Global Advanced Research Journal of Agricultural Science (ISSN: 2315-5094) Vol. 4(11) pp. 796-802, November, 2015.
Available online http://garj.org/garjas/home

Full Length Research Paper

Effect of deficit irrigation on yield and water productivity of onion (*Allium cepa* L.) under different lateral length

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Accepted 29 November, 2015

Surface drip irrigation has been taken a lot of attention due to low consume irrigation water during growth period regarding to plants need and also to decrease deep percolation losses. Lateral length (L) and uniformity coefficient (UC) of applied water and its stability, however, are still a matter of concern especially under limited water resources. In order to study the effect of deficit irrigation on yield and water productivity of onion (*Allium cepa* L., cv Giza 20), a field experiment was conducted on the loamy sandy soil in the National Research and Production Station in Nubaria, Behera Governorate, Egypt during two successive growing seasons (2014 and 2015) under different lateral lengths. Three deficit irrigation relative to evapotranspiration percentage (60, 75 and 90 % ET) under different lateral length (L1:25, L2:30; L3:40 m).The experiment was arranged in a randomized complete block design and adapted to conditions of drip irrigation. Water consumed during onion growing seasons were 1060, 1325; 1590 m^3/fed for 60, 75 ; 90 % irrigation treatments. The highest and lowest yield were 12.46 (60% - L 25m), 13.40 (75% - L 40m); 10.89 (90%-40 m), and 12.12, 12.39, 10.51 for 60, 75, 90 % irrigation treatments at lateral length 25 m. Results pointed out That water crop productivity (WCP) 75 % ET (13.0) followed by 60 % ET and 30; 40 m lateral length 12.1 kg/m^3 irrigation water. Lateral length 30 or 40 m were more effective to improve onion yield with significantly difference at 5 % with value 12.1 and increasing percentage 3% as compared with 25 m. The highest value of uniformity coefficient (UC) were obtained at lateral length 25 m followed by 30 m and lastly 40 m under all irrigation treatments and the opposite was true in case of 40 m lateral length. But in case of the effect of irrigation treatments on UC ,it could arrange them in descending order as follow 90> 75> 60 %, while the rank in case of the lateral length was 25>30> 40 m. Increasing lateral length caused a reduction in UC by about 2.7 and 1.8 % for 30 and 40 m lateral length comparing with 25 m. Highly positive correlation significantly at 1 % was obtained between onion yield with bulb diameter (0.819) and uniformity coefficient (0.788**). The relation between onion yield and WUE is more significant than with uniformity coefficient. These finding means increasing UC has a pronounced effect on maximize onion yield under drip irrigation system.**

Keywords: Water deficit, loamy sand soil, drip irrigation, lateral length, onion, yield, water productivity

INTRODUCTION

Egypt's water resources, particularly in the context of agriculture, are facing extreme stress. With changing lifestyles and rising water consumption in urban areas, water for agriculture is under threat from other users. so maximize water used in crop production is a must especially for cash crop as onion, which consider the third crop for export. Another way to address the issue of water shortage is deficit irrigation, which are not necessarily based on full crop water requirement.

Deficit irrigation provides a means of reducing water consumption while minimizing adverse effects on yield (Zhang, et al., 2004) and Mermoud (2005). In this method, the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season. The expectation is that any yield reduction (especially in water-limiting situations) will be compensated by increased production from the additional irrigated area with the water saved by deficit irrigation (Ali et al, 2007). The estimation of water use efficiency (WUE) in relation to evapotranspiration (ET) can show a more realistic evaluation of irrigation effects, i.e. of the irrigation regime applied in onion crops. whereas, the importance of analyzing WUE is illustrated by the efforts of numerous studies that consider the total water use for ET towards transpiration use as to the productive part of water to plants (Howell et al., 2001) who added that WUE tends to increase with a decrease in the consumed irrigation if that water deficit does not occur at a single growth period. WUE in relation to ET depends on application amount and its distribution. But Wang et al. (1996) reported that yield depends on the rate of used water. They added also the factors that increase yield and decrease water used for ET favorably affect the water use efficiency, which is highest with less irrigation, implying full use of the applied water and perhaps a tendency to promote deeper soil water extraction to make better use of both the stored soil water and the growing-season precipitation (Howell 2001).

Among all the irrigation methods, the drip irrigation are the most efficient that can be practiced successfully to irrigate wide range of crop variety. Applicability and success of drip irrigation changes with soil type, climate and management of system of irrigation and hence it has to be tested for region specific. It is important to study procedures and criteria to obtain longer lateral lines when using non pressure compensating emitters. It is possible to extend the lateral line length using two emitters spacing in different sections (Ludwig and Saad 2013). In this case, the system design consists in the determination of the two emitters spacing utilized and the changing point between spacing.

Increased yield also can be accomplished by applying suitable irrigations but this would require changing in exist irrigation systems. Irrigation water management for onions due to its economic importance can have a significant impact on the uniformity coefficient of a drip irrigation system, care should be taken when thinking of selecting and establish irrigation system. Sammis and Mexal (1999) reported that sustainable agriculture would needs many changes in the future. Perhaps the most significant will be the change in water management. They added that sustainable agriculture will need high profits that will fulfilled by higher financial inputs. The most critical technology in an arid environment is the irrigation system.

The aim of the work was studying the effect of deficit irrigation on yield and water productivity of onion under different lateral lengths.

MATERIAL AND METHODS

The present study was conducted during two consecutive winter growing season (2014 and 2015) in the Research and Production Station, National Research Centre, Nubaria region, Behera Governorate, Egypt. soil chemical properties were carried out after Rebecca (2004). The soil was loamy sand and pH 7.8, EC 2.34 dSm^{-1}, $CaCO_3$ 4.2 % and field capacity 17.2 %. The examined soil have 1.78, 0.624, 3.3, 0.6, 4, 11 for N, P, K%, Fe, Zn and Mn (ppm), respectively. Mineral fertilizers, ammonium nitrate (NH_4NO_3 33.5% N), calcium-super phosphates (15.5% P_2O_5) and potassium sulphate (50 % K_2O) were applied at rate 180, 200 and 50 kg/fed as a recommended doses.

Seedlings of the onion cv. Giza 20 were transplanted on October 20th in both seasons. Treatment plot consisted of 3 lateral lines, 35 m long and 0.9 m between the rows and 0.3m among the drippers. Onion seedlings were planted on 4 rows in both side of drip line 7 cm apart with plant density 27 per m^2.

The following parameters were recorded using 20 randomly sampled bulbs: plant height (cm), no. of leaves per plant, weight of individual bulbs (g), bulb diameter (cm) and. Additionally, the fresh and dry matter of onion leaf and onion bulb were determined.

Uniformity coefficient calculations

The **Uniformity coefficient** was calculated with ASAE EP458 method as adopted by (Camp et al., 1977; Ortega et al., 2002), they were applied to analyze emitter performance ($\bar{q}$) and standard deviation Sq were calculated using the following equations:

$$\bar{q} = \frac{1}{n}\sum_{i=1}^{n} q_i \qquad \text{--(1)}$$

$$S_q = \sqrt{\frac{\sum_{i=1}^{n} q_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} q_i\right)^2}{n-1}} \qquad \text{----------------------(2)}$$

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$$V_{qs} = \frac{S_q}{\bar{q}} \quad \text{---(3)}$$

$$U_{qs} = 100\ (1 - V_{qs}) \quad \text{------------------------------------(4)}$$

Where:
Vqs and Uqs represent the discharge coefficient of variation and the statistical uniformity coefficient, respectively.
The mean hydraulic head (h) and hydraulic coefficient of variation (Vhs) were computed using Eqs. 1, 2, 3 and 4, respectively, substituting hi for qi. For normally distributed discharge data, adjusted uniformity coefficient (UCa) values were calculated using the following equation(Eqs. 5):

$$UC_a = 20.2 + 0.798\ U_{qs} \quad \text{----------------------------(5)}$$

Water crop productivity of onions yield was estimated from the following equation:

$WCP_{kg/\ irrigation\ m^3}$ = Total onion yield / consumed irrigation water
where WCP is water crop productivity
The experiment was conducted in randomized complete-blocks design (RCBD) with 3 replicates Dospekhov (1984). The Least Significant Difference' (LSD 0.05) was used after (SAS Institute, 2001).

RESULTS AND DISCUSSION

According to the obtained plant height (cm), it was observed that there was a rough decrease in plant height values with increasing ET % and lateral length (L) treatments (Table 1). The highest and lowest values were obtained at 60 % ET , L = 25 m (80.9 cm) and 60 % ET , L= 40m (57.1 cm). With respect to ET treatments and its effect on plant height, the obtained data revealed that increasing ET by unite could increase plant height value by 1.04 and 0.97 % over control. Regarding to lateral length treatments, one can notice that a simple increase occurred and the rates of increase were 1.03 and 0.92 % for 25 and 30 m lateral lengths by comparison with control.

According to number of leaves per plant and its effect on yield production, data in table (1) indicated that, there was an increase in no of leaves/plant by increasing ET treatments, but one can notice a clear decrease in values of the number of leaves relative to studied lateral lengths. The maximum and minimum values were at 60 % ET –L:25 m (11.2) and 60 % ET – L:40 m (7.8) respectively. Depending on ET treatment, there were roughly increases in no of leaves by increasing ET treatments with rates of 1.10 and 0.94 % comparing with control. With respect to lateral length treatments, by increasing L treatments, a clear decrease in no of leaves was obtained and the rates of decrease were 1 and 0.89 % for 25 and 30 m with comparison with control.

According to the bulb diameter (D), a decrease in D values happened with increasing ET % and lateral length (L) treatments. The highest and lowest values were obtained at 60 % ET , L:40 m (2.66 cm) and 90 % ET, L: 30 m (2.89 cm). With respect to ET treatment and its effect on bulb diameter, the obtained data revealed that increasing ET by unite could increase D value by 0.04 and 0.03% over control. Regarding to (L) treatments, one can notice that a simple increase occurred and the rates of increase were the same for 25 and 30 m lateral lengths and the increase was slightly in comparison with control (1.01).

Regarding to the fresh (FW) and dry weight (DW) of leaf and onion bulbs and their ratios as affected by irrigation treatments and laterals length (Table 1), data noticed that the highest values were recorded at 75 % (30m) for the studied plant growth characters in same sequences with values 136.7, 32.5, 247.2; 204.1 (g/plant). While the lowest values of those characters were recorded at 60 % irrigation under 40 m lateral length.

Meanwhile, the trend was changed at fresh/dry ratio for leaf and onion bulb, which resulted at 60 and 90 % under 30 and 40 m lateral length, respectively. According to the impact of irrigation treatments on the previous onion plant characters, one can noticed that the maximum values were recorded at 60, 75; 90, 90 % for fresh and dry weight for leaf and onion bulb, respectively. And the lowest ones were resulted at 90, 60; 60, 60 irrigation treatments in same sequences. Whereas, the highest ratio of fresh/dry weight of leaf and onion bulb were attained at 60 % irrigation treatments. Data was clearing that the rate of increase in bulb fresh and dry weight were 5.9, 1.5; 8.7, 1.4 % as compared 75 % and 90 % irrigation T with 60 %, respectively.

Regardless irrigation treatments, data noticed that the lateral length at 30 m was the superior one on affecting the previous plant characters with increasing percentage 5.5, 1.5; 4.8, 5.2 % for same plant characters.

Table (1) and Figure. (2) illustrated the onion yield as affected by irrigation treatments and examined lateral lengths. The highest values of onion yield were produced at 60% under 25 m LL (13.22 ton per fed), 75%/40 m (17.815 ton per fed) and 90%/25 m LL (16.708 ton per fed). With respect to the influence of irrigation quantity that applied, data found that 75 % irrigation treatments had a pronounced effect on the yield of onion with increasing rate by about 1 % wither compared with 60 and 75 % from ET. However lateral length 40 m was the best one and could

Table 1: Effect of irrigation water as a percentage of evapotranspiration on onion growth characters under different lateral lengths (mean of two seasons)

ET %	Lateral length (m)	Plant height cm	No. of leveas of plants	Bulb D cm^2	Leaves weight (g/plant)			Bulb (g/plant)		
					Fresh	Dry	FW/DW	Fresh	Dry	FW/DW
60	25	80.9	11.2	2.74	136.7	32.5	4.21	247.2	188.2	1.31
	30	61.8	8.2	2.65	109.5	17.2	6.37	220.2	175.7	1.25
	40	57.1	7.8	2.66	96.2	16.1	5.98	189.1	166.3	1.14
	Mean	66.6	9.1	2.68	114.1	21.9	5.52	218.8	176.7	1.23
75	25	64.7	10.5	2.69	99.4	26.1	3.80	227.9	196.4	1.16
	30	80.9	11.2	2.81	136.7	32.5	4.21	247.2	204.1	1.21
	40	61.8	8.2	2.85	103.1	17.2	5.99	220.2	175.7	1.25
	Mean	69.1	9.9	2.78	113.1	25.3	4.67	231.8	192.1	1.21
90	25	59.1	7.8	2.84	103.2	16.7	6.17	198.2	174.5	1.14
	30	67.7	10.1	2.89	111.8	26.8	4.17	238.3	208.2	1.14
	40	73.9	10.3	2.88	97.5	22.5	4.33	269.1	201.6	1.33
	Mean	66.9	9.4	2.87	104.2	22.0	4.89	235.2	194.8	1.21
LSD 5%	ET	0.3	0.2	0.08	0.9	0.7		2.3	2.1	
	LL	3.4	2.1	0.11	4.7	1.1		5.4	5.6	
	Interactions	0.2	0.2	0.07	1.0	0.7		2.4	2.3	

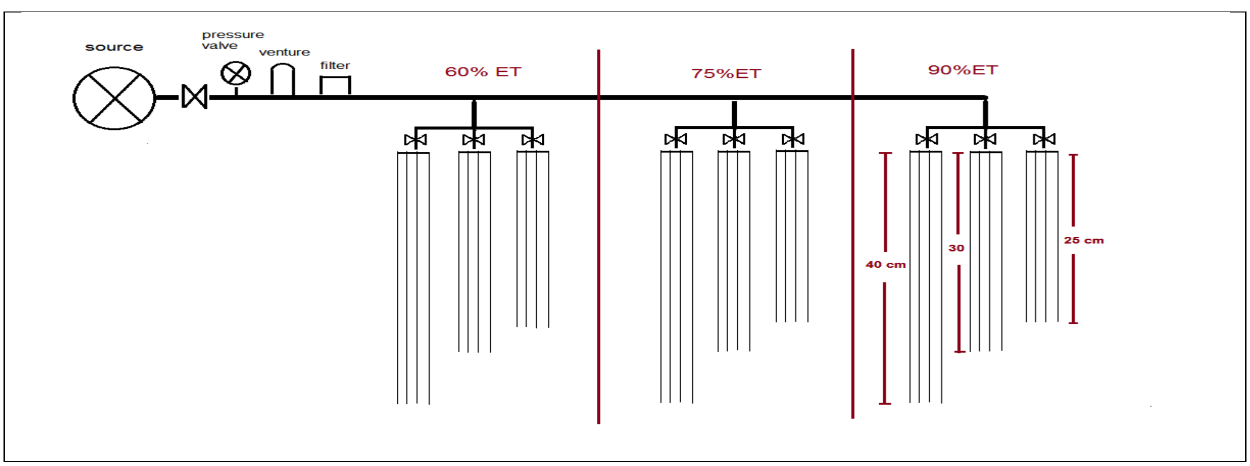


Figure 1. Lay out of the experiment

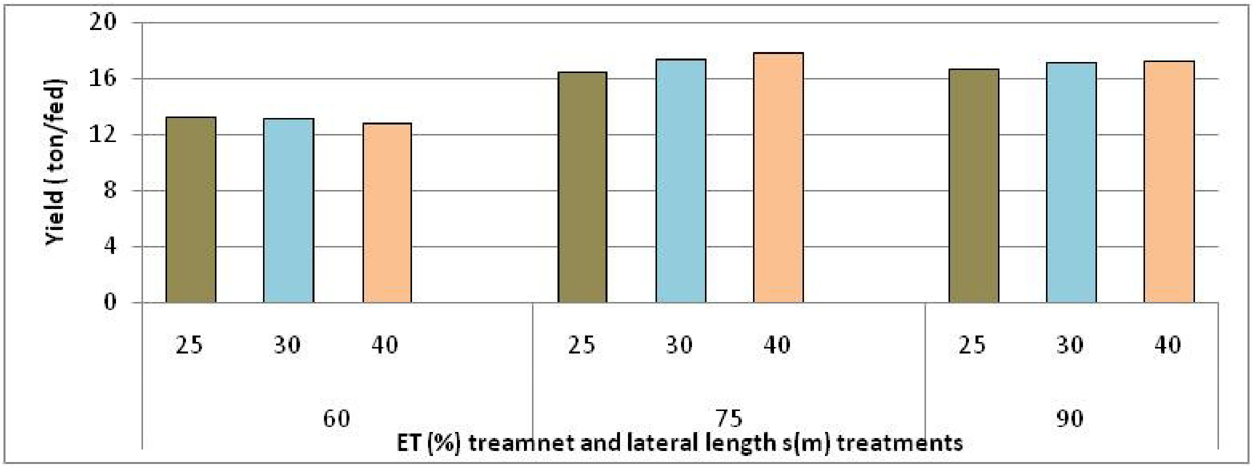


Figure 2: Onion yield as affected by irrigation treatments ET%) and lateral length (m)

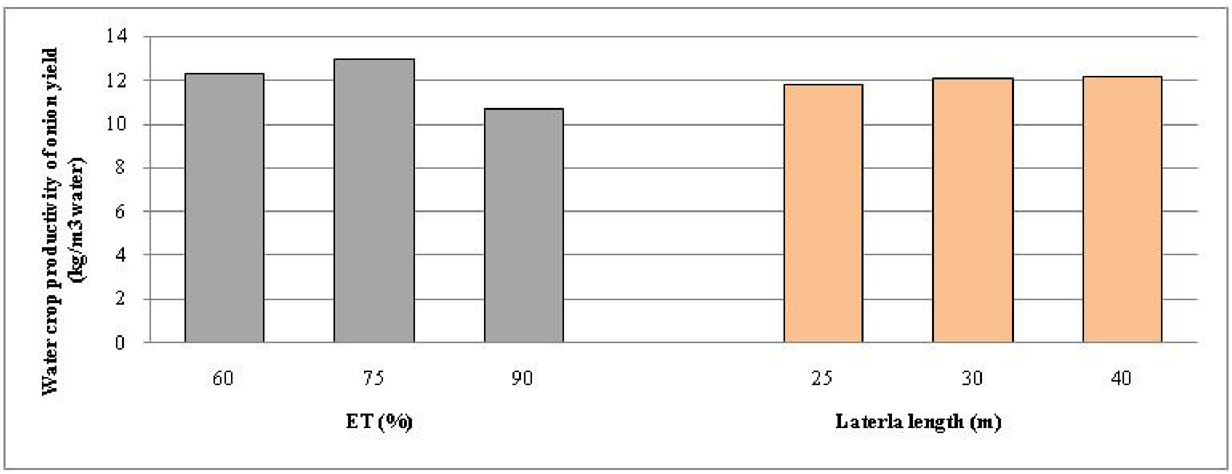


Figure 3: Onion yield as affected by irrigation treatments ET % and lateral length (m)

be arranged in descending order as follow 40>30>25 m. The results agreed with those obtained by Olalla et al. (2004) and Nagaz et al., (2012) indicated that onion bulb size under drip irrigation system is directly related to amount of water applied.

Water consumed during onion growing seasons were 1060, 1325; 1590 m^3/fed for 60, 75 ; 90 % irrigation treatments and could be expressed in mm season as follow 252.4, 315.5; 378.6 in same sequences (Figure 3). Water use efficiency (WUE) is defined as the relationship between units produced and volume of irrigation water applied (Steduto, 1996) and Martin (2009). So, water crop productivity (WCP) estimated on the base of the total amount of water applied. Data mentioned that the highest and lowest yield were 12.46 (60% -L 25m), 13.40 (75% - L 40m); 10.89 (90%/40 m), and 12.12, 12.39, 10.51 for 60, 75, 90 % irrigation treatments at lateral length 25 m. Whereas, the impact of the studied two factors individually were pointed out to 75 % (13.0) followed by 60 % irrigation treatments and 30; 40 m lateral length 12.1 WCP. But 75 % irrigation treatments led to reduce onion yield by 5.5 % compared with 60 and 90 % reduced yield by about 17.5%. While lateral length 30 or 40 m were more effective to improve onion yield with significantly difference at 5 % with value 12.1 and increasing percentage 3% as compared with 25 m. This finding is agreed with those obtained by Ali et al (2007), Magdi et al (2009) and Chouhan et al (2014).

Estimated uniformity coefficient (UC) for the used drip irrigation system could use to clearly the effect of both studied factors (irrigation treatments and lateral length) on

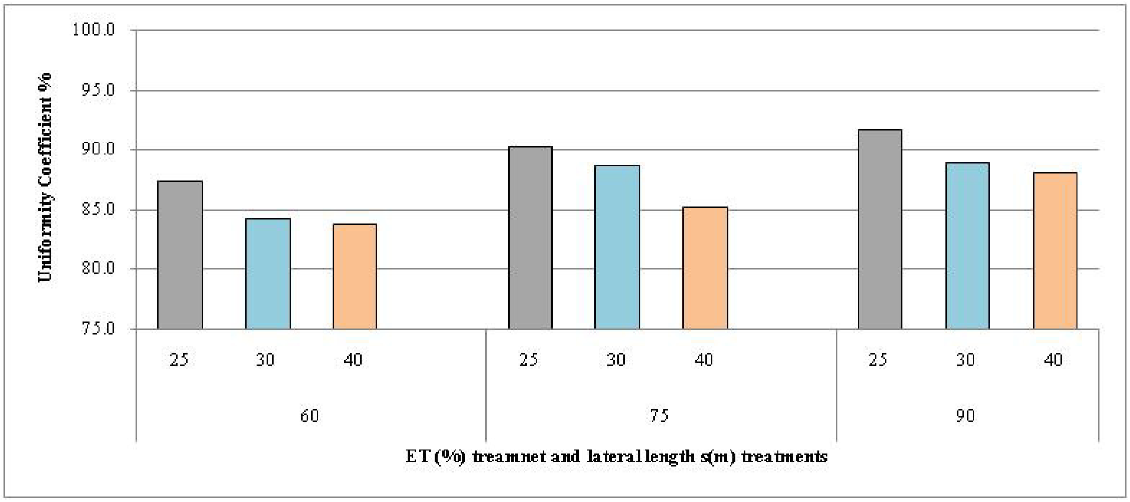
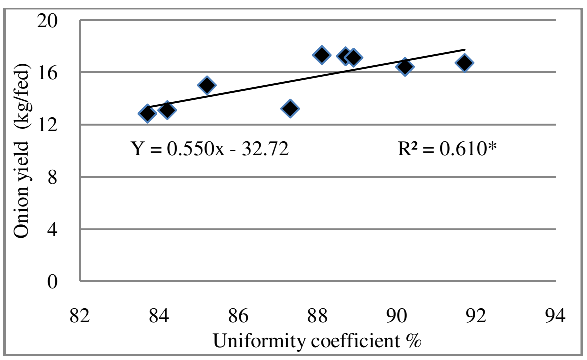
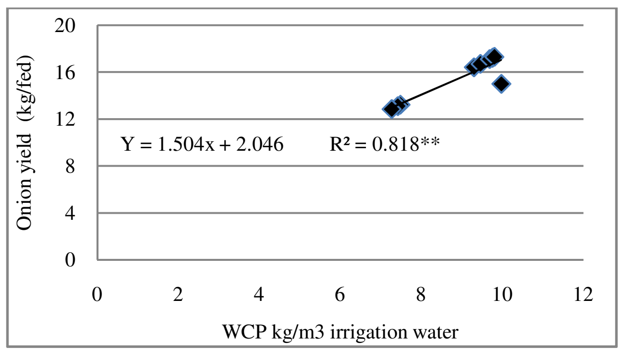


Figure 4: Onion yield as affected by irrigation treatments ET% and lateral length (m)



a- Regression between onion yield and uniformity coefficient



b- Regression between onion yield and water crop productivity.

Figure 5: Regression trend between onion yield and uniformity coefficient under investigated factors

the onion crop were illustrated in Figure (4). Data on hand revealed that the highest value were obtained at lateral length 25 m followed by 30 m and lastly 40 m under all irrigation treatments and the opposite was true in case of 40 m lateral length. But in case of the effect of irrigation treatments on UC ,it could arrange them in descending order as follow 90> 75> 60 %, while the rank in case of the lateral length was 25>30> 40 m. Also, it could notice that the rate of increase were 3.7, 1.7 comparing 75 and 90 % irrigation treatments comparing with 60 % one. Whereas, increasing lateral length caused a reduction in UC by about 2.7 and 1.8 % for 30 and 40 m lateral length comparing with 25 m. This finding was in harmony with those obtained by (Ludwig and Saad 2013).

Water requirements of onion of experiment region vary from 400 to 540 mm for the yield of 30-40 t ha^{-1} (Pejic et al., 2011). From the above mentioned results,, data concluded that increased yield can be accomplished by applying irrigation less than ET but this would require highly fellowship with the nearest metrological station. We cannot neglect the importance of the length of the drip line that play an important role in maximize uniformity coefficient (Zhang et al 2004).

In view of the point relative to resulted statistical analysis, simple correlation was estimated among some of the studied plant characters of onion (onion yield components). Highly positive correlation significantly at 1 % was obtained between onion yield with bulb diameter (0.819**) and uniformity coefficient (0.788**). Also regression equations were obtained from plotting the relation between onion yield versus uniformity coefficient and WCP (Figure 5). One can noticed that the relation between onion yield and WUE is more significant than with uniformity coefficient. These finding means increasing UC has a pronounced effect on maximize onion yield under drip irrigation system.

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