Environment and Ecology 40 (3B) : 1586—1592, July—September 2022
ISSN 0970-0420

Effect of Irrigation Frequency and Lateral Spacing on Irrigation Water use Efficiency and Productivity of *kharif* Onion under Subsurface Drip System

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Received 3 May 2022, Accepted 22 June 2022, Published on 11 August 2022

ABSTRACT

An experiment was conducted to study the effect of lateral spacing (45 cm and 60 cm) and drip irrigation frequencies (one, two, three and four days) on onion crop (Agrifound dark red variety) during *kharif* season 2018 in micro plots (2 m × 2 m) constructed in lab area of Department of Soil and Water Engineering, COEA and T, CCSHAU, Hisar, Haryana, India. The highest yield in A (> 5.0 cm), B (4.0-5.0 cm) and C (3.0-4.0 cm) grade of onion was observed as 0.76, 0.54 and 0.31 kg m^{-2} in two days irrigation frequency with 45 cm lateral spacing. The highest marketable yield of onion (155.23 q ha^{-1}) was observed in two days irrigation frequency with lateral spacing of 45 cm. These parameters show that better quality of onion was obtained in this treatment. The highest yield of onion (175.67 q ha^{-1}) was obtained in two days irrigation frequency with lateral spacing of 45 cm which was 16.8% higher than two days irrigation frequency with lateral spacing of 60 cm. Irrigation water use efficiency was found to be highest (10.23 kg m^{-3}) in two days irrigation frequency with lateral spacing of 45 cm. On the basis of this we can say that, two days irrigation frequency with 45 cm lateral spacing is the most preferable treatment for *kharif* onion in sandy loam soils.

Keywords Irrigation frequency, Lateral spacing, Subsurface drip irrigation, Irrigation water use efficiency.

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INTRODUCTION

Efficient usage of available water resources is vital for a nation like India, which shares 17% global population with only 2.4% of land and 4% of the world's

Fig. 1. A view of experimental site.

water resources. The per capita water availability was 6008 m^3 in 1947 which has been reduced to 1250 m^3 at present and is likely to dwindle to 760 m^3 by the year 2050 (Patel and Rajput 2009). Agriculture sector is the leading consumer of water. To meet out the food security, income and nutritional needs, the food production in India must have to maintain its pace according to growing population. With increasing demands on limited water resources and need to minimize adverse environmental consequences of irrigation, drip irrigation technology will definitely play a significant role in the Indian agriculture (Patel and Rajput 2009).

Micro irrigation is the slow application of water in continuous way in the form of drops, tiny streams or miniature spray on, above, or below the soil surface by drip, subsurface drip, bubbler and micro-sprinkler systems. In drip irrigation water is applied through emitters linked to a water delivery line through low-pressure delivery. As the agriculture sector utilized 80% of the freshwater in India, micro-irrigation is usually promoted by central and state governments as a means to tackle the growing water crisis. The reason being drip and sprinkler irrigation delivers water to farms in far lesser quantities than conventional gravity flow irrigation. As a result of recurring droughts, micro-irrigation has changed into a policy priority in India. The brand new catch-phrase "Per Drop More Crop" of Pradhan Mantri Krishi Sinchai Yojana (PMKSY) mostly relates to micro irrigation. The shift towards micro-irrigation will save water and help to bring more area under irrigation, "save" water and boost crop. Micro irrigation which is largely being promoted in arid and semi arid regions of India where groundwater is the primary source of water (Harsha 2017).

Onion (*Allium cepa* L.) is an important vegetable cash crop in India and a member of Alliaceae family. India has the largest area under onion in the world and second leading producer in the world after China. In India, onion has been grown in an area of 0.83 million hectares with the production of 13.57 million tonnes and the productivity is 16.30 t ha^{-1} which is low. Maharashtra is the leading onion producing state accompanied by Karnataka and Gujarat (Kumar 2010). Onion is an important and necessary item in

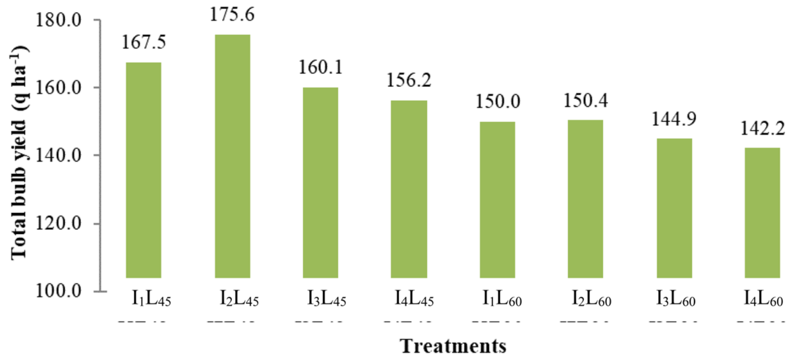

Fig. 2. Total bulb yield of onion under different treatments.

most of the kitchen as vegetable and has good medicinal value. Onions are primarily consumed for their flavor and ability to enhance the flavor of other foods (Kopsell and Randle 1997). Onions are increasingly being utilized in several ways as in fresh, frozen, canned, pickled, powdered, chopped and dehydrated forms. Onion has a relatively shallow root zone limited to top 8 cm and it is very sensitive to irrigation and readily reacts to frequent and light irrigations, hence requires more frequent irrigations as compared to other vegetable crops (Yadav *et al.* 2010). Onion is quite sensitive to moisture stress due to the

Table 1. Plant height (cm) of onion crop at 30, 60, 90 DAT and at harvesting. *I : Irrigation interval, *L : Lateral spacing, *NS : Not significant.

	Plant height (cm)			
	30 DAT	60 DAT	90 DAT	Harvesting
I_1	36.97	52.77	69.63	71.00
I_2	37.11	53.37	70.43	71.02
I_3	35.82	52.18	68.83	70.20
I_4	35.39	51.25	68.25	69.63
CD at 5%	0.716	0.494	0.572	0.504
L_{45}	36.30	52.53	69.42	70.68
L_{60}	36.35	52.25	69.16	70.24
CD at 5%	NS	NS	NS	NS
I_1L_{45}	37.1	52.0	70.5	63.4
I_2L_{45}	35.1	55.8	69.2	62.4
I_3L_{45}	35.9	52.4	68.6	60.1
I_4L_{45}	34.8	52.9	66.2	59.7
I_1L_{60}	34.6	54.0	67.4	61.6
I_2L_{60}	35.6	53.0	67.7	60.6
I_3L_{60}	33.5	55.2	67.4	59.7
I4L60	33.7	53.9	64.3	58.7
CD at 5% (I at same level of L)	NS	NS	NS	NS
CD at 5% (L at same level of I)	NS	NS	NS	NS

Table 2. Equatorial diameter, polar diameter, neck thickness and average weight of bulb for different treatments.

	Equatorial diameter	Polar diameter mm	Neck thickness mm	Average fresh wt of bulb g
I_1	54.28	48.24	13.44	71.23
I_2	54.84	48.22	14.52	72.33
I_3	54.24	45.86	14.01	63.07
I_4	53.58	47.07	13.81	57.63
CD at 5%	0.781	1.637	0.375	1.026
L_{45}	54.60	45.66	14.13	85.367
L_{60}	53.87	49.03	13.76	86.117
CD at 5%	NS	2.638	NS	0.700
I_1L_{45}	54.80	45.30	13.89	73.33
I_2L_{45}	55.30	46.01	14.78	76.60
I_3L_{45}	54.80	44.95	14.13	65.87
I_4L_{45}	53.50	46.39	13.72	57.20
I_1L_{60}	53.76	51.18	12.98	69.13
I_2L_{60}	54.37	50.43	14.26	68.07
I_3L_{60}	53.69	46.77	13.90	60.27
I_4L_{60}	53.66	49.03	13.90	58.07
CD at 5% (I at same level of L)	NS	3.034	0.973	1.556
CD at 5% (L at same level of I)	NS	3.099	1.707	1.394

Table 3. Weight of bulb per m² in different grades (kg) for different treatments.

	Weight of bulb per m² in different grades (kg)			
	Grade A > 5.0 cm	Grade B 4.0-5.0 cm	Grade C 3.0-4.0 cm	Grade D <3.0 cm
I_1	0.68	0.46	0.28	0.17
I_2	0.71	0.47	0.30	0.17
I_3	0.65	0.42	0.28	0.18
I_4	0.63	0.40	0.28	0.19
CD at 5%	0.030	0.031	NS	0.008
L_{45}	0.71	0.49	0.29	0.16
L_{60}	0.62	0.39	0.28	0.19
CD at 5%	0.047	0.024	NS	0.020
I_1L_{45}	0.72	0.51	0.29	0.16
I_2L_{45}	0.76	0.54	0.31	0.15
I_3L_{45}	0.70	0.46	0.28	0.16
I_4L_{45}	0.68	0.43	0.28	0.19
I_1L_{60}	0.65	0.41	0.26	0.18
I_2L_{60}	0.65	0.40	0.28	0.19
I_3L_{60}	0.59	0.39	0.28	0.19
I_4L_{60}	0.58	0.37	0.28	0.19
CD at 5% (I at same level of L)	NS	NS	NS	0.017
CD at 5% (L at same level of I)	NS	NS	NS	0.021

Table 4. Splitting and bolting percentage for different treatments.

	Splitting %	Bolting %
I_1	2.01	1.01
I_2	1.75	1.11
I_3	2.17	1.26
I_4	2.30	1.28
CD at 5%	NS	NS
L_{45}	1.96	0.98
L_{60}	2.16	1.34
CD at 5%	NS	NS
I_1L_{45}	1.93	0.86
I_2L_{45}	1.67	0.83
I_3L_{45}	2.00	1.34
I_4L_{45}	2.23	0.90
I_1L_{60}	2.09	1.17
I_2L_{60}	1.84	1.38
I_3L_{60}	2.33	1.17
I_4L_{60}	2.36	1.66
CD at 5% (I at same level of L)	NS	NS
CD at 5% (L at same level of I)	NS	NS

shallow root system but its roots penetration seldom exceeds 15 cm depth depending upon the soil (Bose and Som 1986). In micro irrigation system, it can be irrigated frequently with measured volume of water in relatively small amount slowly to uphold the ideal moisture condition for plant growth (Tiwari 2006).

MATERIALS AND METHODS

Experiment with four irrigation frequency (I_1 : one day, I_2 : two days, I_3: three days, and I_4 : four days irrigation interval) and two lateral spacing (L_{45} : 45 cm and L_{60} : 60 cm) was carried out during the *kharif* season 2018-19 in micro plots (2m × 2m) constructed in lab area of Department of Soil and Water Engineering, College of Agricultural Engineering and Technology, Chaudhary Charan Singh, Haryana Agricultural University, Hisar during August 2018 to December 2018 as shown in Fig. 1. The experimental site was located at 29°09′0.97″N latitude and 75°42′20.12″E longitude. In subsurface drip system laterals was buried at 5 cm from the soil surface. The recommended dose of nitrogen, phosphorus and potash were 50, 15 and 10 kg/acre, respectively. FYM (10 kg/acre), 100% of P, K and 50% of N were applied before transplanting the Agrifound Dark Red variety of onion. Remaining 50% of N was applied in five split doses through fertigation at fortnightly interval. Hoeing practice was done in the micro plots for proper mixing of FYM and the chemical fertilizer in the soil. Soil of the experimental site was having 78.16, 5.72 and 16.12% of the sand, silt and clay, respectively. Average bulk density of soil was 1.53 g cm^{-3}, whereas the average organic carbon and nitrogen present in the soil were 0.24% and 114.8 kg ha^{-1}, respectively. The pH of the soil profile (0–15, 15–30, 30–45 and 45–60 cm) was 8.03, 8.07, 8.19 and 8.13, respectively whereas the $EC_{1:2}$ (dS m^{-1}) was 0.23, 0.22, 0.19 and 0.19, respectively. After transplanting the plants in micro plots, initially irrigation was applied 10 days through hose pipe for establishment of the crop due to high temperature and hot waves. Irrigation was applied on the basis of 100% pan evaporation (PE) data collected daily from the micro plot area.

Crop evapotranspiration (ETc) was estimated as:

Table 5. Marketable yield, total bulb yield and water productivity for different treatments.

	Marketable yield q ha^{-1}	Total bulb yield q ha^{-1}	Irrigation water use efficiency kg m^{-3}
I_1	132.48	158.77	9.26
I_2	139.38	163.03	9.50
I_3	121.90	152.55	8.88
I_4	115.30	149.22	8.69
CD at 5%	4.001	3.642	0.210
L_{45}	137.82	164.89	9.60
L_{60}	116.72	146.89	8.56
CD at 5%	2.409	1.767	0.106
I_1L_{45}	141.53	167.53	9.76
I_2L_{45}	155.23	175.67	10.23
I_3L_{45}	132.07	160.33	9.33
I_4L_{45}	122.43	156.23	9.09
I_1L_{60}	123.43	150.00	8.75
I_2L_{60}	123.53	150.40	8.77
I_3L_{60}	111.73	144.97	8.44
I_4L_{60}	108.17	142.20	8.29
CD at 5% (I at same level of L)	5.982	5.355	0.309
CD at 5% (L at same level of I)	5.320	4.710	0.273

$$ET_c = K_c \times K_p \times CPE$$

Where, K_c = Crop coefficient values (Allen *et al.* 1998)

K_p = Pan coefficient (0.7)

CPE = cumulative pan evaporation

For different irrigation treatments, depth of irrigation was calculated from CPE upto that day from day of previous irrigation. So, for one day irrigation frequency, volume of irrigation was based on PE of previous day only. Similarly for two, three and four days irrigation frequency, CPE was calculated by adding PE of last two, three and four days, respectively. Volume of water applied was calculated by following formula (Kaulage 2017) :

$$V = \frac{ET_c \times L_s \times E_s \times Wa}{EU}$$

Where, V = volume of water applied (liter/day/emitter)

Ls = lateral spacing

Es = emitter spacing

Wa = wetted area factor (0.8)

EU = Emission uniformity of the system (90%)

Duration of the irrigation was determined by :

$$\text{Irrigation time (h)} = \frac{V}{Q}$$

Where; V = Volume of applied water in liter

Q = Dripper discharge in l h^{-1}

Soil moisture content was determined in the soil profile at 30 days interval after transplanting of the crop. Soil samples were collected from 0–15, 15–30, 30–45 and 45–60 cm depth at a radial distance of 0, 11.25 and 22.5 cm in lateral spacing of 45 cm whereas, in 60 cm lateral spacing soil samples were collected at a radial distance of 0, 15 and 30 cm. Plant height and crop yield parameters were measured at different growth period for onion crop. Onion was harvested in 19th December and weighed from each plots. Crop yield was recorded in each plot for different treatments. IWUE of different treatments was calculated in terms of total bulb yield per hectare to the amount of water applied by the following formula :

$$\text{IWUE (kg m}^{-3}) = \frac{\text{Total bulb yield (kg/ha)}}{\text{Amount of water applied (m}^3\ \text{ha}^{-1})}$$

RESULTS AND DISCUSSION

In drip system, same amount of water was applied in all treatment and average drip discharge was 2.2 l h^{-1}. The emission uniformity of the system was 90%. Total depth of water applied during whole period of experiment in each plot was 171.63 mm (686.53 liters) and rainfall received during the whole experiment was 82.6 mm.

During the research period, plant height (cm) was measured at 30, 60, 90 days after transplanting (DAT) and at harvesting. The effect of different irrigation frequency and lateral spacing on average plant height is presented in Table 1. Maximum plant height growth was found between 30 to 90 DAT and after that (at the harvest), the height was increased gradually. The influence of the irrigation frequencies on plant height at 30, 60, 90 DAT and at harvest were found significant while the influence of lateral spacing on plant height at 30, 60, 90 DAT and at harvest were found non-significant and there interaction between irrigation frequency and lateral spacing were also non-significant. Highest and lowest plant height at the harvest time was observed in I_2L_{45} and I_4L_{60} treatments, respectively. At the time of harvesting, in both lateral spacing no significant difference in plant height was observed between daily and alternate day irrigation but plant height was significantly higher at daily and alternate day irrigation in comparison to irrigation after three and four days. In 45 cm lateral spacing, plant height was almost remained same in daily and alternate day irrigation but there is abrupt decrease in plant height was observed in three and four days irrigation frequency. At harvesting, on comparing L_{45} and L_{60} treatments, maximum plant height was obtained in L_{45} treatment in the respective treatment of irrigation frequency.

The effect of different irrigation frequency and lateral spacing on equatorial diameter, polar diameter, neck thickness and average weight of bulb is presented in Table 2. The influence of the irrigation frequencies on equatorial diameter of bulb was found significant while lateral spacing was non-significant and there interaction between them was also non-significant. Highest (55.30 mm) equatorial diameter of bulb was observed in I_2L_{45} treatment and lowest (53.50 mm) was observed in I_4L_{45} treatment due to low moisture availability for crop growth. The similar results were found by Patel and Rajput (2009). The influence of the irrigation frequencies and lateral spacing on polar diameter of bulb was found significant and there interaction between them was also significant. Highest (51.18 mm) and lowest (44.95 mm) polar diameter of bulb was observed in I_1L_{60} and I_3L_{45} treatments, respectively. The influence of the irrigation frequencies on neck thickness of bulb was found significant while lateral spacing was non-significant and there interaction between them was significant. Highest (14.78 mm) and lowest (12.98 mm) neck thickness of bulb was observed in I_2L_{45} and I_1L_{60} treatments, respectively. The influence of irrigation frequencies and lateral spacing on fresh weight of bulb was found significant and there interaction between them was also significant. In 45 cm lateral spacing, the highest fresh weight of bulb was recorded in alternate irrigation treatment whereas, in 60 cm lateral spacing, its height value was recorded in daily irrigation treatment.

To check the impact of irrigation frequency and lateral spacing, bulb size was graded into four categories (> 5.0 cm, 4.0–5.0 cm, 3.0–4.0 cm and < 3.0 cm, respectively) as described by Fatideh and Asil (2012) and presented in Table 3. The influence of irrigation frequencies and lateral spacing on yield of bulb in grade A (> 5.0 cm) of onion was found significant and there interaction between them was non-significant. Highest and lowest yield of bulb in grade A of onion was observed in I_2L_{45} and I_4L_{60} treatments, respectively. Highest and lowest yield of bulb in grade B of onion was observed in I_2L_{45} and I_4L_{60} treatments, respectively. Highest and lowest yield of bulb in grade C of onion was observed in I_2L_{45} and I_1L_{60} treatments, respectively. Highest yield of bulb in grade D of onion were observed in I_4L_{45}, I_2L_{60}, I_3L_{60} and I_4L_{60} treatments and lowest yield was observed in I_2L_{45} treatment. In A, B and C grade, the highest yield was recorded in I_2L_{45} treatment. This reflects that the alternate irrigation frequency with 45 cm lateral spacing is the best treatment in relation to size of onion bulb.

The effect of different irrigation frequency and lateral spacing on split bulb and bolting is presented in Table 4. The influence of the irrigation frequencies and lateral spacing on split bulb and bolting were found non-significant and there interactions between them were also non-significant. Highest and lowest percentage of split bulb was observed in I_4L_{60} and I_2L_{45} treatments, respectively. Similarly, highest and lowest percentage of bolting of plants was observed in I_4L_{60} and I_2L_{45} treatments, respectively.

The effect of different irrigation frequency and lateral spacing on marketable yield, total bulb yield and irrigation water use efficiency (IWUE) are presented in Table 5. The influence of the irrigation frequencies and lateral spacing on marketable yield was found significant and the interaction between them was also significant. Highest and lowest marketable yield was observed in I_2L_{45} and I_4L_{60} treatments, respectively. Highest percentage marketable yield

(88.4) was observed in I_2L_{45} treatment which reflects alternate day irrigation with 45 cm lateral spacing maintain the appropriate moisture content in the root zone to obtain the best quality onion. The influence of the irrigation frequencies and lateral spacing on total bulb yield was found significant and there interaction between them was also significant. Highest and lowest total bulb yield was observed in I_2L_{45} and I_4L_{60} treatments, respectively. In 45 cm lateral spacing, marketable yield increased from daily irrigation to alternate day irrigation and further decreased with increase in irrigation interval. In L_{45} and L_{60} treatments, the highest yield was recorded in two days irrigation interval as shown in Fig. 2. In L_{45} treatment, irrigation at two days interval got 4.8, 9.7 and 12.4% higher yield than irrigation at one day, three days and four days interval which indicates that irrigation at two days interval gave the best yield. Similarly in L_{60} treatment, irrigation at two days interval got 0.3, 3.8 and 5.8% higher yield than irrigation at one day, three days and four days interval. On comparing L_{45} and L_{60} treatments, frequency plays important role in L_{45} treatment. In I_2L_{45} treatment, the crop yield was 16.8% higher than I_2L_{60} treatment. This indicates that among spacing, L_{45} is better and among frequency I2 is best option. Oktem *et al.* (2003) recommended similar results for sweet corn crop in semi-arid region. The influence of the irrigation frequencies and lateral spacing on irrigation water use efficiency in onion was found significant and the interaction between them was also significant. As amount of water applied was remained same in all the treatments, IWUE of a treatment is directly related to yield of that treatment. The highest and lowest irrigation water use efficiency of onion was observed in I_2L_{45} and I_4L_{60} treatments, respectively. In I_2L_{45} treatment, 16.8% higher IWUE was recorded than I_2L_{60} treatment which indicates that IWUE is also remain highest at 45 cm lateral spacing and two days irrigation interval. On comparing L_{45} and L_{60} treatments, maximum IWUE was obtained in L_{45} treatment. Similar result was reported by Patel *et al.* (2014).

CONCLUSION

Based on the obtained results, we can say that better quality and highest yield of onion for two days irrigation frequency with 45 cm lateral spacing is the most preferable treatment in sandy loam soils.

ACKNOWLEDGEMENT

This research conducted under the guidance of Dr. Sanjay Kumar, professor (Soil and Water Engineering), College of Agricultural Engineering and Technology, CCS Haryana Agricultural University, Hisar, who constantly provided support and guidance during every step of the process.

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