Menoufia J. Soil Sci., Vol. 1 October (2016): 131 - 146

IMPACTS OF ALTERNATE FURROW IRRIGATION AND N-FERTILIZATION LEVEL ON PERFORMANCE OF ONION UNDER MIDDLE EGYPT CONDITIONS

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Received: Jun. 25, 2016 **Accepted: Jul. 20 , 2016**

ABSTRACT: *Two field experiments were conducted in 2012/2013 and 2013/2014 winter seasons at Sids Agric. Res. Station, Beni-Suef, Egypt to find out the extent to which onion crop performance was affected by alternate furrow irrigation technique. Two alternate furrow irrigation regimes were assessed i.e. irrigating at 14 or 28 days intervals, comparing with the common furrow irrigation regime. These irrigation regimes were combined with 60, 90 and 120 kgNfed^{-1} levels and tested in a split plot design with four replicates, where irrigation regimes were represented in the main plots, whereas split ones were assigned for N levels. Onion yield and quality, applied water as well as water, N and consumptive use efficiencies were considered. The most important results could be summarized as follows:*

1- *The marketable onion bulb and total yields were significantly increased under Alternate Furrow Irrigation at 14 days interval (AFI_{14}), comparable with Alternate Furrow Irrigation at 28 days interval (AFI_{28}) and common furrow irrigation (EFI). The highest values of bulb weight, bulb diameter, bulb total soluble solids (TSS %) and bulb dry matter (DM %) were obtained with AFI_{14} regime. Increasing N level resulted in gradual increases in marketable, total, culls onion bulb yields, onion bulb weight, bulb diameter, bulb TSS and DM%. The interaction of AFI_{14} regime and 120 kg Nfed^{-1} level resulted in the highest figures of the abovementioned parameters.*
2- *The highest values of seasonal applied water were under every-furrow irrigation (EFI) and reached to 2247 and 2209 m^{3}fed^{-1}, which reduced by (24.86 and 7.29%) and by (24.52 and 7.22%) under AFI_{28} and AFI_{14} regimes, respectively, in the consecutive two seasons. The highest seasonal Cu (1712.28 and 1642.37 m^{3}fed^{-1}) were recorded under EFI, which tended to reduction under AFI_{28} and AFI_{14} regimes with 17.98 and 5.71% in 1st season, and 19.83 and 6.63% in 2nd season, respectively, lower than that with EFI regime. Increasing N level resulted in gradual increased Cu values, and interaction of EFI regime and 120 kg Nfed^{-1} level revealed the highest Cu value.*
3- *The AFI_{14} regime exhibited the highest values of Irrigation Water Productivity, Water and N Use Efficiencies, whereas Consumptive Use Efficiency was improved with AFI_{28} regime. Irrigation Water Productivity, Water and Consumptive Use Efficiencies, were increased gradually with increasing N level, whereas N use efficiency exhibited a differed trend.*

On conclusion, AFI_{14} regime is capable to mitigate the water stress, during the irrigation cycle, and to increase onion bulb yield. In addition, it is obviously noticed that the alternate furrow irrigation at 14-days interval and120 kgNfed^{-1} is the best combination to achieve higher marketable onion bulb yield and to improve irrigation and N use efficiencies as well.

Key words: *Onion crop, alternate furrow irrigation, N fertilization level, water and consumptive use efficiencies, N-use efficiency*

INTRODUCTION

The available water resources in Egypt are limited which restrict the horizontal crop production in the newly reclaimed areas. Agriculture is heavily relied on irrigation and consumes more than 84% of available water resources (El-Beltagy and Abo-Hadeed, 2008). Furrow irrigation is the common scheme in conveying the water to the row - cultivated crops. Under such irrigation scheme inevitable over irrigation is expected, particularly, in the upper part of the field near the water inlet causing lower water application efficiency. The deeply percolated water resulting in leaching pesticides and other harmful chemicals out the root zone causing an acute environmental pollution in particular for shallow ground water which frequently used for drinking in the most Egyptian rural areas. So, optimizing irrigation water is an important and beneficial issue in saving water, fertilizers and in general sustaining the agricultural sector.

Onion (*Allium cepa* L.) is an important vegetable crop in Egypt for exportation and local consumption. Onion is a shallow-rooted plant that requires frequent irrigation to achieve the yield potential. Accordingly, with furrow irrigation on keeping proper soil moisture in the root zone, irrigation must be applied frequently, so, higher amounts of water is generally applied to the crop. Sammis *et al.* (2000) stated that onion is regarded a fairly large water consumer and water deficiency decrease in its evapotranspiration and consequently yield. Towards achieving the yield potential, the proper inputs for onion production, in particular, water and N fertilizer must be considered. In this respect, Kassam *et al.* (2007) reported that improving the management of agricultural water is the basic need to conserve water, energy and soil while satisfying society's increasing demand for food and fiber.

Alternate furrow irrigation (AFI) is powerful tool to reduce both water applied and irrigation costs and produce acceptable crop yield and water productivity as well. In Egypt, EL- Sharkawy *et al.* (2006) stated that AFI is a way to save irrigation water, improve irrigation efficiency, and increase onion yield. With maize crop, Zhang *et al.* (2000) found that AFI uses less irrigation water but can maintain the same maize grain yield production as that of conventional furrow irrigation with high irrigation amounts. Furthermore, Awad (2013) reported that Irrigation water saving in the AFI_7 and AFI_{14} was approximately 7% and 17%, respectively, and improved both maize crop water use efficiency and irrigation water productivity as compared with EFI. In addition, Okasha *et al.* (2013) with maize, stated that alternative furrows irrigation gave the highest values of irrigation water use efficiency (IWUE) and decreased amount of applied water irrigation by 35% , comparable with continuous flow irrigation.

All crops require nitrogen (N) for the production of a photosynthetically active canopy, whose functionality will strongly influence the crop performance. The supplied nitrogen to the plant will influence the amount of protein, protoplasm and chlorophyll formed. In turn, this influences cell size and leaf area, photosynthetic activity and consequently the final economic yield. Although greater N application has produced higher yields, this is not a linear relationship and there is an economic optimum application offsetting incremental yield increase against the cost of additional N inputs, which needs to be determined for individual cultivars (King *et al.* 2003). Nitrogen is an essential element for both crop growth and productivity. The beneficial effect of nitrogen application on onion yield was previously reported, where Moursy *et al.* (2007) found that application of 190.4 kg N/ha rate gave significantly increased in onion yield, bulb diameter and TSS content as compared with 95.2 kg Nha^{-1} one. In addition, Yaso *et al.* (2007) revealed that increasing mineral nitrogen levels led to significant increases on average bulb weight, marketable and total bulbs yield, and total soluble solid of onion. Moreover, Awad *et al.* (2011) found that application of N at 62, 124, and 248 kg ha^{-1} rates increased onion yield, as compared to those of the plants that received no N. In general, because of shallow and unbranched root system, onion and other alliums are most susceptible compared to many crops in extracting moisture and nutrients (Kebede, 2003), thus water and N management a key factor in its production.

The objectives of the present research study are to investigate the effects of two alternate furrow irrigation regimes, comparable with traditional regime as combined with three different nitrogen levels and their interaction as well on onion yield, quality, irrigation water productivity and consumptive use efficiency in order to find out the most proper combination resulting in higher onion and water productivity under Beni Sueif Government circumstances, Middle Egypt area.

MATERIALS AND METHODS

This investigation was conducted at Sids Agricultural Research Station, Bani-Suef Governorate, Middle Egypt during 2012/2013 and 2013/2014 winter seasons to study the effect of three irrigation schemes and three nitrogen fertilization levels and their interaction on onion bulb yield and some quality traits besides some crop - water relations. The onion cultivar Giza 6 Mohassan (*Allium cepa* L.) was used in this study. Some hydrological and chemical soil properties and particle size distribution as well were determined according to Klute (1986) and Page *et al.* (1982). Data are presented in Tables 1 and 2. A split plot design with four replicates was used. The main plots were devoted to water placement regimes, while the sub plots were assigned to the nitrogen fertilization levels as shown below.

1- Main- plots (water placement regimes)

Every-furrow irrigation (Traditional furrow irrigation at 28 days interval, EFI

Alternate-furrow irrigation at 28 days interval, AFI_{28}.

Alternate-furrow irrigation at 14 days interval, AFI_{14}.

Table 1: Bulk density and some soil - water constants for the experimental site in 2012/2013 and 2013/2014 seasons.

Season	Depth (cm)	Field capacity (%, wt/wt)	Wilting point (%, wt/wt)	Available water (%, wt/wt)	Bulk density (gcm^{-3})
2012/2013	00 – 15	46.56	22.17	24.39	1.17
	15 – 30	37.09	17.66	19.43	1.29
	30 – 45	35.55	16.92	18.63	1.36
	45 – 60	33.19	15.80	17.39	1.38
Mean		**38.10**	**18.14**	**19.96**	**1.29**
2013/2014	00 – 15	45.08	21.58	23.50	1.13
	15 – 30	37.95	18.04	19.91	1.24
	30 – 45	35.95	17.32	18.63	1.28
	45 – 60	33.14	16.04	17.10	1.33
Mean		**38.03**	**18.25**	**19.88**	**1.25**

Table 2: Particle size distribution and some chemical properties of the experimental soil at 2012/2013 and 2012/2013.

Season	Particle size distribution				Textural class	Chemical properties					
	Clay %	Silt %	Sand %			OM %	Ec, dSm^{-1} (at 25°C)	Available (ppm) N	P	K	pH
2012/2013	49.90	33.80	16.30		Clayey	1.20	0.53	45.0	12.5	202.5	7.9
2013/2014	50.20	33.45	16.35		Clayey	1.57	0.66	37.0	11.0	203.8	7.8

2- Sub-plots (nitrogen fertilization levels)

N_1 - 60 kg $Nfed^{-1}$ N_2 - 90 kg $Nfed^{-1}$

N_3 - 120 kg $Nfed^{-1}$

The area of each sub-plot was 42 m^2 (1/100 fed) i.e. 6 m width (10 ridges x 0.60 m apart) x 7 m length. Seedlings were planted on 5-7 cm apart on both sides of ridge. Onion seeds were sown in the nursery on 5th and 15th September, and the seedlings were transplanted on 15th and 20th November in 2012/2013 and 2013/2014 seasons, respectively. The recommended doses of calcium super phosphate (15.5% P_2O_5) and potassium sulphate (48% K_2O) were applied during land preparation. The preceding crops were soybean and maize in 2012/2013 and 2013/2014 seasons, respectively. The adopted N levels were added at two equal doses as ammonium nitrate (33.5% N). The first dose was applied after thirty days from transplanting and the second was applied one month later. Irrigation events and applied water under the adopted irrigation schemes are presented in Table 3. Irrigation water was conveyed to the plots through a circular orifice and its quantity was calculated using the equation described by (Michael, (1978) as follows:

$$Q = CA\sqrt{2gh}$$

Where:

Q = water discharged through the orifice, cm^3sec^{-1}.

C = coefficient of discharge ranged from 0.6 up to 0.8.

A = cross-sectional area of the orifice, cm^2.

g = acceleration of gravity, 981 $cmsec^{-2}$.

h = pressure head causing discharge through the orifice, cm.

At harvest, averages of bulb weight (g), bulb diameter (cm), marketable, culls (double + bolter) and total yields ($tfed^{-1}$), total soluble solids percentage (TSS%) and of dry matter percentage (DM%) in bulbs were determined according to AOAC, 1975.

Statistical analysis:

All collected data were subjected to statistical analysis as described by Snedecor and Cochran (1980). The means were compared using least significant difference (LSD) at 5% probability level.

Consumptive use (Cu):

Consumptive use (Cu) or so called crop evapotranspiration (Etc) was determined based on soil moisture depletion (S.M.D.) in the effective root zone as outlined by Hansen, *et al.* (1979):

$$Cu = \frac{Q_2 - Q_1}{100} \times Bd \times d$$

Where:

Cu = actual water consumptive use in cm.

Q_2 = soil moisture content after 48 hours from irrigation (%, wt/wt).

Q_1 = soil moisture content before irrigation (%, wt/wt).

Bd = bulk density of the specified soil layer (gcm^{-3}).

d = depth of soil layer (60 cm).

Table 3: Number of irrigation and applied water (m^3fed^{-1}) for each irrigation under different irrigation treatments during the 2012/2013 and 2013/2014 seasons.

Irrigation event	EFI		AFI_{28}		AFI_{14}	
	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014
Transplanting	562.8	537.6	562.8	537.6	562.8	537.6
Second	252.0	285.6	252.0	285.6	252.0	285.6
Third	373.8	365.4	243.6	256.2	176.4	168.0
Fourth	365.4	357.0	226.8	239.4	172.2	163.8
Fifth	361.2	344.4	210.0	201.6	168.0	160.0
Sixth	331.8	319.2	193.2	147.0	159.6	159.2
Seventh	---	---	---	---	155.4	155.4
Eighth	---	---	---	---	151.2	147.0
Ninth	---	---	---	---	147.0	138.6
Tenth	---	---	---	---	138.6	134.4
Total (m^3/fed)	2247.0	2209.2	1688.4	1667.4	2083.2	2049.6

EFI: Every-furrow irrigation; AFI_{28} and AFI_{14} are alternate furrow irrigation with 28 and 14 days intervals, respectively

Irrigation Water Productivity (IWP)

Water productivity is an efficiency term calculated as a ratio of product output over water input. The output could be biological goods such as crop grain, fodder, bulbs ....etc. So, water productivity, in the present study, is expressed as kilograms of onion bulbs obtained per the unit of applied irrigation water as follows:

IWP (kgm^{-3}) = Total bulb yield ($kgfed^{-1}$) / Water applied (m^3fed^{-1}), Ali *et al.* (2007)

Water Use Efficiency (WUE, Kgm^{-3}): Water use efficiency was estimated according to Jensen (1983) as follows:

$$WUE = \frac{Y}{CU}$$

Where:

WUE = kgm^{-3}

Y = Total bulb yield ($kgfed^{-1}$)

CU = Seasonal water consumptive use (m^3fed^{-1})

Nitrogen Use Efficiency (NUE): Nitrogen Use Efficiency was computed as onion bulb yield ($kgfed^{-1}$) and N applied ($kgfed^{-1}$) ratio was estimated as below:

NUE = Marketable bulb yield ($kgfed^{-1}$) / N applied ($kgfed^{-1}$)

Consumptive use efficiency (Ecu, %):

The consumptive use efficiency (Ecu) was estimated according to Doornbos and Pruit (1975) as follows:

Ecu% = Water consumptive use (m^3fed^{-1}) X 100 / Water applied (m^3fed^{-1})

RESULTS AND DISCUSSION

Total, Marketable and Culls onion yields ($tfed^{-1}$):

Onion and other alliums crops are characterized with shallow and unbranched root system, so, they are most susceptible compared to many crops in extracting soil moisture and nutrients (Kebede, 2003) so, water and N management a key factor in its production. Data in Table 4 indicated that the adopted irrigation schemes and/or N fertilization levels significantly influenced marketable, culls and total onion yields in the two seasons of study.

Concerning irrigation schemes, AFI_{14} resulted in the highest total onion yield reached 17.19 and 14.92 tonfed^{-1}, respectively, in 1st and 2nd seasons. The values tended to reduction under EFI and AFI_{28} regimes and comprised 7.74 and 13.85% in 1st season and 8.45 and 14.81% in 2nd season, lower than those with AFI_{14} regime. Respecting marketable bulb yield, similar trend was observed, where the highest figures e.g.15.09 and 13.55 tonfed^{-1}were recorded with AFI_{14} regime, respectively, in 1st and 2nd seasons. Under EFI and AFI_{28} regimes the values tended to reduction and amounted to 9.94 and 18.03% in 1st season and to 9.96 and 18.08% in 2nd season, lesser than those with AFI_{14} regime. Data in Table 4 illustrated that culls onion yield exhibited differed trend as influenced by the adopted irrigation schemes. Higher values of culls onion yields were attained with EFI and AFI_{28} regimes, which reached to 2.28 and 2.45 tonfed^{-1} in 1st season and to 1.54 and 1.60 tonfed^{-1} in 2nd season, respectively. Culls onion yield under AFI_{14} regime was decreased by 7.90 and 14.29% in 1st season and by 11.04 and 23.89% in 2nd season, respectively, lower than those with EFI and AFI_{28} regimes. El- Sharkawy *et al.* (2006) reported that modified AFI regime (irrigating at 15 days interval) surpassed both EFI and AFI regimes (both irrigating at 30 days interval) to produce higher onion bulbs yield. Furthermore, Abdel-Maksoud *et al.* (2002) and Awad (2013) with maize crop, found that modified AFI (irrigating at 7 days interval) resulted in higher grain yield, comparable with EFI and AFI those irrigating at 14 days interval.

The substantial decreases in total and marketable yields under AFI_{28} regime, comparing with EFI regime, may be due to less applied irrigation water, which did not match full onion water requirements, caused water stress, and consequently reduced crop yield. Under AFI_{14} regime higher values of total and marketable yields, compared with EFI and AFI_{28} regimes, proved that irrigation timing is a detrimental factor, in water management, and so efficient water use. In addition, with AFI_{14} regime the soil moisture may be more available during the entire irrigation cycle, which enhanced water and nutrient uptake and doubtless reflected on final total and marketable onion yields.

As for the effects of the adopted nitrogen fertilization levels on onion bulb yields, data in Table 4 reveal that increasing N level resulted in gradual increases in total, marketable and culls onion bulb yields, and such findings were true in the two seasons. The increases in total and marketable yields due to 120 kg Nfed^{-1} level were (6.87 and 26.86%) and (6.93 and 28.66%) in 1st season and were (11.92 and 29.51%) and (12.97 and 31.75%) in 2nd season, respectively, higher than those with 90 and 60 kg Nfed^{-1} levels The culls bulb yield exhibited similar trend, where the highest figures e.g. 2.44 and 1.64 tfed^{-1}, respectively, were recorded in 1st and 2nd seasons. Under 90 and 60 kg Nfed^{-1} levels the values tended to reduce and amounted to 6.15 and 14.34% in 1st season and to 8.54 and 17.07% in 2nd season, respectively, comparable with 120 kg Nfed^{-1} level. The present findings are confirming the fact that all crops (including onion) require nitrogen (N) for the production of a photosynthetically active canopy, whose functionality will strongly influence the crop performance Moursy *et al.* (2007) found that application of 190.4 kg N/ha rate gave significantly increasing onion yield, bulb diameter and TSS content as compared with 95.2 kg N/ha one. In addition, Yaso *et al.* (2007) revealed that increasing mineral nitrogen levels led to significant increases on average bulb weight, marketable and total bulbs yield as well as total soluble solid of onion. In connection, Awad *et al.* (2011) found that application of N at 62, 124, and 248 kg ha−1 rates gradually increased onion yield, as compared to those of the plants that received no N. Furthermore, Aliyu *et al.* (2007) and Kemal *et al.* (2013) reported that total yield of onion and shallot (*Allium cepa var. ascalonicum Baker*), respectively, was gradually increased as N rate increased.

The interaction of AFI_{14} regime and 120 kg $Nfed^{-1}$ level resulted in the highest total and marketable bulb yields in the two seasons of study. On the contrary the lowest values were attained due to AFI_{28} regime as interacted with 60 $kgNfed^{-1}$ level in the two seasons of study.

Table 4: Marketable, culls and total yields ($tfed^{-1}$) as affected by irrigation schemes and N levels in 2012/2013 and 2013/2014 seasons.

Irrigation scheme (I)	Nitrogen levels (N)	2012/2013			2013/2014		
		Marketable	Culls	Total	Marketable	Culls	Total
		($tfed^{-1}$)			($tfed^{-1}$)		
EFI	60 kg $Nfed^{-1}$	11.20	2.08	13.29	10.05	1.36	11.41
	90 kg $Nfed^{-1}$	14.19	2.37	16.56	12.39	1.57	13.96
	120 kg $Nfed^{-1}$	15.37	2.38	17.75	14.15	1.68	15.58
Mean		13.59	2.28	15.86	12.20	1.54	13.66
AFI_{28}	60 kg $Nfed^{-1}$	10.56	2.32	12.88	9.52	1.51	11.03
	90 kg $Nfed^{-1}$	12.87	2.38	15.25	11.22	1.56	12.78
	120 kg $Nfed^{-1}$	13.67	2.64	16.31	12.59	1.73	14.32
Mean		12.37	2.45	14.81	11.11	1.60	12.71
AFI_{14}	60 kg $Nfed^{-1}$	13.52	1.88	15.40	12.18	1.22	13.40
	90 kg $Nfed^{-1}$	15.39	2.12	17.51	13.40	1.38	14.79
	120 kg $Nfed^{-1}$	16.36	2.30	18.66	15.07	1.51	16.57
Mean		15.09	2.10	17.19	13.55	1.37	14.92
N levels mean							
60 kg $Nfed^{-1}$		11.76	2.09	13.85	10.58	1.36	11.96
90 kg $Nfed^{-1}$		14.15	2.29	16.44	12.34	1.50	13.84
120 kg $Nfed^{-1}$		15.13	2.44	17.57	13.94	1.64	15.49
LSD, 0.05	(I)	0.53	0.30	0.61	0.68	0.30	0.59
	(N)	0.45	0.25	0.52	0.40	0.15	0.45
	I X N	0.77	0.44	0.90	0.69	0.27	0.78

Bulb weight and bulb diameter

The onion yield components e.g. bulb weight and bulb diameter were affected significantly with the adopted irrigation schemes and/or N fertilization levels in the two seasons of study, Table 5. As for the influence of irrigation schemes, AFI_{14} regime exhibited the highest figures of onion bulb weight and bulb diameter, which amounted to 97.7(g) and 5.86 (cm) in 1st season and 87.83 g and 5.71cm in 2nd season, respectively. Under EFI and AFI_{28} regimes, lower values for bulb weight were recorded and comprised 19.99 and 28.45% in 1st season and 19.86 and 28.37% in 2nd season, respectively, lower than those with AFI_{14} regime. Bulb diameter trait showed similar trend, where the corresponding reduction values, under EFI and AFI_{28} regimes, reached to 8.36 and 15.02% in 1st season and 8.23 and 15.41% in 2nd season, comparable with AFI_{14} regime. The obtained results indicated that onion crop performance was improved under AFI_{14} regime, and the crop was capable to use the water and N inputs efficiently. El- Sharkawy *et al.* (2006) reported a different, where EFI insignificantly surpassed both modified AFI regime (irrigating at 15 days interval) and AFI regimes (irrigating at 30 days interval) to produce higher onion bulbs weight and bulb diameter traits, and such trend could be attributed to varietal differences and soil and prevailing weather conditions. Ayas and Demirtas (2009) found that bulb diameter and bulb weight were increased with the applied irrigation water. Kemal (2013) reported that bulb diameter tended to reduction due to 50% ETc level, comparable with 100 and 120% ETc levels.

Table 5: Bulb weight (g) and bulb diameter (cm) as affected by irrigation treatments and nitrogen levels in 2012/2013 and 2013/2014 seasons.

Irrigation schemes (I)	Nitrogen levels (N)	2012/2013		2013/2014	
		Bulb weight (g)	Bulb diameter (cm)	Bulb weight (g)	Bulb diameter (cm)
EFI	60 kg $Nfed^{-1}$	60.44	4.98	54.46	4.85
	90 kg $Nfed^{-1}$	75.65	5.36	65.89	5.22
	120 kg $Nfed^{-1}$	98.61	5.79	90.82	5.64
Mean		**78.23**	**5.37**	**70.39**	**5.24**
AFI_{28}	60 kg $Nfed^{-1}$	53.55	4.44	48.24	4.33
	90 kg $Nfed^{-1}$	69.37	5.16	60.42	5.04
	120 kg $Nfed^{-1}$	86.95	5.34	80.08	5.12
Mean		**69.95**	**4.98**	**62.91**	**4.83**
AFI_{14}	60 kg $Nfed^{-1}$	90.29	5.40	81.35	5.27
	90 kg $Nfed^{-1}$	96.65	5.99	84.19	5.83
	120 kg $Nfed^{-1}$	106.36	6.19	97.96	6.04
Mean		**97.77**	**5.86**	**87.83**	**5.71**
N levels mean					
60 kg $Nfed^{-1}$		68.09	4.94	61.35	4.82
90 kg $Nfed^{-1}$		80.56	5.50	70.16	5.36
120 kg $Nfed^{-1}$		97.31	5.77	89.62	5.60
LSD, 05	(I)	8.51	0.33	7.54	0.32
	(N)	2.81	0.20	2.27	0.20
	I X N	4.87	0.35	3.92	0.34

Concerning effects of the adopted N levels, 120 kg Nfed^{-1} level exhibited the highest figures of onion bulb weight and bulb diameter which amounted to 97.31 (g) and 5.77(cm) in 1st season, and 89.62 (g) and 5.60 (cm) in 2nd season, respectively. The bulb weight seemed to decrease under 90 and 60 kg Nfed^{-1} levels by 17.21 and 30.03% in 1st season, and by 21.71 and 31.54% in 2nd season, respectively, comparable with120 kg Nfed^{-1} level. The bulb diameter trait exhibited similar trend, where the reduction under 90 and 60 kg Nfed^{-1} levels amounted to 4.68 and 14.38% in 1st season, and to 4.29 and 13.93% in 2nd season, respectively, comparing with120 kg Nfed^{-1} level.

In this sense, Aliyu *et al.* (2007) stated that mean of onion blub weight and bulb diameter were gradually increased due to increasing N level. In addition, Kemal (2013) found that bulb number and average bulb diameter were increased due to increasing N level. Gessesew *et al.* (2015) reported that increasing N fertilizer increased the mean weight of onion bulbs.

The interaction data indicated that AFI_{14} regime as interacted with120 kg Nfed^{-1} level exhibited higher onion bulb weight and bulb diameter, and such trend was true in the two seasons of study, Table 5.

Total soluble solids (TSS %) and dry matter (DM %):

Total soluble solids (TSS %) and dry matter (DM %) of onion bulbs were significantly influenced due to the adopted irrigation schemes and/or N fertilization levels in the two seasons of study, Table 6. As for the tested irrigation schemes, AFI_{14} regime resulted in the highest values of TSS and DM%, which amounted to 14.99 and 14.74% in 1st season, and 14.62 and 14.25% in 2nd season, respectively. The values of TSS% under EFI and AFI_{28} regimes were decreased by 7.81 and 4.87%, comparing with AFI_{14}. El- Sharkawy *et al.* (2006) reported that modified AFI regime (irrigating at 15 days interval) surpassed both EFI and AFI regimes (both irrigating at 30 days interval) to produce higher TSS and DM % values for onion bulbs.

Concerning TSS and DM% for onion blub as affected by N fertilization levels, data revealed that the highest figures were recorded under 120 kg Nfed^{-1} level and reached to14.78 and 14.52% in 1st season, and by 14.41 and 14.03%% in 2nd season, respectively. Under 90 and 60 kg Nfed^{-1} levels, TSS % seemed to reduce by 1.22 and 7.37% in 1st season, and by 3.40 and 7.29% % in 2nd season, respectively, compared with120 kg Nfed^{-1} level.

The values of DM% followed a similar trend, where DM% was reduced by 3.65 and 6.40% in1st season, and by 3.64 and 6.34% in 2nd season, respectively, under 90 and 60 kg Nfed^{-1} levels comparing with120 kg Nfed^{-1} level. In this sense, Yaso and Abdel - Razzak (2007) reported that TSS% and bulb weight of onion bulb were insignificantly increased due to increasing N rate to 90 or 120 kg Nfed^{-1} levels, comparable with 60 one.

The interaction data indicated that AFI_{14} regime as interacted with120 kg Nfed^{-1} level exhibited higher TSS and DM% figures, and such trend was true in the two seasons of study.

Applied Irrigation Water (AIW, m^{3}fed^{-1}):

Data in Table 3 show the amounts of applied irrigation water in each irrigation and seasonally as well. The highest values of seasonally water applied were recorded under every-furrow irrigation (EFI) and reached to 2247 and 2209 m^{3}fed^{-1} in 2012/2013 and 2013/2014, respectively. The values were reduced by (24.86 and 7.29%) and by (24.52 and 7.22%) under AFI_{28} and AFI_{14} regimes, respectively, in 2012/2013 and 2013/2014. It is well known that onion uses most of its water requirement from the top foot of soil due to its shallow root system. Thus, moisture needs per application are small and some deep percolation is inevitable. With onion crop irrigation, water must be controlled in order to minimize the water losses via deep percolation. The present findings indicated the potency of AFI in reducing the quantity of applied water. In this sense, El- Sharkawy *et al.* (2006) in 2 – season trial, found that applied water for onion crop under AFI and modified AFI regimes were lower by (29.30 - 30.57%) and (8.23 and 9.47%), respectively, compared with EFI regime. Furthermore, Zhang *et al.* (2000), Awad (2013) and Okasha *et al.* (2013) with maize crop recorded a similar trend.

Seasonal consumptive use (CU, m^3fed^{-1}):

The crop consumptive use is affected by natural factors such as prevailing weather and soil type and topography. In addition, the management factors including water supply and quality, crop variety, fertilization level, irrigation practice... etc are also affecting consumptive use. Results in Table 7 reveal that, seasonal CU for onion was clearly differed due to the adopted irrigation schemes, and the highest values i.e. 1712.28 and 1642.37 m^3fed^{-1} were recorded under EFI in 2012/2013 and 2013/2014 seasons, respectively. The Cu values tended to reduction under AFI_{28} and AFI_{14} regimes, where the reduction amounted to 17.98 and 5.71% in 1st season, and 19.83 and 6.63% in 2nd season, respectively, comparable with EFI regime. Such reduction in CU with AFI_{28} and AFI_{14} regimes is attributable to lower applied water and soil moisture content that subjected to canopy transpiration and surface soil evaporation, which directly responsible for lower CU values. In connection, Ibrahim and Emara (2010) and Awad (2013) with sugar beet and corn crops, respectively, reported that water applied throughout traditional furrow irrigation was higher than that applied via AFI regime.

Table 6: Total soluble solids (TSS %) and dry mater (DM %) as affected by irrigation treatments and nitrogen levels in 2012/2013 and 2013/2014 seasons.

Irrigation schemes (I)	Nitrogen levels (N)	2012/2013		2013/2014	
		T.S.S. (%)	D.M. (%)	T.S.S. (%)	*D.M. (%)*
EFI	60 kg $Nfed^{-1}$	13.03	12.75	12.72	*12.33*
	90 kg $Nfed^{-1}$	14.40	13.18	13.07	*12.74*
	120 kg $Nfed^{-1}$	14.04	13.73	13.70	*13.24*
Mean		13.82	13.22	13.16	*12.77*
AFI_{28}	60 kg $Nfed^{-1}$	13.52	13.71	13.18	*13.27*
	90 kg $Nfed^{-1}$	14.43	14.03	14.07	*13.56*
	120 kg $Nfed^{-1}$	14.82	14.68	14.46	*14.20*
Mean		14.26	14.14	13.90	*13.67*
AFI_{14}	60 kg $Nfed^{-1}$	14.53	14.29	14.17	*13.82*
	90 kg $Nfed^{-1}$	14.98	14.76	14.61	*14.27*
	120 kg $Nfed^{-1}$	15.47	15.16	15.09	*14.66*
Mean		14.99	14.74	14.62	*14.25*
N levels mean					
60 kg $Nfed^{-1}$		13.69	13.59	13.36	*13.14*
90 kg $Nfed^{-1}$		14.60	13.99	13.92	*13.52*
120 kg $Nfed^{-1}$		14.78	14.52	14.41	*14.03*
Interaction					
LSD, 05	*(I)*	*0.45*	*0.51*	*0.44*	0.49
	(N)	*0.24*	*0.24*	*0.23*	0.23
	I X N	*0.42*	*0.41*	*0.41*	0.40

As for Cu of onion as affected by the adopted N fertilization rates, data in Table 7 reveal a gradual increase in Cu as N level increased, and the highest values e.g. 1709.90 and 1649.32 m^3fed^{-1} were attained with 120 kg $Nfed^{-1}$ level, respectively, in 2012/2013 and 2013/2014 seasons. The higher CU values under 120 kg $Nfed^{-1}$ level reached to 7.36 and 16.45% in 1st season and 9.78 and 23.02% higher than those with 90 and 60 kg $Nfed^{-1}$ levels, respectively. Such increase in seasonal evapotranspiration following nitrogen application may be attributable to the enhancing effect of N-fertilizer on onion growth which consequently extracted more soil moisture which reflected on higher seasonal water use. In this sense, Kemal (2013) reported that Shallot plant height and number of leaves and CU as well were increased due to increasing N rate, and an increase in N by 1 kg ha^{-1} can increase the marketable and total bulb yields by 0.022 and 0.0158 t ha^{-1}.

Interaction effect of EFI regime and 120 kg $Nfed^{-1}$ level exhibited the highest CU values, and those findings were true in 2012/2013 and 2013/2014 seasons. On the contrary, AFI_{28} regime as interacted with 60 kg $Nfed^{-1}$ resulted in the lowest CU values, in the two seasons of study.

Table 7: Water consumptive use (m3fed-1) as affected by irrigation schemes and nitrogen levels in 2012/2013 and 2013/2014 seasons.

Irrigation schemes (I)	Nitrogen levels (N)	Water consumptive use (m^3fed^{-1})		
		2012/2013	2013/20134	Mean
EFI	60 kg $Nfed^{-1}$	1565.32	1475.45	1520.39
	90 kg $Nfed^{-1}$	1712.26	1656.31	1684.29
	120 kg $Nfed^{-1}$	1859.25	1795.35	1827.30
Mean		**1712.28**	**1642.37**	**1677.32**
AFI_{28}	60 kg $Nfed^{-1}$	1297.89	1155.83	1226.86
	90 kg $Nfed^{-1}$	1410.70	1325.70	1368.20
	120 kg $Nfed^{-1}$	1504.85	1468.32	1486.59
Mean		**1404.48**	**1316.62**	**1360.55**
AFI_{14}	60 kg $Nfed^{-1}$	1422..76	1390.80	1406.78
	90 kg $Nfed^{-1}$	1655.25	1525.25	1590.25
	120 kg $Nfed^{-1}$	1765.60	1684.28	1724.94
Mean		**1614.54**	**1533.44**	**1573.99**
N levels mean				
60 kg $Nfed^{-1}$		1428.66	1340.69	1384.68
90 kg $Nfed^{-1}$		1592.74	1502.42	1547.58
120 kg $Nfed^{-1}$		1709.90	1649.32	1679.61

Irrigation Water productivity (IWP, kgm^{-3}) and Water Use Efficiency (WUE, kgm^{-3}):

Data in Table 8 cleared that less applied irrigation water under AFI_{28} regime resulted in higher IWP values comprised 24.22 and 23.30% more than with EFI regime, respectively, in 2012/2013 and 2013/2014 seasons. Similar trends were noticed with AFI_{14} regime, however, the increases in IWP were less and amounted to 16.86 and 17.80%, in 2012/2013 and 2013/2014 seasons respectively, comparable with EFI regime. Regarding WUE for onion crop as influenced by the adopted irrigation regimes, AFI_{14} regime enhanced WUE values by 15.37 and 1.31% in 1st season and by 17.25 and 0.83% in 2nd season as compared with EFI and AFI_{28} irrigation regimes, respectively. These findings confirmed that AFI_{14} regime is advantageous compared with AFI_{28} regime because of improving IWP and WUE via reducing both the applied irrigation water and CU values with increasing onion bulb yield, whereas improving IWP and WUE due to AFI_{28} is attributed to lower applied water and CU values, which accompanied with reduced bulb yield. El- Sharkawy *et al.* (2006) stated that (AFI) improved crop water utilization efficiency for onion crop. Similar trends were recorded by Abdel-Maksoud *et al.* (2002) with maize crop.

Table 8: Irrigation Water Productivity, Water Use Efficiency, N Use Efficiency and Consumptive Use Efficiency as affected by irrigation schemes and/or nitrogen levels in 2012/2013 and 2013/2014 seasons.

Irrigation schemes (I)	Nitrogen level	2012/2013				2013/2014			
		IWP (kgm^{-3})	WUE (kgm^{-3})	Ecu (%)	NUE ($kgkgN^{-1}$)	IWP (kgm^{-3})	WUE (kgm^{-3})	Ecu (%)	NUE ($kgkgN^{-1}$)
EFI	60 $kgNfed^{-1}$	5.91	8.49	69.66	186.67	5.18	7.76	66.79	167.50
	90 $kgNfed^{-1}$	7.37	9.67	76.20	157.67	6.32	8.43	74.97	137.67
	120 $kgNfed^{-1}$	7.90	9.55	82.74	128.08	7.05	8.68	81.27	117.92
Mean		**7.06**	**9.24**	**72.87**	**157.47**	**6.18**	**8.29**	**74.34**	**141.03**
AFI_{28}	60 $kgNfed^{-1}$	7.63	9.92	76.87	176.00	6.62	9.54	69.32	158.67
	90 $kgNfed^{-1}$	9.03	10.81	83.55	143.00	7.66	9.64	79.51	124.67
	120 $kgNfed^{-1}$	9.66	10.84	89.13	113.92	8.59	9.75	88.06	104.92
Mean		**8.77**	**10.52**	**83.18**	**144.31**	**7.62**	**9.64**	**78.96**	**129.42**
AFI_{14}	60 $kgNfed^{-1}$	7.39	10.82	68.30	225.33	6.53	9.63	67.86	203.00
	90 $kgNfed^{-1}$	8.41	10.58	79.46	171.00	7.22	9.70	74.42	148.89
	120 $kgNfed^{-1}$	8.96	10.57	84.75	136.33	8.08	9.84	82.18	125.58
Mean		**8.25**	**10.66**	**77.50**	**177.55**	**7.28**	**9.72**	**74.82**	**159.13**
N levels mean									
60 $kgNfed^{-1}$		6.98	9.74	71.61	196.00	6.11	8.98	67.99	176.39
90 $kgNfed^{-1}$		8.27	10.35	79.74	157.22	7.07	9.26	76.30	137.08
120 $kgNfed^{-1}$		8.84	10.32	85.54	126.11	7.91	9.42	83.84	116.14

As for nitrogen fertilization, the results indicate that the irrigation water productivity was increased gradually as nitrogen levels increased, and the highest values e.g. 8.84 and 7.91 kgm^{-3} were recorded with 120 kg $Nfed^{-1}$ level in the two seasons of study. The value tended to reduction with 90 and 60 kg $Nfed^{-1}$ level to be 6.45 and 21.04% in 1st season, and to 10.62 and 22.76% in 2nd season, respectively, lower than IWP under 120 kg $Nfed^{-1}$ level. In connection, Kemal (2013) reported that WUE for Shallot plant was gradually increased due to increasing N level.

Nitrogen Use Efficiency (NUE, $kgkgN^{-1}$)

Data in Table 8 indicated that AFI_{14} regime exhibited higher NUE values, which comprised 177.55 and 159.13 $kgkgN^{-1}$ in 2012/2013 and 2013/2014 seasons, respectively. Values of NUE tended to reduction, under EFI and AFI_{28} regimes comparing with AFI_{14} regime, by 11.31 and 18.72% in 1st season, and by 11.37 and 18.67% in 2nd one. These findings still proving that onion crop, was capable to use N input efficiently under AFI_{14} regime.

Data revealed that increasing N level was accompanied with gradual reduction in NUE, where the reduction reached to 24.11 and 39.50% in 1st season and to 26.66 and 38.14% in 2nd season under 90 and 120 $kgNfed^{-1}$ levels, respectively, lower than those with 60 kg $Nfed^{-1}$ level.

Interaction of AFI_{14} regime and 60 kg $Nfed^{-1}$ level resulted in the highest NUE values, which comprised 255.33 and 203.00 kg kgN^{-1}, respectively, in 2012/2013 and 2013/2014 seasons.

Consumptive use efficiency (Ecu,%):

In general term, efficiency is a ratio of output to input expressed as percentage. Similarly irrigation efficiency is also expressed as a percentage and is a ratio of irrigation water utilized to the water supplied. The consumptive use efficiency is directly influenced by water placement technique, soil characteristics and plant growth and weather conditions as well. Ecu, % is referred to the capability of the plants to utilize the water stored in the effective root zone plus that evaporated from the soil surface. Data in Table 8 show that the highest Ecu% were recorded with AFI_{28} regime, which reached to 83.18 and 78.96%, comparing with (72.87 and 74.34%) and (77.50 and 74.82%), respectively, in 1st and 2nd seasons under EFI and AFI_{14} regimes. It is seems that AFI_{28} regime is superior in this respect, however, AFI_{14} regime is actually preferable due to both higher onion bulb yield and water use efficiency compared with AFI_{28} regime.

Data revealed that Ecu% was gradually improved with increasing N level, and such trend was true in the two seasons of study. The increase percentages in Ecu% under 120 $kgNfed^{-1}$ level were 24.08 and 6.66% in 1st season and 21.10 and 10.43% in 2nd season, respectively, comparable with 60 and 90 $kgNfed^{-1}$ levels. Such findings are attributable to vigorous growth and higher onion yield, under 120 $kgNfed^{-1}$ level, which in turn the crop consumed more available water that stored in the root zone.

Interaction data illustrated that 120 $kgNfed^{-1}$ level as interacted with either AFI_{28} or AFI_{14} regimes resulted in Ecu% acceptable figures.

CONCLUSION

Alternate-furrow irrigation with appropriate irrigation timing e.g. 14 days interval can be used as an efficient method for onion production in semi-arid areas where the production is depended heavily on irrigation. It could be observed that the AFI_{14} regime is capable to mitigate the water stress, during an irrigation cycle, and to increase onion bulb yield. In addition, it is obviously noticed that the alternate furrow irrigation at 14-days interval and120 $kgNfed^{-1}$ is the best combination to achieve higher marketable onion bulb yield and to improve irrigation and N use efficiencies as well.

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تأثير الري التبادلي للخطوط تحت مستويات مختلفة من التسميد النيتروجينى علي أداء نباتات البصل تحت ظروف اقليم مصر الوسطي – مصر

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الملخص العربى

أجريت تجربتان حقليتان خلال موسمي ٢٠١٢/٢٠١٣ ، ٢٠١٣/٢٠١٤ بمحطة البحوث الزراعية بسدس – محافظة بني سويف وذلك لدراسة تأثير نظامي الري التبادلي للخطوط (كل ١٤ ، ٢٨ يوم مقارنة بالري العادي بالخطوط كل ٢٨ يوم) و ثلاث مستويات من التسميد النيتروجينى هي٦٠ ، ٩٠ ، ١٢٠ كجم نيتروجين /فدان على أداء نباتات البصل والإنتاجية وكفاءات مياة الري و النتروجين وكفاءة الاستهلاك المائي ، وأظهرت النتائج ما يلي :

١- زيادة المحصول القابل للتسويق والمحصول الكلى بنسبة (١١.٠٤ ، ٨.٣٩ %) ، (١١.٠٧، ٩.٢٢ %) عند تطبيق الري التبادلي كل ١٤ يوم بينما انخفض بنسبة (٨.٩٨ ، ٦.٦٢%) ، (٨.٩٣ ، ٦.٩٥%) عند تطبيق الري التبادلي كل ٢٨ يوم مقارنة بتطبيق الري بالخطوط العادية في كلا من الموسمين على الترتيب. كما أدى تطبيق الري التبادلي كل ١٤ يوم إلى انخفاض محصول الأبصال النقضة مقارنة بتطبيق الري بالخطوط العادية وكذلك الري التبادلي للخطوط كل ٢٨ يوم. أدى الري التبادلي كل ١٤ يوم إلى تسجيل أعلى القيم لكل من وزن وقطر البصلة وكذلك نسبة المواد الصلبة الذائبة والمادة الجافة مقارنة بتطبيق الري بالخطوط العادية والري التبادلي للخطوط كل ٢٨ يوم خلال موسمي النمو

٢- سجلت أعلى قيم للماء المضاف والاستهلاك المائي تحت معاملة الري بالخطوط العادية (ري كل الخطوط) بينما أقل القيم تحت معاملة الري التبادلي للخطوط كل ٢٨ يوم. وقد أدى الري التبادلي للخطوط كل ١٤ ، ٢٨ يوم إلى التوفير في ماء الري المضاف بنسبة حوالي (٧.٢٩، ٢٤.٨٦ %) ، (٧.٢٢ ، ٢٤.٥٢ %) خلال موسمي النمو على ،الترتيب مقارنة بالري بالخطوط العادية.

٣- تطبيق الري التبادلي كل ١٤ أدي الي تحسين انتاجية مياه الري و كفاءة استخدام المياة و النتروجين بينما تحسنت كفاءة الاستهلاك المائي مع الري التبادلي كل ٢٨ يوم مقارنة بمعاملة الري بالخطوط العادية.

٤- أدى زيادة معدل الإضافة من النيتروجين حتى ١٢٠كجم نيتروجين للفدان إلى الحصول على أعلى القيم لجميع الصفات تحت الدراسة وكذلك تحسين كفاءات الري خلال موسمي النمو.

ومن نتائج هذه الدراسة يمكن استنتاج أن تطبيق الري التبادلي كل ١٤ يوم والتسميد بمعدل ١٢٠ كجم نيتروجين/فدان أعطى أعلى القيم للمحصول التسويقي للبصل كما أدي الي تحسين كفاءات الري و النتروجين .

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