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Effect of Drip Irrigation Frequency and Lateral Spacing on *Kharif* Onion Crop

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ABSTRACT

Irrigating crops based on evapotranspiration deficit and irrigating after a particular time interval provide scope for optimizing irrigation. Studying the effect of different irrigation frequency on water productivity, is important to develop irrigation schedules under micro irrigation. In this study, effect of different spacing between drip lateral (45 cm and 60 cm) and irrigation frequency (One, Two, Three and Four days) on onion crop (*Allium cepa* L.) under drip irrigation system during *kharif* season 2018 in micro plots (2 m × 2 m) filled with sandy loam soil was evaluated. Irrigation was applied using drip irrigation for different irrigation frequency using same volume. During the experiment different observations like soil physical and chemical properties, different growth and yield parameter were recorded. Highest water productivity (10.1 kg/m^3) and total bulb yield (169.4 q/ha) was observed in two days irrigation frequency with 45 cm lateral spacing. Available moisture depth (cm) in the root zone (0-60 cm) at 90 DAT, for one day irrigation interval with 45 cm lateral spacing was 11.6 cm at the middle of two laterals which was 9.4 % higher than with 60 cm lateral spacing where available moisture was 10.6 cm. More distantly placed laterals may show poor water distribution and with a few of plants at the midpoint between the rows being water stressed. Studying the effect of different irrigation frequency and design parameter like lateral spacing hence becomes important to develop irrigation schedules and practices that can be used for better irrigation water management.

HIGHLIGHTS

- Agrifound Dark Red variety of onion (*Allium cepa* L.) under sandy loam soil was grown under different treatment consisting of drip lateral spacing (45 cm and 60 cm) and irrigation frequency (One, Two, Three and Four days).
- Periodical observation of plant growth and yield parameters were taken. Under the given conditions for Sandy loam soil, two days irrigation frequency with 45 cm lateral spacing treatment came out to be the most preferable treatment on the basis of water productivity and yield of onion crop.

Keywords: Irrigation frequency, lateral spacing, soil moisture, *kharif* onion and drip irrigation

Agriculture is an important part of livelihood in India with more 60 % of rural workforce engaged in activities related to agriculture (Pingali *et al.* 2019). This sector is also the major user of fresh water in India. Average annual per capita water availability in India was 1545 cubic meters in 2011 which is projected reduce to 1486 cubic meters and 1367 cubic meters in the years 2021 and 2031, respectively (PIB, 2020). Agriculture in India depends mainly on

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rainfall having average annual rainfall 1190 mm of which nearly 75 % occurs in short monsoon period of 3 to 4 months (May to September) (Dhawan 2017). Increasing population and declining water resources have made India a water stressed nation. This water scarcity has been worsened by dependence on traditional irrigation practices having relatively low application efficiencies. Use of drip irrigation system has many advantages like better water distribution uniformity, water saving and higher water use efficiency. India has made micro irrigation priority in its policies by launching schemes like Pradhan Mantri Krishi Sinchai Yojana (PMKSY) in 2015 with an aim of increasing access to irrigation, enhance water and nutrient use efficiency. In India, nearly 68.1 Mha area is under irrigation of which 7.74 Mha is under pressurised irrigation consisting of 3.38 Mha under drip irrigation and 4.36 Mha under sprinkler irrigation (Anonymous, 2017). Use of micro irrigation for cultivation of crops has great scope for conserving water. India comes second after China in terms of production of vegetables in the world (Anonymous, 2018a). Onion (*Allium cepa* L.) is a vegetable crop with great national and international significance with annual production of 98.89 Million Metric Ton (MMT) worldwide (Anonymous, 2018a). In India, it is grown in three seasons that are *rabi, kharif* and late *kharif*. Its production is around 23.26 MMT and cultivated in 1.285 Mha (Anonymous, 2017). The *kharif* crop plays an important role stabilizing the onion prices in the country during supply shortages and counter abrupt price fluctuations. In Haryana, it is grown only in 0.03 Mha area and its production is around 0.701 MMT (Anonymous, 2018b). Onion has shallow root system and roots are present in top 0.18 to 0.40 m soil depth (Metwally 2011). Being a shallow rooted crop, it requires frequent irrigation to achieve good yields. Constant soil moisture near surface is important for good root generation in onions, water stress can lead to lower productivity and poor yield (Rajput and Patel 2006). Water requirement of the onion crop is influenced by the variety cultivated, plant density, agro climatic conditions, method of irrigation used etc. Accurate and reliable estimates of ET and crop water requirements are important for maintaining proper soil water balance (Madugundu *et al.* 2017). A number of studies have been conducted on drip irrigated onion crop but more focus have been kept on irrigation level and deficit irrigation (Mane *et al.* 2014; Khalon 2017; Madane *et al.* 2018 and Nandle *et al.* 2018). Irrigating frequency is an important parameter and irrigating crops at frequent frequency have shown positive impacts on yield of different vegetable crops like lettuce, pepper and onion by providing congenial growing environment in root zone and better moisture availability (Hanson *et al.* 2003; Ismail *et al.* 2009 and Bagali *et al.* 2012). Lateral spacing between drip lines influence water distribution and are important for maintaining proper moisture between the plants (Satpute *et al.* 2013; Patel *et al.* 2014 and Chouhan 2015). Farmers are not informed about the specific design of drip system in terms of lateral spacing, drip spacing and crop water requirements which results in poorly designed system on farm which is uneconomical. Governments are providing subsides at lump sum rate to standard designs which are not crop or area specific (Anonymous, 2017). There is need to identify the most suitable irrigation frequency and design parameter like lateral spacing to develop better irrigation schedules and practices that can be used for efficient irrigation management for onion crop. Keeping in view the above consideration present study was undertaken with following objectives:

- To study the effect of drip irrigation frequency and lateral spacing on yield and water productivity of onion.
- To study moisture distribution pattern in soil for onion crop under drip irrigation.

MATERIALS AND METHODS

The experiment was conducted in the field lab of Department of Soil and Water Engineering, College of Agricultural Engineering and Technology, Chaudhary Charan Singh Haryana Agricultural University, Hisar. The experimental site is located in the north-western part of Haryana at 29° 9′ 0.97″N (latitude) and 75° 42′ 20.12″E (longitude) with an average elevation of 215.2 m above mean sea level (MSL). Climate in Hisar is characterized as semi-arid, it receives on an average 459 mm of rainfall in a year. South-West Monsoon (June to September) accounts 75 to 80 % of the annual rainfall received in the district. Crop was cultivated in the micro plots which were raised from ground surface to a height of 1.5 m and are 2 m × 2 m (length × width) brick lined isolated chamber with open bottom filled with field soil. An automated drip irrigation system with a provision to schedule irrigation and fertigation has been installed for the micro plots. Drip lines had inline drippers at an interval of 40 cm along the line and rated discharge was 2 lph.

In this experiment, seedlings of *Agrifound Dark Red* variety of onion (*Allium cepa* L.) were transplanted in the micro plots keeping row to row and plant to plant spacing at 15 cm and 10 cm, respectively during *kharif* season 2018. Field preparation and transplanting was done according to standard package and practises (Anonymous, 2013). Split plot design with three replications was used in this study taking irrigation frequency as subplot factor and lateral spacing as main plot factor because we required higher precision for irrigation frequency factor (Panse and Sukhatme 1985). A total of eight treatments were considered in the study consisting of two lateral spacing (45 cm and 60 cm) and four irrigation frequencies (irrigation at one, two, three and four days interval), layout of the experiment is given in Fig. 1.

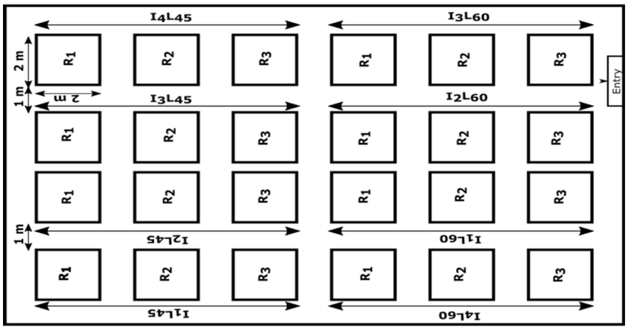

Fig. 1: Layout of the experiment

A brief summary of different treatment combinations is given in Table 1. Lateral spacing of 45 cm is found most suitable for drip irrigation in onion crop by different researchers (Satpute *et al.* 2013; Patel *et al.* 2014 and Chouhan 2015) and is also part of standard package and practises (Anonymous, 2013). Therefore, we compared 45 cm lateral spacing which is most wieldy adopted to 60 cm lateral spacing to compare the except of higher lateral spacing on soil moisture distribution in root zone and production. Irrigation was done based on 100 % of crop evapotranspiration (ET_c) values of Crop coefficient (K_c) was taken according to four growth stages in FAO56 *i.e.,* initial (0.7), development (0.7–1.05), mid-season (1.05) and end (1.05-0.75), respectively (Allen *et al.* 1998). Volume of irrigation for different irrigation treatments was based on cumulative pan evaporation (CPE) upto the day of present irrigation from day of previous irrigation. ET_o was measured using Class A evaporation pan. Total amount water applied per plot after during whole period of experimentation was 167.3 mm (669.2 litre) and rainfall received during that period was 82.6 mm. Crop water requirement during the initial growing stage was high due to hot weather conditions and dry spelt but in later stages with onset winters evapotranspiration decreased resulting in lower crop water requirements at later stages.

Table 1: Different treatments combinations and their abbreviation used

Sl. No.	Treatment	Abbreviation
1	One day irrigation interval with 45 cm spacing between the laterals	I_1L_{45}
2	Two days irrigation interval with 45 cm spacing between the laterals	I_2L_{45}
3	Three days irrigation interval with 45 cm spacing between the laterals	I_3L_{45}
4	Four days irrigation interval with 45 cm spacing between the laterals	I_4L_{45}
5	One day irrigation interval with 60 cm spacing between the laterals	I_1L_{60}
6	Two days irrigation interval with 60 cm spacing between the laterals	I_2L_{60}
7	Three days irrigation interval with 60 cm spacing between the laterals	I_3L_{60}
8	Four days irrigation interval with 60 cm spacing between the laterals	I_4L_{60}

During the experiment different growth and yield parameter were recorded using standard instruments and procedures. Plant height was measured at 30, 60, and 90 days after transplanting (DAT) and at harvesting with the help of ruler by placing one end of ruler on ground and measuring the vertical distance to the tip of the plant. At the time of harvesting polar and equatorial diameter of the selected bulbs from each plot was measured with the help of digital Vernier caliper by measuring the bulb vertically and horizontally, respectively. Neck thickness of the selected plants from each plot was measured with the help of Vernier caliper by measuring girth of the neck of the plants above the bulbs. Average weight of onion bulb from each plot was determined by weighting on an electronic

Table 2: Physical and chemical properties of the soil of experimental site

Soil depth (cm)	Bulk density (g/cm^3)	$pH_{1:1}$	$EC_{1:2}$ (dS/m)	Soil particle fraction (%) and soil texture			N (kg/ha)	P (kg/ha)	K (kg/ha)	Organic carbon (%)	Basic infiltration rate (cm/h)
				Sand (>0.05 mm)	Silt (0.05-0.002 mm)	Clay (<0.002 mm)					
0-15	1.55	8.02	0.23	78.16	5.72	16.12	118.3	15.2	173.3	0.28	2.55
15-30	1.54	8.01	0.19	(Sandy loam)			116.5	14.6	165.8	0.26	
30- 45	1.56	8.03	0.21				115.3	14.4	146.3	0.25	
45-60	1.56	8.04	0.23				114.2	13.8	144.5	0.24	

weight balance. The basic physical and chemical properties of initial soil samples of experimental site are given in Table 2. Collected data for different observations was analysed for statistical significance using split plot design (Panse and Sukhatme, 1985) using OPSTAT (Sheoran *et al.* 1998). Null hypothesis of difference between treatments was tested by using 'F' test at 5 % level of significance and standard errors ($S.E_m.\pm$) were calculated. Critical Difference (C.D.) at 5 % was computed for significant results.

RESULTS AND DISCUSSION

Crop Growth Parameters

Metrological parameters were observed during the period of study (17th August 2018 - 18th December 2018). Weekly sum of pan evaporation and rainfall throughout the study period is also shown in Fig. 2. Weekly metrological parameter *i.e.* minimum and maximum temperature (°C), relative humidity (%), sunshine hours (h) and wind speed (km/h) for the experimental period is also shown in Fig. 3.

During the research experiment, plant height was recorded at 30, 60 and 90 days after transplanting and at harvesting. Plant height observed during experiments for different treatment is given in Table 3. Height of plants increased upto maturity from transplanting after that growth of matured crop started stunting with onset senescence resulting in drying of tips of leafs that result in decreased at harvesting. At 90 DAT, plant height in daily irrigation frequency treatment was 1.8, 2.8 and 6.5 % higher than that in two, three and four days irrigation frequency for 45 cm lateral spacing. 4.7, 2.3, 1.8 and 3.1 % higher plant height was observed in 45 cm lateral spacing under daily irrigation frequency in comparison to 60 cm lateral spacing under one, two, three and four days irrigation frequency treatment, respectively. Higher plant height for frequent irrigated treatments could be due to better vegetative growth due to adequate soil moisture distribution and enhanced nutrient uptake. Irrigation through drip at a shorter interval of one day and two days ensures adequate moisture in the

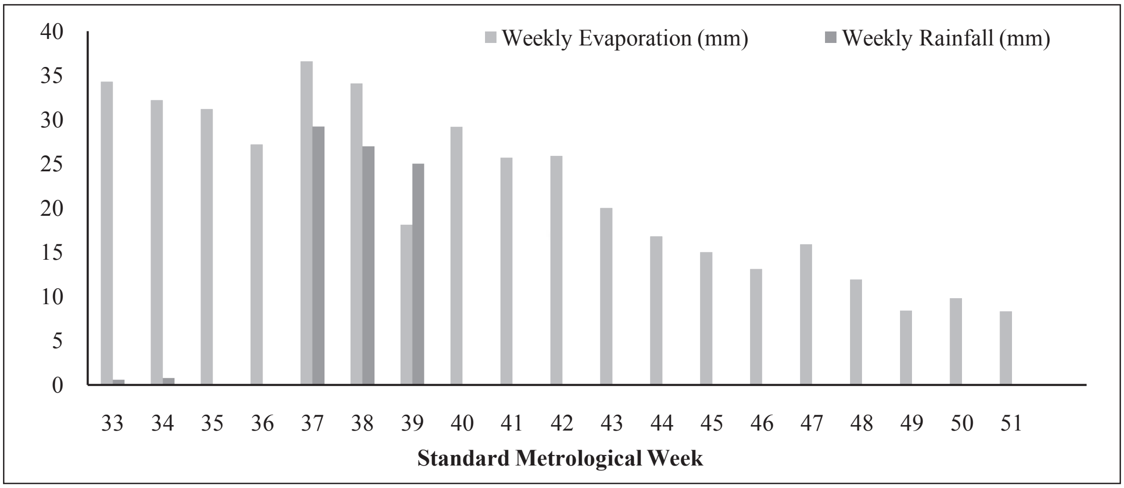

Fig. 2: Weekly evaporation and rainfall during experimental period

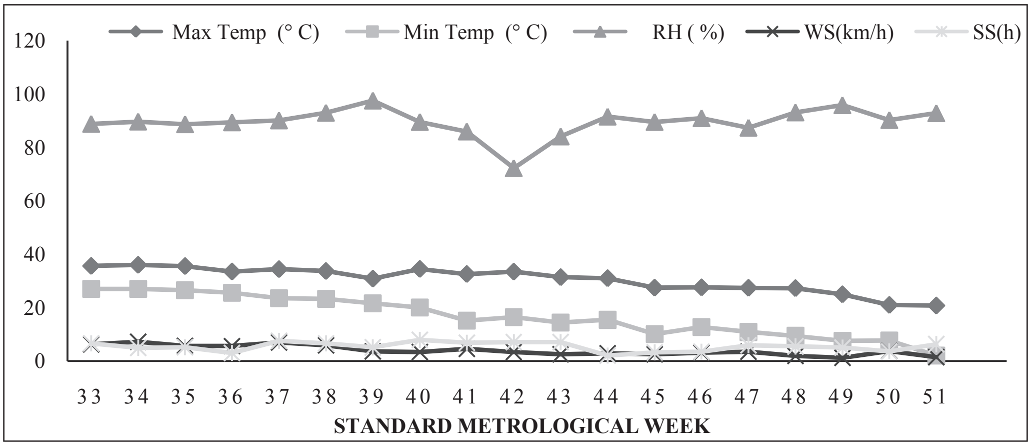

Fig. 3: Weekly metrological parameters during experimental period

crop root zone maintaining optimum soil-water-balance which is congenial for growth of plant. Similar results were reported by Bagali *et al.* (2012).

Table 3: Plant height (cm) of onion crop at 30, 60, 90 DAT and at harvesting as influenced by different treatments

	Plant Height (cm)			
	30 DAT	60 DAT	90 DAT	Harvesting
I_1	35.8	53	69[a]	62.5[a]
I_2	35.4	54.4	68.5[ab]	61.5[ab]
I_3	34.7	53.8	68[ab]	59.9[bc]
I_4	34.2	53.4	65.2	59.2[c]
CD at 5%	NS	NS	1.4	1.7
L_{45}	35.7	53.3	68.6	61.4
L_{60}	34.3	54	66.7	60.1
CD at 5%	NS	NS	NS	NS
I_1L_{45}	37.1	52[a]	70.5	63.4
I_2L_{45}	35.1	55.8[b]	69.2	62.4
I_3L_{45}	35.9	52.4[ac]	68.6	60.1
I_4L_{45}	34.8	52.9[acd]	66.2	59.7
I_1L_{60}	34.6	54[abcde]	67.4	61.6
I_2L_{60}	35.6	53[acdef]	67.7	60.6
I_3L_{60}	33.5	55.2[befg]	67.4	59.7
I_4L_{60}	33.7	53.9[abcdefg]	64.3	58.7
CD at 5% (I at same level of L)	NS	2.2	NS	NS

Note: *NS = Non significant, Numbers followed by same letters in the same column for a treatment are statistically non-significant by CD at 5%.*

Crop Yield Parameters

Fruits dimensions, yields and water productivity for different treatments are given in Table 4. In 60 cm lateral spacing for one day irrigation frequency, equatorial diameter was observed 3.6, 5.6 and 14.0% higher than two, three and four days irrigation frequency treatments, respectively. 1.8, 1.8, 9.6 and 9.6 % higher equatorial diameter was recorded in 60 cm lateral spacing with one day irrigation frequency when compared with one, two, three and four days irrigation frequency treatment in 45 cm lateral spacing. In 45 cm lateral spacing for two days irrigation frequency, polar diameter was observed 2.2, 9.3 and 17.5 % higher than one, three and four days irrigation frequency treatments, respectively. 6.8, 4.4, 11.9 and 11.9 % higher polar diameter was recorded in 45 cm lateral spacing with two days irrigation frequency on comparing with one, two, three and four days irrigation frequency treatment in 60 cm lateral spacing. Similar results were obtained for polar and equatorial diameter by Muhammad *et al.* (2011) and Bagali *et al.* (2012). Neck thickness for three days irrigation frequency with 45 cm lateral spacing was 23.0, 23.0 and 10.6 % higher than one, two and four days irrigation frequency with 45 cm lateral spacing treatments, respectively. 23.8, 35.6, 32.0 and 33.8 % higher neck thickness was observed in three days irrigation frequency with 45 cm lateral spacing than one, two, three and four days irrigation frequency with 60 cm lateral spacing. Average weight of bulb for two days irrigation frequency with 60 cm lateral spacing was 1.8, 4.6 and 6.3 % higher than one, three and four days irrigation frequency treatment with 60 cm lateral spacing and 4.0, 1.1, 4.5 and 6.6 % than one, two, three and four days irrigation frequency with 45 cm lateral spacing, respectively. Marketable yield and total bulb yield were significant for different irrigation frequency, lateral spacing and interaction effect. Significantly, higher marketable yield (161.7 q/ha) and total bulb yield (169.4 q/ha) was obtained

Table 4: Fruits dimensions, yields and water productivity as influenced by different treatments

	Equatorial diameter	Polar diameter	Neck thickness	Average wt. of bulb	Marketable yield	Total bulb yield	Water productivity
	cm	cm	mm	g	q/ha	q/ha	kg/m^3
I_1	5.7^a	4.5^a	16.1	86.3^a	146.2	155.4	9.3
I_2	5.6^a	4.6^a	15.4	88.3^a	156.1	164.7	9.8
I_3	5.3^b	4.3^{ab}	15.9	85^{ab}	137.3	149.3	8.9
I_4	5.1^b	4.1^b	16.4	83.4^b	122.7	138	8.3
CD at 5%	0.2	0.2	NS	2.38	3.1	2.7	0.16
L_{45}	5.4	4.4	17.5	85.4	145.1	155.6	9.3
L_{60}	5.4	4.3	14.4	86.2	136.1	148.1	8.9
CD at 5%	NS	NS	0.5	NS	4.7	4.8	0.28
I_1L_{45}	5.6	4.6	16.1^a	85.4	153.5^a	162.1^a	9.7^a
I_2L_{45}	5.6	4.7	16.1^{ab}	87.8	161.7	169.4	10.1
I_3L_{45}	5.2	4.3	19.8^c	85	139.5^b	150.7^b	9^b
I_4L_{45}	5.2	4	17.9^{abcd}	83.3	125.6	140.2^c	8.4^c
I_1L_{60}	5.7	4.4	16^{abde}	87.2	138.9^{bd}	148.7^{bd}	8.9^{bd}
I_2L_{60}	5.5	4.5	14.6^{abef}	88.8	150.5^a	160.1^a	9.6^a
I_3L_{60}	5.4	4.2	12^f	84.9	135.1^{bd}	147.8^{bd}	8.8^{bd}
I_4L_{60}	5	4.2	14.8^{abef}	83.5	119.7	135.8^c	8.1^c
CD at 5%	NS	NS	2.7	NS	5.6	5.1	0.304

Note: *NS = Non significant, Numbers followed by same letters in the same column for a treatment are statistically non-significant by CD at 5%.*

for I_2L_{45} treatment. Same irrigation was applied in different treatments, so it can be concluded that water productivity is directly proportional to the yield. Water productivity (kg/m^3) was significant for different irrigation frequency, lateral spacing and interaction effect. Significantly, higher water productivity was found maximum (10.1 kg/m^3) for I_2L_{45}. Results suggests that frequent irrigation results in better water productivity as compared to infrequent irrigation and better water productivity is found in treatments with closely spaced laterals. In 45 cm lateral spacing, water productivity for two day irrigation frequency was 4.5, 12.4 and 20.8 % higher than one day, three days and four days frequency. Similarly, 60 cm lateral spacing and two days irrigation frequency had 7.7, 8.3 and 17.9 % higher water productivity than one day, three days and four days frequency. On comparing the two lateral spacing I_2L_{45} treatment had 9.1 % higher water productivity than I_2L_{60} treatment. Similar results were reported by Bagali *et al.* (2012) and Hanson *et al.* (2003).

Water Availability in Root zone

Depth of water available in root zone (0-60 cm) at different distances from the dripper at different stages of growth (30 to 90 DAT) is given in Table 5. Maximum variation of available moisture with respect to irrigation interval was observed at 90 days after transplanting in both 45 and 60 cm lateral spacing. At 90 DAT, available moisture before irrigation for one day irrigation interval with 45 cm lateral spacing just near the dripper, 11.25 cm and 22.5 cm away from dripper was observed 47.2, 37.1 and 52.6 % higher than that for four days irrigation interval, respectively. Similarly, for 60 cm lateral spacing, available moisture at 90 DAT in one day irrigation interval just near dripper, 15 cm and 30 cm away from dripper was observed 71.3, 65.7 and 89.3 % higher than that for four days irrigation interval, respectively. At 90 DAT, for one day irrigation interval with 45 cm lateral spacing available moisture depth (11.6 cm) in the root zone (0-60 cm) at the middle of two lateral was observed higher (9.4 %) than with 60 cm lateral spacing where available moisture was 10.6 cm. On comparing the moisture depth at the middle of laterals for other respective irrigation intervals, usually the available moisture was more in case of 45 cm lateral spacing than 60 cm lateral spacing at different days after transplanting (DAT). This moisture distribution pattern further supports better crop yield in 45 cm

Table 5: Depth of water available (cm) in the root zone (0-60 cm) for various treatments plots

Treatments	30 DAT			60 DAT			90 DAT		
	Radial distance (cm)			Radial distance (cm)			Radial distance (cm)		
	0	**11.25**	**22.5**	**0**	**11.25**	**22.5**	**0**	**11.25**	**22.5**
I_1L_{45}	11.8	10.6	10.1	11.1	10.1	9.6	13.1	12.2	11.6
I_2L_{45}	10.7	8.8	8.5	10.2	8.7	8.2	12.2	10.6	9.8
I_3L_{45}	7.8	7.2	7.8	7.2	6.9	7.4	8.9	8.7	9.2
I_4L_{45}	7.2	7.4	6.7	7.2	7.2	5.8	8.9	8.9	7.6
	Radial distance (cm)			**Radial distance (cm)**			**Radial distance (cm)**		
	0	11.25	22.5	0	11.25	22.5	0	11.25	**22.5**
I_1L_{60}	12.4	10.4	9.0	11.7	10.0	8.5	13.7	12.1	10.6
I_2L_{60}	10.2	8.7	8.1	9.5	8.9	7.7	11.1	10.7	9.4
I_3L_{60}	8.2	7.0	6.8	7.4	6.7	6.3	9.2	8.8	8.0
I_4L_{60}	7.2	6.5	4.9	7.0	6.2	4.5	8.0	7.3	5.6

lateral spacing than 60 cm lateral spacing. Higher plant growth parameters for frequent irrigated treatments could be due to better vegetative growth as a result of adequate soil moisture distribution in root zone indicating that irrigation through drip after shorter interval at one day and two days ensures adequate moisture in the crop root zone maintaining optimum soil-water balance which is congenial for growth of plant.

CONCLUSION

From the results of the field experiment on onion crops response to different irrigation frequency and lateral spacing we could identify significant differences between various treatments in terms of growth, yield, quality and water productivity. Enhanced moisture availability in the root zone for frequently irrigated treatments resulted in better plant heights, above ground biomass and bulb weight. Similarly, for lesser lateral spacing greater and uniform availability of moisture in soil resulted in better crop growth and yield parameters. Marketable yield, total bulb yield, Water productivity was significantly affected by various treatments and significantly highest water productivity among the treatments was found in two days irrigation frequency with lateral spacing of 45 cm treatment (10.1 kg/m^3). Overall, frequent irrigation with 45 cm lateral spacing made much more sense. For Sandy loam soil overall two days irrigation frequency with 45 cm lateral spacing treatment came out to be the most preferable treatment under the given conditions on the basis of yield and water productivity for onion crop.

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