DOI : 10.5958/0974-0112.2019.00073.2

Indian J. Hort. 76(3), September 2019: 457-465

Onion growth, yield and quality as influenced by different drip lateral depths and irrigation levels

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ABSTRACT

This research aimed to evaluate the different lateral depths and irrigation water applied with subsurface drip irrigation on onion production traits during the spring growing seasons of 2009 and 2010 in Tekirdag conditions. Three different lateral depths as 0 (surface drip), 10 and 20 cm (subsurface drip) and four different irrigation (50, 75, 100 and 125 % of Class A pan evaporation). The seasonal evapotranspiration ranged from 337.1 and 715.4 mm depending on irrigation water applied. The highest onion yield obtained in the treatment which lateral was buried in 20 cm depth and the amount of irrigation water was applied based on 125 % of Class A pan evaporation. It can be said that the total marketable onion yield increases as the amount of lateral depth and applied irrigation water increases. The irrigation water use efficiency (IWUE) changed from 4.03 to 18.30 kg m^{-3} while the water use efficiency (WUE) changed from 2.61 to 6.86 kg m^{-3}. The highest IWUE and WUE obtained in the treatment which lateral was buried in 20 cm depth and the amount of irrigation water was applied based on 50% of Class A pan evaporation.

Key words: *Allium cepa*, irrigation method, evapotranspiraton, water use efficiency

INTRODUCTION

Production of onion (*Allium cepa* L.) takes a very important vegetable crop in world agriculture, with a production of about 88 m t harvested and 53 m ha planted area (FAO, 6). Onion is one of the main crops in Turkey where the production is about 1.80 m t harvested from 58 000 ha (FAO, 6). Early studies have shown that water is the most limiting factor for onion production and it is possible to increase production levels by well-scheduled irrigation programs (Şener, 14; Kumar *et al.*, 11; Enciso *et al.*, 5; Patel and Rajput, 13).

The drip irrigation method is predominant in the irrigation of vegetable, fruit trees and ornamental plants in terms of uniform water efficiency, irrigation water saving and ease of operation. Drip irrigation practices in the world began to be implemented after 1960 and, with technological developments in particular, began to spread rapidly throughout the world after 1980's. Especially, in the 1980's, approximately 0.3% of total arable irrigated land in the world was irrigated with drip irrigation method, whereas today, all of irrigated farmland of Israel, 51% of France, 72% of Spain and 57% of the United States is irrigated by pressure irrigation methods including drip irrigation (ICID, 9). The drip irrigation method involves a lot of engineering processes in the project, application and operation phases, and the materials used are constantly changing due to the continuous renewal of the technology. When the world literature is examined, it appears that many different forms of application of drip irrigation have emerged. Subsurface drip irrigation method, which is one of the application of this method, was used especially in the 1990's in the USA, Israel, Italy and other countries for the irrigating of perennial plants such as forage, grass and fruit trees, and nowadays it is used in all the vegetables (Camp *et al.*, 4). Despite the increase of irrigated areas by drip irrigation method in Turkey, subsurface irrigation method has been observed in recent years. These practices are known to be concentrated in the vineyards of the Aegean Region, in industrial tomato fields in the Southeastern Anatolia Region, and in regions with potatoes and onion cultivation in Turkey.

Ayars et al., (3) summarized 15 years of research conducted of row crops in California by observing that significant amount of water can be saved under subsurface drip irrigation. The previous studies shown that crops were irrigated by subsurface drip irrigation, yields were equal to or greater than obtained by the other irrigation methods (Onder *et al.,* 12; Patel and Rajput, 13).

The objectives of study were to determine the effects of drip irrigation lateral depths and irrigation water level on onion water use, vegetative growth, yield and quality parameters under Tekirdag conditions, Turkey.

MATERIALS AND METHODS

This study was conducted in 2009 and 2010 spring growing seasons at the farm at the Karaevli

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Village, Tekirdag, Turkey at 41°02'N, 27°39'E and 148 m altitude. The climate in the research field is semi-arid and the averages of annual temperature, wind speed, relative humidity, sunshine duration per day and total precipitation are 13.9°C, 2.7 m s^{-1}, 78%, 6.5 h and 585.1 mm, respectively.

Soil type in the plot area was clay-loam for the first year and loam for the second year. The bulk density ranged from 1.45 g cm^{-3} to 1.57 g cm^{-3}. The available water in the upper 60 cm of the soil profile was 96.47 mm (2009) and 105.36 mm (2010). Some properties of the experimental field soil related to irrigation are presented in Table 1. Irrigation water quality is classified as C_2S_1 according to U.S. Salinity Lab. (U.S. Salinity Lab. Staff, 15) with 0.33 sodium absorption ratio (SAR) and 0.1 dS m^{-1} electrical conductivity (EC) (Table 2).

Onions (Dry onion, cv. Yarim Imrallı) were direct seeded on April 10 in both the years and harvested on July 24 (2009) and July 20 (2010). Application of fertilizers, herbicides and insecticides were done uniformly to each plot within the growth period. Each plot covered an area of 7.20 m^2 (2.4 m x 3.0 m) and contained 180 plants spaced at 0.20 m x 0.20 m. The plots were irrigated through drip from water collected reservoir pumped from deep well. The drip control unit consisted of screen filter with 25 L s^{-1} capacity, manometers mounted on the inlet and outlet of each unit and a pressure regulator. Polythene (PE) tube was used for 50 mm main and 16 mm manifolds of drip and subsurface drip irrigation systems. The laterals were 16 mm PE, each lateral irrigated two plant rows and the lateral spacing were 0.40 m. Subsurface drip lateral lines were installed below the soil surface and lateral lines were installed just prior to planting. The dripper discharge rate was 1.8 L h^{-1}. The in-line dripper with 20 cm spacing was used. Thus, the percentage of the wetted area (P) that relates dripper spacing to lateral spacing was determined as 50% by the methods described by Keller and Bliesner (10).

A split-plot design with three replications was used with three lateral depths (main plots) and four irrigation regimes (sub-plots). The lateral depth treatments consisted of 0 (D_0, surface drip irrigation), 10 (D_{10}) and 20 (D_{20}) cm depth. The irrigation treatments consisted of four levels of cumulative pan evaporation (E_p) and water quantities applied were as 0.50 (I_1), 0.75 (I_2), 1.00 (I_3) and 1.25 (I_4) times of pan evaporation measured at seven days interval by Class A Pan located in the experimental site. The amount of irrigation water was calculated by using the equation given below:

$$I = E_p \times k_{cp} \times P \quad (1)$$

Where I is the irrigation amount, E_p is the cumulative pan evaporation for the 7-day irrigation interval (mm), k_{cp} is the coefficient of pan evaporation and P is the percentage of wetted area.

Soil water content in the plots was gravimetrically measured every week in the 30 cm depth increments to 0.90 m, using by the hand sampler. Evapotranspiration was estimated using the soil water balance equation (Allen *et al.,* 1). The equation can be written as:

$$ET = I + P \pm \Delta SW - DP - RO \quad (2)$$

where ET is the evapotranspiration (mm), I is the irrigation water applied (mm), P is the precipitation (mm), ∆SW is the change in the soil water storage in the 0.60 m soil profile (mm), DP is the deep percolation (mm) and RO is the amount of runoff (mm). Since the amount of irrigation water was

Table 1. Experimental site soil properties.

Year	Soil depth cm	pH	EC ds m^{-1}	$CaCO_3$ %	Field capacity %	Wilting point %	Bulk density g cm^{-3}
2009	0-30	7.52	0.9	4.45	31.43	21.02	1.52
	30-60	7.58	0.8	6.40	31.02	20.28	1.53
	60-90	7.15	0.8	5.25	30.03	18.20	1.55
2010	0-30	6.86	0.8	1.05	28.83	18.11	1.45
	30-60	6.86	0.8	1.29	29.91	17.03	1.52
	60-90	6.52	0.7	1.45	30.32	15.64	1.57

Table 2. Experimental site irrigation water properties.

Year	Class	EC ds m^{-1}	pH	Cations me L^{-1}				Anions me L^{-1}		
				Na^+	K^+	Ca^{++}	Mg^{++}	HCO^-_3	CL^-_3	SO^-_4
2009	C_2S_1	0.1	7.1	0.41	0.09	1.46	1.61	1.59	0.93	1.05
2010	C_2S_1	0.1	7.2	0.55	0.05	1.45	1.66	2.00	0.94	0.77

controlled, run off was assumed to be zero. The 0.90 m soil depth was measured for determination of deep percolation while irrigation was applied to 0.90 m soil depth.

The plant height and leaf numbers per plant were measured for vegetative parameters while total marketable yield, bulb size, bulb weight and bulb height for yield parameters were determined 10 randomly selected plants in each plot. The quality parameters as dry matter content, soluble solids concentration, pH, protein content, total sugar content and invest sugar content were analyzed. Data were analyzed using of analyses of variance (ANOVA). Treatment means were compared using LDS test (Gomez and Gomez, 7).

Water use efficiency (WUE) and irrigation water use efficiency (IWUE) were determined as total onion marketable yield divided by the seasonal ET and seasonal irrigation water applied, respectively (Howell *et al.,* 8).

RESULTS AND DISCUSSION

The total onion growing period after transplanting was 105 days for the first year and 101 days for the second year. The very low differences in the growing periods can be attributed to climatic factors. Table 3 shows data on applied irrigation water amounts, precipitation, measured soil water depletion and measured evapotranspiration for 2009 and 2010 years, respectively. Precipitation during the total growing period was 33.30 mm in 2009 and 102.70 mm in 2010. The first irrigation as 15 mm on April 10 (DOY 100) within two years applied to the treatments to germination. In 2009, a total of 194.8 mm, 284.5 mm, 374.1 mm and 464.0 mm of irrigation water in total of twelve times were applied to I_1, I_2, I_3 and I_4 treatments, respectively, while 145.5 mm, 210.8 mm, 276.0 mm and 341.3 mm irrigation water in seven times were applied in 2010. Because of the excess rainfall, the applied irrigation water in 2010 was

Table 3. Applied irrigation water and measured seasonal evapotranspiration for treatments.

Year	Lateral depths	Irrigation levels	Soil water depletion mm	Precipitation mm	Irrigation water use mm	Seasonal evapotranspiration mm 60 cm^{-1}
2009	D_0	I_1	205.45	33.30	194.8	433.55
		I_2	190.85		284.5	508.65
		I_3	173.85		374.1	581.25
		I_4	218.09		464.0	715.39
	D_{10}	I_1	185.94		194.8	414.04
		I_2	183.84		284.5	501.64
		I_3	171.86		374.1	579.26
		I_4	187.11		464.0	684.41
	D_{20}	I_1	109.04		194.8	337.14
		I_2	177.51		284.5	495.31
		I_3	163.96		374.1	571.36
		I_4	197.51		464.0	694.81
2010	D_0	I_1	155.88	102.70	145.5	404.08
		I_2	156.94		210.8	470.44
		I_3	172.34		276.0	551.04
		I_4	135.26		341.3	579.26
	D_{10}	I_1	147.38		145.5	395.58
		I_2	142.69		210.8	456.19
		I_3	137.15		276.0	515.85
		I_4	127.06		341.3	571.06
	D_{20}	I_1	140.59		145.5	388.79
		I_2	106.15		210.8	419.65
		I_3	128.91		276.0	507.61
		I_4	125.43		341.3	569.43

lower than in 2009. The average soil water content of irrigation treatment within 0.60 m soil profile was measured from April 10 (DOY 100) through July 24 (DOY 205) in 2009 and from April 10 (DOY 100) through July 20 (DOY 201) in 2010. Total seasonal evapotranspiration by onion varied from 337.1 mm to 715.4 mm in the first year and from 388.8 mm to 579.3 mm in the second year. Overall, it can be shown that the total seasonal evapotranspiration in the second year was lower than the first year because of the rainier days, lower evaporation and less applied irrigation water. In two cultivation seasons, the seasonal evapotranspiration values increased with increasing k_{cp} coefficient. Considering previous studies, the seasonal onion evapotranspiration for Turkey and the other countries conditions were measured from 217 mm to 607 mm (Kumar *et al.,* 11; Patel and Rajput, 13; Şener, 14). When the measured seasonal evapotranspiration was examined among the lateral depths, it decreased as the lateral depth increased. On the surface of drip irrigation surfaces D_0, the average total seasonal evapotranspiration was 559.71 mm in the first year and 501.21 mm in the second year. In the D_{10} treatment, in which the laterals were placed at 10 cm, the total seasonal evapotranspiration was measured as 2.7% lower than the D_0 treatment in both years. Likewise, in the D_{20} treatment, in which laterals were placed at a depth of 20 cm, the total seasonal evapotranspiration was measured as 6.3% in the first year and 6.0% in the second year lower than the D_0 treatment.

The total marketable yield, leaf numbers, bulb weight, size and height, dry matter content, soluble solids concentration, pH, protein content, total sugar concentration and invert sugar concentration obtained from each treatment and summary statistics are given in Tables 4 – 7 for two years. The total onion marketable yield in 2009 ranged from 12.73 t ha^{-1} to 25.99 t ha^{-1} and from 17.82 t ha^{-1} to 32.31 t ha^{-1} in 2010. These average marketable yield differences between cultivation periods can be attributed to the climatic conditions. Similar results on same climatic

Table 4. Vegetative growth and yield parameters of onion.

Year	Irrigation method	Irrigation levels	Leave numbers	Plant height cm	Bulb weight g	Bulb size mm	Bulb height mm	Total marketable yield t ha^{-1}
2009	D_0	I_1	6.0	42.32	50.93	47.93	51.71	12.73
		I_2	6.0	45.62	64.22	51.85	54.75	16.06
		I_3	6.0	40.97	77.78	54.08	60.78	19.44
		I_4	6.0	43.54	74.72	53.67	58.41	18.68
	D_{10}	I_1	6.0	38.96	64.60	45.10	54.20	16.08
		I_2	6.0	43.17	75.40	53.55	57.82	18.85
		I_3	7.0	46.77	98.37	59.38	60.26	24.59
		I_4	6.0	46.86	84.83	55.88	57.02	21.21
	D_{20}	I_1	5.0	39.97	60.54	48.12	52.38	15.13
		I_2	6.0	40.47	71.23	50.90	54.85	17.81
		I_3	6.0	44.53	86.26	56.86	59.62	21.57
		I_4	7.0	46.85	103.98	59.77	65.39	25.99
	LSD		ns	ns	ns	ns	ns	ns
	D_0		6.0	43.11	66.91	51.88	56.41	16.73
	D_{10}		6.3	43.94	80.80	53.48	57.33	20.18
	D_{20}		6.0	42.96	80.50	53.91	58.06	20.13
	LSD		ns	ns	ns	ns	ns	ns
		I_1	5.7	40.42	58.91 b	47.05 b	52.76	14.65 b
		I_2	6.0	43.09	70.28 b	52.10 ab	55.81	17.57 b
		I_3	6.3	44.09	87.47 a	56.77 a	60.22	21.87 a
		I_4	6.3	45.75	87.84 a	56.44 a	60.27	21.96 a
		LSD	ns	ns	12.00 **	6.50*	ns	3.01**

*: Significant at the P < 0.05, **: Significant at the P < 0.01, ns: Not significant, a,b,c,….: LSD groups

Table 5. Vegetative growth and yield parameters of onion.

Year	Irrigation method	Irrigation levels	Leave numbers	Plant height cm	Bulb weight g	Bulb size mm	Bulb height mm	Total marketable yield t ha^{-1}
2010	D_0	I_1	5.0	34.53	71.25	51.15	56.28	17.82
		I_2	6.0	36.60	82.84	56.53	59.02	20.71
		I_3	7.0	37.87	94.48	57.37	56.33	23.62
		I_4	7.0	39.40	102.63	62.12	53.28	25.66
	D_{10}	I_1	6.0	34.07	79.18	48.98	53.08	19.77
		I_2	7.0	34.77	83.99	53.87	55.72	21.00
		I_3	6.0	37.43	95.50	56.07	58.80	23.88
		I_4	9.0	39.43	93.27	57.05	55.67	23.32
	D_{20}	I_1	7.0	39.37	106.67	60.17	57.31	26.67
		I_2	9.0	42.40	109.85	61.08	58.63	27.46
		I_3	8.0	40.20	90.41	55.08	56.35	22.60
		I_4	8.0	44.80	129.22	64.15	60.73	32.31
	LSD		ns	ns	ns	ns	ns	ns
	D_0		7.0	37.10	87.80 b	56.79 b	56.23	21.95 b
	D_{10}		7.0	36.43	87.98 b	53.99 b	55.82	22.00 b
	D_{20}		8.0	41.69	109.04 a	60.12 a	58.26	27.26 a
	LSD		ns	ns	16.30 *	3.52 *	ns	4.08 *
		I_1	6.2 c	35.99	85.70	53.43	55.73	21.42
		I_2	7.2 b	36.91	92.23	57.16	57.79	23.06
		I_3	7.0 bc	38.50	93.46	56.17	57.16	23.37
		I_4	8.2 a	41.21	108.37	61.11	56.56	27.10
		LSD	0.96 **	ns	ns	ns	ns	ns

*: Significant at the $P < 0.05$, **: Significant at the $P < 0.01$, ns: Not significant, a,b,c,….: LSD groups

conditions and onion varieties have been obtained. Arın (2) also reported that total marketable onion yields ranged from 25.09 - 33.53 t ha^{-1}, while Şener (14) found it to be ranged from 17.29 – 43.07 t ha^{-1}. Among the lateral depth treatments (D_0, D_{10} and D_{20}), the highest total marketable yield was found at 10 cm depth (D_{10}) in 2009 and at 20 cm depth (D_{20}) in 2010. No statistically significant differences were found in total marketable yield between lateral depths for the year 2009. Whereas, in the second year of the experiment, it was determined that as the lateral depth increases, the yield values increased and the differences were statistically significant at $P < 0.05$ level. The results obtained are similar to the previous studies. Patel and Rajput (13) reported in their research conducted in India that the highest onion yield was obtained from at 10 cm lateral depth. Among the irrigation levels, the highest total marketable onion yields in both years occurred at I_4 level (k_{cp}= 125%) with 21.96 t ha^{-1} (2009) and 27.10 t ha^{-1} (2010). Also, the total marketable onion yield increased with increasing irrigation water. The total marketable onion yield was only affected by irrigation levels in 2009 according to the variance analysis at confidence level of 1%.

The mean leaf numbers per plant for the treatments ranged from 5 to 7 in the first year and 5 to 9 in the second year. According to the results of the variance analysis conducted to determine the statistical difference between the leaf numbers, it was determined that there was a significant difference in the $P < 0.01$ significance level between irrigation levels for 2010, while no significant differences were obtained in 2009. Also, there were no statistically significant differences among the replications, among the irrigation levels, and between the lateral depth and irrigation levels within the two years of the treatment on onion plant height. The average bulb weight in the first year ranged from 50.93 to 103.98 g, and in the second year from 71.25 to 129.22 g. The values obtained are in line with the researches carried out in the same region conditions (Arın, 2;

Table 6. Quality parameters of onion.

Year	Irrigation method	Irrigation levels	Dry matter content %	Soluable solids concent. %	pH	Protein content %	Total sugar content %	Invert sugar content %
2009	D_0	I_1	14.65	9.33	5.60 a	1.39 cd	9.61	2.29
		I_2	12.65	11.57	5.58 ab	1.80 ab	9.11	1.95
		I_3	14.16	10.70	5.45 c	1.83 a	8.66	2.64
		I_4	15.04	11.64	5.60 a	1.18 d	9.67	2.30
	D_{10}	I_1	14.64	10.30	5.55 abc	1.38 cd	11.50	2.11
		I_2	14.59	12.23	5.54 abc	1.42 cd	10.32	2.75
		I_3	13.72	12.90	5.47 bc	1.46 bcd	7.92	1.84
		I_4	12.25	10.61	5.32 d	1.70 abc	10.61	1.90
	D_{20}	I_1	14.72	8.77	5.58 ab	1.50 abcd	10.64	2.79
		I_2	14.04	10.00	5.61 a	1.61 abc	10.42	2.12
		I_3	14.33	10.50	5.52 abc	1.22 d	13.17	2.78
		I_4	15.01	12.83	5.45 c	1.37 cd	9.44	1.83
	LSD		ns	ns	0.12 *	0.36 **	ns	ns
	D_0		14.13	10.81	5.56 a	1.55	9.26 b	2.30
	D_{10}		13.80	11.51	5.47 a	1.47	10.09 ab	2.15
	D_{20}		14.53	10.53	5.55 a	1.43	10.92 a	2.38
	LSD		ns	ns	0.05 *	ns	1.13 *	ns
		I_1	14.67	9.47 b	5.58 a	1.42	10.58	2.40
		I_2	13.76	11.27 a	5.58 a	1.61	9.95	2.27
		I_3	14.07	11.37 a	5.49 b	1.50	9.92	2.42
		I_4	14.10	11.69 a	5.46 b	1.06	9.91	2.01
		LSD	ns	1.44 *	0.06 **	ns	ns	ns

*: Significant at the P < 0.05, **: Significant at the P < 0.01, ns: Not significant, a,b,c,….: LSD groups

Şener, 14). As a result of the analysis of variance between the bulb weights, differences were observed in the irrigation level during the first year and in the level of significance between the lateral depths in the second year of the experiment. As the amount of irrigation water applied in the first year increased, the unit onion head weight values increased. In the first year of the experiment, onion bulb size was obtained between 45.10 and 59.77 mm and between 48.98 and 64.15 mm in the second year. As a result of the analysis of variance between the bulb size, between the irrigation levels in the first year of the experiment and between the lateral depths in the second year of the experiment were found to differ in $P < 0.05$ significance level. The average bulb height in the first year ranged from 51.71 to 65.39 mm and in the second year from 53.08 to 60.73 mm. Although the highest bulb height was obtained from the $D_{20}I_4$ treatment in both research years, there was no statistically significant difference between the experimental subjects (Tables 4 and 5).

The dry matter contents ranged from 12.25% to 15.04% in the first year and 10.62% to 18.70% in the second year. In the second year of the experiment, $P < 0.05$ between the lateral depths, $P < 0.01$ among the irrigation levels and $P < 0.05$ at the lateral depth and irrigation levels interactions were obtained in terms of dry matter contents. The soluble solid concentration was not statistically significant in the second treatment year while irrigation level only affected it at the 5% confidence level in the second year in 2009. Among the irrigation level, the highest soluble solid concentration was recorded in I_4 level (k_{cp}= 125%) with 11.69 %. Similar results on soluble solid concentration were obtained in the previous research (Arın, 2; Şener, 14). The average pH levels for treatments in 2009 were between 5.32 and 5.61 in 2010 and between 5.64 and 5.77 in 2010. In the first year of the experiment, $P < 0.05$ between the lateral depths, $P < 0.01$ between the irrigation levels and $P < 0.05$ between the lateral depth and irrigation levels interactions were obtained for pH values.

Table 7. Quality parameters of onion.

Year	Irrigation method	Irrigation levels	Dry matter content %	Soluable solids concent. %	pH	Protein content %	Total sugar content %	Invert sugar content %
2010	D_0	I_1	12.65 def	13.13	5.77	1.04	10.35 bc	2.10 cd
		I_2	11.20 ef	15.80	5.66	1.24	9.57 c	2.49 cd
		I_3	18.34 a	15.17	5.70	1.29	9.64 c	2.30 cd
		I_4	10.62 f	15.33	5.63	0.99	12.81 ab	2.56 cd
	D_{10}	I_1	12.81 def	15.97	5.70	1.04	9.91 c	1.48 d
		I_2	16.22 abc	16.13	5.69	1.18	10.58 abc	2.06 cd
		I_3	14.40 bcde	15.40	5.70	1.05	11.00 abc	2.94 bc
		I_4	14.04 cde	13.67	5.64	1.27	8.83 c	2.88 cd
	D_{20}	I_1	16.67 abc	14.83	5.76	1.31	10.24 bc	4.36 ab
		I_2	17.27 ab	15.07	5.69	1.22	13.29 a	4.39 a
		I_3	18.70 a	15.00	5.69	1.30	9.28 c	1.83 cd
		I_4	14.41 bcde	16.20	5.71	1.24	10.73 abc	4.84 a
	LSD		3.19*	ns	ns	ns	2.72 *	1.42 *
	D_0		13.21 b	14.86	5.69	1.14	10.59	2.36
	D_{10}		14.37 ab	15.29	5.68	1.14	10.08	2.34
	D_{20}		16.76 a	15.28	5.71	1.27	10.89	3.85
	LSD		2.65*	ns	ns	ns	ns	1.19 *
		I_1	14.04 bc	14.64	5.74	1.13	10.17	2.65
		I_2	14.90 b	15.70	5.68	1.21	11.15	2.98
		I_3	17.15 a	15.19	5.69	1.21	9.97	2.36
		I_4	13.02 c	15.07	5.66	1.17	10.79	3.40
		LSD	1.75 **	ns	ns	ns	ns	ns

*: Significant at the $P < 0.05$, **: Significant at the $P < 0.01$, ns: Not significant, a,b,c,….: LSD groups

The protein contents ranged from 1.18 to 1.83 in the first year and from 0.99 to 1.31 in the second year. Statistically significant differences for protein contents were only obtained at the level of $P < 0.05$ in the interactions between irrigation level and the lateral depth at the first year of experiment. The total sugar content ranged from 8.66% to 13.17% in 2009 and from 9.28% to 13.29% in 2010 while invert sugar content ranged from 1.83% to 2.79 in 2009 and from 1.83% to 4.84 in 2010. According to statistical analyses, interaction between the irrigation method and irrigation level on total sugar content invert sugar content at confidence level of 5% was only recorded in the second year.

Data on irrigation water use efficiency (IWUE) and water use efficiency (WUE) are presented in Table 8. The average IWUE values in the first year ranged from 4.03 to 8.25 kg m^{-3}, and in the second year from 6.83 to 18.30 kg m^{-3}. As a result of the analysis of variance between IWUE, differences were observed in the irrigation levels during the first year at $P < 0.05$ and in the level of significance between the lateral depths $P < 0.05$ and among the irrigation levels at $P < 0.01$ in the second year of the experiment. As the amount of irrigation water applied in both years increased, IWUE values increased. The highest IWUE values in both years was recorded in I_1 level (k_{cp}= 50%). Among the lateral depths for second year, the D_{20} treatment, which was placed at 20 cm from the lateral depths, gave the high IWUE level. The WUE values varied between 2.61 and 4.49 kg m^{-3} in 2009 and between 4.08 and 6.86 kg m^{-3} in 2010. Statistically significant differences for WUE were only obtained at the level of $p <0.05$ between lateral depths in the second year of experiment. According to the results of the LSD test, the D_{20} treatment, gave the high WUE level.

According to data obtained from this research, amount of irrigation water applied in the first year was 194.8 – 464.0 mm and in the second year 145.5 – 341.3 mm under Tekirdag located in the northwestern part of Turkey. The seasonal evapotranspiration

Table 8. Water use efficiency (WUE) and irrigation water use efficiency (IWUE) for treatments.

Irrigation method	Irrigation levels	Irrigation water use efficiency (IWUE) kg m^{-3}		Water use efficiency (WUE) kg m^{-3}	
		2009	2010	2009	2010
D_0	I_1	6.53	12.20	2.94	4.41
	I_2	5.64	9.82	3.16	4.40
	I_3	5.20	8.56	3.35	4.29
	I_4	4.03	7.52	2.61	4.43
D_{10}	I_1	8.25	13.60	3.88	5.00
	I_2	6.63	9.96	3.76	4.60
	I_3	6.57	8.65	4.25	4.63
	I_4	4.57	6.83	3.10	4.08
D_{20}	I_1	7.77	18.30	4.49	6.86
	I_2	6.26	13.00	3.60	6.54
	I_3	5.77	8.19	3.78	4.45
	I_4	5.60	9.47	3.74	5.67
LSD		ns	ns	ns	ns
D_0		5.35	9.53 b	3.02	4.38 b
D_{10}		6.53	9.76 b	3.75	4.58 b
D_{20}		6.35	12.24 a	3.90	5.88 a
LSD		ns	1.673*	ns	0.77*
	I_1	7.52 a	14.70 a	3.77	5.42
	I_2	6.18 b	10.93 b	3.51	5.18
	I_3	5.85 b	8.47 c	3.79	4.46
	I_4	4.73 c	7.94 c	3.15	4.73
	LSD	0.953*	2.285**	ns	ns

*: Significant at the $P < 0.05$, **: Significant at the $P < 0.01$, ns: Not significant, a,b,c,….: LSD groups

was measured as 337.14 - 715.39 mm in 2009 and 388.79 – 579.26 mm in 2009. Also, seasonal evapotranspiration increased with increasing irrigation water. When measured evapotranspiration was examined between different lateral depths, it was observed that the highest evapotranspiration is obtained from D_0 treatment, which was placed at surface.

When the effects of vegetative growth elements on plant height and leaves numbers were evaluated statistically, it was determined that different irrigation levels only affected leaves numbers in 2010. This result can be explained that different lateral depths and irrigation levels did not affect the growth parameters of onion. In terms of yield and yield components of onion plant, total marketable yield, bulb weight, bulb size and bulb height were investigated. It has been determined that the yield values obtained were in parallel with the yield values obtained from previous studies on same onion variety. It can be said that the total marketable onion yield increases as the amount of lateral depth and applied irrigation water increases. On the other hand, when bulb weight, bulb size and bulb height were evaluated statistically among the subjects, uniform results were not obtained. The quality parameters as dry matter content, soluble solids concentration, pH, protein content, total sugar content, invest sugar content were analyzed. Statistical analyzes for these values gave the different results and were not standard.

Irrigation water use efficiency (IWUE) and water use efficiency (WUE) were evaluated for onion. Both values obtained in the second year of the experiment were higher because of the higher yield values. In statistical analyzes between efficiency values, it is seen that the 20 cm lateral depth treatment, was at the front of the experiment. Also, as a result of statistically significant differences between irrigation levels, it is suggested that 50% of the evaporation value measured from the A-class pan can be applied as irrigation water application for onion.

As a result, it can be said that the subsurface drip irrigation method is a new application method for the Thrace Region and country conditions, but it can be used especially for onion cultivation considering the obtained yield and the amount of applied irrigation water.

ACKNOWLEDGMENT

The authors would like to thank the Namık Kemal University for its financial support to the project of NKUBAP.00.24.YL.09.08.

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Received : January, 2019; Revised : August, 2019; Accepted : August, 2019