Vegetable Science (2021) 48 (2) : 209-213

Effect of drip irrigation scheduling on yield attributes and water productivity of bitter gourd-cabbage-cowpea cropping sequences

Anant Bahadur[1*], Shekhar Singh[1], DK Singh[2] and SNS Chaurasia[1]

Received: November 2021/ Accepted: December 2021

Abstract

Enhanced water and nutrient use efficiency, crop yield with superior quality can be achieved by adopting drip irrigation and fertigation system in vegetables. Drip irrigation study was carried out in bitter gourd, cabbage and cowpea crop sequences respectively during *Kharif*, *Rabi* and *Zaid* seasons. Treatment comprised of four drip irrigation scheduling *i.e.*, drip irrigation at 100% ET or 75% ET with irrigation scheduling daily or alternate day. Conventional furrow irrigation was also kept as control. In bitter gourd, maximum fruit yield of 143.00 q/ha was recorded with drip irrigation scheduling daily at 100% ET, whereas maximum WUE (4.657 q/ha/cm) was recorded in drip irrigation schedule at alternate day with 75% ET. Similarly, in cabbage, drip irrigation scheduling daily or alternate day with 100% ET registered 36.18% and 34.78% higher head yield, respectively over surface irrigation. In summer season, most of the growth and yield parameters in cowpea were significantly enhanced with drip irrigation at 100% ET. However, most of the yield parameters recorded under 100% ET daily or 100% ET with alternate day were noticed *at par*. These two treatments have registered 22.8% and 18.4% higher yield over conventional irrigation. In cowpea, WUE under drip irrigation system were 1.54 to 1.69 times higher than the surface irrigation. It was concluded from present study that drip irrigation at 100% ET daily or alternate day significantly enhanced the productivity of bitter gourd, cabbage and cowpea, however maximum WUE were reported with 75% ET.

Key words: Drip irrigation, Reference evapotranspiration, Bitter gourd, Cabbage, Cowpea, Yield, WUE.

Introduction

Rapid urbanization and industrialization impose constraints of decreased arable land as well as share of water to agriculture year after year. Agriculture in the future has to produce ever increasing quantities of food with decreasing quantities of water available for irrigation. Therefore, optimum and efficient utilization of water in agriculture for irrigation assumes great significance. Conventional irrigation methods such as furrow and flood irrigation are widely used (>90% of irrigated area) to irrigate most of the vegetable crops grown in India; however, these methods have low irrigation or water use efficiency (only 35-50%) as compared to drip-irrigation system. Drip irrigation has proved its superiority over other conventional system of irrigation. Besides, higher water and nutrient-use-efficiency, drip irrigation has known to improve yield and quality, and has flexibility in scheduling water application. Drip irrigation has also advantage of low water delivery rate, precise placement of water and minimum losses resulting less weed growth and improved crop yields, water saving and water use efficiency. In drip irrigation system, water volume needed to achieve maximum productivity of vegetables ranged from 80% ET (Indranil Samui et al. 2020) to 100% ET (Bahadur et al. 2007). In brinjal, it has been reported that drip irrigation saves water about 40% and electricity use about 1554 kwh/ha, beside reductions in vegetable production costs e.g. fertilizer by 31%, enhancing crop yield by 52%, and consequently 54% more income (Narayanamoorty et al. 2018). In a study on drip irrigation in okra, it was found that water and electric savings, reduction of cultivation cost and yield increase to the tune of 47%, 15% and 49%, respectively (Narayanamoorty and Dewika 2017). In India, per capita water availability assessed at more than 5300 m^3 in 1951 had decreased to 1588 m^3 in 2010 and is likely to be less than 1500 m^3 by the year 2025. Availability of fresh water for irrigation is getting scanty. Increasing the demand of water for other sectors, the contribution of water for

[1]ICAR- Indian Institute of Vegetable Research, Varanasi-221305, Uttar Pradesh
[2]ICAR-Indian Institute of Farming System Research, Modipuram-250110, Uttar Pradesh
*Corresponding author; Email: singhab98@gmail.com

Table 1: Effect of drip irrigation scheduling on yield attributes and WUE of bitter gourd

Irrigation scheduling	No. of fruits/plant	Fruit length (cm)	Fruit diameter (cm)	Fruit yield (g/ plant	Fruit yield (q /ha)	WUE (q /ha/cm)
T1: Drip at 100% ET daily	13.67	15.74	4.07	849.67	143.00	4.414
T2: Drip at 100% ET alternate day	12.33	15.28	4.05	794.93	134.13	4.140
T3: Drip at 75% ET daily	11.50	13.94	3.76	681.87	113.17	4.657
T4: Drip at 75% ET alternate day	9.67	12.15	3.43	563.80	98.72	4.063
T5: Surface irrigation	10.33	12.38	3.58	693.33	113.27	1.743
SEm±	0.65	0.67	0.12	45.15	7.28	-
CD	1.84	1.89	0.33	130.93	21.11	-

Table 2: Effect of drip irrigation scheduling on yield attributes and WUE of cabbage

Irrigation scheduling	Head weight (g)	TDM (g)	Head yield (q /ha)	WUE (q /ha/cm)
T1: Drip at 100% ET daily	1.883	145.54	440.91	26.40
T2: Drip at 100% ET alternate day	1.780	128.06	436.39	26.13
T3: Drip at 75% ET daily	1.318	120.65	392.45	31.35
T4: Drip at 75% ET alternate day	1.305	109.71	362.46	28.95
T5: Surface irrigation	1.198	98.91	323.77	13.43
SEm±	0.14	7.98	22.30	-
CD	0.41	22.90	63.99	-

irrigation may likely to reduce from present level of 84 to 69% by 2025, but on the other hand, demand of water for agricultural purposes would increase to produce more foods. Keeping in view of commercialization of drip irrigation system in eastern Uttar Pradesh, the present study was carried out to optimize the drip fertigation scheduling (quantity and frequency of water) in bitter gourd- cabbage- cowpea crop sequences to achieve higher productivity.

Materials and Methods

The study was carried out at ICAR-IIVR, Varanasi during *Kharif* (June-September), *Rabi* (October- February) and *Zaid* (March-May) season in 2019-20 and 2020-21. Experimental soil was loam (Inceptisol) with pH 7.6, EC 0.42 dS/m, organic C 0.41% and available N, P and K as 250, 22 and 320 kg/ ha, respectively. The field capacity and permanent wilting point of soil was 20.34 and 10.82%, respectively. Drip irrigation was applied as per schedule of experiment treatments in bitter gourd, cabbage and cowpea. Treatments comprised of five irrigation scheduling, including conventional irrigation. There were four drip irrigation scheduling *i.e.*, drip irrigation quantity of 100% ET or 75% ET with irrigation scheduling at daily or alternate day. Drip irrigation was compared with conventional furrow irrigation scheduled

Table 3: Effect of drip irrigation scheduling on yield attributes and WUE of cowpea

Irrigation scheduling	Plant height (cm)	No. pods/ plant	Pod length (cm)	Pod weight (g)	Pod yield (g/ plant)	Pod yield (q /ha)	WUE (q /ha /cm)
T1: Drip at 100% ET daily	62.31	26.44	32.26	13.25	340.33	107.35	5.51
T2: Drip at 100% ET alternate day	60.57	24.89	31.44	12.74	318.50	103.51	5.31
T3: Drip at 75% ET daily	57.44	22.11	30.06	11.96	273.83	84.80	5.81
T4: Drip at 75% ET alternate day	54.5	20.17	30.1	10.9	217.03	80.05	5.48
T5: Surface irrigation	56.43	21.05	29.45	11.3	252.43	87.39	3.43
SEm±	1.42	1.19	0.52	0.44	22.29	5.41	-
CD	4.06	3.40	1.48	1.26	63.98	15.52	-

Table 4: Effect of drip irrigation scheduling on water savings and cowpea equivalent yield (CEY) of bitter gourd-cabbage-cowpea sequences

Treatment	Bitter gourd*			Cabbage*			Cowpea*	
	Water used (cm)	Water saving (%)	CEY (q/ha)	Water used (cm)	Water saving (%)	CEY (q/ha)	Water used (cm)	Water saving (%)
T1	32.4	50.15	114.40	16.7	30.70	141.09	19.5	23.53
T2	32.4	50.15	107.30	16.7	30.70	139.64	19.5	23.53
T3	24.3	62.61	90.54	12.5	48.13	125.58	14.6	42.74
T4	24.3	62.61	78.98	12.5	48.13	115.99	14.6	42.74
T5	65.0	-	90.62	24.1	-	103.61	25.5	-

*Selling price of bitter gourd @Rs 20/kg, Cabbage @Rs 8/kg and cowpea @Rs 25/kg.

at IW/CPE=1.0 with 5 cm water depth in each irrigation. Thus, a total of five treatments were replicated 4 times in Randomised Block Design fashion. In-build, inline emitters of 2 lph were fixed in 16 mm laterals at spacing of 50 cm in bitter gourd and cabbage and 30 cm in cowpea. For fertigation, water soluble granular fertilizer of 19:19:19, Urea and 13:0:46 grades were supplied through Venturi in 5-10 split doses @ 120:60:80 kg NPK/ ha in bitter gourd and cabbage, while 40:60:60 kg NPK/ ha was supplied in cowpea. The amount of water under 100% ET was decided as per equation-

Water requirement at 100% ET (lit.) =

$$\frac{PE\ (mm)\ x\ Kc\ x\ Kp\ x\ Area\ (m^2)}{IE}$$

where PE = pan evaporation from USWB Class-A open pan evaporimeter; Kc = crop coefficient (adopted from Dorenbos and Pruitt 1977); Kp =pan coefficient (0.75 taken as constant); and IE = irrigation efficiency of drip system (0.9). Water use efficiency (WUE) was calculated as ratio of marketable yields obtained (q/ha) and water supplied (cm). Total dry matter production (TDM) was the dry weight of all plant parts such as, leaves, stem, root and head. All recommended agronomic practices and pest control measures were adopted. Cowpea equivalent yield (CEY) was calculated on the basis of yield obtained and selling price of the produce.

Results and Discussion

Bitter gourd (Kharif season): Drip irrigation scheduling significantly influenced the yield attributes in bitter gourd. Significantly higher number of fruits (13.67 and 12.33), fruit length (15.74 and 15.28 cm), fruit diameter (4.07 and 1.05 cm) and fruit yield (143.00 and 134.13 q/ha) was recorded with drip irrigation at100% ET and scheduling daily (T1) or alternated day (T2), respectively (Table 1). These two treatments registered 26.24% and 18.42% higher fruit yields than the surface irrigation (T5). In corroborate to our findings, Sharma et al. (2014) in a study on melon (*Cucumis melo*) also reported that deficit drip irrigation (50% ETc) caused 30% reduction in marketable yield, besides 20% reduction in fruit number and 16% in fruit weight. The increased in growth and yield attributes in bitter gourd under drip irrigation at higher evapotranspiration (100% ET) might be attributed due to maintain soil moisture at field capacity, which facilitated better water and nutrient uptake, better soil-water-air relationship (Bahadur et al. 2007). Water stress results in stomatal closure and reduced transpiration rates, a decrease in leaf water potential, decrease in photosynthesis and growth inhibition. Reduction in stomatal conductance also lowers photosynthetic rate due to restriction of CO_2 availability at assimilation site (eg chloroplast) and lower internal CO_2 concentration inside the leaf (Lawlor and Cornic 2002).

Maximum water use efficiency (4.657 q/ha/cm) in bitter gourd was achieved in drip irrigation at 75% ET with schedule at alternate day. It was followed by drip irrigation daily with 100% ET (4.414 q/ha/cm). Minimum WUE *i.e.* 1.743 q/ha/cm was noticed in surface irrigation. A total of 650 mm water was used in surface irrigation while 324 mm water was given under drip irrigation system. As compared to surface irrigation, 50.15% water was saved in drip irrigation at 100% ET. Improved WUE can be achieved either by achieving the same yield with less water or less water use resulting in proportionally lower reduction in yield as compared with corresponding reduction in water used. Drip irrigation is the most efficient method of irrigation for vegetable cultivation. The delivery of low amounts of water at a high frequency usually limits water evaporation and drainage, thus represents high water use efficiency (Sharmasarkar et al. 2001; Sun et al. 2013).

Cabbage (Rabi season): In cabbage, the maximum and significantly higher head weight (1.883 and 1.780 kg) and total dry matter of 145.54 and 128.06 g were observed 100% ET, respectively irrigating daily or alternate day (Table 2). Maximum and significantly higher total dry matter (TDM) production was registered in daily irrigation with 100% ET (145.54 g DW/ plant), which was about 47% higher than the control (T5). Drip irrigation scheduling daily (T1) or alternate day (T2) with 100% ET registered significantly higher head yields over other treatments. These two treatments recorded 36.18% and 34.78% higher head yield, respectively over surface irrigation. Khodiakov et al. (2021) also reported that increase in soil moisture and irrigating cabbage at full moisture content (80-90%) significantly enhanced the head yields. In contrast to our findings, Imtiyaz et al. (2000) obtained highest marketable yield of broccoli, carrot and cabbage with drip irrigation at 80% of pan evaporation replenishment.

As far as water use efficiency in cabbage was concerned, maximum WUE of 31.35 q/ha/cm was recorded in drip irrigation daily at 75% ET (T3), which was more than 2.33 times than the surface irrigation. In cabbage, water used under drip irrigation at 100% ET was 167 mm, whereas in surface irrigation 241 mm. Drip irrigation at 100% ET saved 30.7% water, whereas at 75% ET about 48% water saved over surface irrigation. Maximum WUE under 75% ET may be due to insignificant yield reduction (about 11%) with less use of water (25% less) as compared to 100% ET.

Similar to our findings, Gupta and Chattoo (2014) obtained maximum WUE in knol-khol with drip irrigation in range of 60-80% ET, besides water savings to tune of 39.5-54.6%.

Cowpea (Zaid season): Most of the growth and yield parameters in cowpea were significantly enhanced with drip irrigation at 100% ET (Table 3). Maximum plant height (62.31 cm), number of pods (26.44), pod length (32.26 cm), pod weight (13.25 g), pod yield (340.33 g/ plant and 107.35 q/ha) were noticed under T1 (drip irrigation daily at 100% ET), however most of the yield parameters recorded under T1 were *at par* to T2 (drip at alternate day with 100% ET). T1 and T2 has registered 22.8% and 18.4% higher yield over conventional irrigation (T5). The study conducted by Tiwari et al. (1998) indicated that 100% irrigation requirement met through drip irrigation along with black plasticmulch gave the highest yield of okra with 72% increase in yield as compared to furrow irrigation.

In cowpea, WUE in all drip irrigation treatments weresimilar, but they were remarkably higher (5.31-5.81 q/ha/cm) than the surface irrigation (3.43 q/ha/ cm). WUE under drip irrigation system were 1.54 to 1.69 times higher than the surface irrigation. As far as water used was concerned, drip irrigation at 100% ET used 195 mm, whereas in surface irrigation it was 255 mm, thereby 23.5% water was saved through drip irrigation, beside 18-23% more pod yields. Improved WUE can be achieved either by achieving the same yield with less water or less water use resulting in proportionally lower reduction in yield as compared with corresponding reduction in water used. In our study, 72% higher yield was recorded in cowpea with investing 25% more water as in case of T3 and T4.

Cowpea equivalent yield (CEY): In bitter gourd-cabbage-cowpea crop sequences, the maximum CEY was reported with 100% ET in cabbage (139.64 -141.09 q/ha) followed by bitter gourd (107.30- 114.40 q/ha) mainly because of higher market prices (Table 4). Maximum water savings at 100% ET as compared to conventional irrigation system was observed in bitter gourd (50.15%) followed by cabbage (30.70). The drip irrigation system was in use for a total of 275 days in a year with studied cropping sequence indicating higher utility of the irrigation system as well as resources. The CEY of the above cropping sequence was found to be 0.994 q/day over the year.

Conclusion

Application of drip irrigation in crop sequence of bitter gourd-cabbage-cowpea realized significantly higher yield with daily drip irrigation at 100% ET to the tune of 26.24%, 36.18% and 22.8%, respectively over conventional furrow irrigation system. However, maximum WUE was achieved with irrigation at 75% ET. Daily and alternate day drip irrigation either at 100% ET or at 75% ET had insignificant effect on yield and WUE. The equivalent yield of crop sequences under drip irrigation could also be achieved higher than the conventional irrigation. Hence, it is concluded that drip irrigation in vegetables have higher productivity as compared to conventional furrow irrigation method. Use of drip irrigation in above crop sequences could realize higher productivity as well as utility of drip irrigation and resources over the year.

सारांश

ड्रिप सिंचाई में पानी की विभिन्न मात्राओं (100 प्रतिशत या 75 प्रतिशत ई.टी.) को ज्ञात करने के लिये सिंचाई अंतराल (प्रत्येक दिन या एक दिन अंतराल पर) का करेला–पत्तागोभी एवं लोबिया फसल चक्र पर क्रमशः खरीफ, रबी, एवं जायद मौसम में प्रयोग किया गया। ड्रिप सिंचाई की 100 ई.टी. मात्रा, जिसे चाहे प्रत्येक दिन या एकान्तर दिन पर किया जाये उससे इन सब्जियों में अन्य सिंचाई मात्राओं की अपेक्षा सार्थक अधिक उपज प्राप्त की गयी। इन सब्जियों में 75 प्रतिशत ई.टी. की अपेक्षा लगभग 18–36 प्रतिशत अधिक उपज दर्ज की गयी। इन सभी सब्जियाँ में ड्रिप सिंचाई की मात्रा 75 प्रतिशत ई.टी. पर करने से अधिक जल उपयोग दक्षता प्राप्त की जा सकती है।

References

Bahadur Anant, Singh RK, Singh KP, Singh R and Singh MC (2007) Response of okra genotypes to drip irrigation scheduling. Haryana J Hortic Sci 36(1&2): 139-141.

Gupta AJ and Chattoo MA (2014) Response of knol-khol cv. Early White Vienna to drip irrigation and fertigation in Kashmir Region. Indian J Ecol 41(1): 152-157.

Imtiyaz M, Mgadla NP, Manase SK, Chendo K and Mothobi EO (2000) Yield and economic return of vegetable crops under variable irrigation. Irrigation Science 19: 87-93.

Indranil Samui, Milan Skalicky, Sukamal Sarkar et al. (2020) Yield response, nutritional quality and water productivity of tomato (*Solanum lycopersicum* L.) are influenced by drip irrigation and straw mulch in the Coastal saline ecosystem of Ganges delta, India. Sustainability 12: 6779; doi:10.3390/ su12176779.

Khodiakov E, Akhmedov A, Borovoy E, Milovanov S and Bondarenko K (2021) Management of the water regime of soil to increase the vegetable crops yield with different irrigation methods in the south of Russia. E3S Web Conferences 282, 05001 FSC2021. https://doi.org/10.1051/ e3sconf/20212820500.

Lawlor DW and Cornic C (2002) Photosynthetic carbon assimilation and associated metabolism in relation to water deficit in higher plants. Plant Cell Environ 25: 275-294.

Leskovar D, Bang H, Crosby K, Maness N, Franco J and Perkins-Veazie P (2004) Lycopene, carbohydrates, ascorbic acid and yield components of diploid and triploid watermelon cultivars are affected by deficit irrigation. J Hortic Sci Biotechnol 79: 75-81.

Narayanamoorthy A and Devika N (2017) Economics and resource impact of drip method of irrigation on okra cultivation. An analysis of field survey data. J. Land Rural Studies 6(1); 15-33.

Narayanamoorthya A, Bhattaraib M and Jothic P (2018) An assessment of the economic impact of drip irrigation in vegetable production in India. Agric Econ Res Rev 31(1): 105-112.

Sharma SP, Leskovar DI, Crosby KM, Volder Astrid and Ibrahim AMH (2014) Root growth, yield, and fruit quality responses of reticulatus and inodorus melons (*Cucumis melo* L.) to deficit subsurface drip irrigation. Agric Water Manage 136:75-85.

Sharmasarkar EC, Sharmasarkar S, Miller SD, Vance GF and Zhang R (2001) Assessment of drip and flood irrigation on water and fertilizer use efficiencies for sugar beets. Agric Water Manage 46: 241-251.

Sun Y, Hu KL, Fan ZB, Wei YP, Lin S and Wang JG (2013) Simulating the fate of nitrogen and optimizing water and nitrogen management of greenhouse tomato in North China using the EU-Rotate N model. Agric Water Manage 128: 72-84.

Tiwari KN, Mal PK, Singh RM and Chattopadhyay A (1998) Response of okra (*Abelmoschus esculentus* (L.) Moench.) to drip irrigation under mulch and non-mulch conditions. Agric Water Manage 38:91-102.