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EFFECT OF IRRIGATION LEVELS, CULTIVATION METHODS AND PLANT DENSITIES ON PRODUCTIVITY, QUALITY OF ONION CROP AND SOME WATER RELATIONS IN HEAVY CLAY SOILS

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ABSTRACT

A field investigation was conducted at Sakha Agricultural Research Station during the successive winter growing seasons 2012/13 and 2013/14 to study the effect of irrigation levels, cultivation methods and plant density on productivity, quality of onion crop and some water relations in heavy clay soils. A strip split plot design with four replications was used in this present study, where, the horizontal plots were assigned to irrigation treatments which were, I_0 (Traditional irrigation, like practice by local farmers in the studied region), while, I_1, I_2 and I_3 irrigation at 90, 80 and 70% of field capacity, respectively. While, the vertical plots were also randomly assigned by cultivation methods which were, A (Cultivation on raised-beds) and B (Cultivation on normal furrows). Sub-sub plots were randomly assigned by plant densities which were D_1 (30 plants/m²), D_2 (45 plants/m²), and D_3 (60 plants/m²) under the two cultivation methods. The main results can be summarized as follows:

- The results showed that the plants irrigated at 80% of field capacity, produced the highest average bulb weight, onion bulbs yield and good quality bulbs with the highest values of remainder bulbs% at the end of storage periods. Marketable and total bulbs yield increased above 25.72 and 33.84 % resulted from plots irrigated at 80% of field capacity as compared to traditional irrigation as an average for the two seasons. Abundance of the available soil moisture (Traditional irrigation like practice by local farmers in the studied area) significantly increased N, P, K and Zn contents of onion bulbs as well as culls yield, physiological, decay, sprouting losses and final loss % of onion bulbs at three storage periods in both seasons.
- Concerning, the effect of cultivation methods on average bulb weight, marketable and total bulbs yields as well as bulb diameter, TSS and dry matter % were evident in both seasons. In general, all the previous characters positively increased significantly with raised-beds than normal furrows. On the contrary, the culls yield, N, P, K and Zn contents were significantly higher under normal cultivation method, and the lowest with raised-beds cultivation method. Also, the lowest values of physiological loss, decay and sprouting losses % of onion bulbs at three storage periods were obtained under raised-beds cultivation method. Culls yield decreased above 19.16 % in the plots transplanted on raised-beds as compared to normal furrows methods as average for the two years.
- Results revealed that increasing population of onion plants from 30 plants/m^2 to 45 plants/m^2 gradually decreased average bulb weight and bulb diameter as well as physiological, decay and sprouting losses % and final loss % at three storage period. However, the medium planting density of 45 plants/m^2 compared to lower planting density of 30 plants/m^2 led to an increase in marketable and total yields

per fed., TSS and dry matter % above 17.08, 22.26, 10.71 and 14.21% as an average for the two years, respectively. The inverse was true in culls yield, where 60 plants/ m^2 gave the highest of culls yield above 88.22 % compared to 30 plants/m^2 as an average for the two years.

- The first and the second order interaction had a significant effect on yield and storability. The maximum yield and the best quality with the highest remainder bulbs% at the end of storage periods were achieved from plants irrigated at 80% of field capacity and grown at 45 plants/m^2 with raised-beds cultivation method in both seasons.
- The highest overall mean values through the two growing seasons for seasonal water applied, water consumptive use and consumptive use efficiency were recorded under irrigation treatments I_0 (Traditional irrigation) and normal cultivation method (B) and the values are 56.63 cm (2378.38 m^3/fed.), 51.86cm (2177.82 m^3/fed.) for seasonal water applied, 36.61cm (1537.73 m^3/fed.) for water consumptive use and 64.66% and 63.38% for consumptive use efficiency under normal cultivation method and raised-beds, respectively. Meanwhile, the lowest values were recorded under irrigation treatment I_3 (water stress conditions) and raised-beds cultivation method and the values are 40.01cm (1680.52 m^3/fed.), 36.23cm (1521.48 m^3/fed.) for seasonal water applied, 24.62cm (1033.97 m^3/fed.), 21.88cm (919.14 m^3/fed.) for water consumptive use and 61.53% and 60.41% for consumptive use efficiency under normal cultivation method and raised-beds, respectively. Regarding, the effect of plant densities, the highest values for water consumptive use and consumptive use efficiency were recorded under the highest density D_3 (60 plants/m^2) under the two cultivation methods and all irrigation treatments. Concerning, the values of seasonal water applied were not affected by plant densities treatments.
- The highest overall mean values for water productivity (WP, kg/m^3) and productivity of irrigation water (PIW, kg/m^3) were recorded with irrigation treatment I_2 (irrigation at 80% of field capacity), raised-beds cultivation method (A) and plants density (45 plants/m^2). Meanwhile, the lowest values for WP and PIW were recorded under I_0 (traditional irrigation), normal cultivation method (B) and plant density (60 plants/m^2).
- It can be concluded that the irrigation at 80% of field capacity with a population of 45 plants/m^2 under raised-beds cultivation method was the recommended treatments for optimum productivity, quality of onion and remainder bulbs% at the end of storage periods and maximizing water productivity (WP, kg/m^3) and productivity of irrigation water (PIW, kg/m^3) at Kafr El-Sheikh Governorate conditions.

INTRODUCTION

Onion plant is often considered to be a medium water use crop, this arises from the facts that onion is sensitive to water stress, has a relatively shallow root zone depth and is often grow in soils with low to medium water holding capacities. These conditions necessitate reliable irrigation system capable of light, frequent and uniform water application. Onion plant growth and its bulbs yield as well as some physical and chemical properties are strongly affected by water regime (Kadam *et al.,* 2006, Sen *et al.,* 2006, Ali *et al.,* 2007, Bolondzar *et al.,* 2007, Samson and Tilahum, 2007 and Satyendra-Kumar *et al.,* 2007).

Water is the medium for photosynthesis transfer within the plant and is the solvent system of the cell. Water is one of the raw materials for photosynthesis required for the production of new compounds. Moisture stress is generally detrimental to plant growth reducing both yield and quality of the crop. The degree and duration of water stress can determine the severity of growth reduction (Lincoln and Eduaro, 2006). However, the growth rate may never return to the level it was before the stress. The phenological stage where plants are subjected to moisture stress is important (Woldetsadik, 2003). Generally, plant growth is associated with the available irrigation water; it means that, the irrigation before the available water reaches the critical limit gains the vigor plant growth and the highest crop yield.

In Egypt, water is the most critical factor in crop production. Rainfall is low with erratic distribution. Therefore, almost agricultural production mainly dependent upon irrigation. Water resources are limited and concentrated on the Nile River and sometimes groundwater. The Nile River supplies Egypt with about 97% from total freshwater. The Egyptian water budget from the Nile is 55.5 milliard cubic meter. The present share of water in Egypt is less than 1000 m^3/capita/share which is equivalent to the international standards of water poverty limit (El-Quosy, 1998). Irrigation is the main sector in water demand at national level. Water allocated to irrigation is about 85% from the total renewable water. So, effective water management at the irrigation sector is the principal way towards the rationalization policy for the country. In this aspect, effective on farm irrigation management becomes a must.

Onion crop has shallow root system and needs frequent irrigation after short intervals. So, supply of water is irregular and crop faces shortage of water during its active growth period i.e. February –April. Irrigation or supplemental watering must be provided if the crop is to maintain efficient growth.

Cultivation method considers one of the effective means for rationalization of irrigation water. Raised-beds may allow saving irrigation water and still maintaining satisfactory levels of production. Therefore, there is an urgent need to improve irrigation water management for local farmers. Also, plant densities consider one of the main procedures to make maximizing for both water and soil units and so, saving irrigation water. The optimum use of spacing or plant population has dual advantage. It also avoids strong competition between plants for growth factor such as water, nutrient, and light. Jilani *et al.* (2009), Gashua and Abbator (2013) and Mansouri *et al.* (2014) found that maximum number of leaves, leaf length, bulb diameter and average bulb weight were recorded in thinly populated crop (20 plants/m^2). The highest bulb yield was achieved in medium populated crop (30 plants/m^2) followed by thinly (20 plants/m^2) and thickly populated crops (40 plants/m^2)

Storage loss of onions is caused by rotting, sprouting, and physiological weight loss. Many factors, such as cultivars, bulb maturity, moisture content of the bulb, temperature, relative humidity, etc. are associated with spoilage of onion during storage. Thus, irrigation may have some effect on storability of onion as it helps increase moisture content of bulb (Chung, 1989). Many authors investigated the effect of irrigation on onion yield, but the literature revealed scanty information about the effect of irrigation on storage of onion. Soujala *et al.* (1998) reported that irrigation had only a minor effect on the storage performance and shelf life of onion.

A substantial increase of decomposition in onion during storage with increasing irrigation was reported by Shock *et al.* (1998). Keeping in view the importance of onion production efficacy.

The present study was carried out to find the best planting space, irrigation treatment, cultivation methods and their effects on the bulb yield, related parameters in onion crop and some water relations under the existing agro-climatic conditions of the Kafr El-Sheikh Governorate region.

MATERIALS AND METHODS

A field investigation was conducted to study the effect of irrigation, cultivation methods and plant densities on productivity, quality, storability of onion crop and some water relations in heavy clay soils. The Experimental Farm was at Sakha Agricultural Research Station, Kafr El-Sheikh Governorate. The site is located at 31˚ 07¯ N Latitude, 30˚ 57¯ E Longitude with an elevation of about 6 meters above mean sea level (MSL). This location is representative the conditions of the North Middle Nile Delta region during the successive winter growing seasons 2012/2013 and 2013/2014. Soil samples for different depths at the experimental site were collected at each (15 cm soil depth) up to 45cm. and analyzed for some physical characteristics Table (1). Other soil samples were taken from the same experimental site which were collected at each (15cm. soil depth) up to 45cm. and analyzed for some chemical characteristics Table (2). Mean of some meteorological data for Kafr El-Sheikh area during the two growing seasons were shown in Table (3). The preceding crop of experiments soil was maize (*Zea mays* L.) in both seasons.

Physical and chemical characteristics for the studied experimental site.

Physical characteristics of the studied site such as soil field capacity (F.C %), was determined at the site, permanent wilting point (PWP %) and available water (AW) were determined according to James (1988) and soil bulk density was determined according to Klute (1986). To study the soil texture, the particle size distribution was determined according to the international method (Klute, 1986). The obtained results indicated that the soil texture is clayey.

Chemical characteristics for the studied site such as total soluble salts (soil EC), soil reaction (pH), both soluble cations and anions were determined according to the methods described by Jackson (1973). But SO_4^{--} was calculated by the difference between soluble cations and anions.

Table (1): The mean values for some physical characteristics of the experimental site before cultivation in the two growing seasons.

Soil depth (cm.)	Particle size distribution			Texture class	Soil moisture characteristics			Bulk density Mg/m^3
	Sand %	Silt %	Clay %		F.C. %	P.W.P. %	A.W. %	
0-15	19.18	30.13	50.69	Clayey	42.60	22.12	20.48	1.15
15-30	17.81	28.50	53.69	Clayey	40.30	21.50	18.80	1.23
30-45	18.69	26.75	54.56	Clayey	37.80	20.30	17.50	1.36
Mean 0-45	18.56	28.46	52.98	Clayey	40.23	21.30	18.93	1.25

Table (2): The mean values of some chemical characteristics for the studied experimental site before cultivation in the two growing seasons.

Soil depth (cm.)	pH 1:2.5 Soil water suspension	EC dsm^{-1}	Soluble cations (meq L^{-1})				Soluble anions (meq L^{-1})			
			Na^+	Ca^{+2}	Mg^{+2}	K^+	Co_3^{--}	Hco_3^-	CL^-	So_4^{--}
0-15	7.86	2.45	16.76	5.25	3.12	0.50	0.00	2.50	13.70	9.43
15-30	7.95	2.85	19.45	6.31	3.42	0.60	0.00	3.00	15.60	11.18
30-45	8.23	3.48	24.92	7.62	4.59	0.80	0.00	4.00	17.30	16.63
Mean 0-45	-	2.93	20.38	6.39	3.71	0.63	0.00	3.17	15.53	12.41

Where: $So4^-$ was calculated by difference between soluble cations and anions

Table (3): Mean of some meteorological data for Kafr El-Sheikh area during the two growing seasons.

Month	$T(C^0)$			RH (%)			W_s m/sec at 2m height	Pan Evap. mm/day	Rain mm
	Max.	Min.	Mean	Max.	Min.	Mean			
2012/13									
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	--
2013/14									
Dec.	19.64	8.51	14.06	92.07	67.61	79.84	0.61	4.15	81.90
Jan.	20.34	7.55	13.95	93.69	70.55	80.55	0.54	1.60	20.70
Feb.	20.64	8.19	14.42	91.90	67.15	79.53	0.79	2.52	16.50
Mar.	22.94	11.71	17.33	86.10	56.80	71.45	0.96	3.14	26.20
April.	27.50	15.53	21.52	81.80	49.80	65.80	1.07	4.91	20.20
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˚ 07¯ N Latitude, 30˚ 57¯ E Longitude with an elevation of about 6 metres above mean sea level (MSL).

Experimental layout,

Onion seeds cv. Giza red were hand drilled in the nursery bed on 8th and 9th October in the first and second season, respectively. Seedlings of nearly sixty days old when they usually were 25 cm in height were pulled tied and moved to the permanent land for transplanting on 10 -17th of December in 2012/13 and 2013/14 seasons, respectively. The recommended doses of phosphorus as calcium super phosphate (15.5% P_2O_5) and potassium as potassium sulphate (48% K_2O) were applied at the rate of 45kg P_2O_5/fed. and 50 kg K_2O/fed., respectively during the soil preparation. Other farming practices were performed as recommended for the crop and the studied area except the studied parameters (irrigation treatments), cultivation methods and plant densities. The irrigation plot area was 226.8 m^2(31.5 m length* 7.2 m width) this area included the two cultivation methods (Raised-beds and traditional furrows). So, the area of each cultivation method under each irrigation treatment 113.4 m^2 (31.5 m length* 3.6m width). The area of each plant density treatment was 12.6 m^2 (3.5m length*3.6 m width). These treatments were arranged in a strip split plot design with four replications in the two growing seasons. The horizontal plots were randomly assigned by irrigation treatments which were

Horizontal plots (irrigation levels):

I_0 = Traditional irrigation like practice by local farmers in the studied area (Control),

I_1 = irrigation at 90% of field capacity,

I_2 = irrigation at 80% of field capacity and

I_3 = irrigation at 70% of field capacity.

Vertical plots (Cultivation methods):

A- Cultivation on wide furrows (raised-beds),

B- Cultivation on normal furrows (Traditional).

Sub plots (plant densities, D):

D_1 = 30 plants/m²,

D_2 = 45 plants/m² and

D_3 =60 plants/m². All the plant densities were performed under the two cultivation methods (Traditional and raised. beds).

Soil moisture content was determined gravimetrically on oven dry basis before each irrigation and also after irrigation with 48 hours and as well as at harvesting times. Four soil samples were taken with a soil auger from four consecutive layers, every 15 cm depth to the total depth of 60 cm. On the other hand, harvesting process was carried out on 15 and 12th May in the first and second growing seasons, respectively

Data collection:

A- Onion bulbs yield and its quality:

At harvesting (155 days from transplanting date), all the remaining bulbs in each plot were uprooted and bulbs yield of onion expressed as: average bulb weight (g), marketable bulbs yield (ton/fed.), culls bulb weight (ton/fed.) and total bulbs yield (ton/fed.). In the same time, sample of 5 bulbs were randomly taken for recording the bulb quality properties, i.e. bulb diameter (cm), total soluble solids (TSS%) and dry matter content (%).

B- Macro elements content:

At harvesting time, onion bulb samples from each sub-plot were randomly selected for elemental analysis. Bulb tissues were oven dried at 70^oC until a constant mass was reached and then they were grounded for chemical analysis. Bulb dried samples were wet digested as described by Wolf (1982). Total nitrogen, phosphorus and potassium as macronutrients were determined in acid digested solution of dried bulb samples. Nitrogen percentage was determined by the method provided by Hach *et al.* (1985). Phosphorus and potassium contents were determined according to A.O.A.C. (1990) and Knudsen *et al.* (1982), respectively.

C- Storability:

After curing, random samples (each of 10 kg) were taken from every treatment, all bulbs were stored unbagged under room temperature for 180 days (3 storage periods). The following measurements were recorded at 60 days intervals:

1- Physiological loss % $= \dfrac{\text{drying loss} \times 100}{\text{total weight}}$

2- Decay and sprouting losses % $= \dfrac{\text{decaying and sprouting losses} \times 100}{\text{total weight}}$

3- Final loss % $= \dfrac{\text{final weight loss} \times 100}{\text{primary storage bulb weight}}$

4- Remainder bulb % = 100- final weight loss %.

D- Amount of seasonal water applied (cm & m³/fed.):

Amount of irrigation water applied for each irrigation treatment was measured using cutthroat flume (30 * 90 cm) and then seasonal water applied was recorded during the whole growing season and calculated as cm & m³/fed. according to (Early, 1975). Then the water applied was computed as follows:

$$Wa = IW + R$$

Where:

Wa = water applied (cm & m³/fed.),

IW = the amount of water delivered to the field plot by irrigation and

R = effective rainfall which equals to incident rainfall * 0.7 (Novica, 1979)

E- Water consumptive use (Cu, cm & m³/fed.):

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

$$Cu = SMD = \sum_{i=1}^{i=4} \frac{(\theta 2 - \theta 1)}{100} * Dbi * Di * 4200$$

Where:

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

ϴ2 = Gravimetric soil moisture percentage 48 hours after irrigation,

ϴ1 = Gravimetric soil moisture percentage before the next irrigation,

Dbi = Soil bulk density (Mg/ m³) for the given depth,

Di = Soil layer depth (15cm)

i = Number of soil layers each (15cm.) depth and

4200= feddan area in m^2.

F- Irrigation water efficiencies:

1- Consumptive use efficiency (Ecu, %):

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

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

Where:

Ecu = consumptive use efficiency (%),

Cu = water consumptive use (m^3/fed.) and

Wa = seasonal water applied (m^3/fed.)

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

Water productivity is defined as crop production per unit amount of water used (Molden, 1997). It was calculated according to (Ali *et al.,* 2007).

$$WP = \frac{Y}{ET} (kg/m^3)$$

Where:

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

Y = Onion bulb yield (kg/fed.) and

ET=Total water consumption≈consumptive use (m^3/fed.) ≈ Evapotranspiration

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

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

$$PIW = Y/ Wa$$

Where:

PIW = productivity of irrigation water (kg/m^3),

Y = onion bulb yield (kg/fed.) and

Wa = seasonal water applied (m^3/fed.)

Statistical analysis:

All obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) as published by Gomez and Gomez (1984) by using "MSTAT-C" computer software package. Treatments means were compared according to Duncan's multiple range test (Duncan, 1955).

RESULTS AND DISCUSSION

Effect of irrigation, cultivation methods and plant density on:

A- Onion bulbs yield and its quality:

There were significant differences among yield and quality parameters under different irrigation levels. The treatment I_2 (irrigation at 80% of field capacity) had the highest average bulb weight, marketable and total yield followed by I_1 and I_0 irrigation treatments. The I_3 had the lowest average bulb weight, marketable and total yield. However, I_1, I_0 and I_2 had less culls yield compared to treatment I_3 (Tables 4 and 5). Marketable and total bulbs yield increased by 25.72 and 33.84 % in the plots irrigated at 80% of field capacity as compared to traditional irrigation as an average for the two years, respectively. Concerning bulb quality, irrigation levels had a significant effect on this character in the first and second seasons. In general, it can be noticed that the lower TSS and dry matter content was obtained from the wet level of irrigation(I_0), while maximum values were recorded from dry and medium treatments of irrigation (I_0 and I_1). These findings indicate that TSS and dry matter content in bulbs at harvest time was lower under wet conditions and tended to decrease by increasing soil moisture stress. While, bulb diameter tended to increase with irrigation at 80% of field capacity (I_2). In this connection, Al-Harbi (2002), Hassan Khan *et al.* (2005), Abo Dahab and Fouad (2012) and El-Akram (2012) stated that the highest values of marketable, total yield (ton/fed.), average bulbs weight and bulb diameter were recorded from the wet treatment. However, bulb total soluble solids and bulb dry matter content were significantly increased with decreasing number of irrigations.

Tables 4&5 show bulb yield and quality parameters (bulb weight, bulb yield, bulb diameter, TSS and dry matter %) of the onion bulbs as affected by cultivation methods. The highest mean values for bulb weight and bulb yield were better for raised-beds as compared to normal furrows methods, while normal furrows treatment gave the highest values for culls yield in both seasons. Culls yield decreased by 19.16 % in the plots transplanted on raised-beds as compared to normal furrows methods as an average for the two years. Also, the quality parameters increased significantly with raised-beds than normal furrows methods treatment in both seasons except for the bulb diameter which was significantly higher in second season only. The results are in agreement with those obtained by Farrag (1995) who concluded that flat beds system gave the highest yield for total and single bulbs seemed to be the best treatment.

Plant density significantly affected yields of onion bulbs and average bulb weight. Higher marketable and total yields (10.13, 12.71, 12.58 and 15.85 ton/fed. during 2012/2013 and 2013/14 seasons, respectively) were harvested from medium populated plots (45 plants/m^2) against minimum yield from thickly planted plots (60 plants/m^2) (6.55, 9.62, 9.01 and 13.19 ton/fed. during 2012/13 and 2013/14 seasons, respectively). On the contrary, average bulb weight and bulb diameter were gradually decreased by increasing plant population. However, the inverse was true in culls yield, where 60 plants/ m^2 gave the highest culls yield above 88.22 % compared to 30 plants/m^2 an average for the two years. Increased plant population linearly increased marketable and total onion yield and decreased mean bulb size. This may be attributed to increased competition among dense plants which caused a reduction in leaf area and dry weight per plant and in turn bulb diameter and bulb weight. Similar results were reported by Gashua and Abbator (2013), Bardisi *et al.* (2013) and Mansouri *et al.* (2014). The results are in agreement with those obtained by Dawar *et al.* (2007). They concluded that Lower density of 40 plants/m^2 has been found to increase weight of large size bulbs. The increase in planting density up to 60 plants/m^2 has been observed to exhibit optimum results. Planting density at 80 plants/m^2, exhibited negative impacts on all parameters except for the total yield of bulbs. Similarly, Farrag (1995) and Muhammad *et al.* (2011) found that lower plant densities (160,000 and 200,000 plants/ha) increased both bulb diameter and cured bulb weight but decreased total yield. Regarding, TSS and dry matter % they were significantly increased by increasing plant population up to 45 plants/ m^2

(Table 5). Over this plant population, TSS and dry matter % were reduced. However, in closer spacing, bulb diameter was so small that does not suitable to choice of consumers. This can be attributed to increased competition for nutrients and moisture at high plant density that resulted in bulbs of smaller diameter, when extra plants are overcrowded per meter, leaves are overlapped at an early stage and the benefits from light interception, on a ground area basis, are eroded (Scott and Jaggard, 1993).

Table (4): Average bulb weight (g) and yields of onion bulbs (ton/fed.) as affected by irrigation levels cultivation methods, plant densities and their interaction in 2012/13 and 2013/14 seasons.

Treatments	2012/13				2013/14			
	Average bulb weight (g)	Culls yield (t /fed.)	Marketable yield (t/ fed.)	Total yield (t/fed.)	Average bulb weight (g)	Culls yield (t/fed.)	Marketable yield (t/ fed.)	Total yield (t/ fed.)
Irrigation levels (I):								
I_0-100 %	70.87[b]	1.95[c]	8.39[c]	10.34[bc]	81.16[c]	2.12[c]	9.99[c]	12.11[c]
I_1-90 %	77.25[b]	2.25[c]	8.77[b]	11.02[b]	89.21[b]	2.84[bc]	12.04[b]	14.88[b]
I_2-80 %	93.14[a]	2.70[b]	9.64[a]	12.34[a]	97.46[a]	3.30[ab]	13.64[a]	16.94[a]
I_3-70 %	57.56[c]	3.35[a]	6.77[d]	10.12[c]	65.23[d]	4.14[a]	7.70[d]	11.84[c]
F-tes	**	**	**	**	**	**	**	**
Cultivation methods (M):								
Raised-beds	77.60[a]	2.30[b]	8.66[a]	10.96	86.55[a]	2.88[b]	11.33[a]	14.21[a]
Normal furrows	71.81[b]	2.83[a]	8.12[b]	10.95	79.98[b]	3.32[a]	10.36[b]	13.68[b]
F-test	**	**	**	N.S	**	*	**	*
Plant density (P):								
30	90.28[a]	2.04[c]	8.50[b]	10.54[b]	100.10[a]	1.85[c]	10.94[b]	12.79[c]
45	71.[39b]	2.59[b]	10.13[a]	12.71[a]	85.64[b]	3.27[b]	12.58[a]	15.85[a]
60	62.45[c]	3.07[a]	6.55[c]	9.62[c]	64.07[c]	4.18[a]	9.01[c]	13.19[b]
F-test	**	**	**	**	**	**	**	**
Interaction:								
IxM	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
IxP	**	N.S	**	*	**	N.S	**	**
MxP	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
IxMxP	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

***, ** and NS indicated P<0.05, P<0.01 and not significant, respectively. Means within the same column for each factor designated by the same letter are not significantly different at 5% level according to Duncan's multiple range test.**

Effect of interaction:

The interactions between irrigation levels plant densities for average bulb weight (g), marketable bulbs yield (ton/fed.), total bulbs yield (ton/fed.) and bulb diameter (cm) and irrigation levels cultivation methods for bulb diameter (cm) were significant. Means of onion bulbs yield and its quality as influenced by the first and the second order interaction are presented in Tables 6, 7 & 8.

Table (5): Bulb quality of onion plants as influenced by irrigation treatments, cultivation methods, plant densities and their interaction in 2012/13 and 2013/14 seasons.

Treatments	2012/13			2013/14		
	Bulb diameter (cm)	TSS (%)	Dry matter (%)	Bulb diameter (cm)	TSS (%)	Dry matter (%)
Irrigation levels (I):						
I_0-100 %	5.72 c	11.83 d	15.46c	6.06 c	13.54d	14.50c
I_1-90 %	6.44 b	12.61 c	16.78b	6.95 b	15.55c	17.18b
I_2-80 %	7.80 a	14.13 b	17.58b	7.66 a	16.54b	17.70b
I_3-70 %	4.94 d	15.03 a	18.80a	4.76 d	17.51a	18.77a
F-test	**	**	**	**	**	**
Cultivation methods (M):						
Raised-beds	6.50	13.76a	17.98a	6.83a	16.17a	17.68a
Normal furrows	5.95	13.03b	16.33b	5.90b	15.51b	16.39b
F-test	N.S	**	*	**	**	*
Plant density (P):						
30	7.47a	12.70c	15.97c	7.49 a	15.14c	15.97c
45	6.08b	14.02a	18.42a	6.34 b	16.81a	18.06a
60	5.14c	13.47b	17.07b	5.24 c	15.58b	17.08b
F-test	**	**	**	**	**	**
Interaction:						
IxM	**	N.S	N.S	**	N.S	N.S
IxP	**	*	N.S	*	*	N.S
MxP	N.S	N.S	N.S	N.S	N.S	N.S
IxMxP	N.S	*	N.S	N.S	N.S	**

***, ** and NS indicated P<0.05, P<0.01 and not significant, respectively. Means within the same column for each factor designated by the same letter are not significantly different at 5% level according to Duncan's multiple range test.**

Irrigation levels X cultivation methods interaction: bulb diameter (cm) was greater in the raised-beds than normal furrows at any soil moisture level. Irrigation at 80% of field capacity significantly exceeded the other three levels in the two seasons. Data in Table (6) show clearly that plants irrigated at 80% of field capacity which grown under raised-beds produced the highest bulb diameter. While irrigation at 70% of field capacity at normal furrows produced the lowest one.

Table (6): Effect of the interaction between irrigation levels and cultivation methods on average bulb diameter (cm) in 2012/13 and 2013/14 seasons.

Irrigation levels	2012/13		2013/14	
	Cultivation methods			
	Raised-beds	Normal furrows	Raised-beds	Normal furrows
I_0-100 %	6.02 e	5.41 f	6.61 d	5.51 e
I_1-90 %	6.73 c	6.15 d	7.41 b	6.49 d
I_2-80 %	8.13 a	7.46 b	8.22 a	7.10 c
I_3-70 %	5.11 g	4.77 h	5.09 f	4.42 g

Means designated by the same letter are not significantly different at 5% level, using Duncan's multiple range test

Irrigation levels X plant density interaction: The plants irrigated at 80 or 90% of field capacity significantly exceeded those irrigated at 100 or 70% of field capacity for all traits at any plant population as shown in Table(7). The maximum marketable bulbs yield and total bulbs yield (ton/fed.) were achieved from plants grown at a population of 45 plant/m^2 and irrigated at 80% of field capacity. However, a significant decrease in average bulb weight and diameter were observed with increasing plant density. Minimum plant population (30 plants/m^2) had significantly larger bulb diameter (8.83 and 8.77 cm), and heavier bulb weight (111.70 and 116.10 g) under irrigation at 80% of field capacity level during both years, respectively. Against smaller bulb diameter and weight of wider plants density (60 plants/ m^2) and irrigation at 100% of field capacity. This can be attributed to increased competition for nutrients and moisture at high plant density that resulted bulbs of smaller diameter and lower bulb weight. A similar result was reported by jilani *et al.*, 2009. However, in closer spacing, bulb size was so small that does not suitable to choice of consumers.

Table (7): Average bulb weight (g), marketable bulbs yield, total bulbs yield (ton/fed.), bulb diameter (cm) and TSS (%) as affected by the interaction between irrigation levels and plant densities in 2012/13 and 2013/14 seasons.

Irrigation levels	2012/13			2013/14		
	Plant density (plant/m^2)					
	30	45	60	30	45	60
	Average bulb weight (g)					
I_0-100 %	85.71^{c}	66.56^{ef}	60.35^{fg}	97.90^{c}	83.67^{e}	61.91^{i}
I_1-90 %	94.69^{b}	71.43^{de}	65.61^{ef}	104.70^{b}	93.96^{d}	68.92^{g}
I_2-80 %	111.70^{a}	93.14^{b}	74.63^{d}	116.10^{a}	98.31^{c}	77.99^{f}
I_3-70 %	69.06^{ef}	54.43^{gh}	49.19^{h}	81.58^{e}	66.62^{h}	47.47^{j}
	Marketable bulbs yield (ton/fed.)					
I_0-100 %	8.40^{c}	10.00^{b}	6.80^{d}	10.39^{e}	11.42^{cd}	8.17^{fg}
I_1-90 %	8.74^{c}	10.66^{b}	6.90^{d}	11.77^{c}	14.13^{b}	10.22^{e}
I_2-80 %	9.94^{b}	11.94^{a}	7.00^{d}	14.10^{b}	16.12^{a}	10.69^{de}
I_3-70 %	6.91^{d}	7.90^{c}	5.50^{e}	7.51^{gh}	8.65^{f}	6.96^{h}
	Total bulbs yield (ton/fed.)					
I_0-100 %	9.90^{efg}	12.07^{c}	9.06^{g}	11.47^{h}	13.70^{f}	11.16^{h}
I_1-90 %	10.55^{de}	12.92^{b}	9.59^{fg}	13.39^{f}	17.00^{b}	14.26^{e}
I_2-80 %	12.15^{bc}	14.71^{a}	10.14^{ef}	16.19^{c}	19.37^{a}	15.25^{d}
I_3-70 %	9.53^{fg}	11.15^{d}	9.69^{fg}	10.12^{i}	13.33^{f}	12.07^{g}
	Bulb diameter (cm)					
I_0-100 %	7.48^{c}	5.30^{f}	4.38^{gh}	7.35^{d}	6.01^{g}	4.81^{i}
I_1-90 %	7.52^{c}	6.43^{d}	5.36^{f}	8.17^{b}	6.92^{e}	5.77^{gh}
I_2-80 %	8.83^{a}	7.92^{b}	6.65^{d}	8.77^{a}	7.73^{c}	6.48^{f}
I_3-70 %	6.04^{e}	4.58^{g}	4.19^{h}	5.67^{h}	4.69^{i}	3.91^{j}
	TSS%					
I_0-100 %	11.23^{h}	12.27^{fg}	11.98^{g}	12.75^{f}	15.04^{e}	12.83^{f}
I_1-90 %	12.12^{fg}	13.13^{e}	12.57^{f}	14.93^{e}	16.15^{d}	15.57^{de}
I_2-80 %	13.38^{e}	14.67^{bc}	14.33^{cd}	15.92^{d}	17.51^{bc}	16.19^{d}
I_3-70 %	14.08^{d}	16.02^{a}	14.99^{b}	16.95^{c}	18.54^{a}	17.71^{b}

Means designated by the same letter are not significantly different at 5% level, using Duncan's multiple range test

Irrigation levels X cultivation methods X plant densities interaction: TSS and dry matter (%) was greater in raised-beds than normal furrows when plants were grown at 45 plant/m^2 and irrigated at 70% of field capacity as compared to other combinations. A population of 30 plant/m^2 with irrigation at 100% of field capacity under normal furrows method achieved the minimum percent of TSS and dry matter in both seasons (Table, 8). This result is in agreement with the findings of Biswas *et al.* (2010) who reported that irrigation has a trend to decrease the bulb dry matter content and total soluble solids.

Table (8): TSS and dry matter % as affected by the interaction among irrigation levels, plant densities and cultivation methods in 2012/13 and 2013/14 seasons.

Irrigation levels	Cultivation methods	TSS%			DM%		
		2012/13			2013/14		
		Plant densities(plant/m^2)					
		30	45	60	30	45	60
I_0-100 %	Raised-beds	11.80^{lm}	12.50^{jkl}	12.33^{jkl}	14.43^{j}	16.21^{h}	15.17^{i}
	Normal furrows	10.67^{n}	12.05^{klm}	11.62^{m}	12.80^{l}	14.68^{ij}	13.72^{k}
I_1-90 %	Raised-beds	12.33^{jkl}	13.33^{hi}	12.75^{ijk}	17.51^{ef}	18.33^{cd}	17.95^{cde}
	Normal furrows	11.90^{lm}	12.92^{ij}	12.40^{jkl}	14.98^{ij}	17.67^{de}	16.66^{gh}
I_2-80 %	Raised-beds	13.42^{ghi}	15.25^{bc}	14.83^{bcd}	16.83^{gh}	19.26^{b}	18.49^{c}
	Normal furrows	13.33^{hi}	14.09^{efg}	13.83^{fgh}	16.37^{gh}	18.26^{cd}	16.98^{fg}
I_3-70 %	Raised-beds	14.25^{def}	16.92^{a}	15.42^{b}	17.90^{cde}	20.71^{a}	19.37^{b}
	Normal furrows	13.92^{e-h}	15.12^{bc}	14.57^{cde}	16.91^{fg}	19.38^{b}	18.33^{cd}

Means designated by the same letter are not significantly different at 5% level, using Duncan's multiple range test.

B- Macro elements content:

Mean contents of N, P, K and Zn in the dry matter of bulbs tissue were significantly affected by different irrigation treatments, as shown in Table 9. The N, P, K and Zn contents in the onion bulbs tissue appeared significantly higher for irrigation treatment I_0 (Traditional irrigation) compared to other irrigation treatments. Whereas, the longest interval of irrigation had the lowest values of the abovementioned bulb chemical content. It is known that water is the medium of transfer and is the solvent in the system of the cell.

Concerning, the effect of cultivation methods on N, P, K and Zn contents, data showed that there were significant differences between cultivation methods. The N, P, K and Zn contents were significantly higher under normal furrows cultivation method, and the lowest with raised-beds cultivation method.

As in Table 9, increasing of plant spacing increased mineral content in the onion bulb in both seasons, compared to the narrowest one. However, the highest mineral content were achieved in thinly populated (30 plants/m^2) followed by medium populated crops (45 plants/m^2) and thickly populated (60 plants/m^2) during both years. This result confirms the findings of Rizk (1997) and Jilani *et al.* (2009), that increasing plant density decreased the nitrogen content of onion bulbs.

Table (9): Effect of irrigation levels, cultivation methods, plant density and their interaction on mineral content of onion bulbs in 2012/13 and 2013/14 seasons.

Treatments	2012/13				2013/14			
	N (ppm)	P (ppm)	K (ppm)	Zn (ppm)	N (ppm)	P (ppm)	K (ppm)	Zn (ppm)
Irrigation levels (I):								
I_0-100 %	3.04[a]	1.16[a]	0.60[a]	324.89	1.64[a]	1.58[a]	1.00[a]	335.78[a]
I_1-90 %	2.79[bc]	1.08[ab]	0.49[b]	316.39	1.49[b]	1.43[ab]	0.77[b]	319.90[b]
I_2-80 %	2.74[c]	0.88[c]	0.48[b]	310.88	1.35[c]	1.26[b]	0.55[c]	306.91[c]
I_3-70 %	2.82[b]	1.03[b]	0.41[c]	303.33	1.53[b]	0.97[c]	0.47[d]	278.76[d]
F-test	**	**	**	N.S	**	**	**	**
Cultivation methods (M):								
Raised-beds	2.77[b]	0.99[b]	0.47[b]	304.54[b]	1.48[b]	1.25[b]	0.64[b]	302.77[b]
Normal furrows	2.92[a]	1.08[a]	0.52[a]	323.21[a]	1.53[a]	1.37[a]	0.76[a]	317.90[a]
F-test	*	**	*	*	*	*	**	**
Plant density (P):								
30	3.04[a]	1.18[a]	0.57[a]	344.60[a]	1.57[a]	1.46[a]	0.86[a]	328.03[a]
45	2.84[b]	1.03[b]	0.49[b]	323.02[b]	1.49[b]	1.31[b]	0.67[b]	312.26[b]
60	2.67[c]	0.91[c]	0.43[c]	274.00[c]	1.44[c]	1.16[c]	0.56[c]	290.71[c]
F-test	**	**	**	**	**	**	**	**
Interaction:								
IxM	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
IxP	N.S	N.S	**	**	**	N.S	**	**
MxP	**	N.S	**	N.S	N.S	N.S	**	N.S
IxMxP	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

***, ** and NS indicated P<0.05, P<0.01 and not significant, respectively. Means within the same column for each factor designated by the same letter are not significantly different at 5% level according to Duncan's**

Effect of interaction:

The interaction between irrigation levels plant densities on K and Zn and cultivation method x plant densities for K % were significant in the two seasons. However, the other interactions did not reach the level of significance for these respects.

Irrigation levels X plant density interaction: Data show clearly that plants irrigated at 100% of field capacity which grown at a population of 30 plants/m^2 produced the highest percent of K and Zn. While those irrigated at 70% of field capacity at a population of 60 plants/m^2 produced the lowest one (Table, 10). The improvements of macro elements content response to high amounts of total water application could be attributed to the enhancing effects of water to crop's biological functions and growth in addition to the improving effects of water on nutrients availability.

Cultivation methods X plant density interaction: Results in Table (11) show that K % of onion under normal furrows method with lowest plant density (30 plants/m^2) gave maximum values of K as compared to other treatments. However, minimum percent of k was observed in raised-beds cultivation method with planting density of 60 per square meter.

Table (10): K and Zn of onion bulbs as affected by the interaction between irrigation levels plant densities for 2012/13 and 2013/14 seasons.

Irrigation levels	2012/13			2013/14		
	Plant densities (plant/m^2)					
	30	45	60	30	45	60
K (ppm)						
I_0-100 %	0.72[a]	0.58[b]	0.49[d]	1.07[a]	1.01[ab]	0.93[c]
I_1-90 %	0.56[bc]	0.50[d]	0.42[e]	0.98[bc]	0.76[d]	0.59[e]
I_2-80 %	0.54[c]	0.50[d]	0.42[e]	0.77[d]	0.46[f]	0.41[f]
I_3-70 %	0.47[d]	0.40[ef]	0.37[f]	0.63[e]	0.46[f]	0.32[g]
Zn (ppm)						
I_0-100 %	358.00[a]	355.00[a]	261.70[f]	351.00 [a]	332.10[b]	324.20[c]
I_1-90 %	356.00[a]	314.70[c]	278.50[de]	337.30[b]	321.00[cd]	301.40[e]
I_2-80 %	335.20[b]	313.90[c]	283.60[d]	331.20[b]	317.50[d]	272.00[h]
I_3-70 %	329.30[b]	308.5 [c]	272.30[e]	292.60[f]	278.50[g]	265.10[i]

Means designated by the same letter are not significantly different at 5% level, using Duncan's multiple range test.

Table (11): K content as affected by the interaction between cultivation methods plant densities in 2012/13 and 2013/14 seasons.

Cultivation methods	2012/13			2013/14		
	Plant densities (plant/m^2)					
	30	45	60	30	45	60
K (ppm)						
Raised-beds	0.53[b]	0.48[c]	0.41[e]	0.77[b]	0.63[d]	0.51[e]
Normal furrows	0.62[a]	0.51[b]	0.44[d]	0.95[a]	0.71[c]	0.60[d]

Means designated by the same letter are not significantly different at 5% level, using Duncan's multiple range test.

C- Storability:

Tables (12 and 13) illustrated the results of storability characters (physiological loss as well as decay and sprouting losses % of onion bulbs) was significantly ($p<0.05$) affected by irrigation levels after six months of storage in the two seasons. Physiological loss percentage was higher for onions from the wet treatment, which was irrigated at 100 % of field capacity (Traditional irrigation) while the lowest values were obtained from the dry treatment, which irrigated at 70% of field capacity. The medium level of irrigation values were found to be in between. Decay and sprouting losses % of onion bulbs gave similar trend to those obtained from physiological loss % at three storage periods during 2012/13 and 2013/14 seasons. So, the lowest values of final loss% were obtained with application of $\mathbf{I_3}$ (irrigated at 70% of field capacity) and finally it resulted in the highest values of remainder bulbs%. The higher weight loss in the first two months might be due to higher initial moisture content of the bulbs at the onset of the experiment and during 120th to 180th days, the weight loss increased in I_0 and I_1 as a result of rotting and sprouting during this period. It can be concluded that wet conditions seemed to increase the amount of moisture in bulbs, which may be less by storage. This pattern may explain the higher weight loss of moisture in bulbs after storage from wet treatment than dry one. These results coincided with the results given by Biswas *et al.* (2010).

For the effect of cultivation methods, data in Tables (12 and 13) reported that the effect of cultivation methods on physiological loss, decayed and sprouting, final loss and remainder bulbs% were significant at all storage periods (60, 120 and 180 days), in both seasons. The values of physiological, decayed and sprouting and final loss % of onion bulbs tended to decrease, and the remainder bulbs percentage to increase under raised-beds cultivation methods comparing with normal furrows during the whole period of storage.

The result for storability characters is presented in Tables 12 and 13 below. The population of 30 plants/m^2 gave the highest percentage of physiological loss, decayed and sprouting and final loss % at three storage periods in the two seasons. Also the maximum physiological loss, decayed and sprouting and final loss % of onion bulbs was observed at the 30 plants/m^2 density after 120 and 180 days of storage while the 45 plants/m^2 density gave the lowest values of physiological loss and decay and sprouting losses % of onion bulbs during 2012/13 and 2013/14 seasons . Plant density of 45 plants/m^2 attained the highest remainder bulbs% at the end of storage periods. While plant density of 30 plants/m^2 gave the worst results.

Table (12): Effect of irrigation levels, cultivation methods, plant densities and their interaction on physiological, decay and sprouting losses % of onion bulbs at three storage periods during 2012/13 and 2013/14 seasons.

Treatments	2012/13					2013/14				
	60 days	120 days		180 days		60 days	120 days		180 days	
	Phys.	rotted	Phys.	rotted	Phys.	Phys.	rotted	Phys.	rotted	Phys.
Irrigation levels(I):										
I_0-100 %	8.85^a	3.43^a	5.49^a	8.85^a	9.26^a	12.86^a	2.08^a	5.76^a	6.38^a	5.91^a
I_1-90 %	7.37^b	2.97^b	5.30^a	7.79^b	7.85^b	9.59^c	1.98^a	4.18^{ab}	4.58^b	5.61^b
I_2-80 %	6.45^c	2.76^b	4.77^a	5.65^c	6.15^c	10.29^b	1.52^b	4.92^b	4.12^b	4.86^c
I_3-70 %	5.56^d	2.18^c	3.80^b	3.52^d	4.47^d	7.67^d	0.79^c	4.09^c	2.84^c	4.54^d
F-test	**	**	**	**	*	**	**	**	**	**
Cultivation methods(M):										
Raised-beds	6.75^b	2.42^b	4.13^b	6.08^b	6.20^b	9.20^b	1.39^b	4.54^b	3.89^b	4.95^b
Normal furrows	7.36^a	3.25^a	5.55^a	6.82^a	7.66^a	11.01^a	1.80^a	5.43^a	5.06^a	5.51^a
F-test	*	**	**	N.S	*	**	**	*	*	*
Plant density(P):										
30	7.71^a	3.57^a	6.07^a	8.07	8.72^a	13.05^a	2.08^a	6.21^a	5.49^a	5.83^a
45	6.31^c	2.23^c	3.93^c	5.04	5.44^c	7.15^c	1.15^c	3.84^c	3.66^c	4.68^c
60	7.15^b	2.70^b	4.52^b	6.25	6.64^b	10.11^b	1.56^b	4.91^b	4.29^b	5.17^b
F-test	**	**	**	N.S	*	**	**	*	**	*
Interaction:										
IxM	**	N.S	N.S	N.S	**	**	N.S	N.S	N.S	N.S
IxP	**	N.S	**	**	N.S	**	N.S	**	**	N.S
MxP	N.S	**	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
IxMxP	N.S	**	N.S	N.S	N.S	*	N.S	N.S	N.S	N.S

***, ** and NS indicated P<0.05, P<0.01 and not significant, respectively. Means within the same column for each factor designated by the same letter are not significantly different at 5% level according to Duncan's multiple range test.**

Table (13): Final loss and remained bulbs% of onion after storage for 180 days as affected by different irrigation levels, cultivation methods, plant densities and their interaction in 2012/13 and 2013/14 seasons.

Treatments	2012/13		2013/14	
	Final loss (%)	Remained bulbs%	Final loss (%)	Remained bulbs%
Irrigation levels (I):				
I_0-100 %	35.89[a]	64.11[d]	32.99[a]	67.01[d]
I_1-90 %	31.27[b]	68.73[c]	26.93[b]	73.07[c]
I_2-80 %	25.78[c]	74.22[b]	25.70[c]	74.30[b]
I_3-70 %	19.52[d]	80.48[a]	19.93[d]	80.07[a]
F-test	**	**	**	**
Cultivation method (M):				
Raised-beds	25.59[b]	74.41[a]	23.97[b]	76.03[a]
Normal furrows	30.64[a]	69.36[b]	28.81[a]	71.19[b]
F-test	**	**	**	**
Plant density (P):				
30	34.14[a]	65.86[c]	32.65[a]	67.35[c]
45	22.95[c]	77.05[a]	20.47[c]	79.53[a]
60	27.25[b]	72.75[b]	26.04[b]	73.96[b]
F-test	**	**	**	**
Interaction:				
IxM	N.S	N.S	N.S	N.S
IxP	N.S	N.S	N.S	N.S
MxP	N.S	N.S	N.S	N.S
IxMxP	*	*	*	*

***, ** and NS indicated P<0.05, P<0.01 and not significant, respectively. Means within the same column for each factor designated by the same letter are not significantly different at 5% level according to Duncan's multiple range test.**

Effect of interaction:

Significant ($p<0.05$) interaction effect was recorded between the irrigation levels cultivation method on mean physiological loss % at 60 day storage period, and irrigation levels plant density for physiological loss at 60 and 120 day storage periods and decay and sprouting losses % at 180 day storage periods, and irrigation levels cultivation method plant density for decay and sprouting losses % at 120 day storage periods in the first season and physiological loss % at 60 day storage periods in the second season as well as final loss and remained bulbs% in both seasons.

Irrigation levels X cultivation methods interaction: Data in Table (14) illustrated that cultivation on raised-beds method under irrigation treatment I_3 (irrigation at 70% of field capacity) attained the lowest percentages of physiological loss at 60 day storage period (4.94 and 6.87 %) in both seasons, respectively. However the highest values were obtained by irrigation treatment I_0 (traditional irrigation) with normal furrows as cultivation method during the whole period of storage.

Table (14): Effect of the interaction between irrigation levels and cultivation methods on physiological loss at 60 day storage period in 2012/13 and 2013/14 seasons.

Irrigation levels	2012/13		2013/14	
	Cultivation method			
	Raised-beds	Normal furrows	Raised-beds	Normal furrows
I_0-100 %	8.64[b]	9.07[a]	12.19[b]	13.53[a]
I_1-90 %	7.22[d]	7.52[c]	8.20[e]	10.98[c]
I_2-80 %	6.22[f]	6.68[e]	9.52[d]	11.05[c]
I_3-70 %	4.94[g]	6.18[h]	6.87[f]	8.47[e]

Means designated by the same letter are not significantly different at 5% level, using Duncan's multiple range test.

Irrigation levels X plant density interaction: The maximum physiological loss % at 60 and 120 day storage periods and decay and sprouting losses % at 180 day was recorded with irrigation treatment I_0 (traditional irrigation) at a population of 30 plants/m^2. While those irrigated at 70% of field capacity at a population of 45 plants/m^2 produced the lowest one (Table 15). This result reflects the role of TSS and dry matter on improving bulb quality, which in turn, prevent excessive losses from decay and sprouting and lengthen the storage life of the bulbs.

Table (15): physiological loss % at 60 and 120 day storage periods and decay and sprouting losses % at 180 day as affected by the interaction between irrigation levels and plant density in 2012/13 and 2013/14 seasons.

Irrigation levels	2012/13			2013/14		
	Plant density(plant/m^2)					
	30	45	60	30	45	60
Physiological loss % at 60 DAS						
I_0-100 %	9.33[a]	8.23[c]	9.00[b]	15.96[a]	9.77[e]	12.87[c]
I_1-90 %	8.15[c]	6.73[e]	7.24[d]	13.63[b]	6.05[h]	9.07[f]
I_2-80 %	7.13[d]	5.53[g]	6.70[e]	12.46[c]	7.71[g]	10.69[d]
I_3-70 %	6.24[f]	4.76[h]	5.68[g]	10.15[de]	5.06[i]	7.79[g]
Physiological loss % at 120 DAS						
I_0-100 %	7.38[a]	4.20[fg]	4.90[de]	7.57[a]	4.30[e]	5.41[cd]
I_1-90 %	6.61[b]	4.26[fg]	5.02[d]	6.69[b]	3.66[fg]	5.19[cd]
I_2-80 %	5.68[c]	4.20[fg]	4.43[ef]	5.69[c]	4.03[ef]	5.03[d]
I_3-70 %	4.61[def]	3.06[h]	3.74[g]	4.88[d]	3.37[g]	4.02[ef]
Decay and sprouting losses % at 180 DAS						
I_0-100 %	10.15[a]	7.18[cd]	9.23[b]	6.99[a]	5.99[bc]	6.14[b]
I_1-90 %	9.68[ab]	6.63[d]	7.06[cd]	5.77[bc]	3.56[e]	4.43[d]
I_2-80 %	7.71[c]	4.20[fg]	5.04[e]	5.54[c]	2.95[f]	3.86[e]
I_3-70 %	4.75[ef]	2.15[h]	3.66[g]	3.65[e]	2.14[g]	2.74[f]

Means designated by the same letter are not significantly different at 5% level, using Duncan's multiple range test.

Irrigation levels X cultivation methods X plant density interaction: Decay and sprouting losses % at 120 days in the first season and physiological loss % at 60 days in the second season while final loss and remained bulbs % in both seasons were presented in Table (16) which indicated that, minimum decay and sprouting loss and physiological (1.59 and 4.12 %, respectively) was recorded with I_3 (irrigation at 70% of field capacity) x raised-beds as cultivation method x 45 plants/m^2 and the maximum values (5.45 and 16.56 %, respectively) was found in onion of wet irrigation treatment I_0 (traditional irrigation) at a population of 30 plants/m^2 with normal furrows cultivation method. Therefore, final loss appeared significantly lower (11.07 and 12.34% in both seasons, respectively) for the combination of I_3 (irrigation at 70% of field capacity), along with a population of 45 plants/m^2 with raised-beds cultivating method, and the remained bulbs percentage was significantly higher (88.93 and 87.66 % in both seasons, respectively).

Table (16): Decay and sprouting losses % at 120 day, physiological loss % at 60 day, final loss and remained bulbs % as affected by the interaction among irrigation levels, cultivation methods and plant densities in 2012/13 and 2013/14 seasons.

Irrigation levels	Cultivation methods	Decay and sprouting losses % at 120 DAS			Physiological loss % at 60 DAS		
		2012/13			2013/14		
		Plant density(plant/m^2)					
		30	45	60	30	45	60
I_0-100 %	Raised-beds	3.45^{cde}	2.51^{g-k}	2.70^{f-i}	15.35^{b}	9.03^{i}	12.19^{de}
	Normal furrows	5.45^{a}	2.90^{e-h}	3.58^{cd}	16.56^{a}	10.50^{gh}	13.54^{c}
I_1-90 %	Raised-beds	3.24^{def}	2.00^{klm}	2.54^{g-k}	11.62^{ef}	5.04^{o}	7.92^{jkl}
	Normal furrows	4.18^{b}	2.60^{g-j}	3.27^{de}	15.64^{b}	7.07^{lm}	10.22^{h}
I_2-80 %	Raised-beds	3.17d^{ef}	1.82^{lm}	2.12^{j-m}	11.89^{ef}	6.60^{mn}	10.08^{h}
	Normal furrows	3.86b^{c}	2.37^{h-k}	3.23^{def}	13.03^{cd}	8.81^{ij}	11.30^{efg}
I_3-70 %	Raised-beds	2.24^{i-l}	1.59^{m}	1.71^{lm}	9.10^{i}	4.12^{p}	7.38^{klm}
	Normal furrows	2.99e^{fg}	2.08^{j-m}	2.45^{g-k}	11.20^{fg}	6.01^{n}	8.20^{ijk}
Final loss (%)							
I_0-100 %	Raised-beds	38.07^{c}	28.87^{fg}	33.61^{de}	37.02^{c}	25.21^{h}	30.57^{e}
	Normal furrows	44.89^{a}	32.11^{e}	37.77^{c}	42.29^{a}	28.62^{fg}	34.21^{d}
I_1-90 %	Raised-beds	35.50^{d}	23.80^{i}	26.64^{h}	20.69^{e}	17.59^{j}	23.39^{i}
	Normal furrows	41.47^{b}	28.54^{fg}	32.68^{e}	38.86^{b}	22.18^{i}	28.89^{fg}
I_2-80 %	Raised-beds	29.64^{i}	18.79^{k}	22.19^{ij}	29.48^{ef}	17.75^{j}	23.44^{i}
	Normal furrows	33.63^{de}	22.93^{ij}	27.49^{gh}	32.69^{d}	22.76^{i}	28.10^{fg}
I_3-70 %	Raised-beds	23.55^{i}	11.07^{m}	16.36^{m}	22.63^{i}	12.34k	17.52^{j}
	Normal furrows	27.38^{gh}	17.48^{kl}	21.30^{j}	27.55^{g}	17.33^{j}	22.19^{i}
Remained bulbs%							
I_0-100 %	Raised-beds	61.93^{k}	71.13^{gh}	66.39^{ij}	62.98^{i}	74.79^{d}	69.43^{g}
	Normal furrows	55.11^{m}	67.89^{i}	62.23^{k}	57.71^{k}	71.38^{ef}	65.79^{h}
I_1-90 %	Raised-beds	65.50^{j}	76.20^{e}	73.36^{f}	69.31^{g}	82.41^{b}	76.61^{c}
	Normal furrows	58.53^{l}	71.46^{gh}	67.32^{i}	61.14^{j}	77.82^{c}	71.11^{ef}
I_2-80 %	Raised-beds	70.36^{h}	81.21^{c}	77.81^{de}	70.52^{fg}	82.25^{b}	76.56^{c}
	Normal furrows	66.37^{ij}	77.07^{de}	72.51^{fg}	67.31^{h}	77.24^{c}	71.90^{ef}
I_3-70 %	Raised-beds	76.45^{e}	88.93^{a}	83.64^{b}	77.37^{c}	87.66^{a}	82.48^{b}
	Normal furrows	72.62^{fg}	82.52^{bc}	78.70^{d}	72.45^{e}	82.67^{b}	77.81^{c}

Means designated by the same letter are not significantly different at 5% level, using Duncan's multiple range test.

Effect of irrigation, Cultivation methods and plant density on:
D- Amount of seasonal water applied (cm & m³/fed.):

Seasonal amount of water applied (Wa) for onion as a winter crop consists of two components; water delivered to the field plot by irrigation (IW) and effective rainfall, Doorenbos and Pruitt (1975). Effective rainfall means (incident rainfall*0.7) Novica (1979).The amount of effective rainfall was 100.16 mm (420.672 m^3/fed.) and 165.5 mm(695.10 m^3/fed.) in the first and second growing seasons , respectively. Presented data in Table (17) clearly illustrated that the overall mean values for seasonal water applied were greatly affected by irrigation treatments and cultivation methods but not affected by plant densities. Concerning, the effect of irrigation treatments, the highest overall mean values through the two growing seasons were recorded under irrigation treatment I_0 (Traditional irrigation) and the overall mean values under the two cultivation methods is 54.25 cm(2278.5 m^3/fed.). Meanwhile, the lowest overall mean value under the two cultivation methods is 38.12cm (1601.04 m^3/fed.). Generally, the overall mean values for seasonal water applied can be descended in order $I_0 > I_1 > I_2 > I_3$. Increasing the values of seasonal water applied under irrigation treatment I_0 in comparison with other irrigation treatments I_1, I_2 and I_3 may be due to increasing time of irrigation and also number of watering under the conditions of this treatment and hence, increasing amount of seasonal water applied. These results are in a great harmony with those reported by El-Akram (2012) in Egypt, who found that, amount of water applied was higher with frequent irrigation i.e. irrigation at 40% of available soil moisture was depleted in comparison with irrigation at 60 and 80 % depletion of available soil moisture treatments. These findings are also in the same line with those found by Eid (2012), Rashed and Moursi (2012) and Moursi and Darwesh(2014).

Regarding, the effect of cultivation methods on seasonal amount of water applied. The values of seasonal amount of water applied under all irrigation treatments were greatly affected by cultivation methods, where the highest values were recorded under normal furrows (normal cultivation method) comparing with using wide furrows cultivation method (raised-beds technique). The overall mean values through the two growing seasons under normal cultivation method are 56.63cm (2378.38 m^3/fed.), 50.14cm (2105.73 m^3/fed.), 45.33cm (1904.3 m^3/fed.) and 40.01cm (1680.52 m^3/fed.) under irrigation treatments I_0, I_1, I_2 and I_3, respectively. The corresponding values under raised-beds cultivation method are 51.86 cm (2177.82m^3/fed.), 46.92cm (1970.29 m^3/fed.), 41.79cm (1755.27 m^3/fed.) and 36.23cm (1521.48 m^3/fed.) under irrigation treatments I_0, I_1, I_2 and I_3, respectively. The overall mean values of water saving under all irrigation treatments in case of using raised-beds cultivation method is 160.95 m^3/fed. (8.03 %) as shown in Table (18). The amount of water saving at the national level is 24551.15 m^3 where, the cultivated area is 152,539 fed. (2015)*.

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* **Source: Agriculture Directorates of Governorates.**
Publisher: Economic Affairs Sector.

Increasing the seasonal amount of water applied under normal cultivation method in comparison with raised-beds cultivation method may be attributed to increasing irrigation inlets and water ways (furrows). Therefore, increasing irrigated area and amount of water losses by evaporation from the soil surface. So, to compensate these losses and to avoid water stress which plants will suffer from it, irrigation interval should be shortened and hence, increasing amount of water applied. These results are in a great harmony with those obtained by Eid (2012) and Rashed and Moursi (2012).

Concerning, the effect of plant densities on the seasonal amount of water applied as clearly shown in the same table, plant densities did not have any effect on seasonal amount of water applied. These findings are in the same line with those reported by Moursi *et al.* (2010).

Table (17): Effect of irrigation levels, cultivation methods and plant densities on seasonal amount of water applied for onion crop in the two growing seasons.

Irrigation levels (I)	plant density (D)	1st growing season				2nd growing season				The overall mean values through the two growing seasons			
		Cultivation methods											
		Raised- beds		Normal furrows		Raised- beds		Normal furrows		Raised- beds		Normal furrows	
		cm	m^3/fed.	cm	m^3/fed.	cm	m^3/fed.	cm	m^3/fed.	cm	m^3/fed.	cm	m^3/fed.
I_0	D_1	52.27	2195.31	56.80	2385.60	51.44	2160.33	56.46	2371.16	51.86	2177.82	56.63	2378.38
	D_2	52.27	2195.31	56.80	2385.60	51.44	٢١٦٠.٣٣	56.46	2371.16	51.86	2177.82	56.63	2378.38
	D_3	52.27	2195.31	56.80	2385.60	51.44	٢١٦٠.٣٣	56.46	2371.16	51.86	2177.82	56.63	2378.38
Mean		52.27	2195.31	56.80	2385.60	51.44	2160.33	56.46	2371.16	51.86	2177.82	56.63	2378.38
I_1	D_1	47.39	1990.18	50.27	2111.17	46.44	1950.40	50.01	2100.28	46.92	1970.29	50.14	2105.73
	D_2	47.39	1990.18	50.27	2111.17	46.44	١٩٥٠.٤٠	50.01	2100.28	46.92	1970.29	50.14	2105.73
	D_3	47.39	1990.18	50.27	2111.17	46.44	١٩٥٠.٤٠	50.01	2100.28	46.92	1970.29	50.14	2105.73
Mean		47.39	1990.18	50.27	2111.17	46.44	١٩٥٠.٤٠	50.01	2100.28	46.92	1970.29	50.14	2105.73
I_2	D_1	42.15	1770.26	45.65	1917.25	41.44	1740.28	45.02	1890.80	41.79	1755.27	45.33	1904.03
	D_2	42.15	1770.26	45.65	1917.25	41.44	1740.28	45.02	1890.80	41.79	1755.27	45.33	1904.03
	D_3	42.15	1770.26	45.65	1917.25	41.44	1740.28	45.02	1890.80	41.79	1755.27	45.33	1904.03
Mean		42.15	1770.26	45.65	1917.25	41.44	1740.28	45.02	1890.80	41.79	1755.27	45.33	1904.03
I_3	D_1	36.30	1524.73	40.24	1690.18	36.15	1518.23	39.78	1670.85	36.23	1521.48	40.01	1680.52
	D_2	36.30	1524.73	40.24	1690.18	36.15	1518.23	39.78	1670.85	36.23	1521.48	40.01	1680.52
	D_3	36.30	1524.73	40.24	1690.18	36.15	1518.23	39.78	1670.85	36.23	1521.48	40.01	1680.52
Mean		36.30	1524.73	40.24	1690.18	36.15	1518.23	39.78	1670.85	36.23	1521.48	40.01	1680.52

Table (18): The overall mean values for amount and percentage of water saving under using raised- beds cultivation method.

Irrigation levels	Amount of water saving (m^3/fed.)	Water saving (%)
I_0-Traditional irrigation	200.56	8.43
I_1-90 %	135.54	6.43
I_2-80 %	148.76	7.81
I_3-70 %	159.04	9.46
The overall mean	160.95	8.03

E- Water consumptive use (Cu, cm & m³/fed.):

Water consumptive use or which so- called evapotranspiration (ET) can be defined as the combined upward movement of moisture from the soil to the atmosphere through transpiration from plant surfaces and evaporation from the surface of the field. Evapotranspiration can be estimated in the field by using evaporation pans, calculated on the basis of climatological data or determined by taking soil samples (direct method) which depends upon soil moisture depletion (SMD). Data in Table (19) clearly indicated that, the overall mean values for water consumptive use (CU) were greatly affected by irrigation treatments, cultivation methods and plant densities. Concerning, the effect of irrigation treatments, the highest overall mean values were recorded under irrigation treatment I_0 in comparison with other irrigation treatments I_1, I_2 and I_3. The highest overall mean values under the two cultivation methods are 34.74 cm (1459.08 m^3/fed.). Meanwhile, the lowest overall mean values were recorded under irrigation treatment I_3 and the value is 23.25 cm (976.50 m^3/fed.). Generally, the overall mean values for water consumptive use can be descended in order $I_0 > I_1 > I_2 > I_3$, this may be attributed to increasing amount of water applied under I_0. Consequently, increasing availability of soil nutrients and hence, increasing uptake rate of these nutrients. So, forming strong plants with a thick vegetative cover. So, increasing exposed area to the sunlight and hence increasing transpiration rate from plant surfaces which consider one of the main components to water consumptive use (cu). So, increasing the values of Cu under the conditions of irrigation treatment I_0 (traditional irrigation method) in comparison with other irrigation treatments $I_{1,}$ I_2 and I_3. These results are in a great harmony with those reported by El-Akram (2012) in Egypt, who found that, onion crop evapotranspiration (ETC) was higher with frequent irrigation, i.e. irrigating at 40% depletion of available soil moisture in comparison with irrigating at 60 and 80 % depletion of available soil moisture treatments. Also, these results are in the same line with those reported by Eid (2012), Rashed and Moursi (2012) and Moursi and Darwesh (2014).

Regarding, the effect of cultivation methods, the highest overall mean values were recorded under normal cultivation method (B) under all irrigation treatments comparing with raised-beds cultivation methods (A). The value under treatment (B) is 36.61cm (1537.73m^3/fed.). Meanwhile, under treatment (A) is 32.86 cm (1380.18 m^3/fed.). On the other hand, the lowest values were recorded under irrigation treatment I_3 and the values are 24.62cm (1033.97m^3/fed.) under treatment (B) and 21.88cm (919.14m^3/fed.) under treatment (A). Increasing the water consumptive use under normal cultivation method (B) in comparison with raised-beds cultivation method (A) may be attributed to increasing amount of water applied under the conditions of (B) comparing with (A). These results are in the same line with those reported by Eid (2012) and Rashed and Moursi (2012).

Regarding, the effect of plant densities, the highest overall mean values were recorded under treatment D_3 (60 plant/m^2) under (A) and (B) cultivation methods comparing with 45 and 30 plant/m^2 under the same cultivation methods. Increasing, the values of water consumptive use under the highest plant densities in comparison with other ones may be due to increasing the exposed plant surfaces to sunlight and hence, increasing transpiration rate from these surfaces. Consequently, increasing the values of water consumptive use under the conditions of this treatment. These findings are in the same line with those reported by Moursi *et al.* (2010).

Table (19): Effect of irrigation levels, cultivation methods and plant densities on water consumptive use (cm&m^3/fed.) for onion crop in the two growing seasons.

Irrigation levels (I)	plant density (D)	1st growing season				2nd growing season				Overall mean values through the two growing seasons			
		Cultivation methods											
		Raised-beds		Normal furrows		Raised-beds		Normal furrows		Raised-beds		Normal furrows	
		cm	m^3/fed.	cm	m^3/fed.	cm	m^3/fed.	cm	m^3/fed	cm	m^3/fed.	cm	m^3/fed
I_0-100 %	30	32.62	1370.18	36.32	1525.30	32.39	1360.20	36.21	1520.70	32.50	1365.19	36.26	1523.00
	45	32.86	1380.20	36.74	1543.20	32.76	1375.80	36.69	1540.90	32.81	1378.00	36.72	1542.05
	60	33.31	1398.90	36.92	1550.70	33.23	1395.77	36.80	1545.60	33.27	1397.34	36.86	1548.15
Mean		32.93	1383.09	36.66	1539.73	32.79	1377.26	36.57	1535.73	32.86	1380.18	36.61	1537.73
I_1-90 %	30	29.17	1225.33	31.79	1335.18	28.60	1201.30	31.20	1310.27	28.89	1213.32	31.49	1322.73
	45	29.53	1240.20	32.15	1350.27	29.25	1228.32	31.67	1330.32	29.39	1234.26	31.91	1340.30
	60	29.75	1249.30	32.43	1362.17	29.41	1235.17	32.12	1348.93	29.58	1242.24	32.28	1355.55
Mean		29.48	1238.28	32.12	1349.21	29.09	1221.60	31.66	1329.84	29.29	1229.94	31.89	1339.53
I_2-80 %	30	25.67	1078.23	27.86	1170.13	25.01	1050.38	27.63	1160.34	25.34	1064.31	27.74	1165.24
	45	25.98	1090.95	28.34	1190.32	25.73	1080.74	28.23	1185.70	25.85	1085.85	28.29	1188.01
	60	26.17	1099.32	28.59	1200.63	26.00	1092.13	28.53	1198.39	26.09	1095.73	28.56	1199.51
Mean		25.94	1089.50	28.26	1187.03	25.58	1074.42	28.13	1181.48	25.76	1081.96	28.20	1184.26
I_3-70 %	30	21.79	915.18	24.29	1020.33	21.69	910.78	24.20	1016.32	21.74	912.98	24.25	1018.33
	45	21.93	921.17	24.98	1049.22	21.79	915.21	24.50	1028.40	21.86	918.19	24.73	1038.81
	60	22.15	930.15	25.11	1054.42	21.96	922.34	24.65	1035.15	22.05	926.19	24.88	1044.79
Mean		21.96	922.17	24.79	1041.32	21.81	916.11	24.44	1026.62	21.88	919.14	24.62	1033.97

F- Irrigation water efficiencies:

The studied irrigation water efficiencies were consumptive use efficiency (Ecu,%), water productivity(WP, kg/m^3) and productivity of irrigation water (PIW, kg/m^3). Concerning, consumptive use efficiency (Ecu, %), the values in Table (20) were clearly affected by irrigation treatments, cultivation methods and plant densities. Regarding, irrigation treatments, the highest overall mean values were recorded under irrigation treatment I_0 (traditional irrigation) under the two cultivation methods (64.02%). Meanwhile, the lowest overall mean values were recorded under the two cultivation methods under irrigation treatment I_3 and the value is (60.97%). Generally, the overall mean values for Ecu under the two cultivation methods can be descended in order $I_0 > I_1 > I_2 > I_3$.

Regarding, the effect of cultivation methods, the highest overall mean values were recorded under normal cultivation method (B) in comparison with raised-beds cultivation method (A) which recorded the lowest values under the same irrigation treatments. The overall mean values under normal cultivation method are 64.66, 63.62, 62.20 and 61.53%. The corresponding values under raised-beds cultivation method(B) are 63.38, 62.43, 61.65 and 60.41% under irrigation treatment I_0, I_1, I_2 and I_3,respectively.These results are in the same line with those reported by Eid (2012) and Rashed and Moursi (2012). Concerning, the effect of plant densities on (Ecu, %), the highest overall mean values were recorded under plant density D_3 (60 plant/m^2) under all irrigation treatments and the two cultivation methods. These results are in the same line with those found by Moursi *et al.* (2010).

Regarding, the values of water productivity (WP) and productivity of irrigation water (PIW), in Table (21) were clearly affected by the three studied treatments (irrigation, cultivation methods and plant densities). Concerning the effect of irrigation treatments, the highest overall mean values were recorded under irrigation treatment I_2(irrigation at 80% of field capacity) and the values are 12.93 kg/m^3 and 8.01 kg/m^3 for WP and PIW, respectively. Meanwhile, the lowest values were recorded under irrigation treatment I_0 (traditional irrigation method) and the values are 7.70 kg/m^3 and 4.94 kg/m^3 for WP and PIW, respectively. As clearly shown the values of WP and PIW were increased under water stress conditions comparing with traditional conditions. So, the values of WP and PIW can be descended in order I_2 > I_3>I_1 > I_0. Increasing the values of WP and PIW under water stress conditions comparing with non- stressed ones (Control) may be attributed to decreasing amount of seasonal water applied and water consumptive use. Also, the values of WP were higher than those of PIW. This may be due to increasing the values of seasonal water applied comparing with the values of water consumptive use. These results are in harmony with those reported by El-Akram (2012) and Moursi and Darwesh(2014). For the effect of cultivation methods on WP and PIW, the highest overall mean values were recorded under raised-beds cultivation method(A) comparing with normal cultivation method(B) and the values under (A) are 10.93 and 6.79 kg/m^3 for WP and PIW. Meanwhile, under (B) are 9.68 kg/m^3 and 6.11 kg/m^3 for WP and PIW, respectively. These findings are in harmony with those reported by Rashed and Moursi (2012).

Table (20): Effect of irrigation levels, cultivation methods and plant densities on consumptive use efficiency (Ecu %) for onion crop in the two growing seasons.

Irrigation levels (I)	plant density (D)	1st growing season		2nd growing season		The overall mean values through the two growing seasons	
		Cultivation methods					
		Raised-beds (A)	Normal furrows (B)	Raised-beds (A)	Normal furrows (B)	Raised-beds (A)	Normal furrows (B)
		Ecu (%)					
I_0-100 %	D_1	62.41	63.94	62.96	64.13	62.69	64.04
	D_2	62.87	64.69	63.68	64.99	63.28	64.84
	D_3	63.72	65.00	64.61	65.18	64.17	65.09
Mean		63.00	64.54	63.75	64.77	63.38	64.66
I_1-90 %	D_1	61.57	63.24	61.59	62.39	61.58	62.82
	D_2	62.32	63.96	62.98	63.34	62.65	63.65
	D_3	62.77	64.52	63.33	64.23	63.05	64.38
Mean		62.22	63.91	62.63	63.32	62.43	63.62
I_2-80 %	D_1	60.91	61.03	60.36	61.37	60.64	61.20
	D_2	61.63	62.08	62.10	62.71	61.87	62.40
	D_3	62.10	62.62	62.76	63.38	62.43	63.00
Mean		61.55	61.91	61.74	62.49	61.65	62.20
I_3-70 %	D_1	60.02	60.37	59.99	60.83	60.01	60.60
	D_2	60.42	62.08	60.28	61.55	60.35	61.82
	D_3	61.00	62.39	60.75	61.95	60.88	62.17
Mean		61.48	61.61	60.34	61.44	60.41	61.53

Table (21): Effect of irrigation levels, cultivation methods and plant densities on water productivity (WP, kg/m^3) and productivity of irrigation water (PIW, kg/m^3) for onion crop in the two growing seasons.

Treatments		1st growing season		2nd growing season		The overall mean values through the two growing seasons	
		WP (Kg/m^3)	PIW (Kg/m^3)	WP (Kg/m^3)	PIW (Kg/m^3)	WP (Kg/m^3)	PIW (Kg/m^3)
Irrigation levels:							
I_0-100 %		7.08	4.51	8.31	5.34	7.70	4.93
I_1-90 %		8.52	5.37	11.66	7.35	10.09	6.36
I_2-80 %		10.84	6.69	15.02	9.33	12.93	8.01
I_3-70 %		10.31	6.30	12.19	7.43	11.25	6.87
Cultivation method:							
Raised-beds		9.46	5.86	12.39	7.71	10.93	6.79
Normal furrows		8.56	5.40	10.79	6.81	9.68	6.11
Plant density:							
D_1	Raised-beds	9.19	5.64	11.31	6.94	10.25	6.29
	Normal	8.35	5.20	10.22	6.37	9.29	5.79
Mean		8.77	5.42	10.77	6.66	9.77	6.04
D_2	Raised-beds	10.97	6.80	13.78	8.60	12.38	7.70
	Normal	9.90	6.27	12.47	7.89	11.19	7.08
Mean		10.44	6.54	13.13	8.25	11.79	7.40
D_3	Raised-beds	8.23	5.14	11.36	7.16	9.80	6.15
	Normal	7.45	4.75	10.29	6.57	8.87	5.66
Mean		7.84	4.95	10.83	6.87	9.34	5.91

Regarding, plant density, the highest overall mean values were recorded under D_2 (45 plant/m^2) comparing with D_1 (30 plant/m^2) and D_3 (60 plant/m^2). Generally the values of WP and PIW can be descended in order $D_2 > D_1 > D_3$

It can be concluded that irrigation onion crop at 80 % of field capacity, cultivation on raised-beds and with plant density of (45 plant/m^2) to achieve the maximum yield, and good onion quality with a better shelf life at the end of storage periods as well as water productivity and productivity of irrigation water instead of using traditional irrigation and normal cultivation which affect badly on both yield and decreasing water productivity and productivity of irrigation water. However, further study should be done to assess an economic analysis after six months' storage to determine the level of irrigation which will be more profitable for onion yield and storage.

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تأثير مستويات الري و طرق الزراعة والكثافة النباتية على إنتاجية وجودة محصول البصل وبعض العلاقات المائية فى الأراضى الطينية الثقيلة

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أجريت تجربة حقلية بمحطة البحوث الزراعية بسخا – محافظة كفر الشيخ – خلال موسمى النمو ٢٠١٢/٢٠١٣ ، ٢٠١٣/٢٠١٤ وذلك لهدف دراسة تأثير معاملات الرى وطرق الزراعة والكثافات النباتية على إنتاجية وجودة وبعض العلاقات المائية لمحصول البصل فى الأراضى الطينية الثقيلة – التصميم الأحصائى المستخدم فى الدراسة هو الشرائح المتعامدة المنشقة فى أربعة مكررات حيث القطع الرئيسية شغلت بمعاملات الرى والتى كانت I. (رى عادى كما يمارس بالمنطقة موضع الدراسة)،I٢، I١ و I٣ رى عند ٩٠، ٨٠، ٧٠% من السعة الحقلية. القطع الافقية شغلت بطرق الزراعة والتى وزعت بشكل عشوائىحيث كانت A

(زراعة مع مصاطب) ، B (زراعة مع خطوط عادية) وكانت المعاملات تحت الرئيسية هى الكثافات النباتية والتى كانت D_1 (٣٠ نبات/م٢)، D_2 (٤٥ نبات/م٢) و D_3 (٦٠ نبات/م٢).

أهم النتائج يمكن تلخيصها :

- وقد أعطت النباتات المرويه عند إستنفاذ ٨٠% من الماء السعة الحقلية أعلى انتاجية من محصول الأبصال الصالح للتسويق ، محصول الأبصال الكلى ومتوسط وزن وقطرالبصلة وكذلك النسبة المئوية للمواد الصلبة الكلية الذائبة ، النسبة المئوية للمادة الجافة والقدرة التخزينية للأبصال . فقد زاد المحصول الصالح للتسويق والكلي بنسبة ٢٥.٧٢و ٣٣.٨٤ على التوالى مقارنة بالرى التقليدى (الرى عند ١٠٠% من السعة الحقلية). بينما عند الرى عند وفرة الرطوبة الارضية وهى الطريقة المتبعة من معظم المزارعين بمنطقة الدراسه أدت الى زيادة محصول نقضة/فدان مع زيادة محتوى الابصال من النيتروجين والبوتاسيوم وزيادة نسبة الفقد نتيجة للتزريع والاعفان والفقد الفسيولوجى اثناء فترات التخزين.
- أظهرت النتائج ان طريقة الزراعة كان لها تأثير واضح على كل من متوسط وزن البصلة ، محصول الأبصال الصالح للتسويق ، محصول الأبصال الكلى ، وزن الأبصال النقضة/فدان ، قطر البصلة ، النسبة المئوية للمواد الصلبة الكلية الذائبة ، النسبة المئوية للمادة الجافة بالأبصال والقدرة التخزينية للأبصال وذلك فى كلا الموسمين. حيث أدت الزراعة على مصاطب الى زيادة جميع الصفات المدروسة تحت الدراسة . فقد انخفض محصول النقضة عند الشتل على مصاطب بنسبة ١٩.١٦% مقارنة بالشتل على حطوط. وكان التأثير عكسى على وزن الأبصال النقضة/فدان و محتوى الابصال من النيتروجين والبوتاسيوم وزيادة نسبة الفقد نتيجة للتزريع والاعفان والفقد الفسيولوجى اثناء فترات التخزين عند الشتل على الخطوط (الزراعة العادية).
- أوضحت النتائج زيادة كثافة نباتات من ٣٠ إلى ٦٠ نبات/م٢ أدت إلى إنخفاض تدريجى فى متوسط وزن البصلة، قطر البصلة، الفقد الفسيولوجى%، وفقد التزريع%، والفقد النهائى% وبتالى زيادة نسبة وزن الابصاال المتبقية فى نهاية فترة التخزين. وقد أعطت الكثافة ٤٥ نبات/م٢ اعلى محصول الصالح للتسويق والكلي ، النسبة المئوية للمواد الصلبة الكلية الذائبة ، النسبة المئوية للمادة الجافة بنسبة ١٧.٠٨، ٢٢.٢٦، ١٠.٧١، ١٤.٢١% على الترتيب عند مقارنتها بالكثافة٦٠ نبات/م٢. على العكس من ذلك فقد زادت نسبة وزن الأبصال النقضة للفدان عند الشتل بالكثافة٦٠ نبات/م٢الى ٨٨.٢٢ عند مقارنة بالكثافة٣٠ نبات/م٢.
- أثرت كل التفاعلات بين العوامل المختلفه معنوياعلى كل من متوسط وزن البصلة ،المحصول الصالح للتسويق والكلي ، وزن الأبصال النقضة للفدان ، قطر البصلة ،المواد الصلبة الذائبة والنسبة المئوية للمادة الجافة بالأبصال والقدرة التخزينية للأبصال. وقد تحقق أعلى إنتاجية وجودة مع زيادة القدرة التخزينية للابصال فى كثافة ٤٥ نبات/م٢ والمرويه عند ٨٠% من السعة الحقلية و الزراعة على مصاطب لذلك تعتبر هذه المعامله أفضل المعاملات.
- سجلت أعلى القيم فى كلا موسمى الدراسة للماء الموسمى المضاف والأستهلاك المائى وكفاءة الأستهلاك المائى تحت معاملة الرى I. (رى عادى) وطريقة الزراعة العادية (A) وكانت القيم ٥٦.٦٣سم (٢٣٧٨.٣٨م³/فدان)، ٥١.٨٦سم (٢١٧٧.٨٢م³/فدان) للماء الموسمى المضاف ، ٣٦.٦١سم (١٥٣٧.٧٣م³/فدان) للأستهلاك المائى و ٦٤.٦٦% و ٦٣.٣٨% لكفاءة الأستهلاك المائى تحت طريقة الزراعة العادية والمصاطب على الترتيب.
- سجلت قل القيم تحت معاملة الرى I_3 (ظروف الأجهاد المائى) وطريقة الزراعة على مصاطب والقيم هى ٤٠.٠١سم (١٦٨٠.٥٢م³/فدان)، ٣٦.٢٣سم (١٥٢١.٤٨م³/فدان) للماء الموسمى المضاف، ٢٤.٦٢سم (١٠٣٣.٩٧م³/فدان) ٢١.٨٨سم (٩١٩.١٤م³/فدان) للأستهلاك المائى و ٦١.٥٣% و ٦٠.٤١% لكفاءة الأستهلاك المائى تحت طريقة المصاطب و الزراعة العادية على الترتيب.
- بالنسبة لتأثير الكثافات النباتية سجلت أعلى القيم بالنسبة للأستهلاك المائى وكفاءة الأستهلاك المائى تحت أعلى الكثافات النباتية D_3 (٦٠ نبات/م٢) تحت طريقتى الزراعة وكل معاملات الرى . بينما بالنسبة للماء المضاف لم يتأثر بالكثافة النباتية.
- سجلت أعلى القيم لأنتاجية وحدة المياه المستهلكة WP، المضافة PIW سجلت تحت معاملة الرى ٨٠% من السعة الحقلية وطريقة الزراعة على مصاطب(A) والكثافة النباتية ٤٥نبات/م² ، بينما سجلت أقل القيم سجلت تحت معاملة الرى I. (رى تقليدى). وطريقة الزراعة العادية والكثافة النباتية ٦٠ نبات/م٢.