harvested rain water, there is a need to generate critical information on developing irrigation scheduling based on soil water retention and transmission characteristics with respect to atmospheric demand not only for obtaining profitable marketable yields but also higher nutrient and Water Use Efficiency (WUE). The present study was conducted at Experimental Farm of CSK HPKV, Palampur, during 2009-10 and 2010-11 with the objective of evaluating the effect of soil suction based irrigation scheduling, vermicompost and NPK levels on growth, productivity and WUE of broccoli. The treatments comprised of a) Irrigation management *viz.*, I_1 ($I_{20(3)}$) - Irrigation of 3 cm at 20 cm mercury rise, I_2 ($I_{20(6)}$) - Irrigation of 6 cm at 20 cm mercury rise and I_3 ($I_{36(6)}$) - Irrigation of 6 cm at 36 cm mercury rise, b) Nutrient management *viz.,* M_1 - Vermicompost $(VC)_{2.5}$ + 100% Recommended Dose of Fertilizers (RDF), M_2 - VC_5 + 50% RDF and M_3 - $VC_{7.5}$ and c) Control - I_{Rec} + Farm Yard Manure $(FYM)_{20}$ + 100% RDF. The results indicated that I_2 treatment had higher profile water depletion in comparison to I_1, I_3 and I_{Rec} in both the years. Because of favorable soil water status treatment I_1 led to better root and shoots growth, marketable curd yield (by 13.3 and 38.0% during 2009-10 and 2010-11) and WUE in comparison to I_3. Likewise, M_1 treatment had higher root and shoot growth, marketable curd yield (almost double during both years) and WUE in comparison to M_3. The highest marketable curd yield, WUE, economic returns was obtained under I_1M_1 treatment. From the above study, it is concluded that the application of 3 cm irrigation at 20 cm mercury rise and VC @ 2.5 t ha^{-1} + 100% NPK should be followed for obtaining higher returns and WUE.

1. INTRODUCTION

In Himachal Pradesh (India), about 18% of the cultivated area has assured irrigation facilities, which is generally occupied by vegetable crops. Now a days, the cultivation of broccoli (*Brassica olerarasea* var. *italica*) is becoming very popular in this area and cultivated by large number of farming community during winter season (October-February) due to its high nutritive value and in turn, high market demand. It is rich source of Ca, Fe, K, Na and vitamins C, K, A, niacin, riboflavin and thiamin (Nonnecke 1989). It also has dietary fiber and contains multiple nutrients with anti-cancer properties. For efficient utilization of harvested rain water, it is generally advised either to schedule irrigation at the most critical stages or as a life saving irrigation as and when required depending upon rains, especially, during winter season. Soil suction based irrigation scheduling is one of such approach which takes in to account the availability of soil water in terms of soil water potential to plant in relation to atmospheric demand (Evapo-transpiration). Also, the response of crop to soil moisture and nutrient is closely related and it changes with change in soil climate complex (Sharma and Parashar 1982). Vermicompost has been considered as a soil additive to reduce the use of mineral fertilizers since, it provides required nutrients, increases cations exchange capacity, improves water-holding capacity (Tejada and Gonzalez 2009), bulk density and total porosity (Azarmi *et al.* 2008). Morover, the Integrated Nutrient Management (INM) of inorganic and organic sources *viz.*, FYM, rhizobium and vermicompost leads to multi-benefits in addition to maximum and stable yields with better quality of vegetables (Jaggi 2007). Keeping in view of above importance, the present study has been undertaken for quantifying change of soil suction based irrigation scheduling under INM cropping system.

2. MATERIALS AND METHODS

The field experiments were conducted on broccoli cv. Palam Smaridhi during *rabi* 2009-10 and 2010-11 in the experimental farm (32.6^0 N latitude and 76.3^0 E longitude, at an elevation of 1290 m) Soil Science, CSK HPKV, Palampur. The transplanting was done during first week of October during both the study years at 45 x 45 cm spacing. The fertilizer doses were calculated based on RDF for broccoli *i.e.* 150:100:100. Whole of P and K and half nitrogen was applied at transplanting and rest 50% N was applied in two split at monthly intervals. The hand weeding was done periodically for removal of weeds. Initially, the soil of the experiment field was silty clay loam, pH 5.6, bulk density 1.26 Mg m^{-3}, particle density 2.35 Mg m^{-3}, CEC 12 C mol (P$^+$) kg^{-1} and organic carbon 10.30 g kg^{-1}. The soil was low in available nitrogen (246.3 kg ha^{-1}), high in phosphorus (38.4 kg ha^{-1}) and medium in potassium (278.6 kg ha^{-1}). The mean weight diameter of the aggregates was 2.40 mm with infiltration rate of 2.33 x 10^{-5}ms^{-1}. The treatments comprised of three irrigation management (I) *viz.,* I_1 - Irrigation of 3 cm at 20 cm mercury rise (0.2 bar) , I_2 - Irrigation of 6cm at 20 cm mercury rise (0.2 bar) and I_3 - Irrigation of 6 cm at 36 cm mercury rise (0.4 bar), three INM (M) *viz.*, M_1 - Vermicompost @ 2.5 t ha^{-1} and 100% of RDF (150:100:100), M_2 - Vermicompost @ 5 t ha^{-1} and 50% of RDF (75:50:50) and M_3 - Vermicompost @7.5 t ha^{-1} and unfertilized control was run as recommended practice - Irrigation of 6 cm at 8-10 days interval, FYM application @ 20 t ha^{-1} and recommended fertilizer doses. Ten treatment combinations were replicated thrice. For soil suction based irrigation scheduling, the mercury rise in mercury monotype tensiometers installed at 0.075 m soil depth was taken in to account from transplanting to curd initiation and thereafter, the mercury rise in tensiometer installed at 0.15 m soil depth was considered for irrigation scheduling. The mercury rise was recorded either daily or on alternate days and after every irrigation, it was flushed to zero. Root growth parameters, *viz.*, root volume, root length and root mass were determined from a fixed soil volume at harvest of broccoli. The profile water depletion (ΔS_Z) was calculated during broccoli crop growth by taking the difference of water stocks during related intervals. The plant height of broccoli was determined at harvest by randomly selected five plants per plot. Average height of these plants was recorded from ground level to the base of the fully developed youngest leaf. The number of leaf of broccoli was recorded at harvest by randomly selected five plants per plot. The fresh marketable curd yield of broccoli was recorded at harvest and expressed in Mg ha^{-1}. WUE (kg ha^{-1} mm^{-1}) was computed from curd yield production per unit Consumptive Water Use (CWU).

3. RESULTS AND DISCUSSION

Plant Height

The plant height was recorded significantly higher with I_1 (44.89 and 42.89 cm) in comparison to I_2 (43.00 and 36.56 cm) and I_3 (40.33 and 32.44 cm) during both study years (Table 1). The higher plant height in I_1 may be attributed due to frequent light irrigation throughout the crop growth period. The similar findings were also obtained earlier by Haffez and Cornillon (1976) and Deb *et al.* (2009). Among nutrient management during 2009-10 year, the highest plant height was recorded in M_1 (47.00 cm) followed by M_2 (44.89 cm), both of them were statistically at par to one another. However, the plant height recorded in M_1 was significantly greater over M_3 (41.33 cm). The treatment receiving lower level of vermicompost (2.5 t ha^{-1}) and 100% RDF during 2010-11, M_1 gave significantly highest (45.00 cm) plant height over M_2 (36.33 cm) and M_3 (30.56 cm). This may be due to application of recommended NPK dose and vermicompost complementation which increased the availability of nutrients in soil and in turn, enhanced nutrient uptake in comparison to M_3, where only vermicompost was applied. Similar findings were also reported by Kanwar and Paliyal, (2005) and Kumar and Sharma (2007) that integrated use of fertilizer and manure substantially improved crop yield. There was non significant difference in 'control' and 'others' during first year, however, during second year, the plant height was recorded highest in 'control' (43.00 cm) as compared to 'others' (37.30 cm).

Number of Leaves Per Plant

The highest number of leaves per plant during 2009-10 were recorded with I_2 (33.11) followed by I_1 (30.89), both of them were statistically at par. However, number of leaves per plant recorded in I_2 was significantly higher over I_3 (27.89). Further, the number of leaves during 2010-11 were recorded significantly higher under I_1 (24.22) followed by I_2 (21.11) and I_3 (19.44). The number of leaves per plant was higher under I_1 due to application of frequent and more quantity of irrigated water indicating higher soil moisture availability in comparison to I_3. Similar findings were observed by Khan *et al.* (2005). The highest number of

Table: 1
Effects of irrigation and nutrient management on shoot and root growth at harvest of broccoli

Treatment	Shoot growth				Primary roots								Secondary roots					
	Plant height (cm)		No of leaves		Root length (cm)		Root volume (x 10^{-6} m^3)		Root weight (g)		Average diameter (mm)		Root length (cm)		Root volume (x 10^{-6} m^3)		Root weight (g)	
Irrigation Management	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
I_1 ($I_{20(3)}$)	49.89	42.89	30.89	24.22	10.11	28.00	26.67	40.00	14.27	22.54	19.63	16.99	250.49	236.7	13.56	31.67	6.43	12.41
I_2 ($I_{20(6)}$)	43.00	36.56	33.11	21.11	12.67	28.22	28.33	46.11	16.19	25.80	18.04	18.86	226.69	244.4	14.89	41.11	7.29	13.57
I_3 ($I_{36(6)}$)	40.33	32.44	27.89	19.44	12.22	29.11	28.89	40.56	13.44	19.82	19.52	16.83	200.30	211.1	11.00	31.11	6.06	11.53
CD at 5%	2.32	3.55	3.89	2.47	2.02	NS	NS	NS	1.52	1.82	NS	NS	30.97	NS	1.47	NS	0.69	1.01
Nutrient Management																		
M_1 ($V_{2.5}$ + 100% RDF)	47.00	45.00	32.44	24.22	10.44	25.22	32.56	54.44	15.46	23.60	18.96	19.96	224.45	270.0	15.78	41.11	6.96	13.46
M_2 ($V_{5.0}$ + 50% RDF)	44.89	36.33	31.78	20.78	13.33	29.56	25.37	42.22	13.43	21.36	20.78	18.03	239.40	234.4	12.78	36.11	6.05	11.65
M_3 ($V_{7.5}$)	41.33	30.56	27.67	19.78	11.22	30.56	25.67	30.00	15.02	23.21	17.44	14.69	213.63	187.8	10.89	26.67	6.76	12.40
CD at 5%	2.32	3.55	3.89	2.47	2.02	3.87	3.84	15.37	1.52	1.82	1.95	3.49	NS	42.33	1.47	NS	0.69	1.01
Control Vs Others																		
Control (I_{Rec} FYM_{20}+ 100% RDF)	42.67	43.00	29.67	21.33	10.33	25.33	25.67	51.67	12.47	19.83	24.67	20.27	205.07	216.7	12.00	33.33	5.62	11.24
Others	44.41	37.30	30.63	21.59	11.67	28.44	27.96	42.22	14.63	22.72	19.06	17.56	225.83	230.4	13.15	34.63	6.59	12.51
CD at 5%	NS	4.59	NS	NS	NS	NS	NS	NS	1.97	2.35	2.52	NS	NS	NS	NS	NS	0.89	NS

leaves per plant were recorded with M_1 (32.44) followed by M_2 (31.78), both of them were statistically at par during 2009-10. However, number of leaves per plant recorded in M_1 was significantly higher than M_3 (27.67) during the same year. Further, the number of leaves during 2010-11 were recorded significantly higher under M_1 (24.22) followed by M_2 (20.78) and M_3 (19.78). The higher of number of leaves per plant was due to integrated use of recommended doses of NPK and vermicompost application. Similar observations have also been reported by Jha and Jana, (2009).

Primary Roots

The data presented in Table 1 revealed that the highest primary root length was recorded with I_2 (12.67 cm) followed by I_3 (12.22 cm). Also, I_2 had 20.2% higher root length in comparison to I_3. In case of root weight, the treatment I_2 gave 11.86 and 16.99% during 2009-10 and 12.64 and 23.18% during 2010-11 higher root weight over I_1 and I_3. The reduced growth of primary roots might be attributed due to higher availability of soil moisture in the surface layers due to frequent irrigation in comparison to I_2 and I_3. The highest root length was recorded with M_2 (13.33 cm) which was significantly superior over M_1 (10.44 cm) and M_3 (11.22 cm) in 2009-10. However, higher root length was recorded with M_3 (30.56 cm), followed by M_2 (29.56 cm), both of them statistically at par with each other and M_3 was significantly superior over M_1 (25.22 cm) in 2010-11. Further, the root volume was significantly higher under M_1 (32.56 x 10^{-6} m^3) followed by M_2 (25.37 x 10^{-6} m^3) and M_3 (25.67 x 10^{-6} m^3) in 2009-10. In 2010-11, higher root volume was recorded with M_1 (54.44 x 10^{-6} m^3) followed by M_2 (42.22 x 10^{-6} m^3), both of them statistically at par with each other and M_1 was significantly superior over M_3 (30.00 x 10^{-6} m^3) in 2010-11. Similarly, root weight was highest under M_1 (15.46 and 23.60 g) followed by M_3 (15.02 and 23.21 g) and lowest under M_2 (13.43 21.36 g) in 2009-10 and 2010-11. The higher root volume and weight under M_1 may be attributed due to the application of recommended dose of NPK and vermicompost complementation (Samawat *et al.,* 2001).

The higher root growth under M_3 may be due to application of higher level of vermicompost (7.5 t ha^{-1}) in comparison to M_2 (5 t ha^{-1} + 50% NPK). Azarmi *et al.* (2008) also reported proportional increase in root growth with each increase of recommended vermicompost. The highest average root diameter was recorded with M_2 (20.78 mm) followed by M_1 (18.96 mm). The average root diameter in M_2 however was significantly higher over M_3. Also, the highest average root diameter was recorded with M_1 (19.96 mm) followed by M_2 (18.03 mm) both of them were statistically at par with each other during 2010-11. The average root diameter in M_2 however was significantly higher over M_3 in 2010-11.

Secondary Roots

The highest root length was recorded under I_1 (250.44 cm) followed by I_2 (220.69 cm). However, I_1 treatment had significantly higher root length over I_3 treatment (200.30 cm). Root volume was highest in I_2 (14.89 x 10^{-6} m^3) followed by I_1 (13.56 x 10^{-6} m^3). I_2 (Application of 6 cm irrigation at 20 cm mercury rise) had significantly higher root volume in comparison to I_3. The I_2 treatment had significant higher root weight (11.78 and 16.87%) and (8.55 and 15.03%) over I_1 and I_3 in 2009-10 and 2010-11. The highest root length was recorded with M_1 (270 cm) followed by M_2 (234.4 cm). The treatment I_1 had significantly higher root length over M_3 (187.8 cm) in 2010-11. The root volume was significantly higher under M_1 (15.78 x 10^{-6} m^3) over M_2 (12.78 x 10^{-6} m^3) and M_3 (10. 98 x 10^{-6} m^3) in 2009-10. Further, the highest root weight was recorded with M_1 (6.96 g) followed by M_3 (6.76 g). The significantly highest root weight was recorded under M_1 (13.46 g) over M_2 (11.55 g) and M_3 (12.40 g) in 2010-11. The higher root weight in M_1 might be attributed due to application of recommended dose of NPK and vermicompost complementation in comparison to M_2. Similar result has been obtained by Samawat *et al.* (2001). The highest root weight in M_3 may be due to higher rate of vermicompost (7.5 t ha^{-1}) in comparison to M_2 (5 t ha^{-1} + 50% NPK). Azarmi *et al.* (2008) had also recorded similar finding. The highest average primary root diameter (Table 2) was recorded with I_3M_1 (21.78 mm) and lowest with I_2M_3 (15.78 mm) in 2009-10. However, highest primary root weight was recorded in I_2M_2 (17.59 and 27.97 g) and lowest under I_3M_2 (11.08 and 17.61 g) in 2009-10 and 2010-11. Further, the highest secondary root volume was recorded in I_1M_1 (19 x 10^{-6} m^3) and lowest in I_2M_3 (10 x 10^{-6} m^3) in 2009-10. Likewise, the highest secondary root length was recorded in I_1M_3 (279.45 cm) and lowest under I_3M_3 (168.67 cm) in 2009-10. Secondary root weight were higher with I_2M_2 (7.92 and 14.51 g) and lower under I_3M_2 (4.99 and 9.98 g) in 2009-10 and 2010-11. The integrated use of chemical fertilizers along with vermicompost might have resulted in improvement in soil physical as well as soil physic-chemical properties, thereby increasing the availability of soil water and of nutrient for enhancing the productivity of broccoli.

Biological yield

The curd yield of broccoli increased significantly with increase in irrigation frequency (Table 3). The highest curd yield was recorded under I_1 (6.52 Mg ha^{-1}) followed by I_2 (6.47 Mg ha^{-1}). However, the curd yield obtained with I_1 was significantly superior (11.8%) over I_3 (5.75 Mg ha^{-1}). In the second year of experimentation, curd yield was recorded highest under I_1 (7.08 Mg ha^{-1}) which was significantly superior over I_2 (6.18 Mg ha^{-1}) and I_3 (5.13 Mg ha^{-1}). The broccoli curd yield significantly increased with increase in frequency of irrigation due to better availability of soil water thereby improving the plant shoot and root growth parameters. The

Table:2
Interaction effect of irrigation and nutrient management on shoot and root parameters of broccoli

Irrigation Management	Primary root Average diameter (mm)			Primary root weight (g)						Secondary root Volume (x 10^{-06} m^3)			Secondary Root length (cm)			Secondary root weight (g)					
				2009-10			2010-11									2009-10			2010-11		
	Nutrient management			Nutrient management			Nutrient management			Nutrient management			Nutrient management			Nutrient management			Nutrient management		
	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3			
I_1	18.33	20.44	20.11	16.06	11.61	15.14	25.04	18.49	24.08	19.00	10.67	11.00	212.67	259.34	279.45	7.23	5.23	6.82	13.80	10.46	12.98
I_2	16.78	21.56	15.78	15.03	17.59	15.94	24.10	27.97	25.34	17.00	17.67	10.00	241.21	246.09	192.76	6.77	7.92	7.18	13.54	14.51	12.65
I_3	21.78	20.33	16.44	15.29	11.08	13.96	21.65	17.61	20.20	11.33	10.00	11.67	219.48	212.77	168.67	6.89	4.99	6.29	13.04	9.98	11.58
CD at 5%		3.38			2.64			3.16			2.55			53.65			1.19			1.75	

Table: 3
Effects of irrigation and nutrient management on biological yield of broccoli

Treatment	Curd yield (Mg ha^{-1})	
Irrigation Management	2009-10	2010-11
I_1 ($I_{20(3)}$)	6.52	7.08
I_2($I_{20(6)}$)	6.47	6.18
I_3($I_{36(6)}$)	5.75	5.13
CD at 5%	0.25	0.64
Nutrient Management		
M_1 ($V_{2.5}$ + 100 RDF)	7.64	8.93
M_2 ($V_{5.0}$ + 50 RDF)	6.29	5.43
M_3 ($V_{7.5}$)	4.84	4.03
CD at 5%	0.25	0.64
Control Vs Others		
Control (I_{rec} FYM_{20}+100% RDF)	6.13	8.35
Others	6.26	6.13
CD at 5%	NS	0.82

results are in accordance with the earlier finding of Deb *et al.* (2009). Likewise, nutrient management practices significantly affected the curd yield of broccoli. The treatment M_1 gave highest (7.64 and 8.93 Mg ha^{-1}) curd yield, which showed an increase of 17.67 and 39.19 and 36.65 and 54.87 % over M_2 (6.29 and 5.43 Mg ha^{-1}) and M_3 (4.84 and 4.03 Mg ha^{-1}), respectively, in both the study years. The higher curd yield under M_1 might be attributed to application of 100% NPK with vermicompost complementation which improved the root and shoot growth parameters resulting in increased nutrient uptake. A similar finding has also been observed by Jha and Jana (2009). The highest curd yield was recorded with I_1M_1 (9.04 and 10.05 Mg ha^{-1}) which was significantly superior over all treatment combinations and lowest under I_3M_3 (4.70 and 3.10 Mg ha^{-1}) in both study years. This may be due to frequent scheduling of irrigation with 100% NPK and vermicompost complementation which resulted in better root and shoot growth due to increased nutrient availability. Nandi *et al*., (2002), had also recorded similar results.

The gross returns were highest under I_1M_1 (₹ 135576 and 150718 in 2009-10 and 2010-11) and lowest under I_1M_3 (₹ 67949) in 2009-10 and I_3M_3 (₹ 46462) in 2010-11 (Table 4). Also, the net return was highest in I_1M_1 (₹ 123076 and 138218 in 2009-10 and 2010-11) and lowest under I_1M_3 (₹ 63449) in 2009-10 and I_3M_3 (₹ 41962) in 2010-11. Further, the B:C ratio was highest in I_2M_3 (16.66 and 15.99) and lowest in I_3M_1 (6.72) in 2009-10 and I_3M_2 (6.21) in 2010-11.

Consumptive/Crop Water Use (CWU) and Water Use Efficiency (WUE)

The total profile water depletion calculated during broccoli growth was 3.9, 1.7, 5.0 and 1.4 mm during 2009-10 and 5.00, 2.10, 5.90 and 1.70 mm in 2010-11 at 0-0.60 m soil depth under I_1, I_2, I_3 and I_{Rec}, respectively (Table 5). Further, the crop water use under I_1, I_2, I_3 and I_{Rec} was 1094.0, 1301.8, 1185.1 and 1301.5 mm in 2009-10 and 1253.8, 1330.9, 1314.7 and 1330.5 mm in 2010-11 at 0-0.60 m soil depth, respectively. The treatment I_1 had lesser CWU

Table: 4
Effects of irrigation and nutrient management on WUE, returns and B:C ratio of broccoli

Treatment	Treatment details	Curd yield (Mg ha^{-1})		CWU (mm)		WUE (kg ha^{-1} mm^{-1})		Gross return (₹)		Net Return (₹)		B:C ratio	
		2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
Control	I_{Rec}+ FYM_{20} + 100% RDF	6.13	8.35	1301.50	1330.5	4.71	6.28	91,987	1,25,267	78,987	1,12,267	6.07	8.64
I_1M_1	$I_{20(3)}$ + $V_{2.5}$ + 100% RDF	9.04	10.05	1094.00	1253.8	8.26	8.01	1,35,576	1,50,718	1,23,076	1,38,218	9.85	11.06
I_2M_1	$I_{20(6)}$+ $V_{2.5}$ + 100% RDF	7.44	8.79	1301.80	1330.9	5.71	6.60	1,11,538	1,31,795	99,038	1,19,295	7.92	9.54
I_3M_1	$I_{36(6)}$+ $V_{2.5}$ + 100% RDF	6.43	7.97	1185.10	1314.7	5.43	6.06	96,474	1,19,551	83,974	1,07,051	6.72	8.56
I_1M_2	$I_{20(3)}$ + $V_{5.0}$ + 50% RDF	6.00	7.31	1094.00	1253.8	5.49	5.83	90,064	1,09,582	81,064	1,00,582	9.01	11.18
I_2M_2	$I_{20(6)}$ + $V_{5.0}$ + 50% RDF	6.73	4.65	1301.80	1330.9	5.17	3.49	1,00,961	69,744	91,961	60,744	10.22	6.75
I_3M_2	$I_{36(6)}$ + $V_{5.0}$ + 50% RDF	6.13	4.33	1185.10	1314.7	5.17	3.29	91,987	64,894	82,987	55,894	9.22	6.21
I_1M_3	$I_{20(3)}$ + $V_{7.5}$	4.53	3.88	1094.00	1253.8	4.14	3.09	67,949	58,181	63,449	53,681	14.10	11.93
I_2M_3	$I_{20(6)}$ + $V_{7.5}$	5.30	5.10	1301.80	1330.9	4.07	3.83	79,487	76,467	74,987	71,967	16.66	15.99
I_3M_3	$I_{36(6)}$ + $V_{7.5}$	4.70	3.10	1185.10	1314.7	3.97	2.36	70,512	46,462	66,012	41,962	14.67	9.32
CD at 5%		0.24	0.46		0.03	0.35							

CWU: Consumptive water use; WUE: Water use efficiency in comparison to I_2, I_3 and I_{Rec} in 0-0.60 m soil depth primarily due to less quantity of water application. The WUE under I_1, I_2, I_3 and I_{Rec} were 5.96, 4.99, 4.86 and 4.71 kg ha^{-1} mm in 2009-10 and 5.65, 4.64, 3.90 and 6.28 kg ha^{-1} mm in 2010-11 at 0-0.60 m soil depth, respectively. The higher WUE in I_1 may be attributed due to more marketable yield and less CWU. The significantly highest WUE was recorded under I_1M_1 (8.26 and 8.01 kg ha^{-1} mm^{-1}) in comparison to rest of the treatment combinations (Table 5) and lowest was recorded under I_3M_3 (3.97 and 2.36 kg ha^{-1} mm^{-1}) in both study years. The highest WUE was due to highest curd yield with less amount of water used.

4. CONCLUSIONS

The study indicated that soil suction based irrigation of 3 cm depth at 20 cm mercury rise resulted in better soil water status leading to better plant growth which resulted in higher marketable curd yield, NPK uptake and WUE. The application of 100% NPK with 2.5 t ha^{-1} vermicompost application resulted in better root and shoot growth which resulted in higher marketable curd yield and WUE. The treatment combination with irrigation of 3 cm depth at 20 cm mercury rise and application of 100% NPK with 2.5 t ha^{-1} vermicompost resulted in higher marketable curd yield, water use efficiency, gross and net returns. These results suggest that integrated nutrient management is a viable option for improving WUE and better crop yields and productivity. Hence, INM is one of the best options for hilly areas where manure production are limited and application rate of chemical fertilizers are restricted due to non availability of the fertilizer materials to farmers.

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Table: 5
Effect of irrigation management on Consumptive water use (mm) during broccoli crop growth stages

Soil suction based irrigation	No of irrigations applied		Total irrigation (mm) (A)		Effective rainfall (mm) (B)		Cumulative profile water depletion (mm) (C)		Crop water use (mm) (A+B+C)		Curd yield (Mg ha^{-1})		Water Use Efficiency (kg ha^{-1} mm^{-1})	
							0-0.60 m		0-0.60 m				0-0.60 m	
	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11	2009-10	2010-11
I_1 ($I_{20(3)}$)	23	25	990	840	100.10	308.8	3.90	5.00	1094.00	1253.8	6.52	7.08	5.96	5.65
I_2($I_{20(6)}$)	23	25	1200	1020	100.10	308.8	1.70	2.10	1301.80	1330.9	6.49	6.18	4.99	4.64
I_3($I_{36(6)}$)	21	23	1080	900	100.10	308.8	5.00	5.90	1185.10	1314.7	5.75	5.13	4.86	3.90
I_{Rec}	23	25	1200	1020	100.10	308.8	1.40	1.70	1301.50	1330.5	6.13	8.35	4.71	6.28