J.Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 6 (8): 961 - 982, 2015

MAXIMIZING WATER PRODUCTIVITY BY INTERCROPPING ONION ON SUGAR BEET IN THE NORTH MIDDLE NILE DELTA REGION.

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ABSTRACT

Two field experiments were conducted at Sakha Agricultural Research Station, Kafr El-Sheikh Governorate, during the two successive seasons 2012/2013 and 2013/2014. The investigation was aimed to maximize water productivity by intercropping onion on sugar beet through investigate the effect of irrigation and intercropping treatments on onion and sugar beet yield, yield components, quality and some water relations in the North Middle Nile Delta region (31^0 07^- N Latitude and 30^0 57^- E longitude with an elevation of about 6 metres above mean sea level). The experimental design was split plot with three replicates, the main plots were randomly assigned by three irrigation treatments, I_1 (irrigation with 0.8 Ep), I_2 (irrigation with 1.0 Ep) and I_3 (irrigation with 1.2 Ep), while sub main plots were also randomly assigned by intercropping treatments, D_1 (Intercropping onion with sugar beet by planting sugar beet as in pure stand and planting one row only of onion on the back of bed as in pure stand), D_2 (Intercropping onion with sugar beet by planting sugar beet as in pure stand and planting two row only of onion on the back of bed as in pure stand), D_3 (Intercropping onion with sugar beet by planting sugar beet as in pure stand and planting three row only of onion on the back of bed as in pure stand), D_4 (pure stand of sugar beet was planted in bed 120 cm width, spaced 20 cm between hills on both sides of beds to give 35000 plants/ fad.) and D_5 (pure stand of onion with planted in rows on the back of bed, 120 cm width, 15 cm between rows and hills).

The main results can be summarized as follows:

- The highest values for water applied (Wa) and consumptive use (Cu) were recorded under irrigation treatment I_3 and the values are 69.03 cm. (2899.41 m^3/fed.), 73.23 cm. (3075.55 m^3/ fed.) for Wa and 41.26 cm. (1733.13 m^3/fed.) and 42.25 cm. (1774.55 m^3/ fed.) for Cu in the first and second growing seasons, respectively. Meanwhile, the lowest overall mean values for Wa and Cu were recorded under irrigation treatment I_1 and the values are 60.89 cm. (2557.33 m^3/fed.) and 34.84 cm (1463.26 m^3/fed.) for Wa and Cu, respectively. For intercropping treatments, didn't have any effect on Wa but for Cu, the highest mean values were recorded under D_4. On the other hand, the lowest recorded under D_5. Generally, the values of Cu can be descended in order $D_4 > D_3 > D_2 > D_1 > D_5$ in the two seasons.
- The highest values for water productivity (WP) and productivity of irrigation water (PIW) were recorded under I_2 and the values are 23.3 and 22.3 kg/ m^3 for WP and 10.3 and 9.3 kg/ m^3 for PIW in the first and second growing seasons, respectively. Meanwhile, the lowest mean values were recorded under I_3 and the values are 18.4 and 17.7 kg/ m^3 for WP and 8.5 and 8.0 kg/ m^3 for PIW in the first and second growing seasons, respectively. For consumptive use efficiency (Ecu), the highest values were recorded under I_3 and the values are 45.98 and 44.69% but the lowest were recorded under I_1 and the values are 42.86% and 40.38% in the first and second seasons, respectively. Regarding, the effect of intercropping treatments

generally, the highest values were recorded under D_4 but the lowest under D_5 in the two seasons.

- Sugar beet yield, yield components and quality were highly significantly affected by irrigation (I), intercropping treatments (D), and the interactions between (I * D) in the two growing seasons. Generally, the highest mean values for the studied parameters were recorded under irrigation treatment under I_2 and intercropping pattern D_4 (pure sugar beet).
- Onion yield and the studied yield attributes, were highly significantly affected by irrigation (I), intercropping patterns (D) and the interactions between (I * D) in the two seasons. Generally, the mean values for onion yield and yield attributes can be descended in order $I_2 > I_3 > I_1$ in the two seasons. Concerning, intercropping patterns, the highest mean values were recorded under D_4 (pure onion cultivation) in comparison with other intercropping patterns in the two seasons.
- Regarding, the interactions between irrigation treatments (I) and intercropping systems (D) & (I * D) showed highly significant effect on all the studied parameters for sugar yield, yield components and quality and also for onion yield and yield components.
- Concerning, land equivalent ratio (LER), the values can be descended in order $I_3 > I_2 > I_1$. While, for gross return $I_2 > I_3 > I_1$. The effect of intercropping treatments, the highest mean values for (LER) and gross return were recorded under D_3 but the lowest under D_1 .

Keywords: Sugar beet, onion, irrigation regime, water productivity, water consumptive use, water applied, productivity of irrigation water and consumptive use efficiency.

INTRODUCTION

Sugar beet is one of the most important crops not only in Egypt but also world wide, production of sugar is not enough. So, the agricultural policy has been given much attention to grow sugar beet to narrow the gap between production and consumption. Increasing sugar yield per unit area had national interest and it can be achieved by adopting suitable cultural practices such as intercropping systems to maximize productivity of both soil and water units. The area that allocated to sugar beet in Egypt had increased mostly in the recent years (16900 fad. in 1982 season to 450000 fad. in 2012 season), also, the contribution of sugar beet to sugar production increased largely, as it reached 35.5% of the total sugar production in 2012 season. Since the cultivated area in Egypt is limited, the agricultural intensification had become urgent necessity to optimize the utilizing of unit area.

Onion (Allium cepa L.) is a valuable crop since ancient times and ranks second after Tomatoes crop in the list of the worldwide cultivated vegetables. In 2010, about 74 million tons of onions were produced in 3.7 million hectares according to the FAOSTAT database *(FAO, 2012)*. In Egypt, total harvested area was 61535 ha. Producing 2208080 metric tons *(FAOSTAT, 2010).* The unit of both water and area productivity still low and it is needed to be increased according to the increasing people demands throughout improved agricultural practices such as irrigation management and intercropping system to maximize productivity of water and soil units.

In Egypt, irrigated agriculture is the dominant type of farming. The rapid increasing in water demand. Irrigation uses more than 85% of the total renewable water supply. Moreover, the annual per capita of water for different purposes is in decreasing gradually to less than the water poverty edge 1000 m^3 per annum *(EL-Quosy, 1998)*, in addition, the water demand is continuously increasing due to population growth, increased economic activities and the escalating standards of living, and it is prospected to reach to the threshold level of less than 500 m^3/y/capita. *Ustun et al. (2014)* found that effect of full root zone wetting and partial root zone drying irrigation techniques with 4 and 8 day (12) irrigation intervals increased by 34.9% irrigation water use efficiency of sugar beet. *Yonts (2011)* expressed that root and sugar yield of sugar beet was the highest for full irrigation and sugar content did not significantly change by reducing irrigation to 25%. *Kiziloglu et al. (2006)* indicated that the deficit in irrigation practices significantly decreased root, leaf, and total sugar yield of sugar beet under semiarid and cool season climatic conditions. There was a linear relationship between evapotranspiration and root yield. Water use efficiency was the highest at non-irrigated conditions.

The intercropping system greatly contributes to crop production by its effective utilization of resources, as compared to the monoculture cropping system *(Zhang and Li, 2003).* Currently, this system was interestingly increasing in low-input crop production systems and was being extensively investigated *(Li et al., 1999). Besheit et al. (2002)* found that the highest sugar beet quality and productivity were obtained from beet planted on ridge (100 cm) width and intercropped with two onion rows, while intercropping onion on the other side of sugar beet ridge (50 cm) width was higher and negativity affected sugar beet quality and quantity.

Under the importance of sugar beet and onion crops and the limited of irrigation water resources. So, studying irrigation scheduling for these crops becomes urgent necessity. Therefore, the main targets for this present study were to:

- Investigate the effect of intercropping onion with sugar beet on yield, quality of sugar beet as well as on land equivalent ratio and the net income.
- Study water behavior of onion which intercropped on sugar beet.
- Maximize productivity of both soil and water units.
- Study some water relations for onion and sugar beet as well as water productivity and productivity of irrigation water.

MATERIALS AND METHODS

Two field experiments were conducted at Sakha Agricultural Research Station, kafr El–Sheikh Governorate. The station is situated at 31^o-07' N latitude, 30^o-57' E longitude with an elevation of about 6 metres above mean sea level. It represents the conditions and circumstances of the Northern part of the Middle Nile Delta region. The investigation was to maximize water productivity by intercropping onion on sugar beet through investigate the effect of irrigation and intercropping treatments on onion and sugar beet yield, yield components, quality and some water relations. Agro meteorological data of Sakha station during the two successive winter growing seasons 2012/2013 and 2013/2014, in Table (1).

Table (1): Mean of some Agro meteorological data for kafr El –Sheikh area during the two growing seasons.

a- 2012/2013 season.

Month	T (C^0)			RH (%)			$W_{s,}$ m/sec	Pan Evap., mm.	Rain, mm
	Max	Min	Mean	Max	Min	Mean			
Nov.	25.32	15.47	20.40	89.53	61.80	75.67	0.66	1.87	28.20
Dec.	21.35	10.52	15.94	84.77	60.83	72.80	0.73	2.25	13.02
Jan.	19.22	7.62	13.42	91.06	65.35	78.21	0.52	1.99	78.74
Feb.	20.68	8.88	14.78	89.89	64.04	76.97	0.73	2.89	-------
Mar.	24.56	12.45	18.51	79.48	50.84	65.16	1.03	4.46	-------
April.	26.04	15.87	20.96	74.20	43.90	59.05	1.11	5.30	8.40
May	31.43	21.85	26.64	75.03	45.78	60.41	1.20	6.35	------

b- 2013/2014 season.

Month	T (C^0)			RH (%)			Ws, m/sec	Pan Evap., mm.	Rain, mm
	Max	Min	m/sec	Max	Min	Mean			
Nov.	25.39	15.14	20.27	87.00	64.43	75.72	0.80	2.28	-------
Dec.	19.64	8.51	14.06	92.07	67.61	79.84	0.61	4.15	81.9
Jan.	20.34	7.55	13.95	93.69	70.55	80.55	0.54	1.60	20.7
Feb.	20.64	8.19	14.42	91.90	67.15	79.53	0.79	2.52	16.5
Mar.	22.94	11.71	17.33	86.10	56.80	71.45	0.96	3.14	26.2
April.	27.50	15.53	21.52	81.80	49.80	65.8	1.07	4.91	20.2
May	30.47	19.57	25.02	77.20	48.60	62.90	1.14	5.87	-----

Source: Meteorological Station at Sakha Agricultural Research Station 31°-07N latitude, 30°-57E longitude with an elevation of about 6 metres a above mean sea level.
T = Air temperature,
RH = Relative humidity and
Ws = Wind speed.

Some physical and chemical characteristics of the studied site were shown in Tables (2and 3), of particle size distribution, soil bulk density, soil field capacity and permanent wilting point were determined according to (Klute, 1986) in Table (2). The studied chemical characteristics, in Table (3): Soil reaction (pH) in 1:2.5 soil water suspension, Total soluble salts (Ec_e) and soluble cations and anions were determined in soil paste extract by the standard methods as described by (Jackson, 1973).

Table (2): The mean values of some physical characteristics of the studied site before cultivation

Soil Depth, cm.	Particle Size Distribution			Texture classes	F.C %	P.W.P %	AW %	Bd, Mg/m^3
	Sand%	Silt %	Clay %					
0 – 15	17.1	20.8	62.1	Clay	48.6	24.9	23.7	1.18
15 – 30	19.3	22.7	58.0	Clay	41.7	22.3	19.4	1.23
30 – 45	18.6	23.5	57.9	Clay	39.2	22.1	17.1	1.27
45 – 60	20.1	23.7	56.2	Clay	37.3	20.3	17.0	1.35
Mean	18.8	22.7	58.6	Clay	41.7	22.4	19.3	1.26

Where:-

F.C % = Soil field capacity,
P.W.P % = Permanent wilting point,
AW % = Available water and
Bd, Mg/m^3 = Soil bulk density.

Table (3): The mean values of some chemical characteristics of the studied site before cultivation

Soil Depth, Cm	Ec, dS/m	PH 1: 2.5 soil water Suspension	Soluble ions, meq/ L							
			Soluble cations, meq/L				Soluble anions, meq/L			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
0-15	2.77	8.41	11.05	7.69	18.22	8.99	0.00	6.17	17.21	22.57
15-30	3.00	8.22	15.72	7.05	17.68	10.07	0.00	6.09	16.67	27.76
30-45	3.26	8.13	19.33	6.88	15.11	8.55	0.00	6.02	16.15	27.70
45-60	3.96	7.95	20.17	5.14	11.99	3.26	0.00	5.81	13.97	20.78
Mean	3.25	8.18	16.57	6.69	15.75	6.90	0.00	6.02	16.00	24.70

Note: SO_4^{--} was determined by the difference.

The treatments were arranged in a spilt plot design with three replicates as follows:-

The main treatments (irrigation levels, I):

I_1 = irrigation with 0.8 Ep (Pan evaporation),
I_2 = irrigation with 1.0 Ep and
I_3 = irrigation with 1.2 Ep.

The sub main treatments (intercropping systems, D):

D_1 = Intercropping onion with sugar beet by planting sugar beet as in pure stand and planting one row only of onion on the back of bed as in pure stand, this provides 125% total population. i.e. 100% sugar beet plus 25% of onion.

D_2 = Intercropping onion with sugar beet by planting sugar beet as in pure stand and planting two row only of onion on the back of bed as in pure stand, this provides 150% total population. i.e. 100% sugar beet plus 50% of onion.

D_3 = Intercropping onion with sugar beet by planting sugar beet as in pure stand and planting three row only of onion on the back of bed as in pure stand, this provides 175% total population. i.e. 100% sugar beet plus 75% of onion.

D_4 = pure stand of sugar beet was planted in bed 120 cm width, spaced 20 cm between hills on both sides of beds to give 35000 plants/ fad.

D_5 = pure stand of onion with planted in rows on the back of bed, 120 cm width, cm between rows and hills.

Sugar beet and onion a winter crops were planted on 28/10/2013 and 17/11/2013 and harvested 6/6/2014 in first, and in second season 25/10/2014 and 14/11/2014 and harvested 15/6/2015, respectively. The recommended seed rate is 4 kg/fed. Of sugar beet (Beta Vulgaris L.) variety Gloria Cv. and 3 kg/fed of onion (Allium cepa L.) variety Giza 20 Cv. All agronomic practices and fertilization were performed as recommended for the crops and the studied area except the studied treatments. The area of each plot was 12.6 m^2 (3.5 m length * 3.6 m width), with ridges 120 cm width, 3.5 m in length.

*** Data collection:-**

1- Amount of irrigation water applied (m^3/fed)

Amount of irrigation water applied for each irrigation was measured using cut throat flume (30*90 cm) and then seasonal water applied was recorded during the whole growing season and calculated as m^3/ fed. according to *(Early, 1975)*. Then the water applied was computed as follows:-

$$\mathbf{Wa = Iw + R}$$

Where:

Wa = Water applied,

Iw = The amount of water delivered by irrigation, and

R = Effective rainfall.

2- Water consumptive use (m^3/fed.):

Water consumptive use was calculated as soil moisture depletion (SMD) according to *Hansen et al. (1979)*.

$$\mathbf{Cu = SMD =} \sum_{i=1}^{i=N} \frac{\theta_2 - \theta_1}{100} \mathbf{\,*\, Dbi \,*\, Di \,*\, 4200}$$

Where:

CU = Water consumptive use in the effective root zone (60 cm),

Θ_2 = Gravimetric soil moisture percentage 48 hours after irrigation,

Θ_1= Gravimetric soil moisture percentage before irrigation,

Dbi = soil bulk density (Mg/m^3) for the given depth,

D_i = soil layer depth (20 cm),

i = Number of soil layers each (15 cm) depth and 4200= Area of fadden (m^2).

3- Water productivity (WP, kg/m^3):

Water productivity is generally defined as crop yield per cubic meter of water consumption. Water productivity is defined as crop production per unit amount of water used *(Molden, 1997)*. Concept of water productivity in agricultural production systems is focused on producing more food with less water resources or producing the same amount of food with less water resources. Water productivity was calculated according to *(Ali et al., 2007)*.

$$\mathbf{Wp =} \frac{Y}{ET}$$

Where:

WP = water productivity (kg /m^3),

Y = Seed yield (kg/fed) and

ET = Total water consumption, m^3/ fed.

4- Productivity of irrigation water (PIW, kg root/m^3)

Productivity of irrigation water (PIW) as calculated according to *(Ali et al., 2007)*

$$PIW = y / Wa$$

Where:

PIW = productivity of irrigation water (kg /m^3),
y = Seed yield kg/fed and
Wa = seasonal water applied, (m^3/fed.) (irrigation water + effective rainfall).

5- Consumptive use efficiency (Ecu, %):

Values of consumptive use efficiency (Ecu) was calculated according to Bos (1980).

$$Ecu = (ETc / Wa) * 100$$

Where:

Ecu = Consumptive use efficiency (%),
ETc = Total evapotranspiration ~ consumptive use and
Wa = Water applied to the field.

Competitive relationships and yield advantages:

1-Land equivalent ratio (LER):

This was determined according to *Willey (1979)*:

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

Where:

Yab = Mixture yield of a (when combined with b).
Yaa = Pure stand yield of crop (a).
Yba = Mixture yield of b (when combined with a).
Ybb = Pure stand yield of crop (b).

Economic evaluation:-

Gross return (L.E.fed^{-1}):

Gross return from each treatment was calculated in Egyptian pounds (L.E.)/ton of sugar beet and (L.E.)/ton of onion in both seasons as follows:-

Ton of sugar beet = 275 L.E. and ton of onion = 1400 L.E. for the first season, and Ton of sugar beet = 350 L.E. and ton of onion = 1700 L.E. for the second season.

Price of sugar beet was obtained by Egyptian sugar and Integrated Industries Company and price of onion was obtained by market search.

Yield and yield components:

1-Sugar beet growth and quality:

- Root yield ton fed^{-1}: was taken from one ridge and repeated 3 times for each treatment.
- Root diameter (cm).
- Root length (cm).
- Root fresh weight plant^{-1}.
- Gross sugar yield, kg fed.$^{-1}$
- Number of leaves plant^{-1}.
- Leaves weight plant^{-1} (gm.).
- TSS (total soluble solids, %).

- Sucrose % (pol %) was estimated in fresh samples of sugar beet root using saccharometer according to the method described by *A.O.A.C (1995).*
- Purity (%).

2-Onion growth: - At 90 days from transplanting the onion traits were determined;

- Bulb yield ton fed^{-1}.
- Plant height (cm).
- Number of leaves.
- Bulb diameter (cm).
- Bulb weight (gm.)

Statistical analysis:

The collected data were statistically analyzed according to the technique of analysis of variance for the spilt plot design by means of "MSTAT-C computer software package by *Freed et al. (1988)* according to *Gomez and Gomez (1984)*. Means of the treatments were compared by the least significant difference (LSD) at 5 % level of significance which developed by Waller and Duncan (1969).

RESULTS AND DISCUSSION

Effect of irrigation and intercropping treatments on:

1- Irrigation water applied:

Presented data in Table (4) clearly showed that, sugar beet and onion consider winter field crops. So, the seasonal water applied (Wa) of the two studied crops consists of the two main components, these are irrigation water delivered to the field plot (IW) and rainfall. The total amount of the effective rainfall during the two growing seasons of crops was 12.836 cm. (539.11 m^3 / fed.) and 16.55 cm. (695.10 m^3 / fed.) in the first and second growing seasons, respectively. As reported in Table (4), irrigation treatments were greatly affected on irrigation water delivered in two growing seasons. The highest seasonal values for water applied were recorded under irrigation treatment I_3 (irrigation with 1.2 Ep) and the values are 69.03 cm (2899.41 m^3 / fed.) and 73.23 cm (3075.55 m^3 / fed.) in the first and second growing seasons, respectively. Meanwhile, the lowest seasonal values were recorded under irrigation treatment I_1 (irrigation with 0.8 Ep) and the values are 58.79 cm (2469.26 m^3 / fed.) and 62.99 cm (2645.40 m^3 / fed.) in the first and second growing seasons, respectively. Generally, the seasonal values of water applied can be descended in order $I_3 > I_2 > I_1$. Increasing the seasonal values of water applied under irrigation treatment I_3 in comparison with other irrigation treatments I_2 and I_1 might be attributed to increasing time of irrigation and hence increasing the amount of water applied. These results are in a great harmony with those reported by *Khalifa and Ibrahim (1995), Gharib and El-Henawy (2011), Mona. S. M. Eid (2012) and Moursi and Darwesh (2014).* Data in the same table also illustrated that intercropping system didn't have any effect on seasonal water applied.

Table(4): Effect of irrigation treatments and intercropping systems on amount of seasonal water applied for onion intercropped on sugar beet in the two growing seasons.

Irrigation Treatments (I)	Intercropping systems (D)	1st growing season 2012/2013		2nd growing season 2013/2014		The overall mean values during the two growing seasons	
		cm.	m^3/ fed.	cm.	m^3/ fed.	cm.	m^3/ fed.
I_1	D_1	58.79	2469.26	62.99	2645.40	60.89	2557.33
	D_2	58.79	2469.26	62.99	2645.40	60.89	2557.33
	D_3	58.79	2469.26	62.99	2645.40	60.89	2557.33
	D_4	58.79	2469.26	62.99	2645.40	60.89	2557.33
	D_5	58.79	2469.26	62.99	2645.40	60.89	2557.33
Mean		58.79	2469.26	62.99	2645.40	60.89	2557.33
I_2	D_1	61.41	2579.31	65.84	2765.45	63.63	2672.38
	D_2	61.41	2579.31	65.84	2765.45	63.63	2672.38
	D_3	61.41	2579.31	65.84	2765.45	63.63	2672.38
	D_4	61.41	2579.31	65.84	2765.45	63.63	2672.38
	D_5	61.41	2579.31	65.84	2765.45	63.63	2672.38
Mean		61.41	2579.31	65.84	2765.45	63.63	2672.38
I_3	D_1	69.03	2899.41	73.23	3075.55	71.13	2987.48
	D_2	69.03	2899.41	73.23	3075.55	71.13	2987.48
	D_3	69.03	2899.41	73.23	3075.55	71.13	2987.48
	D_4	69.03	2899.41	73.23	3075.55	71.13	2987.48
	D_5	69.03	2899.41	73.23	3075.55	71.13	2987.48
Mean		69.03	2899.41	73.23	3075.55	71.13	2987.48

2- Water consumptive use (Cu, cm & m^3 / fed.):

Water consumptive use or which so-called evapotranspiration for any crop means the summation of the two components evaporation (E) from the soil surface and transpiration (T) from plant surface. Tabulated data in Table (5) clearly indicated that, the overall mean values for water consumptive use were greatly affected by both irrigation and intercropping treatments. Concerning, the effect of irrigation treatments on water consumptive use, under all intercropping systems, the highest overall mean values for (Cu) were recorded under irrigation treatment I_3 (irrigation with 1.2 Ep) and the value is 41.76 cm (1753.84 m^3 / fed.). Meanwhile, the lowest overall mean value was recorded under irrigation treatment I_1 (irrigation with 0.8 Ep.) and the value is 34.84 cm. (1463.26 m^3 / fed.). Generally, the overall mean values of water consumptive use can be descended in order $I_3 > I_2 > I_1$ and the values are 41.76cm (1753.84 m^3 / fed.), 36.58 (1536.19 m^3 /fed.) and 34.84 cm (1463.26 m^3 /fed.) for I_3, I_2 and $I_{1,}$ respectively. Increasing the values of water consumptive use under irrigation treatment I_3 in comparison with other irrigation treatments I_2 and I_1 might be attributed to increasing the amount of water applied under the conditions of this treatment and hence forming strong plants with a thick vegetative growth. Consequently, increasing the exposed area to sunlight, therefore, increasing transpiration from plant surfaces which considers one of the main components of water consumptive use in addition evaporation. These results are in a great agreement with those reported by *Gharib and El-Henawy (2011), Mona, S. M. Eid (2012) and Moursi and Darwesh (2014).*

Table(5): Effect of irrigation treatments and intercropping systems on water consumptive use (cm. & m³/ fed.) for onion intercropped on sugar beet in the two growing seasons.

Irrigation Treatments (I)	Intercropping systems (D)	1st growing season 2012/2013		2nd growing season 2013/2014		The overall mean values during the two growing seasons	
		cm.	m³/ fed.	cm.	m³/ fed.	cm.	m³/ fed.
I_1	D_1	34.62	1453.98	34.79	1461.23	34.71	1457.61
	D_2	35.09	1473.88	35.29	1482.15	35.19	1478.02
	D_3	35.56	1493.53	35.67	1498.22	35.62	1495.88
	D_4	35.70	1499.57	35.80	1503.43	35.75	1501.50
	D_5	32.64	1370.97	33.23	1395.64	32.94	1383.31
Mean		34.72	1458.39	34.96	1468.13	34.84	1463.26
I_2	D_1	36.43	1529.88	36.71	1541.72	36.57	1535.80
	D_2	36.82	1546.34	37.15	1560.18	36.99	1553.26
	D_3	37.23	1563.52	37.44	1572.28	37.34	1567.90
	D_4	37.40	1570.96	37.74	1585.14	37.57	1578.05
	D_5	33.82	1420.37	35.04	1471.53	34.43	1445.95
Mean		36.34	1526.21	36.81	1546.17	36.58	1536.19
I_3	D_1	42.16	1770.55	42.39	1780.32	42.28	1775.44
	D_2	42.43	1781.91	42.68	1792.49	42.56	1787.20
	D_3	42.87	1800.47	43.10	1810.12	42.99	1805.30
	D_4	43.22	1715.12	43.40	1822.72	43.31	1818.92
	D_5	38.04	1597.58	39.69	1667.11	38.87	1632.35
Mean		41.26	1733.13	42.25	1774.55	41.76	1753.84

Regarding, the effect of intercropping treatments under all irrigation treatments, the highest overall mean values were recorded under intercropping treatment D_4 (pure sugar beet) and the values are 43.31 cm.(1819.02 m^3 / fed.), 37.57 cm. (1577.94 m^3 / fed.) and 35.75 cm (1501.50 m^3 / fed.) under I_3 , I_2 and I_1 irrigation treatments, respectively. Also, as shown in the same Table, by increasing plant densities (intercropping systems) on the raised- bed the values of water consumptive use were increased. So, the values of water consumptive use can be descended in order $D_4 > D_3 > D_2 > D_1$ under the two growing seasons and all irrigation treatments. Concerning, intercropping treatment D_5 , the lowest overall mean values for water consumptive use were recorded in comparison with other treatments D_1 , D_2 , D_3 and D_4 because D_5 means (cultivation onion only on the raised-bed without sugar beet and So, the water consumptive use for onion is less than for sugar beet only or sugar beet intercropped with onion. Increasing the overall mean values for water consumptive use under D_4 in comparison with D_5 because of the vegetative growth for sugar beet is bigger than that for onion. So, the losses by transpiration through this cover will be more than those under cultivation onion only and hence, increasing the values of water consumptive use. These findings are in the same line with those reported by *Moursi, et al. (2010) and Moursi, et al. (2014).*

3- Irrigation efficiencies:

Water productivity (WP, kg/ m^3), productivity of irrigation water (PIW, kg/ m^3) and consumptive use efficiency (Ecu, %).

Presented data in Table (6) clearly illustrated that the values of the abovementioned efficiencies (WP, PIW and Ecu) were affected by both the two studied treatments (irrigation and intercropping patterns). Concerning, the effect of irrigation treatments on WP and PIW, the highest mean values were recorded under irrigation treatment I_2 (irrigation with 1.0 Ep) in the two growing seasons and the values are 23.3 and 22.3 kg/ m^3 for WP and 10.3 and 9.3 kg/ m^3 for PIW in the first and second growing seasons, respectively. Meanwhile, the lowest mean values were recorded under irrigation treatment I_3 (irrigation with 1.2 Ep) and the values are 18.4 and 17.7 kg/ m^3 for WP and 8.5 and 8.0 kg/ m^3 for PIW in the first and second growing seasons, respectively. Generally, the mean values for WP and PIW can be descended in order $I_2 > I_1 > I_3$ in the two growing seasons under all intercropping patterns. Increasing the mean values of WP and PIW under irrigation treatment I_2 in comparison with other irrigation treatments I_1 and I_3 in the two growing seasons may be attributed to increasing yield and decreasing the amount of water applied and consumptive use under the conditions of irrigation treatment I_2 comparing with irrigation treatment I_3 which received the highest values for water applied and recorded the highest values for water consumptive use. Consequently, under these conditions recorded the lowest mean values for WP and PIW. These results are in a great harmony with those obtained by *Khalifa and Ibrahim (1995), Gharib and El-Henawy (2011) and Moursi and Darwesh (2014).*

Data in the same Table indicated that the mean values of consumptive use efficiency (Ecu, %) were affected by irrigation treatments under all intercropping treatments. The highest mean values were recorded under irrigation treatment I_3 (irrigation with 1.2 Ep) in the two growing seasons and values are 45.98 and 44.69 % in the first and second growing seasons, respectively. Meanwhile, the lowest mean values were recorded under irrigation treatment I_1 (irrigation with 0.8 Ep.) in the two growing seasons and the values are 42.86 % and 40.38 % in the first and second growing seasons, respectively. Generally, the mean values of Ecu in the two growing seasons can be descended in order $I_3 > I_2 > I_1$. Increasing the mean values of Ecu under irrigation treatment I_3 in comparison with other irrigation treatments I_2 and I_1 may be due to increasing the values of water consumptive use under the conditions of this treatment comparing with I_2 and I_1. These results are in the same line with those reported by *Moursi and Darwesh (2014) and Moursi et al. (2014).*

Regarding the effect of intercropping treatments on WP, PIW and Ecu, data in the same table showed that under all irrigation treatments, intercropping treatments didn't have a clear and static effect on the studied efficiencies. Generally, for all efficiencies, the highest mean values were recorded under intercropping treatment D_4 (pure sugar beet) in the two growing seasons. Meanwhile, the lowest mean values for WP, PIW and Ecu in the two growing seasons were recorded under D_5 (pure onion). These results are in a great harmony with those obtained by *Moursi et al. (2014).*

Table (6): Effect of irrigation treatments and intercropping systems on water productivity (WP, kg/m^3), productivity of irrigation water (PIW, kg/m^3) and consumptive use efficiency (Ecu, %) for onion intercropped with sugar beet in 2012/2013 and 2013/2014 seasons.

Irrigation Treatments (I)	Intercropping systems (D)	WP, kg/m^3			PIW, kg/ m^3			Ecu, %		
		1st growing season	2nd growing season	The overall mean during two growing seasons	1st growing season	2nd growing season	The overall mean during two growing seasons	1st growing season	2nd growing season	The overall mean during two growing seasons
I_1	D_1	24.9	20.7	22.7	10.6	8.2	9.4	42.68	40.12	41.40
	D_2	23.9	23.1	23.5	10.4	8.5	10.0	43.49	40.91	42.20
	D_3	22.8	22.1	22.5	10.1	9.2	9.7	44.29	41.51	42.90
	D_4	24.4	24.0	24.2	10.8	10.0	10.4	44.53	41.71	43.12
	D_5	12.7	11.6	12.2	5.0	4.4	4.7	39.32	37.64	38.48
Mean		21.7	20.3	21.0	9.4	8.3	8.8	42.86	40.38	41.62
I_2	D_1	26.6	25.9	26.3	11.7	10.7	11.2	43.81	41.29	42.55
	D_2	25.5	24.2	24.9	11.3	10.2	10.8	44.44	41.95	43.20
	D_3	24.6	23.8	24.2	11.1	10.1	10.6	45.11	42.39	43.75
	D_4	25.5	24.9	25.2	11.6	10.7	11.2	45.40	42.86	44.13
	D_5	14.2	12.6	13.4	5.6	4.9	5.3	39.56	42.86	41.21
Mean		23.3	22.3	22.8	10.3	9.3	9.8	43.66	41.14	42.40
I_3	D_1	20.6	20.0	20.3	9.7	9.0	9.4	47.27	44.88	46.08
	D_2	20.0	19.5	19.8	9.5	8.8	9.2	47.66	45.28	46.47
	D_3	19.4	19.8	19.6	9.4	9.1	9.3	48.30	45.85	47.08
	D_4	21.4	19.7	20.6	9.7	9.1	9.4	45.36	46.26	45.81
	D_5	10.5	9.3	9.9	4.3	3.8	4.1	41.30	41.20	41.25
Mean		18.4	17.7	18.0	8.5	8.0	8.3	45.98	44.69	45.34

4- Sugar beet yield, some yield components, gross sugar yield, sucrose (%) and sugar quality:

Tabulated data in Table (7 and 8) clearly indicated that, the mean values of sugar beet root yield, the studied yield components, gross sugar yield, sucrose (%) and sugar quality were highly significantly affected by both irrigation and intercropping treatments in the two growing seasons. Concerning, the effect of irrigation treatments, the highest mean values for root yield (ton/ fed.), root diameter (cm.), root weight (g), gross sugar yield (ton/fed.), number of leaves/ plant and sucrose (%) were recorded under irrigation treatment I_2 (irrigation with 1.0 Ep) in the two growing seasons and the values are 27.27 and 26.80 ton/ fed. for root yield, 20.63 and 19.87 (cm)for root diameter, 750.8 and 683.3 (g) for root weight, 470.07 and 451.98 (ton/ fed.) for gross sugar yield, 28 and 27 for number of leaves, 390.8 and 333.3 (g.) for leaves weight/ plant and 17.5 and 17.7 (%) for sucrose in the first and second growing seasons, respectively. Meanwhile, the lowest mean values for the abovementioned studied parameters were recorded under irrigation treatment I_1 (irrigation with 0.8 Ep.) except sucrose (%) which recorded under irrigation treatment I_3 (irrigation with 1.2 Ep). Generally, the mean values of these parameters can be descended in order $I_2 > I_3 > I_1$ in the two growing seasons. Increasing the mean values for the abovementioned studied parameters under irrigation treatment I_2 in comparison with other irrigation treatments I_1 and I_3 might be attributed to under the conditions of this treatment the amount of water applied is suitable for plants (no stress or flooding). So, the plants have a good chance to take their nutritional requirements and solar radiation and hence grow well and this reflects on both yield and yield components vice versa under stress or flooding conditions which give the same bad effect on plant growth. Consequently, decreasing in yield and yield components. Regarding root length and purity, the highest mean values were recorded under irrigation treatment I_1 (irrigation with 0.8 Ep.) and the values are 26.7 and 26.7 cm for root length and 86.2 and 85.9 % for purity in the first and second growing seasons, respectively. Meanwhile, the lowest mean values were recorded under irrigation treatment I_3 (irrigation with 1.2 Ep). Generally, the mean values for root length and purity can be descended in order $I_1 > I_2 > I_3$ in the two growing seasons. Increasing the mean values for the two parameters under irrigation treatment I_1 which means that water stress in comparison with I_2 and I_3, this may be due to under these conditions, root moves downward to search for water and hence it increases in length vica versa under the conditions of irrigation treatments I_2 and I_3. For purity, decreasing the amount of water applied will decrease the absorbed impurities by plants because of decreasing its availability and hence, increasing the mean values of purity. So, for the same reason the highest mean values for TSS % were recorded under irrigation treatment I_3 in comparison with I_1 and I_2 in the two growing seasons and the highest mean values are 23.0 and 23.2% in the first and second growing seasons, respectively. These results are in a great harmony with those reported by *Khalifa and Ibrahim (1995), Gharib and El-Henawy (2011), Mona. S. M. Eid (2012) and Moursi and Darwesh(2014).*

Concerning, intercropping treatments, showed highly significant effect on all studied parameters. The highest mean values for root yield (ton/ fed.), root diameter (cm.), root length (cm.), root weight (g.), gross sugar yield and number of leaves/ plant were recorded under D_4 in the two growing seasons. Meanwhile, the lowest mean values were recorded under D_3 in the two growing seasons. For leaves weight (g.), sucrose and purity (%), the highest mean values were recorded under D_1 but the lowest were recorded under D_3 for leaves weight and purity but D_4 for sucrose %. The highest mean values for TSS% were recorded under D_3. On the other hand, the lowest mean values were recorded under D_4. These results may be due to competition between sugar beet and onion plants for nutrients, carbon dioxide moisture and solar radiation. These results are in a great agreement with those obtained by *Hussein and Yousrya (2012), Abou Khadra et al. (2013) and Abdel Motagally and Metwally (2014).*

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Regarding, the interactions between the studied treatments (irrigation and intercropping patterns) showed highly significant effect on all the studied parameters in the two growing seasons.

5- Onion yield and some yield components:

Presented data in Table (9) clearly illustrated that the values of onion yield and some yield components were highly significantly affected by both irrigation and intercropping treatments in the two growing seasons. Concerning, the effect of irrigation treatments on onion yield and some yield components (onion yield, ton/ fed., plant height, cm., number of leaves, bulb diameter, cm. and bulb weight (gm.)). The highest mean values were recorded under irrigation treatment I_2 (irrigation with 1.0 Ep) in comparison with other irrigation treatments I_1 (irrigation with 0.8 Ep) and I_3 (irrigation with 1.2 Ep) in the two growing seasons. Generally, the mean values of onion yield and some yield components can be descended in order $I_2 > I_3 > I_1$ in the two growing seasons. The highest values are 5.79 and 5.35 ton/ fed. for onion yield, 51.50 and 50.78 cm. for plant height, 6 and 6 for number of Leaves, 6.97 and 6.27 cm. for bulb diameter and 88.58 and 87.32 (g.) for bulb weight in the first and second growing seasons, respectively. Meanwhile, the lowest mean values for the abovementioned studied parameters were recorded under irrigation treatment I_1 in the two growing seasons.

Increasing the values of onion yield and the studied yield attributes under irrigation treatment I_2 in comparison with other irrigation treatments I_1 (stress conditions) and I_3 (excess in irrigation water applied) might be due to, onion is a sensitive crop for irrigation (stress or excess) because, under the two conditions the availability of soil nutrients will be greatly affected. So, the rate of nutrients uptake will decrease either by low availability under the conditions of irrigation treatment I_1 or increasing availability and hence increasing leaching of these nutrients under the excess irrigation conditions (I_3). Therefore, yield and yield attributes affected by irrigation treatments, but under the conditions of irrigation treatment I_2 the amount of irrigation water applied is suitable for plants to grow well and take their nutritional requirements and hence forming plants with good characters which reflected on both yield and yield attributes. Also, decreasing yield and yield attributes under the water stress conditions, might be due to moisture stress in this treatment have adversely affected the cell division and cell enlargement because of reduction in the level of endogenous phytohormones viz., auxins *(Nandi et al. 2002)* and *Abd El-Gawwed, (2008)*. Also, these results are in a great harmony with those obtained by *Pelter et al. (2004)*. Moreover, *Satyendra et al. (2007)* found that onion yield was significantly affected by irrigation. In addition, *El-Akram (2012)* in Egypt, found that onion bulb yield was higher with frequently irrigation i.e. irrigation as 40% of available soil moisture was depleted, in comparison with irrigation at 60 and 80% ones.

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Concerning, intercropping treatments, showed highly significant effect on onion yield and the studied yield components in the two growing seasons. Regarding, onion yield (ton/ fed.) the highest mean values were recorded under intercropping treatment D_5 (pure onion cultivation) and the values are 12.33 and 11.57 ton/ fed. under irrigation treatment I_1 , 14.47 and 13.54 ton/ fed. under I_2 and 12.54 and 11.76 ton/fed. under I_3 in the first and second growing seasons, respectively. Meanwhile, the lowest mean values for onion yield were recorded under intercropping treatment D_1 under all irrigation treatments. Concerning, plant height (cm.), number of leaves, bulb diameter (cm.) and bulb weight (gm.), the highest mean values were recorded under intercropping treatment D_1 but the lowest mean values were recorded under treatment D_3 in the two growing seasons. Increasing onion yield under intercropping treatment D_5 and the studied yield components under D_1 might be due to decreasing the competition rate between plants on their nutritional and light requirements and hence, increasing the studied parameters under the abovementioned intercropping treatments. Regarding, the interaction effects between irrigation and intercropping treatments on onion yield and the studied yield components, all interactions showed highly significant effect on all the studied parameters. These results are in a great harmony with those reported by *Moursi et al. (2010), Abdel Motagally and Metwally (2014) and Moursi et al. (2014).*

6- Land equivalent ratio (LER) and gross return (L.E., fed^{-1}):

Presented data in Table (10) showed that, the values of both land equivalent ratio and gross return were greatly affected by irrigation and intercropping treatments in the studied growing seasons. Concerning, the effect of irrigation treatments on land equivalent ratio, the highest values in the two growing seasons were recorded under irrigation treatment I_3 and the values are 1.094 and 1.076. Meanwhile, the lowest values were recorded under irrigation treatment I_1 and the values are 1.050 and 1.038 in the first and second growing seasons, respectively. Generally, the values of land equivalent ratio (LER) can be descended in order $I_3 > I_2 > I_1$ in the two growing seasons. Regarding, the effect of intercropping treatments on LER, generally, the highest values were recorded under D_3 but the lowest were recorded under $D_{1.}$ This indicated that intercropping onion with sugar beet increased land equivalent ratio in all intercropping patterns. The highest land equivalent ratio values are 1.109 and 1.089 were recorded under D_3 in the first and second growing seasons, respectively. While, the lowest LER values are 1.031 and 1.023 were recorded under D_1 in the first and second growing seasons, respectively. Generally, LER value was greater than 1.0 for all intercropping patterns. This showed that the actual productivity was higher than the expected productivity when sugar beet with onion. These results are in the same line those obtained by *Abou Khadra et al. (2013)* they showed that LER values were greater than one at any intercropping systems.

Regarding, gross return, the highest values were recorded under irrigation treatment I_2 and the values are 11309.67 and 13508.83 (L.E. / fed.). Meanwhile, the lowest values were recorded under irrigation treatment I_1 and the values are 8469.00 and 11386.00 in the first and second growing seasons, respectively. Generally, the values of gross return can be descended in order $I_2 > I_3 > I_1$. For the effect of intercropping patterns on gross return, the highest values were recorded under D_3 but the lowest values were recorded under D_1 in the two growing seasons. These results are in a great harmony with those reported by *Abdel Motagally and Metwally (2014)*

Table (10): Effect of irrigation treatments and intercropping sugar beet with onion on land equivalent ratio (LER) and gross return (L.E., fed.$^{-1}$) in the two growing seasons.

Irrigation Treatments (I)	Intercropping systems (D)	Land equivalent ratio		Gross return (L.E. fed^{-1})	
		2012/2013	2013/2014	2012/2013	2013/2014
I_1	D_1	1.031	1.023	8543.50	9037.00
	D_2	1.056	1.041	9610.50	11453.50
	D_3	1.064	1.051	10253.00	12267.50
Mean		1.050	1.038	6469.00	10919.33
I_2	D_1	1.087	1.084	10795.00	13126.50
	D_2	1.079	1.055	11205.25	13254.00
	D_3	1.088	1.077	11928.75	14146.00
Mean		1.085	1.072	11309.67	13508.83
I_3	D_1	1.078	1.057	9721.00	11580.50
	D_2	1.095	1.083	10430.25	12557.50
	D_3	1.109	1.089	11141.75	13331.50
Mean		1.094	1.076	10431.00	12489.83

CONCLUSION

Under the bad need for maximizing both water and land units through shortage of water resources and available fertile lands. This research recommends that under the conditions of this present study, onion intercropping with sugar beet should be irrigated with 1.0 Ep. (I_2) to obtain the best yield, quality and gross return and with intercropping pattern D_4.

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تعظيم أقصى استفادة من وحدة المياة بتحميل البصل مع بنجر السكر فى منطقة شمال وسط دلتا النيل.

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**** معهد بحوث الأراضى والمياة والبيئة- مركز البحوث الزراعية- الجيزة- مصر.**

أجريت تجربتان حقليتان بمحطة البحوث الزراعية بسخا خلال موسمى النمو 2013/2012 ، 2014/2013 وذلك بهدف تحقيق أقصى استفادة من وحدة المياة بتحميل البصل على بنجر السكر فى منطقة شمال وسط دلتا النيل وكان التصميم الاحصائى المستخدم هو القطع المنشقة مرة واحدة فى 3 مكررات حيث القطع الرئيسية تم توزيع بها معاملات الرى بطريقة عشوائية وهى I_1 (رى ب 0.8 من قراءات وعاء البخر) ، I_2 (رى ب 1.0 من قراءات وعاء البخر) ، I_3 (رى ب 1.2من قراءات وعاء البخر) والقطع تحت الرئيسية تم توزيع بها معاملات التحميل وهى D_1 (تحميل بصل مع بنجر السكر بحيث يكون بنجر السكر منزرع بالمعدل الموصى به بينما يزرع سطر واحد فقط بصل على ظهر المصطبة) ، D_2 (تحميل بصل مع بنجر السكر بحيث يكون بنجر السكر منزرع بالمعدل الموصى به بينما يزرع سطرين فقط بصل على ظهر المصطبة) ،D_3 (تحميل بصل مع بنجر السكر بحيث يكون بنجر السكر منزرع بالمعدل الموصى به بينما يزرع ثلاث سطور بصل على ظهر المصطبة) ،D_4 (يتم زراعة بنجر السكر فقط بالمعدل الموصى به وهى معاملة كنترول بنجر) ،D_5 (يتم زراعة البصل فقط بالمعدل الوصى به وهى معاملة كنترول بصل).

أهم النتائج يمكن تلخيصها كما يلى:

* أعلى القيم بالنسبة للماء المضاف والاستهلاك المائى سجلت تحت معاملة الرىI_3 والقيم كانت 69.03 سم (2899.41 م^3 / فدان) ، 73.23 سم (3075.55 م^3 / فدان) للماء المضاف و 41.26 سم (1733.13 م^3 / فدان) و 42.25 سم (1774.55 م^3 / فدان) للاستهلاك المائى فى الموسم الاول والثانى على الترتيب. بينما أقل القيم سجلت تحت معاملة الرى I_1 والقيمة كانت 60.89 سم (2557.33 م^3 / فدان) و 34.84 سم (1463.26 م^3 / فدان) للماء المضاف والاستهلاك المائى على الترتيب. بالنسبة لمعاملات التحميل لم يكن لها تأثير على الماء المضاف ولكن بالنسبة للاستهلاك المائى أعلى القيم سجلت تحت المعاملة D_4 والأقل تحت D_5 وبصفة عامة فان قيم الاستهلاك المائى يمكن ترتيبها تنازليا $D_4 > D_3 > D_2 > D_1 > D_5$ فى كلا موسمى النمو.
* أعلى القيم لانتاجية وحدة المياة المستهلكة والمضافة سجلت تحت معاملة الرى I_2 والقيم كانت 23.3 و 22.3 كجم/ م^3 لانتاجية وحدة المياة المستهلكة ، 10.3 و 9.3 كجم/ م^3 للمياه المضافة فى الموسم الاول والثانى على الترتيب. أقل القيم سجلت تحت معاملة الرىI_3 والقيم بلغت 18.4 و 17.7 كجم/ م^3 الانتاجية وحدة المياة المستهلكة و 8.5 و 8.0 كجم/ م^3 للمياه المضافة فى الموسم الاول والثانى على الترتيب. أما بالنسبة لكفاءة الاستهلاك المائى أعلى القيم سجلت تحت معاملة الرىI_3 والقيم كانت 45.98 % و 44.69 % والأقل سجلت تحت معاملة الرى I_1 والقيم كانت 42.86 و 40.38 % فى الموسم الاول والثانى على الترتيب. بالنسبة لتأثير معاملات التحميل على الكفاءات السالفة الذكر. بصفة عامة أعلى القيم سجلت تحت الرى D_4والأقل تحتD_5 .
* بالنسبة لمحصول بنجر السكر ومكوناته والجودة تأثر بصورة عالية المعنوية بمعاملات الرى والتحميل وكذلك بالتفاعل بينهما. بصفة عامة أعلى القيم سجلت تحت معاملة الرىI_2 ومعاملة التحميل D_4 .
* بالنسبة لمحصول البصل ومكوناته تأثر بصورة عالية المعنوية بمعاملات الرى والتحميل وكذلك بالتفاعل بينهما فى كلا موسمى الدراسة.بصفة عامة القيم يمكن ترتيبها تنازليا كما يلى $I_2 > I_3 > I_1$ بالنسبة لمعاملات التحميل أعلى القيم سجلت تحت المعاملةD_4 (بصل بمفردة) بالمقارنة بباقى المعاملات.
* التفاعلات بين معاملات الرى (I) و نماذج التحميل (D) و (D * I) أوضحت تأثير عالى المعنوية مع كل الصفات المدروسة للبنجر والبصل.
* يمكن ترتيب المكافئ الأرضى (LER) ترتيباً تنازليا كما يلى $I_3 > I_2 > I_1$ بينما اجمالى الدخل يكون كالآتى $I_3 > I_1 > I_2$. بالنسبة لتأثير معاملات التحميل بالنسبة للمكافئ الأرضى واجمالى الدخل سجلت تحت D_3 والأقل تحت D_1.

Table (7): Effect of irrigation treatments and intercropping systems on yield and yield components of sugar beet in the two growing seasons.

Irrigation Treatments (I)	Intercropping systems (D)	Root yield (ton/ fed.)		Root diameter (cm.)		Root length (cm)		Root weight (g.)		Gross sugar yield, kg/ fed.	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
I_1	D_1	25.06	20.72	19.22	18.26	26.6	26.8	650.0	616.7	433.54	427.66
	D_2	23.34	23.01	18.14	17.34	27.1	27.4	550.0	466.7	396.78	391.17
	D_3	21.96	21.45	17.27	16.41	28.0	28.8	403.3	383.3	377.72	371.09
	D_4	26.79	26.51	22.37	21.53	29.5	29.7	800.0	750.0	439.36	426.81
Mean		24.29	23.92	19.25	18.39	27.8	28.2	600.8	554.2	411.85	404.18
I_2	D_1	27.80	27.45	21.60	20.75	25.2	25.3	840.0	800.0	503.18	502.34
	D_2	26.39	25.58	19.87	19.46	26.4	26.2	670.0	616.7	464.46	455.32
	D_3	25.05	24.68	18.03	17.43	27.2	27.3	443.3	416.7	433.37	434.37
	D_4	29.84	29.47	23.00	21.85	27.9	28.0	1050.0	900.0	507.07	506.88
Mean		27.27	26.80	20.63	19.87	26.7	26.7	750.8	683.3	470.07	451.98
I_3	D_1	26.44	26.19	21.30	20.75	24.2	24.4	716.7	516.7	438.90	437.37
	D_2	25.15	24.95	19.67	19.22	25.4	25.5	570.0	516.7	409.95	404.19
	D_3	23.97	23.13	18.18	17.90	26.2	26.4	383.3	350.0	393.11	383.96
	D_4	28.17	27.97	21.91	21.42	26.8	27.0	783.3	766.7	445.09	441.93
Mean		25.93	25.56	20.27	19.82	25.7	25.8	613.3	583.3	421.76	416.86
L.S.D. 5% at I.		0.4789	0.3624	0.3502	0.3533	0.2922	0.1967	46.584	34.588	7.985	10.113
F. Test		**	**	**	**	**	**	**	**	**	**
L.S.D. 5% at D.		0.6181	0.6324	1.055	1.033	0.2630	0.2959	61.719	45.426	11.442	10.575
F. Test		**	**	**	**	**	**	**	**	**	**
I. * D.		**	**	**	**	**	**	**	**	n.s	n.s

***, ** and NS: significant at p ≤ 0.05, 0.01 or not significant, respectively. Means separated at P≤ 0.05, LSD test.**

Table (8): Effect of irrigation treatments and intercropping systems on yield, yield components and sugar quality of sugar beet in the two growing seasons.

Irrigation Treatments (I)	Intercropping systems (D)	Number of leaves/ plant		Leaves weight/ plant (g.)		TSS (%)		Sucrose (%)		Purity (%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
I_1	D_1	22	21	380.0	353.3	21.3	21.5	17.3	17.3	88.8	87.6
	D_2	20	19	263.3	220.0	22.0	22.1	17.0	17.0	87.7	87.5
	D_3	20	19	233.3	233.3	22.7	22.7	17.2	17.3	83.5	83.0
	D_4	23	23	356.7	316.7	19.9	20.0	16.4	16.1	87.2	86.9
Mean		21	21	308.3	280.8	21.5	21.6	17.0	16.9	86.8	86.3
I_2	D_1	30	29	446.7	383.3	22.3	22.5	18.1	18.3	88.6	88.4
	D_2	27	26	380.0	333.3	22.5	22.7	17.6	17.8	86.9	86.8
	D_3	25	23	270.0	200.0	23.3	23.5	17.3	17.6	82.8	82.6
	D_4	32	31	466.7	416.7	20.6	20.7	17.0	17.2	86.3	85.7
Mean		29	27	390.8	333.3	22.2	22.4	17.5	17.7	86.2	85.9
I_3	D_1	24	23	400.0	350.0	23.1	23.3	16.6	16.7	88.4	87.7
	D_2	21	21	340.0	243.3	23.4	23.7	16.3	16.3	86.6	86.3
	D_3	20	20	270.0	246.7	24.1	24.3	16.4	16.6	82.6	82.2
	D_4	25	24	366.7	366.7	21.3	21.5	15.8	15.8	85.8	84.6
Mean		23	22	344.2	301.7	23.0	23.2	16.3	16.4	85.9	85.2
L.S.D. 5% at I.		0.641	0.803	18.016	25.98	0.322	0.311	0.164	0.374	0.498	0.591
F. Test		**	**	**	**	**	**	**	**	**	**
L.S.D. 5% at D.		1.015	0.693	37.361	38.514	0.3224	0.543	0.140	0.385	0.754	0.294
F. Test		**	**	**	**	**	*	**	**	*	**
I. * D.		**	**	**	**	***	**	**	**	**	**

***, ** and NS: significant at p ≤ 0.05, 0.01 or not significant, respectively. Means separated at P≤ 0.05, LSD test.**

Table (9): Effect of irrigation treatments and intercropping systems on yield and yield components for onion in the two growing seasons.

Irrigation Treatments (I)	Intercropping systems (D)	Yield (ton/ fed.)		Plant height (cm)		Number of leaves		Bulb diameter (cm)		Bulb weight (g.)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
I_1	D_1	1.18	1.05	45.34	45.20	5	5	5.36	5.39	84.98	84.68
	D_2	2.28	2.00	44.60	44.06	5	5	5.03	4.90	82.86	82.69
	D_3	3.01	2.80	42.95	42.66	4	4	4.22	3.93	81.09	80.92
	D_5	12.33	11.57	45.08	44.94	5	5	5.85	5.31	87.02	86.25
Mean		4.70	4.36	44.49	44.22	5	5	5.12	4.88	83.99	83.64
I_2	D_1	2.25	2.07	53.06	52.29	8	7	7.50	7.05	90.30	86.87
	D_2	2.82	2.53	52.04	51.35	6	6	6.66	6.35	86.79	85.50
	D_3	3.60	3.24	50.05	49.91	5	5	6.11	5.89	85.48	82.65
	D_5	14.47	13.54	50.86	49.57	6	6	7.61	5.80	91.75	94.26
Mean		5.79	5.35	51.50	50.78	6	6	6.97	6.27	88.58	87.32
I_3	D_1	1.75	1.42	50.41	50.18	6	6	6.22	6.05	84.51	84.24
	D_2	2.51	2.25	49.83	49.72	5	4	5.18	4.85	84.59	83.85
	D_3	3.25	3.08	48.20	47.46	5	4	4.70	4.46	82.47	81.71
	D_5	12.57	11.76	49.15	45.78	5	5	5.61	5.22	90.99	90.62
Mean		5.02	4.63	49.15	48.29	5	5	5.43	5.15	85.64	85.11
L.S.D. 5% at I.		0.2077	0.2470	0.3146	0.3302	0.6532	0.6387	0.2518	0.2245	0.5638	0.6329
F. Test		**	**	**	**	**	**	**	**	**	**
L.S.D. 5% at D.		0.2197	0.3852	0.3564	0.4201	0.5363	0.5989	0.3227	0.2377	0.6389	0.4560
F. Test		**	**	**	**	**	**	**	**	**	**
I. * D.		**	**	**	**	**	**	**	**	**	**

***, ** and NS: significant at $p \leq 0.05$, 0.01 or not significant, respectively. Means separated at $P \leq 0.05$, LSD test.**