RESPONSE OF ONION TO DIFFERENT LEVELS OF IRRIGATION WATER AND FERTILIZATION: (I) SOIL MOISTURE CONTENT, GROWTH PARAMETERS AND BULB YIELD

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ABSTRACT

This study evaluated of irrigation deficit and NPK fertilization on growth and yield of onion grown in the semi arid area of Libya. A field experiment was conducted using onion grown in northeast Libya at Elbyda (البيضاء) *in 2011 and 2012. Four irrigation deficits and four NPK fertilization rates were arranged in a randomized split-plot design. Irrigation treatments were a ratio of crop evapotranspiration (ET) as: 1.0 ET, 0.85 ET, 0.75 ET, and 0.65 ET. Fertilizer treatments were 100, 75, 50, and 0 % of the applied recommended rate of NPK. The results showed that the interaction between different water levels and NPK rates had no significant effects on growth and yield parameters when transit from 100 to 85% ET or when decreasing NPK rates from 100 to 75 %. The growth and yield parameters (fresh bulb weight, bulb diameter, bulb length, and bulb yield) where non significantly decreased (2.2 and 14.6 %), (3.2 and 13.8%), (3.7 and 1.9 %), and (2.1 and 14.6%) in 2011 and (0.12 and 9.6 %), (2.8 and 3.5 %), (0.27 and 2.6 %), and (0.12 and 9.6%) in 2012, respectively when compared to 100 % ET or 75 % NPK rate. An optimal treatment was statistically developed based on crop response in deficit irrigation and NPK fertilization rate to achieve maximum yield of onion.*

Keywords: water deficit, NPK fertilization, growth parameters, yield, onion, soil moisture content

INTRODUCTION

Irrigation water and nutrient stresses are two major constraints in agriculture production and lower yield in many countries. Water stress affects crop growth and productivity depending on drought tolerance, drought resistance or growth periods of the crops. To improve water productivity, there is a growing interest in deficit irrigation. Deficit irrigation is irrigating the root zone with less water than required for evapotranspiration (***Zegbe-Dominguez et al., 2003***). Under conditions of scarce water supply, deficit irrigation can provide greater economic returns than maximizing yields per unit of water. To manage plant water

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stress it is necessary to carefully schedule irrigation which consists of determining the amount and timing of irrigation applications (***Martin et al., 1990***). The water saving strategy of reducing irrigation rates at predetermined developmental stages where deficits would not severely impact productivity is called regulated deficit irrigation (RDI) (***Kirda, 2002; Mpelasoka et al., 2001***). There are two main methods to schedule irrigation; first by replacing crop evapotranspiration (*ETc*) fractions according to a soil water balance, or second by triggering irrigation according to water content status of the soil and allowable depletion levels (***Hanson et al., 2000***). One of the difficulties of irrigation scheduling using crop evapotranspiration (ET_c) is that local crop coefficients are needed, and these vary according to crop varieties, plant densities, row configurations and planting dates (***Enciso et al., 2007***). The adoption of deficit irrigation implies appropriate knowledge of crop evapotranspiration (ET), crop response to water deficits, including the identification of critical crop growth periods, and the economic impacts of yield reduction strategies; therefore growers may have difficulty in using it (***Pereira et al., 2002***).

A positive approach to attain the goal of improving water use efficiency (WUE) is deficit irrigation (***Topcu et al., 2007***), a water saving strategy under which crops are deliberately allowed to sustain some degree of water deficit and yield reduction (***Pereira et al., 2002***). WUE can be optimized by the adoption of more efficient irrigation practices (***Costa et al., 2007***). ***Kirda (2000)*** stated that properly practiced deficit irrigation may increase crop quality. For instance, the protein content and baking quality of wheat, the length and strength of cotton fibers, and the sucrose concentration of sugar beet and grape have been reported to increase under deficit irrigation. Deficit irrigation is a way of maximizing water use efficiency for higher yields per unit of irrigation water applied: the crop is exposed to a certain level of water stress either during a particular period or throughout the whole growing season (***Kirda, 2000***). Moreover, studies have shown that water deficit during certain stages of growing season improves fruit quality, although water limitations may also determine fruit yield losses (***Patanè and Cosentino, 2010***). Some scientists have found bigger yield differences when the onion crop is stressed at certain growing stages such as the study of ***Martin de Santa Olalla et al. (2004)*** who showed that inducing water deficits at the bulbification and ripening stages lead to significant differences on yields. While ***Enciso et al. (2009)*** stated that yields were not affected when water applications were reduced from 100% to 75% ET_c. Onions under deficit irrigation have lower evapotranspiration rates and yields (***Sammis et al., 2000***). For optimum yield, it is necessary to prevent the crop from experiencing water deficit, especially during the bulb development stage. During the vegetative and ripening periods, the crop appears to be less sensitive to water deficit. Nitrogen (N) and phosphorus (P) stresses lead to the change of growth, physiology and water use of plants (***Lovelock et al., 2006***). Decreasing the water content in a soil decreased K uptake by onion roots; the drought resulted in an increasingly steep K gradient around the root (***Kuchenbuch et al., 1986***). In soybean, the K content of the xylem sap decreased with decreasing water potential (***McQuate et al., 1986***). Application of nitrogen and potassium influenced the different growth components of onion at all the stages of crop growth.

In this paper, the objective is investigating the effects of different irrigation water levels and different levels of NPK fertilization upon growth parameters and total bulb yield of onion.

MATERIALS AND METHODS

1. Study area

The study was conducted at the experimental farm of Horticultural Department, Faculty of Agriculture, Omar El-Mukhtar University. The experiment was conducted in 2011 and 2012. Some chemical and physical characteristics of the experimental field soil are shown in tables (1) and (2). Also table (3) shows some physical analysis of irrigation water used in the experiment and table (4) shows the average monthly climatic data (1946 – 2011) from May to September.

Table (1): Some chemical analyses of soil samples.

Depth, cm	$EC_{e1:1}$ dS/m	Cations (meq/L)				Anions (meq/L)		
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-} + CO_3^{--}	SO_4^{--}
0 - 30	0.86	2.4	1.5	4.5	0.3	3.5	2.2	2.8
30 - 60	0.76	2.0	1.4	3.8	0.4	3.4	2.1	2.1

Table (2): Some physical analyses of soil samples.

Depth, cm	Particle size distribution (%)			Texture class	F.C %	W.P %	Soil Bulk Density, g/cm^3
	Sand	Silt	Clay				
0 - 30	28.2	34.1	37.7	Clay loam	35.2	21.1	1.29
30 - 60	22.3	38.0	39.7	Clay loam	37.5	22.2	1.27

Table (3): Some chemical analyses of water samples.

EC	Cations (meq/L)				Anions (meq/L)		
ds/m	Na^{+}	Ca^{++}	Mg^{++}	K^{+}	HCO_3^{-}	Cl^{-}	SO_4^{--}
0.72	3.2	2.1	1.5	0.4	2.6	3.5	1.1

Table (4): Monthly climatic data of the experimental area.

Climatic parameters	Months				
	May	Jun.	Jul.	Aug.	Sep.
T_{min}, ^{o}C	13.6	16.6	18.8	19	17.8
T_{max}, ^{o}C	24.0	27.2	28.1	28.1	26.3
T_{ave}, ^{o}C	18.8	21.9	23.5	23.6	22.1
RH, %	59.0	58.9	61.3	62.3	62.3
Rainfall, mm/month	9	0	0	0.7	9.8
Wind speed, m/sec	3.8	4.16	4.57	4.38	2.52
Sunshine, h	10	12	12	12	10

2. Planting and agronomic practices

Pegou onion (*Allium cepa* L.) variety was used for the study. Seeds were sown in a nursery on a well prepared seed bed. When seedlings were at the 3 to 4 leaf stage or 12 to 15 cm height, they were transplanted in the experimental field. Planting was done on furrows of about 25 cm height and 16 m length, adopting the recommended spacing of 50 cm between furrows and 15 cm between plants with a total of 106 plants per row. A distance of 1 m was maintained between plots and 1 m between blocks. Each experimental plot had three rows. The fertilizer sources were urea

(46 %), Phosphoric acid (P_2O_2, 80 %) and liquid Potassium (K_2O 36 %) for Nitrogen (N), Phosphor (P) and Potassium (K), respectively. The half doses of NPK for each treatment were applied after three weeks of transplanting and the remaining half doses of NPK were applied after two months of transplanting manually (table 5). The recommended fertilizers of NPK were 75 kg/ha, 100 kg/ha and 50 kg/ha for urea, phosphoric acid and liquid potassium, respectively.

Table (5): Production operations and crop growth parameters for the two seasons this study was conducted.

Operation	2011	2012
Planting	29 April 2011	23 April 2012
1st fertilizer application	20 May 2011	15 May 2012
2nd fertilizer application	28 June 2011	24 June 2012
Last irrigation	12 September 2011	9 September 2012
Harvest	27 September 2011	26 September 2012

3. Experimental design

In this study, four crop water requirements (I) and four NPK fertilization treatments (F) were designed in open field experiment. The water treatments were I_{100} = 100 %, I_{85} = 85 %, I_{75} = 75 % and I_{65} = 65 % of ET_c) and the fertilization treatments were F_{100} = 100 % dose of NPK, F_{75} = 75 % dose of NPK, F_{50} = 50 % dose of NPK, and F_0 = 0 % dose of NPK. This experimental plan yielded 16 treatments (i.e. 4 × 4) and each treatment was replicated three times. The trickle irrigation system was used and the emitters were pressure compensated with a flow rate of 4 L/h, the emitters were spaced at 20 cm with polyethylene tubes (16 mm in external diameter) with 50 cm spacing between tubes. The treatment combinations were arranged in a Randomized Split-Block Design with three replications.

4. Measurements

4.1. Determination of crop irrigation water requirement of onion

The FAO Penman–Monteith method (***Allen et al., 1998***) was used to calculate the reference evapotranspiration ET_o in the CROPWAT Program. Crop water requirements (ET_c) over the growing season were determined from ET_o according to the following equation using crop coefficient K_c:

$$ET_c = K_c\, ET_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where ET_c is the crop water requirement, K_c is the crop coefficient and ET_o is the reference evapotranspiration. According to ***Allen et al., 1998***, Kc of onion is ranged from 0.4 to 1.05. The total amounts of irrigation water applied (from transplantation to harvest) I_{100}, I_{85}, I_{75}, and I_{65} in this study were respectively 564, 482, 423, and 368 mm for first year and 582, 494, 436, and 378 mm for second year. The water requirement was determined for different months based on crop growth stages and climatic data.

4.2. Soil moisture content

To determine moisture content for each treatment, Theta-meter instrument was used. The location was defined according to its x, y and z coordinates with respect to the emitter. The sample locations with respect to the x-direction were taken at 0, 5, and 10 cm for all treatments. With respect to the y-direction, perpendicular to the emitters line, the sample locations were taken at 0, 5, 10, 15, 20, and 25 cm for all treatments. For each of these locations, moisture content was determined for different layer depths from soil surface, which were (0 – 10), (10 – 20), (20 – 30), (30 – 40), and (40 – 50) cm. The initial soil moisture content before water application ranged from 20.3 to 25.7 % by weight.

4.3. Water use efficiency (WUE)

Water use efficiency (WUE_y, kg/m^3) was calculated as the ratio between total fresh yield at harvest (kg/ha) and total water used (m^3/ha) (***Lovelli et al., 2007***).

4.4. Plant characteristics and yield

Measurements on the following growth parameters and bulb characters were recorded during physiological maturity and at harvesting time. Leaf number per plant refers to the total count of leaves per plant at maturity. The length of the longest leaf was measured with meter scale from the base to its apex. Leaf diameter refers to the maximum diameter of the longest leaf and neck thickness was measured at the narrowest point using vernier caliper. Bulb length and diameter refer to the height of the bulb and the average width at the widest point in the middle portion of the mature bulb measured using vernier caliper. Average bulb weight computed by weighing ten bulbs together and calculating the average. The data set is the average of ten randomly taken plants in each experimental plot. Total bulb yield was computed based on the weight of matured bulbs yield per plot and converted into hectare base and expressed in ton. Split bulbs percentage was determined by counting the number of split bulbs per plot and expressed in percentage in reference to total number of normal bulbs per plot.

4.5. Statistical analysis

Analysis of variance (ANOVA) was performed using two-way ANOVA from MSTAT software. All the treatment means were compared for any significant differences using the Duncan's multiple range tests at significant level of $P_{0.05}$.

RESULTS AND DISCUSSION

1. Soil moisture content

The percentage of water found in the soil profile at different distances from the emitter at the end of irrigation time tabulated in table (6) and figure (1).

As shown in table (6) and figure (1**),** the first and the second vertical layers in the X-direction (0 – 10 cm) and (10 – 20 cm) had 54.2, 54, 51.6, and 49.7% of the total applied water volume for the treatments I_{100}, I_{85}, I_{75} and I_{65}, respectively, while they had 36.6, 37.7, 39.3, and 39.7% of the total applied water volume in third and forth vertical layers, (20 – 30) and (30 – 40), for treatments I_{100}, I_{85}, I_{75} and I_{65}, respectively. The total applied water volume for all treatments in the last vertical layer had very little percentage of water content. The results showed that the percent of the total applied water volume in both first and second layers decreased with decreasing applied water due to water movement laterally than vertically. The highest water soil content (I_{100}) produced greater radius to depth ratio while the reverse was true for the lowest water soil content (I_{65}).

In the Y-Z direction as indicated in table (6), the first and the second vertical layers (0 -10 cm) and (10 – 20 cm) had 38.3, 39.7, 37.6 and 38 % of the total applied water volume for the treatments I_{100}, I_{85}, I_{75}, and I_{65}, respectively, while the third and the fourth vertical layers, (20 -30 cm) and (30 – 40 cm), had 48.5, 48.1, 50.2 and 47.1 % of the total applied water volume for the treatments I_{100}, I_{85}, I_{75} and I_{65}, respectively. Thus, in the Y-direction, the third and fourth layers had the maximum water volumes for all treatments because as illustrated in figure (1) the first and the second vertical layers had little soil volume attributed furrow shape, but in the X-direction the first and second layers had the maximum water volumes for all treatments because all layers had the same volume of soil (fig. 1).

A saturated zone below the trickle line was obtained only for treatments I_{100}, I_{85} and I_{75}. For the lower soil water contents, there was no saturated zone below the emitter.

Table (6): The percentage of water found in the soil profile of different water treatments.

Depth, cm	Treatments			
	I_{100}	I_{85}	I_{75}	I_{65}
	X – Z direction			
0 – 10	27.8	27.5	25.9	25.0
10 – 20	26.4	26.5	25.7	24.7
20 – 30	21.1	22.8	22.5	24.1
30 – 40	15.5	14.9	16.8	15.6
40 – 50	9.2	8.3	9.1	10.6
	Y – Z direction			
0 – 10	17.4	18.2	16.9	16.7
10 – 20	20.9	21.5	20.7	21.3
20 – 30	27.2	27.9	28.5	27.0
30 – 40	21.3	20.2	21.7	20.1
40 – 50	13.2	12.2	12.2	14.9

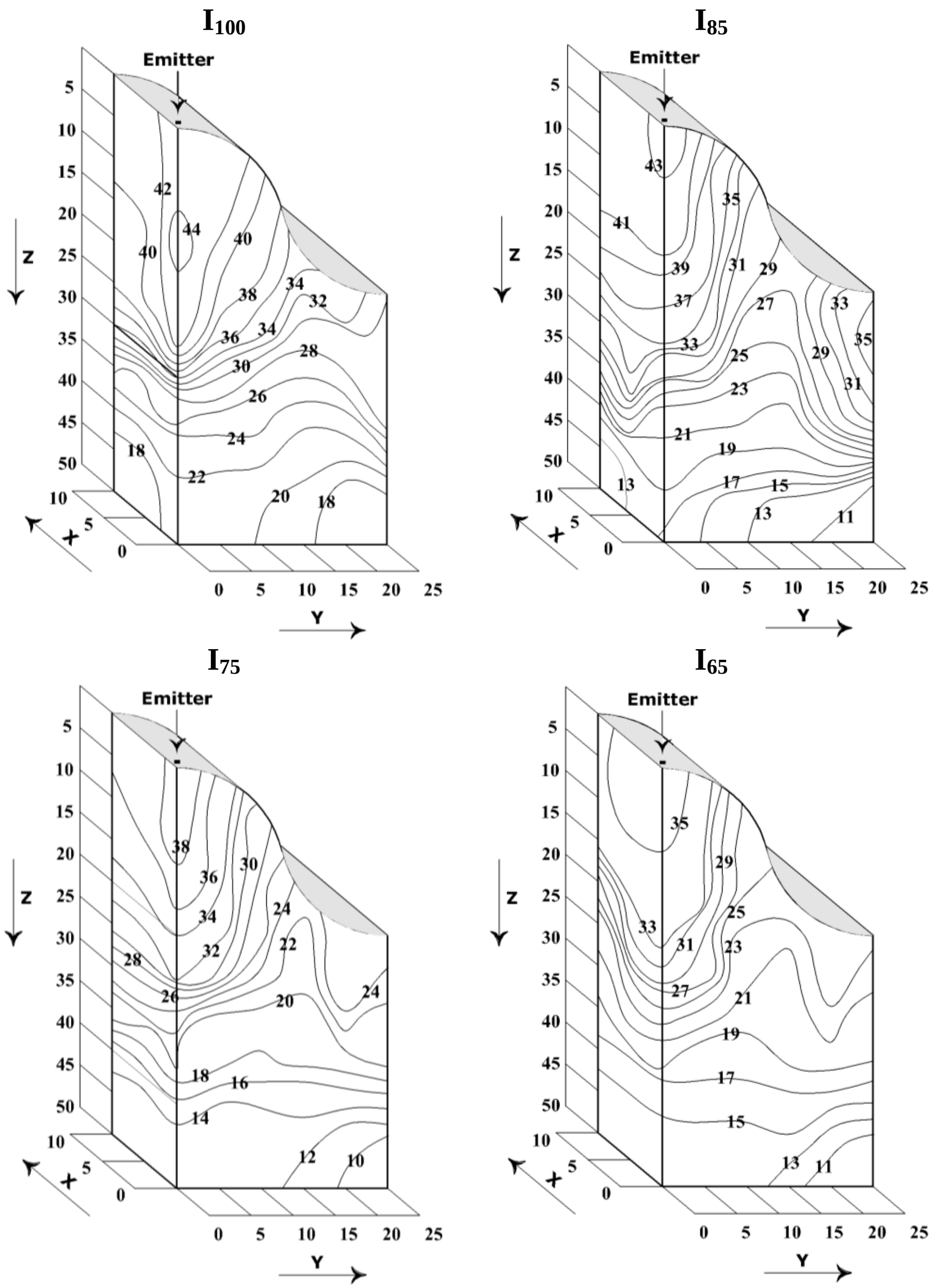

Figure (1): Distributions of water patterns in furrow for the four water treatments.

2. Growth parameters of onion

Table (7) shows the average values of fresh bulb weight, leaf length and diameter, leaves per plant and leaf weight after 60 days from transplanting. The minimum values of fresh bulb weight, leaf weight, leaves per plant, leaf length and diameter were (6.59 g, 23.93 g, 5.63, 34.25 cm and 0.78 cm) found with treatments $I_{65}F_0$, $I_{65}F_0$, $I_{100}F_0$, $I_{65}F_{50}$ and $I_{65}F_{50}$ in 2011, respectively and were (6.24 g, 29.10 g, 5.56, 34.56 cm and 0.70 cm) found with treatment $I_{65}F_0$ in 2012, while the maximum values of fresh bulb weight, leaf weight, leaves per plant, leaf length and diameter were (22.1 g, 54.88 g, 7.13, 45.69 cm and 1.44 cm) found with treatments $I_{100}F_{100}$, $I_{100}F_{100}$, $I_{100}F_{100}$, $I_{100}F_{100}$ and $I_{85}F_{75}$, respectively in 2011 and were (23.92 g, 56.45 g, 7.26, 48.67 cm and 1.42 cm) found with treatment $I_{100}F_{100}$ in 2012.

The results showed that the growth parameters of onion significantly decreased by decreasing water applied except leaf weight and leaves per plant in 2011 and fresh bulb weight and leaf weight in 2012, while fresh bulb weight and leaf weight significantly decreased by decreasing the rate of NPK in 2011 and fresh bulb weight, leaf length and leaf diameter significantly decreased by decreasing the rate of NPK in 2012. The reason for these results is due to decreasing water level decrease the above-mentioned measurements.

The interaction of irrigation and NPK levels showed a significant influence on fresh bulb weight in 2011 and 2012. There is no significant influence between treatments $I_{100}F_{100}$, $I_{100}F_{75}$ and $I_{85}F_{100}$. Treatments $I_{100}F_{75}$ and $I_{85}F_{100}$ decreased fresh bulb weight non-significantly by about 13.3 and 14.3 %, respectively in 2011 and by about 22.4 and 26.5 %, respectively in 2012 as compared to the treatment $I_{100}F_{100}$.

The similar trend was also observed with leaf weight, number of leaves per plant and leaf length. Treatments $I_{100}F_{75}$ and $I_{85}F_{100}$ decreased leaf weight, number of leaves per plant and leaf length by about (11.1 and 13.5), (6.9 and 0.1) and (4.6 and 1.9 %), respectively in 2011 and by about (12.6 and 12.7%), (5.1 and 8.1%) and (8 and 10.8%), respectively in 2012 as compared to the $I_{100}F_{100}$ treatment.

Table (7): Effect of different rates of irrigation and NPK fertilization on average fresh bulb weight, leaf weight, leaves per plant, leaf length and leaf diameter of onion after 60 days from transplanting.

Treatments	Fresh bulb weight, g		Leaf weight, g		Leaves per plant		Leaf length, cm		Leaf diameter, cm	
	2011	2012	2011	2012	2011	2012	2011	2012	2011	2012
$I_{100}F_{100}$	22.10[a]	23.92[a]	54.88[a]	56.45[a]	7.13[a]	7.26[a]	45.69[a]	48.67[a]	1.03[bcd]	1.42[a]
$I_{100}F_{75}$	19.16[ab]	18.57[ab]	48.78[ab]	49.34[ab]	6.63[ab]	6.89[ab]	43.58[abc]	44.78[ab]	1.02[bcd]	1.40[a]
$I_{100}F_{50}$	12.43[bc]	10.70[bc]	43.58[abc]	41.97[ab]	6.43[ab]	6.56[abc]	43.44[abc]	42.11[bc]	1.06[abcd]	1.01[bcde]
$I_{100}F_0$	9.72[c]	13.00[bc]	32.70[bcd]	40.84[ab]	5.63[b]	6.00[cde]	42.28[abc]	41.89[bc]	1.34[ab]	0.99[cde]
$I_{85}F_{100}$	18.95[ab]	17.57[ab]	47.48[ab]	49.29[ab]	7.12[a]	6.67[abc]	44.81[ab]	43.41[bc]	1.24[abc]	1.33[ab]
$I_{85}F_{75}$	13.04[bc]	13.81[abc]	45.06[abc]	45.64[ab]	6.03[ab]	6.37[bcde]	43.58[abc]	43.22[bc]	1.44[a]	1.32[abc]
$I_{85}F_{50}$	13.91[bc]	12.61[bc]	43.48[abc]	40.15[ab]	5.93[ab]	6.22[bcde]	42.31[abc]	41.33[bcd]	1.39[ab]	0.98[cde]
$I_{85}F_0$	10.59[c]	10.87[bc]	32.71[bcd]	39.61[ab]	6.20[ab]	6.11[bcde]	41.75[abcd]	40.67[bcd]	1.38[ab]	0.97[de]
$I_{75}F_{100}$	13.07[bc]	13.46[bc]	46.86[ab]	48.27[ab]	5.70[b]	6.44[abcd]	43.19[abc]	43.11[bc]	1.07[abcd]	1.14[abcd]
$I_{75}F_{75}$	8.90[c]	10.18[bc]	45.84[abc]	46.99[ab]	6.33[ab]	6.11[bcde]	42.89[abc]	43.11[bc]	0.94[cd]	1.10[abcd]
$I_{75}F_{50}$	8.32[c]	7.56[bc]	37.79[abcd]	30.76[b]	6.17[ab]	6.00[cde]	42.19[abc]	39.67[cd]	1.10[abcd]	0.88[de]
$I_{75}F_0$	8.65[c]	7.32[bc]	31.81[bcd]	30.65[b]	5.70[b]	5.89[cde]	38.14[cde]	36.86[de]	1.03[bcd]	0.86[de]
$I_{65}F_{100}$	8.24[c]	8.00[bc]	45.90[abc]	48.49[ab]	6.37[ab]	5.89[cde]	41.39[abcd]	42.46[bc]	0.84[d]	1.08[abcd]
$I_{65}F_{75}$	6.82[c]	7.85[bc]	30.49[bcd]	45.46[ab]	6.43[ab]	5.89[cde]	38.64[bcde]	42.16[bc]	0.89[cd]	1.02[bcde]
$I_{65}F_{50}$	7.03[c]	7.27[bc]	26.69[cd]	30.36[b]	5.87[b]	5.67[de]	34.25[e]	34.67[e]	0.78[d]	0.84[de]
$I_{65}F_0$	6.59[c]	6.24[c]	23.93[d]	29.10[b]	5.97[ab]	5.56[e]	35.67[de]	34.56[e]	0.82[d]	0.70[e]
F-test **Irrigation** **Fertilization** **Irri. × Fert.**	 * * *	 NS * *	 NS * *	 NS NS *	 NS NS *	 * NS *	 * NS *	 * * *	 * NS *	 * * *

NS and *: Non-significant, significant at P > 0.05, respectively. Means with the same treatment and column sharing the same letters are not significantly different at P<0.05.

Table (8) shows the average values of neck thickness, bulb diameter, bulb length, bulb weight and split bulbs percentage after harvesting. The minimum values of neck thickness, bulb diameter, bulb length and bulb weight were (1.05 cm, 43.25 cm, 72.5 cm and 63.68 g) found with treatments $I_{85}F_{50}$, $I_{75}F_0$, $I_{65}F_{75}$ and $I_{65}F_{75}$, respectively in 2011 and were (1.01 cm, 46.37 cm, 72.78 cm and 60.55 g) found with treatment $I_{100}F_{100}$, $I_{65}F_0$, $I_{65}F_0$ and $I_{65}F_0$ in 2012, while the maximum values of neck thickness, bulb diameter, bulb length and bulb weight were (1.79 cm, 84.05 cm, 92.69 cm and 200.84 g) found with treatments $I_{75}F_{75}$, $I_{100}F_{100}$, $I_{100}F_{75}$ and $I_{100}F_{100}$, respectively in 2011 and were (1.65 cm, 77.77 cm, 87.95 cm and 190.85 g) found with treatments $I_{100}F_{75}$, $I_{100}F_{100}$, $I_{100}F_{100}$ and $I_{100}F_{100}$, respectively in 2012.

Water levels and NPK fertilization did not significantly affect the formation of thick-necked bulbs in 2011 and 2012 (Table 8). In agreement with this assessment, ***Brewester (1987)*** reported that neck thickness is a physiological disorder that is influenced by seasons, sites and cultivars, not by fertility. In contrast, ***Jilani (2004)*** reported that increasing application of N increased the number of thick-necked bulbs. The similar trend was observed with the percent of split bulbs in 2011 and 2012 (Table 8).

As shown in table (8) there was no significant decrease of bulb weight with $I_{100}F_{100}$, $I_{100}F_{75}$, $I_{100}F_{50}$, and $I_{85}F_{100}$ treatments in 2011 but there was no significant decrease in bulb weight with the first five treatments in 2012. Treatments $I_{100}F_{75}$, $I_{100}F_{50}$ and $I_{85}F_{100}$ decreased bulb weight by about 2.2, 5.5 and 14.6 % in 2011 and by about 0.12, 9.44 and 9.6 % in 2012 as compared to the $I_{100}F_{100}$, respectively. Also, water stress and NPK fertilization significantly affected the bulb diameter and length. Treatment $I_{100}F_{75}$ decreased non-significantly the diameter by about 3.2 % in 2011 and by about 2.8 % in 2012 as compared to the $I_{100}F_{100}$ treatment, while water level significantly affected the bulb length and NPK fertilization had no affect but the interaction between water levels and NPK rates showed that the treatment $I_{100}F_{75}$ increased the bulb length by about 3.7 % in 2011 and decreased the bulb length by about 0.27 % in 2012 as compared to the $I_{100}F_{100}$ treatment (Table 8).

Growth parameters over all the treatments of this study were not significantly different between the $I_{100}F_{100}$, $I_{100}F_{75}$ and $I_{85}F_{100}$ treatments in 2011 and 2012 (Table 7). Lower growth parameters were observed for the 65, 75 % ET_c, 0, and 50% NPK treatments. Even though numerically higher growth parameters were observed with the 100 % than with the 85 % ET_c treatments, they were not statistically different. Similar results were observed for these treatments, because the 100% and 85% ET_c treatments kept a same water moisture content at first and second layers (0 – 10 cm and 10 – 20 cm) and onions have shallower root (30 cm) systems (Fig. 2) and onion growth parameters were not affected.

Table (8): Effect of different rates of irrigation and NPK fertilization on average neck thickness, bulb diameter and length and bulb weight of onion after harvested.

Treatments	Neck thickness, cm		Bulb diameter, mm		Bulb length, mm		Bulb weight, g	
	2011	2012	2011	2012	2011	2012	2011	2012
$I_{100}F_{100}$	1.15[a]	1.01[a]	84.05[a]	77.77[a]	89.35[ab]	87.95[a]	200.84[a]	190.85[a]
$I_{100}F_{75}$	1.08[a]	1.65[a]	81.33[a]	75.58[a]	92.69[a]	87.71[a]	196.57[a]	190.62[a]
$I_{100}F_{50}$	1.65[a]	1.48[a]	64.49[d]	56.89[bc]	79.11[de]	79.03[abc]	189.84[a]	172.82[a]
$I_{100}F_{0}$	1.12[a]	1.50[a]	57.83[ef]	56.47[bc]	77.76[de]	77.21[bc]	137.85[abcd]	148.82[ab]
$I_{85}F_{100}$	1.59[a]	1.08[a]	72.45[b]	75.04[a]	87.69[abc]	85.70[ab]	171.45[ab]	172.52[a]
$I_{85}F_{75}$	1.35[a]	1.31[a]	68.67[b]	72.83[a]	81.84[bcd]	85.50[ab]	158.77[abc]	120.10[abc]
$I_{85}F_{50}$	1.05[a]	1.46[a]	61.00[de]	56.40[bc]	76.84[de]	76.91[bc]	95.15[cde]	93.15[bc]
$I_{85}F_{0}$	1.37[a]	1.58[a]	56.21[fg]	54.15[bc]	76.09[de]	76.78[bc]	79.92[de]	94.34[bc]
$I_{75}F_{100}$	1.64[a]	1.26[a]	54.69[fg]	66.89[ab]	75.20[de]	85.20[ab]	101.02[bcde]	86.49[bc]
$I_{75}F_{75}$	1.79[a]	1.24[a]	54.27[g]	64.82[ab]	79.36[de]	84.19[ab]	99.49[cde]	80.13[bc]
$I_{75}F_{50}$	1.54[a]	1.59[a]	55.16[fg]	50.29[c]	79.72[cde]	75.53[bc]	99.49[cde]	65.35[c]
$I_{75}F_{0}$	1.19[a]	1.15[a]	43.25[i]	47.31[c]	72.67[e]	75.39[bc]	75.31[de]	84.06[bc]
$I_{65}F_{100}$	1.51[a]	1.28[a]	47.79[h]	59.18[bc]	73.89[de]	82.37[abc]	104.07[bcde]	79.92[bc]
$I_{65}F_{75}$	1.26[a]	1.37[a]	46.71[hi]	58.59[bc]	72.50[e]	80.98[abc]	69.50[de]	60.55[c]
$I_{65}F_{50}$	1.42[a]	1.42[a]	47.81[h]	46.64[c]	74.07[de]	73.21[c]	67.47[de]	64.21[c]
$I_{65}F_{0}$	1.28[a]	1.57[a]	46.59[hi]	46.37[c]	79.58[de]	72.78[c]	63.68[e]	66.90[c]
F-test								
Irrigation	NS	NS	*	*	*	NS	*	*
Fertilization	NS	NS	*	*	NS	*	*	NS
Irri. * Fert.	NS	NS	*	*	*	*	*	*

NS and *: Non-significant, significant at P > 0.05, respectively. Means with the same treatment and column sharing the same letters are not significantly different at P<0.05.

In conclusion, Pegue onion plant showed differential response to different water applied with different rates of NPK. Best response, as observed by the vegetative growth parameters of Pegue onion, was obtained when planting with treatment $I_{100}F_{100}$, $I_{100}F_{75}$ and $I_{85}F_{100}$.

3. Bulb yield of onion

The bulb yield significantly (P < 0.05) increased with increasing applied water level while different rates of NPK did not significantly affect the bulb yield. The increase in yield was mainly because of a positive association between yield and yield attributing characters like bulb diameter, bulb length and bulb weight. In 2011, significantly higher bulb yields (27.73, 26.98, 25.61, 23.63 and 21.83 t/ha) were obtained with $I_{100}F_{100}$, $I_{100}F_{75}$, $I_{100}F_{50}$, $I_{100}F_{0}$ and $I_{85}F_{100}$ treatments, respectively as shown in table (9). Lower yields were observed for the 65, 75 % ET_c, 0 and 50% NPK treatments. In 2011, even though numerically higher yield was observed with the 100 % than with the 85 % ET_c treatments, they were not statistically different. However, yields dropped significantly with the interaction of 65, 75 % ET_c, 0 and 50 % NPK treatments.

Similar results were observed for these treatments in 2012, probably, because the 100 % and 85 % ET_c treatments has approximately the same soil moisture conditions (Fig. 2) and crop yields were not affected. However, yields dropped significantly with the 65, 75 % ET_c, 0 and 50 % NPK treatments in both seasons.

4. Water use of onion

There was significant effect of irrigation levels on WUE of onion (table 10) but there was no significant effect of NPK rates on WUE of onion in 2011 and 2012. The maximum WUE values were observed with 85 and 100 % ET_c while the minimum values were observed with 65 and 75 % ET_c in the two years. As shown in table (10), when the water level decreased from 100% ET_c to 85% ET_c, the treatment $I_{85}F_{100}$ decreased non significantly the WUE by about 7.93 % than treatment $I_{100}F_{100}$ in 2011, while treatment $I_{85}F_{100}$ increased non significantly the WUE by about 6.44 % than treatment $I_{100}F_{100}$ in 2012.

Also as shown in table (10), when decreased the NPK rate from 100 % to 75 %, the treatment $I_{100}F_{75}$ was non significantly decreased the WUE by about 2.85 % than treatment $I_{100}F_{100}$ in 2011, while treatment $I_{100}F_{75}$ decreased non significantly the WUE by about 2 % than treatment $I_{100}F_{100}$ in 2012. Therefore, the same yield can be obtained without significant effect when decreasing the water irrigation by about 15 % or by decreasing NPK fertilization by about 25 %.

Table (9): Effect of different irrigation levels and NPK fertilization application on onion (var. Pegou) yield parameters (ton/ha).

Treatments	Split, ton/ha		Total yield, ton/ha	
	2011	2012	2011	2012
$I_{100}F_{100}$	0.95[a]	0.73[a]	27.73[a]	26.18[a]
$I_{100}F_{75}$	0.77[ab]	0.27[b]	26.98[a]	25.69[a]
$I_{100}F_{50}$	0.30[ab]	0.11[b]	25.61[a]	23.15[a]
$I_{100}F_{0}$	0.77[a]	0.09[b]	23.63[ab]	19.93[ab]
$I_{85}F_{100}$	0.66[a]	0.68[ab]	21.83[abc]	23.68[a]
$I_{85}F_{75}$	0.46[ab]	0.16[b]	18.84[abcd]	16.17[abc]
$I_{85}F_{50}$	0.28[ab]	0.11[b]	14.16[bcd]	12.53[bc]
$I_{85}F_{0}$	0.12[b]	0.05[b]	13.38[bcd]	12.63[bc]
$I_{75}F_{100}$	0.17[b]	0.25[b]	13.64[bcd]	11.78[bc]
$I_{75}F_{75}$	0.47[ab]	0.08[b]	13.73[bcd]	10.76[bc]
$I_{75}F_{50}$	0.19[b]	0.12[b]	11.61[cd]	8.83[c]
$I_{75}F_{0}$	0.08[b]	0.06[b]	10.73[d]	11.27[bc]
$I_{65}F_{100}$	0.14[b]	0.14[b]	12.82[bcd]	10.80[bc]
$I_{65}F_{75}$	0.12[b]	0.06[b]	9.39[d]	8.13[c]
$I_{65}F_{50}$	0.06[b]	0.08[b]	9.06[d]	8.64[c]
$I_{65}F_{0}$	0.04[b]	0.15[b]	8.52[d]	9.07[c]
F-test				
Irrigation	NS	NS	*	*
Fertilization	NS	NS	NS	NS
Irri. * Fert.	*	*	*	*

NS and *: Non-significant, significant at P > 0.05, respectively. Means with the same treatment and column sharing the same letters are not significantly different at P < 0.05.

Table (10): The influence of different applied water and different rates of NPK on WUE of onion.

Treatments	WUE, kg/m³	
	2011	2012
$I_{100}F_{100}$	4.92^{a}	4.50^{a}
$I_{100}F_{75}$	4.78^{ab}	4.41^{ab}
$I_{100}F_{50}$	4.54^{abc}	3.98^{abc}
$I_{100}F_{0}$	4.19^{abcde}	3.42^{abcd}
$I_{85}F_{100}$	4.53^{abcd}	4.79^{a}
$I_{85}F_{75}$	3.91^{abcde}	3.27^{abcd}
$I_{85}F_{50}$	2.94^{bcde}	2.54^{bcd}
$I_{85}F_{0}$	2.78^{cde}	2.56^{bcd}
$I_{75}F_{100}$	3.22^{abcde}	2.70^{bcd}
$I_{75}F_{75}$	3.25^{abcde}	2.47^{bcd}
$I_{75}F_{50}$	2.74^{cde}	2.03^{d}
$I_{75}F_{0}$	2.54^{de}	2.58^{bcd}
$I_{65}F_{100}$	3.48^{abcde}	2.86^{abcd}
$I_{65}F_{75}$	2.55^{de}	2.15^{d}
$I_{65}F_{50}$	2.46^{de}	2.29^{cd}
$I_{65}F_{0}$	2.32^{e}	2.40^{bcd}
F-test		
Irrigation	*	*
Fertilization	NS	NS
Irri. * Fert.	*	*

CONCLUSION

The study showed that:

1. Calculated water irrigation requirements by FAO Penman–Monteith equation (100% ET_c) was 564 and 582 mm/season in 2011 and 2012, respectively.
2. There is no significant effect on growth and yield parameters when transit from 100% to 85% ET_c or 100% to 75% NPK rates.
3. Bulb weight, bulb diameter, bulb length, and yield were non significantly decreased from 100 % to 85 % ET_c or from 100 % to 75 % NPK rates in the two years (table 11).
4. The water use efficiencies (WUE) were deceased by increasing water irrigation applied in the two years. The maximum WUE was

4.76 and 4.52 kg/m^3 for treatments $I_{100}F_{100}$ and $I_{85}F_{100}$ in 2011 and 2012, respectively, while the minimum value was 2.09 and 1.89 kg/m^3 for treatments $I_{65}F_0$ and $I_{75}F_{50}$ in 2011 and 2012, respectively.

Table (11): The treatments significantly did not affected by decreasing water level from 100 to 85% ET_c or by decreasing NPK rates from 100 to 75%.

Treat.	Bulb diameter, cm		Bulb length, cm		Bulb weight, g		Yield, ton/ha	
	2011	2012	2011	2012	2011	2012	2011	2012
$I_{100}F_{100}$	84.05	77.77	89.35	87.95	200.84	190.85	27.73	26.18
$I_{100}F_{75}$	81.33	75.58	92.69	87.71	196.57	190.62	26.98	25.69
$I_{85}F_{100}$	72.45	75.04	87.69	85.70	171.45	172.52	21.83	23.68
$I_{85}F_{75}$	68.67	72.83	81.84	85.50	158.77	120.10	18.84	16.17

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الملخص العربي

استجابة البصل لمستويات مختلفة من الري والتسميد (أ) التوزيع الرطوبي في التربة، المؤشرات النباتية والانتاجية الكلية

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يهدف هذا البحث إلى دراسة تأثير مستويات مياه (١٠٠، ٨٥، ٧٥ و ٦٥ % من الاحتياجات المائية للبصل) ومعدلات تسميد (١٠٠، ٧٥، ٥٠ و ٠ % NPK الموصي به) على نمو وانتاجية محصول البصل. أجريت التجربة بمزرعة قسم البستنه – كلية الزراعة – جامعة عمر المختار - مدينة البيضاء (ليبيا) في المواسم ٢٠١٢/٢٠١١. تم حساب الاحتياجات المائية الفعلية بناء على الظروف المناخية الخاصة بالمنطقة باستخدام معادلة (Penman–Monteith).

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وقد بينت الدراسة ما يلي:

١. كانت الاحتياجات المائية المحسوبة بمعادلة (FAO Penman–Monteith) للبصل ٥٦٤ و ٥٨٢ مم/موسم (تمثل ١٠٠ % من الاحتياجات المائية الفعلية للبصل) للمواسم ٢٠١١ و ٢٠١٢ على الترتيب.

٢. لا يوجد تأثير معنوي على نمو وانتاجية البصل عند تخفيض الاحتياجات المائية من ١٠٠ % الى ٨٥ % وكذلك عند تخفيض معدلات التسميد من ١٠٠ % الى ٧٥ %.

٣. وزن وقطر وطول البصلة لم يتأثر معنوياً عند تخفيض الاحتياجات المائية من ١٠٠ % الى ٨٥ % وكذلك عند تخفيض معدلات التسميد من ١٠٠ % الى ٧٥ % كما هو موضح بالجدول (١١).

٤. انخفضت كفاءة الاستخدام المائي بانخفاض كمية المياه المضافة في الموسمين ٢٠١١ و ٢٠١٢. وكانت أقصى قيمة لكفاءة الاستخدام المائي ٤.٧٦ و ٤.٥٢ كجم/م^{3} للمعاملات $I_{100}F_{100}$ و $I_{85}F_{100}$ للمواسم ٢٠١١ و ٢٠١٢ على الترتيب. بينما كانت أقل قيمة لكفاءة الاستخدام المائي ٢.٠٩ و ١.٨٩ كجم/م^{3} للمعاملات $I_{65}F_{0}$ و $I_{75}F_{50}$ للمواسم ٢٠١١ و ٢٠١٢ على الترتيب.