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# IMPACT OF DIFFERENT IRRIGATION METHODS ON THE YIELD, WATER PRODUCTIVITY, QUALITY AND STORAGE LOSSES OF SOME ONION CULTIVARS IN NILE DELTA, EGYPT

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## Abstract

A field investigation was conducted at the Experimental Farm, Sakha Agricultural Research Station, Kafr El-Sheikh Governorate during the two successive winter seasons, 2016/17 and 2017/18 to investigate the effect of irrigation methods on yield, quality and some water relations for some onion cultivars. A strip-plot design with four replications was used in this present study, where, the horizontal plots were assigned to irrigation methods which were I0 (Conventional furrow irrigation), I1 (Fixed furrow irrigation), I2 (Alternate furrow irrigation) and I3 (Cut-off irrigation from 90% of strip length).While vertical plots were randomly assigned by onion cultivars, CV1 (Giza 20), CV2 (Giza white) and CV3 (Giza red). Results can be summarized as follows:

Irrigation methods had significant effect on yield parameters of onion as well as onion bulb quality. The best yields were recorded from I2 and I1, associated with the higher percentage of dry matter and Total Soluble Solids (TSS) and bulbs having the greatest bulb diameter (cm). In addition, bulb contents of the macro-element (NPK) were determined under exchange alternative irrigation (I2). The loss in marketable produce during the storage was also highest in I0. The storage losses of onion were found to be decreased gradually with alternate furrow irrigation (I2) during the storage period of onion. Giza red cultivar was found to be superior to Giza 20 lastly Giza white with respect to bulb weight (g), marketable bulb yield and total bulb yield (t/fed.). On the contrary, Giza red cultivar gives the lowest culls bulb weight, followed by Giza 20 and eventually Giza white. In contrast, Giza white cultivar presented positive significant values, for the percentage of dry matter, TSS and bulb contents of the macro-elements with a great loss during storage compare the other cultivars. The results showed that the highest overall mean values for seasonal amount of applied water were recorded under traditional irrigation (I0) in both seasons. Meanwhile, the lowest overall mean values were recorded under irrigation methods I2 in the successive seasons. Generally, the overall mean values can be descended in order I0 > I3 > I1 > I2. Concerning, the effect of irrigation methods on productivity of irrigation water PIW, (Kg/m3), the overall mean values can be descended in order I2 > I1 >I3 > I0, respectively. Regarding the effect of onion cultivars on the values of PIW, the values can be descended Giza red > Giza 20 > Giza white, respectively. The combination of Giza red cultivar and I2 was found to increase onion yield. Maximum quality with best of dry matter and TSS of onion bulbs could be realized using a combination of Giza red or Giza white cultivars and exchange alternative irrigation method.

***Keywords:*** Irrigation methods, Water productivity, Onion cultivars, Yield and quality.

## Introduction

Onion (Allium cepa, L.) consider one of the oldest bulb crops, known to worldwide and furthermore the highest consumed. It is one of the most import ant business vegetable crops believed to be begun in Central Asia and is important vegetable crop grown in many parts of the world as food materials (Kukanoor, 2005). It is esteemed for its distinct pungent flavor and is a basic element for the cooking in numerous districts. Onion is preferred mainly because of its green leaves, immature and mature bulbs that utilized either crude or cooked. Onion cultivars are commonly arranged by day length (short, transitional, and long). A cultivar performs contrastingly under various agro-climatic conditions and different cultivars of similar species become even in the same environment give diverse yield the performance of a cultivar mainly relies upon the interaction of genetic structure and environment. These two elements give a plan to the breeders to pick the correct technique and test locales for optimal characters. Abdou et al. (2009) recorded that after studying the irrigation at 80, 60 and 40% available soil moisture that the highest bulb yields were 19.80 and 18.33 ton/fed. and water use efficiency was 11.41 and 10.57 kg/m3in the first and second seasons, respectively occurred under 60% of available soil moisture. In addition to, the T.S.S were insignificant in the two respective seasons.

In the semi-parched zones of Egypt, water is the most basic factor in crop production. Downpour fall is low with unpredictable dispersion. In this way, almost agricultural production is mainly depending on irrigation. Water resources are limited and concentrated on the Nile River which supplies Egypt by about 95% from its needs with fresh water. The Egyptian water budget from the Nile is 55.5 milliard cubic meters.

Water resources in Egypt suffer from severe water scarcity, which increases with increasing population growth. Increasing competition is competing for scarce water resources using modern irrigation techniques to increase water productivity and improve crop productivity and quality characteristics (Marwa et al., 2017). In semi-arid and dry areas with high population density and freshwater boundaries, there is significant pressure on the agricultural sector to reduce the limited freshwater consumption for irrigation to other sectors (Hozayn et al., 2016).

Egypt is country of water scarcity due to general low precipitation high evaporation and the temporal and spatial distribution of rainfall. There for, water saving, and conservation is a vital and essential demand to face the water gap problem and support agriculture activities which account of 85 % of the total water consumed in semiarid region. In irrigated agriculture it is necessary to optimize water management and increase the efficiency of water productivity by a group of technical procedures providing the information needed to irrigation at the optimal frequency and time (Sing and Chouman, 1996). So, irrigation is one of the most important inputs in agricultural practices and in all crops cultivation to increase crop productivity.

Using alternative furrow irrigation system in areas where there is water scarcity and heigh labor cost is the best options to increase the production of onion and other vegetables. Further research work is needed to give the appropriate irrigation interval with alternative furrow irrigation system (Gelu, 2018).

The present share of water in Egypt is less than 1000 m3/capital/year which is equivalent to the international standards of water poverty limit (EL-Quosy, 1998). Irrigation is the main sector in water demand at the National level. So, effective water management at the irrigation sector is the principal way towards the rationalization policy of the country. In this aspect, effective on farm irrigation management is becoming a must.

There is a bad need for making management for water in agricultural sector because it consumes the highest amount from water budget in Egypt (48 billiard cubic metre), this management plays an important role for keeping soil fertility by decreasing the losses of plant nutrients. So, improving productivity of crops. Also, management process for water lauds to maximizing water productivity, through decreasing water losses on the farm level.

Tremendous efforts should be implemented towards the aim of such effective water management at the farm level some of these efforts included

Determination of irrigation water which should be applied and Using modified surface irrigation techniques such as alternative and cut off irrigation.

Irrigation water management implies the application of suitable water to crops in right amount at the right time. Salient features of any improved method of irrigation is the controlled application of the required amount of water at desired time, which leads to minimization of range of variation of the moisture content in the root zone, thus reducing stress on the plants (Ulsido and Alemu, 2014).

The main objectives of this present study were to saving water through using different irrigation techniques, improve both of water unit and yield production and study the best onion cultivars which grow well under the condition of the studied area.

## Materials and Methods

Afield investigation was conducted at the Experimental Farm, Sakha, Agricultural Research station, Kafr El-Sheik Governorate during the two successive winter growing seasons 2016/2017 and 2017/2018 to investigate the effect of irrigation methods on yield, quality parameters and some water relationships for some onion cultivars. 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). Soil sample were analyzed for some physical characteristics such as, water holding capacity (62.8%), soil field capacity (38.9%), permanent wilting point (PWP, 24.6%) and available water (AW, 14.3%) according to (Klute, 1986). Some chemical characteristics were determined and measured in the taken soil sample as soil reaction pH (7.89), EC (1.75 ds/m), organic matter (1.77%), available N (24.76 ppm), available P (17.67 ppm) and available K (278.50 ppm) according to (Jackson, 1973). Data in Table (1) showed the metrological parameters during the studied recorded from Sakha agrometeorological Station. The studied parameters included; air temperature T (C0), relative humidity RH (%), wind speed Ws (m/sec at 2 m height), evaporation pan EP (mm/day) and finally rainfall (mm/month).

**Table 1:** Mean of some meteorological data for Kafr El-Sheikh area during the two growing seasons.

| Month | T ($C^0$) | | | RH (%) | | | $W_s$ m/sec | Pan Evap. mm. | Rainfall (R) mm/month |
|---|---|---|---|---|---|---|---|---|---|
| | Max | Min | Mean | Max | Min | Mean | | | |
| 2016/2017 | | | | | | | | | |
| Dec. 2016 | 19.7 | 16.7 | 15.2 | 85.4 | 65.3 | 75.4 | 0.72 | 1.47 | 25.8 |
| Jan.2017 | 18.2 | 5.7 | 11.9 | 87.8 | 62.4 | 75.1 | 0.60 | 1.36 | 9.6 |
| Feb. | 19.6 | 9.8 | 14.7 | 86.1 | 59.9 | 73.0 | 0.73 | 1.96 | 25.6 |
| Mar. | 22.5 | 18.0 | 20.2 | 84.9 | 60.3 | 72.6 | 0.97 | 2.97 | 0.00 |
| April. | 26.5 | 21.6 | 24.1 | 79.4 | 50.8 | 65.1 | 1.03 | 4.54 | 10.6 |
| May | 30.6 | 25.8 | 28.2 | 77.7 | 45.6 | 61.7 | 1.23 | 6.59 | 0.00 |
| 2017/2018 | | | | | | | | | |
| Dec. 2017 | 21.5 | 18.4 | 20.0 | 88.2 | 64.8 | 76.5 | 0.50 | 1.47 | 5.6 |
| Jan.2018 | 18.9 | 19.0 | 18.9 | 89.3 | 64.8 | 77.1 | 0.35 | 3.05 | 36.4 |
| Feb. | 21.5 | 14.5 | 18.0 | 87.8 | 63.5 | 75.6 | 0.37 | 2.74 | 16.6 |
| Mar. | 25.5 | 16.6 | 21.1 | 89.3 | 48.4 | 68.8 | 0.54 | 4.24 | 0.00 |
| April. | 27.2 | 19.9 | 23.6 | 80.9 | 43.9 | 62.4 | 0.85 | 5.78 | 0.00 |
| May | 31.2 | 23.9 | 27.6 | 75.6 | 43.3 | 59.4 | 1.10 | 6.34 | 0.00 |

Source: Meteorological Station at Sakha Agricultural Research Station 31˚ 07¯ N Latitude, 30˚ 57¯ E Longitude with an elevation of about 6 meters above mean sea level (MSL).

A field layout over two successive seasons including three onion cultivars and four irrigation treatments. The studied onion cultivars were hand drilled in the nursery bed on 15th and 16th October in the two successive seasons, respectively. Seedlings of nearly sixty days old (when they usually were 25 cm height) were uprooted, tied and transported for transplanting in the permanent field on 8th - 9th December in both seasons, respectively. The seedlings were cultivated following Egyptian culture standard practices in terms of fertilization and combating pests. The recommended doses of phosphorus as calcium superphosphate (15.5% P2O5) 45 kg/fed. (fed. = 4200 m2) and potassium as potassium sulphate (48% K2O) 50 kg/fed. Nitrogen fertilizer (120 kg N) in the form of ammonium nitrate (33.5% N; 358.2 kg/fed.) were added after transplanting in two equal doses each 179.1 kg portions; before the first irrigation (after 30 days from transplanting) and the second irrigation (30 days from the first addition).

The experiment was laid out in strip-plot design with four replications over the two growing seasons. In this context, the horizontal plots were randomly assigned by irrigation treatments, each irrigation plot area was 226.8 m2 (31.5 m length x 7.2 m width), while vertical plots area for each cultivar was 302.4 m2 (126 m length x 2.4 m width) x 4 replicates = 1209.6 m2, Irrigation systems has been esigned according to Mansour et al (2019 a,b,c,d,), Mansour et al., (2015, 2016; 2019), Mansour et al., (2013), Mansour et al., (2014), (2016a-c), (2019a,b).

Horizontal plots (Irrigation treatments):

Four irrigation treatments were as the following,

I0= Conventional furrow irrigation as farmers practice (Control),

I1= Fixed furrow irrigation,

I2= Alternate furrow irrigation,

I3= Cut-off irrigation after 90% of strip length.

Vertical plots (Onion cultivars):

C1- Giza 20,

C2- Giza white,

C3- Giza red.

Soil moisture content was determined gravimetrically on oven dry basis before each irrigation and 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. Harvesting was carried out on 15th and 12th May in the first and second growing seasons, respectively.

Evaluation Parameters:

Onion yield and yield components

At harvesting time about 155 days after transplanting, onion bulbs in each plot were uprooted, and yield was expressed as: average bulb weight (g), marketable bulb yield, culls bulb weight and total bulb yield (t/fed.). Bulbs were harvested when the leaves begin to yellow, and 50% of the plant tops were down.

2- Onion bulb quality

Sample of bulbs were randomly taken for bulb diameter (cm), dry matter percentage and total soluble solids (TSS) were determined immediately after harvest by a hand refractometer in representative samples of the five bulbs.

3-Macroelements content

After harvest, onion bulb samples were taken for phytochemical analysis. Bulb tissues were oven aired at 70oC until constant weight mass was reached. The samples were ground into fine powder using automatic gridding machine and stored into air-tight glass bottles in freeze (about 4oC) until analysis. The powdered samples were wet digested and then assessed for their composition of total nitrogen, phosphorous and potassium components. Nitrogen percentage was determined by the method provided by Hach et al. (1985). Phosphorus and potassium contents were estimated according to A.O.A.C. (1990) and Knudsen et al. (1982), respectively.

4-Storage losses

After harvested bulbs were left in the field to cure for 3 weeks, under a shade, then tops and roots were removed from each treatment. 100 bulbs of marketable yield were randomly taken after curing of each plot as a representative sample and stored in common burlap bags and kept under normal storage conditions. Each bulb was weighed, using electronic digital scale and their initial weight including diameter were recorded and labeled before they were introduced into the storage structure. Ambient storage atmosphere having 25-28°C maximum and 13-11°C minimum average temperatures with 62-42% mean relative humidity during both storage seasons. The pathological and physiological activities of these bulbs were carefully monitored and the weight of spoiled onions in the form of rotting, sprouted bulbs, physiological weight loss and total weight loss in each lot were determined and recorded throughout the storage period from May to November.

4-1-Physiological loss in weight

The physiological loss in weight was determined by periodical weighing of onion bulbs at 60, 120 and 180 days after storage using a digital electronic balance. The cumulative loss in weight of bulbs was calculated based on the initial bulb weight and expressed as a percent at physiological loss in weight for each treatment using the equation given below as described by Sharma et al. (2020).

$$\text{PWL} = \frac{\text{W0} - \text{W1 or W2 or W3}}{\text{W0}} \times 100$$

Where: PWL = Physiological weight in loss (%); W0 = Initial weight; W1, 2, 3 =Weight after 60 days, 120 days; and 180 days.

4-2- Sprouting:

To determine sprouting (%) intensity the sprouted bulbs were separated from the experiment and were calculated using the formula of Kukanoor (2005):

$$\text{Storage sprouting losses } (\%) = \frac{\text{Wi} - \text{Ws1 or Ws2 or Ws3}}{\text{Wi}} \times 100$$

Where: Wi = Initial weight; and Ws1, 2, 3 = Weight of sprouting bulbs after 60 days, 120 days; and 180 days.

4-3-Rotting

Following formula was used to determine the rotting loss (%) (Sharma et al., 2020):

$$\textbf{Storage rot losses } (\%) = \frac{\textbf{Wi} - \textbf{Wr1 or Wr2 or Wr3}}{\textbf{Wi}} \times \textbf{100}$$

Where: Wi = Initial weight; and Wr1, 2, 3 = Weight of rotten bulbs after 60 days, 120 days; and 180 days.

4-4- Total weight losses

Total losses in weight were calculated by combining both losses during the two study seasons.

5- Amount of seasonal applied water (AW)

The amount of applied irrigation water (AW) was measured by using cutthroat flume, 30 x 90 cm. The quantity of irrigated water was calculated as volume of irrigated water divided by plot area and calculated as cm, m3/fed. Total seasonal water applied during the whole growing season including effective rainfall was calculated according to Early (1975), the following formula given below.

$$AW = IW + R(\mathrm{cm}, \mathrm{m}^3/\mathrm{fed})$$

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

R = effective rainfall which equals to incident rainfall * 0.7 (Novica, 1

6- Productivity of irrigation water (PIW)

Productivity of irrigation water (PIW; kg/m³) was defined as bulbs crop yield divided by total amount of water supplied including rainfall. It was calculated according to Ali et al. (2007) using the following formula:

$$PIW = \frac{Y}{AW}(\mathrm{kg}/\mathrm{m}^3)$$

Where: Y = onion bulb yield (kg/fed.) AW = seasonal applied water (m³/fed.)

Statistical analysis

All data collected were subjected to statistical analysis as described by Snedecor and Cochran (1980) at 5% of significance level and the means were compared using LSD test to check difference. All statistical analyses were performed with a software package Costat® Statistical Software, ver. 6.311 (CoStat Sowftware, 2005); a product of, Cohort Software, Monterey, California.

## RESULTS AND DISCUSSION

**1- Onion yield and yield components:**

Data in table (2) clearly presented a high significant difference among all different irrigation treatments on onion yield with an exception in the first season where culls bulb showed no significant difference. However, exchange alternative irrigation (I2) showed the highest total and marketable bulbs yield as well as bulb weight with a decrease in the cull bulbs weight during the two growing seasons. Moreover, it is followed by fixed irrigation (I1) and cut off the irrigation after 90% of furrow length (I3) in compare with traditional irrigation (I0) that gave the lowest values. This can be due to equate and adequate water supply as well as distribution. Higher values of yield parameters in high humid systems may be the result of applying more water since the early growth stages encourage better growth and development (Rajanna et al., 2016). Geries et al., 2015 found that the onion plants irrigated at 80% of field capacity, produced the highest average bulb weight, onion bulbs yield. However, the highest yield and quality were recorded for lowest efficiencies and vice versa. It is concluded that optimum production occurred at optimum water use efficiency at 20% water stress (Bhagyawant et al., 2016 and David et al., 2016). Mebrahtu (2018) indicated that the alternate furrow irrigation can allow saving a substantial amount of water and labor without highly reduction of onion yield. However, under scarce water condition, 100% irrigation level with alternative furrow irrigation can be practiced.

Concerning the effect of cultivars on yield, it is clearly that Giza red cultivar gave the highest total and marketable yield with lowest culls bulb, followed by Giza 20 and eventually Giza white. Mebrahtu (2018) in areas under no limitation of irrigation water, yield of onion cultivar could be improved substantially by applying 100% irrigation amount with conventional furrow irrigation.

The interaction effect of irrigation methods and tested onion cultivars had high significant effect on yield and its components. However, there were no significant differences for culls bulb weight in the two seasons. The values of total bulbs yield, marketable bulb yield, culls bulb weight (t/fed.) and average bulb weight showed high significant differences as the result of the interaction between irrigation methods and onion cultivars, The highest values of onion yield, marketable bulb yield and average bulb weight and the lowest culls bulb weight during both seasons were obtained by Giza red cultivar under the exchange alternative irrigation method (Table 2). Studies conducted on irrigation of onion indicated that the farmer method caused significant reductions in yield components and resulted in increase of water usage 45 and 33% (Nagaz et al., 2012).

**2- Onion bulb quality:**

Table 3 showed that the irrigation methods during both growing seasons had high significant effect on quality parameters of the cultivated onion cultivars. The effect of irrigation methods on onion traits and its quality could be arranged in descending order of I2 > I1 >I3 >I0. In exchange alternative irrigation (I2), bulb diameter, total soluble solids **%** as well as bulb dry matter content values increased by 35.46, 14.45 and 14.36%**,** respectively, compared to traditional irrigation method (I0), this is due to application of irrigation water alternatively by increasing the portion of wetting front and the lowest values were observed from farmer practice. A similar effect of various irrigation water levels on size of onion bulb was observed by David et al. (2016) indicated that the variation in yield ranged from 34.4 ton/ha to 18.9 ton/ha and the bulb size ranged from 64 mm to 35 mm in diameter for deficit irrigation at the 100% to 50% ETc, respectively. Therefore, the changed interval irrigation treatment (I2) achieved the best result for bulb diameter, total soluble and dry mater content during the two growing seasons.

**Table 2:** Response of bulb onion yield and yield components for the different irrigation treatments and their interactions with the cultivated onion cultivars during the two growing seasons.

| Treatment | | 2016/2017 | | | | 2017/2018 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Total bulbs yield (t/fed.) | Marketable bulbs yield (t/fed.) | Culls bulb weight (t/fed.) | Bulb Weight (g/bulb) | Total bulbs yield (t/fed.) | Marketable bulbs yield (t/fed.) | Culls bulb weight (t/fed.) | Bulb Weight (g/bulb) |
| Irrigation treatments | | | | | | | | | |
| $I_0$-Farmers practice | | 13.87 | 12.18 | 1.69 | 67.73 | 14.04 | 12.91 | 1.14 | 65.05 |
| $I_1$-Fixed furrow | | 16.03 | 14.23 | 1.80 | 91.25 | 17.06 | 15.09 | 1.97 | 90.65 |
| $I_2$-Alternativefurrow | | 17.14 | 15.36 | 1.78 | 107.07 | 17.81 | 16.18 | 1.63 | 101.47 |
| $I_3$-Cut-off | | 14.75 | 12.77 | 1.99 | 80.05 | 15.60 | 13.36 | 2.24 | 72.58 |
| LSD $_{(0.05)}$ | | 0.56 | 0.76 | N.S | 3.49 | 0.74 | 0.72 | 0.20 | 9.19 |
| Cultivars | | | | | | | | | |
| Giza 20 | | 15.39 | 13.34 | 2.04 | 89.30 | 15.92 | 14.17 | 1.76 | 84.94 |
| Giza white | | 12.39 | 10.08 | 2.31 | 72.35 | 12.95 | 10.94 | 2.01 | 68.13 |
| Giza red | | 18.57 | 17.48 | 1.09 | 97.93 | 19.51 | 18.04 | 1.47 | 94.24 |
| LSD $_{(0.05)}$ | | 0.28 | 0.30 | 0.29 | 3.07 | 0.59 | 0.57 | 0.13 | 5.74 |
| Interaction (IxV) | | | | | | | | | |
| $I_0$ | Giza 20 | 13.63 | 11.54 | 2.09 | 67.20 | 13.37 | 12.22 | 1.16 | 68.75 |
| | Giza white | 11.18 | 9.09 | 2.09 | 57.93 | 10.26 | 8.97 | 1.29 | 50.85 |
| | Giza red | 16.81 | 15.92 | 0.90 | 78.07 | 18.49 | 17.53 | 0.96 | 75.55 |
| $I_1$ | Giza 20 | 16.10 | 13.86 | 2.24 | 95.57 | 17.18 | 15.22 | 1.96 | 94.90 |
| | Giza white | 12.91 | 10.71 | 2.20 | 76.35 | 14.23 | 11.97 | 2.26 | 75.00 |
| | Giza red | 19.09 | 18.13 | 0.96 | 101.83 | 19.77 | 18.07 | 1.70 | 102.05 |
| $I_2$ | Giza 20 | 16.93 | 15.41 | 1.52 | 108.72 | 17.90 | 16.32 | 1.58 | 103.10 |
| | Giza white | 13.70 | 11.18 | 2.52 | 90.27 | 15.20 | 13.17 | 2.03 | 80.08 |
| | Giza red | 20.78 | 19.48 | 1.30 | 122.20 | 20.33 | 19.04 | 1.28 | 121.23 |
| $I_3$ | Giza 20 | 14.89 | 12.57 | 2.32 | 85.70 | 15.25 | 12.92 | 2.33 | 73.00 |
| | Giza white | 11.77 | 9.34 | 2.44 | 64.85 | 12.12 | 9.67 | 2.45 | 66.61 |
| | Giza red | 17.60 | 16.40 | 1.20 | 89.60 | 19.43 | 17.49 | 1.94 | 78.13 |
| LSD $_{(0.05)}$ | | 0.55 | 0.61 | N.S | 6.14 | 1.18 | 1.15 | N.S | 11.47 |

**Table 3:** Bulb quality parameters in response to the different irrigation treatments and onion cultivated cultivars as well as their interactions during the two growing seasons.

| Treatment | | 2016/2017 | | | 2017/2018 | | |
|---|---|---|---|---|---|---|---|
| | | Bulb diameter (cm) | Total soluble solids % | Dry matter content % | Bulb diameter (cm) | Total soluble solids % | Dry matter content % |
| Irrigation treatments (I) | | | | | | | |
| $I_0$-Farmers practice | | 5.55 | 12.79 | 14.93 | 5.06 | 11.96 | 14.30 |
| $I_1$-Fixed furrow | | 7.41 | 13.81 | 16.17 | 7.54 | 13.45 | 16.70 |
| $I_2$-Alternativefurrow | | 8.08 | 14.45 | 17.07 | 8.36 | 14.48 | 17.06 |
| $I_3$-Cut-off | | 6.86 | 12.93 | 15.91 | 6.09 | 12.31 | 16.30 |
| LSD $_{(0.05)}$ | | 0.23 | 0.44 | 0.19 | 0.28 | 0.17 | 0.15 |
| Cultivars (V) | | | | | | | |
| Giza 20 | | 7.07 | 13.50 | 16.01 | 6.91 | 13.01 | 16.38 |
| Giza white | | 6.33 | 13.73 | 16.49 | 6.06 | 13.59 | 16.42 |
| Giza red | | 7.53 | 13.26 | 15.56 | 7.31 | 12.54 | 15.47 |
| LSD $_{(0.05)}$ | | 0.18 | 0.35 | 0.15 | 0.25 | 0.18 | 0.17 |
| Interaction (I x V) | | | | | | | |
| $I_0$ | Giza 20 | 5.77 | 12.76 | 15.14 | 5.20 | 11.94 | 14.71 |
| | Giza white | 4.96 | 13.11 | 15.33 | 4.19 | 12.50 | 14.69 |
| | Giza red | 5.92 | 12.51 | 14.31 | 5.79 | 11.43 | 13.48 |
| $I_1$ | Giza 20 | 7.52 | 13.81 | 16.04 | 7.64 | 13.49 | 17.11 |
| | Giza white | 6.62 | 14.04 | 16.62 | 7.00 | 13.69 | 16.76 |
| | Giza red | 8.10 | 13.57 | 15.86 | 7.98 | 13.15 | 16.22 |
| $I_2$ | Giza 20 | 7.97 | 14.49 | 17.02 | 8.26 | 14.51 | 17.18 |
| | Giza white | 7.40 | 14.58 | 17.48 | 7.98 | 15.11 | 17.56 |
| | Giza red | 8.87 | 14.26 | 16.71 | 8.83 | 13.82 | 16.44 |
| $I_3$ | Giza 20 | 7.01 | 12.94 | 15.82 | 6.55 | 12.08 | 16.52 |
| | Giza white | 6.33 | 13.17 | 16.53 | 5.09 | 13.09 | 16.65 |
| | Giza red | 7.24 | 12.69 | 15.37 | 6.63 | 11.76 | 15.73 |
| LSD $_{(0.05)}$ | | 0.36 | N.S | 0.31 | 0.50 | 0.36 | 0.35 |

$LSD_{(0.05)}$: Least significant difference and N.S indicate not significant at P: 0.05 probability.

There were also significant differences among onion cultivars. In general, Giza red cultivar had the highest values of bulb diameter compared to the other tested cultivars during both growth seasons. However, Giza white and Giza 20 showed the highest total soluble solids % and bulb dry matter content values compared to the other studied cultivars. This effect was in conformity with the results obtained by Abou-El-Hassan (2018).

Table (3) demonstrates that the interaction between irrigation treatments and onion cultivars had significant effects on bulb quality. The best bulbs quality was register for the treatment I2 with the cultivar Giza white on some bulb quality as TSS and dry matter content. At the same time, the cultivar of Giza red gives the highest bulb diameter when irrigated with exchange alternative irrigation treatment (I2) in both seasons.

**3- Macro-elements content:**

Bulb contents of the macro-elements was found to be significantly affected in response to the different irrigation treatments (Table 4). The best results obtained were found when irrigating with exchange alternative irrigation method (I2) along the two successive seasons of the study. This is due to irrigation with a traditional method or exchange alternative irrigation, and when the irrigation water increases or improves water distribution, it increases the availability of nutrients in the soil, thus increasing the content of the elements in the plant. Geries et al., 2015 stated that 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.

The highest content of nitrogen, phosphorus and potassium were recorded in yellow onion cultivar (Giza 20). The lowest content of the elements was recorded in white cultivar (Giza white). These results are consistent with the observations of many studies by other researchers concerning the chemical composition of onion cultivars. Malecka et al., 2015 show yellow cultivars accumulated significantly greater amounts of nitrogen, phosphorus, potassium, magnesium, iron and manganese. Information in this context is limited in onion crop.

The interaction between onion cultivars and irrigation treatments disclosed a higher positive impact with phosphorus content in the first season only. Remarkable results were obtained with Giza 20 or Giza red under exchange alternative irrigation treatments. The abundance of irrigation water may be a major reason for increasing the plant's ability to absorb nutrients from soil, and thus accumulate well in the resultant bulbs.

**4- Storage losses:**

Different kinds of losses of onion (rotting, sprouting, and total weight loss) under various irrigation methods during over 180 days storage period have been presented in Table 5. Percentage of rotten bulbs, sprouting and the total weight loss of onion were significantly influenced by different methods of irrigation. All different characteristics of losses of treatments with I0 and I3were higher without significant difference during 180 days of storage period. The lowest values were found in exchange alternative irrigation treatment (I2), It is the best in storage. The lowest rotting loss in the I2 treatment may be since plots did not receive any irrigation that kept the bulbs less succulent and as a result less attacked by bacteria and fungi during storage. The result indicated that onion crop grown under traditional irrigation method has not exposed to water stress and hence it was forced to delay maturity. Thus, it resulted into development of either immature or partial matured bulbs, which started rotting during storage at an early date in season. Metwally (2010) and Geries et al. (2015) reported that the highest water quantity resulted in the highest weight loss percent after both 90 and 180 days of storage. Wise irrigation greatly facilitates for the maintenance of the main quality features of onion bulbs in storage (Bhagyawant et al., 2016).

The results showed significant difference in the storage ability attributes of the onion cultivars (Table, 5). The minimum percentage of rotten bulbs, sprouting and total weight loss of onion bulbs was noted by the cultivar Giza red followed by cultivar Giza 20 and Giza white. The maximum total weight losses percentage was noted by the cultivar Giza white through the storage period of 180 days in the all seasons. Breeders must be collected between high yield and long storage to develop profitable onion cultivars for farmers and consumers. Thomson et al. (1972) reported that the onion bulbs are naturally dormant at maturity and the length of dormant period varies with the cultivar and conditions which the bulbs were grown and stored. Omar et al. (2005) reported that weight loss and decay percentage were significantly higher in stored bulbs of Giza 6 mohassan than Giza 20. Because of the positive correlation of storage losses with bulb weight, therefore we need to develop large size bulbs with good storability. White bulb onions were reported to have very poor storability (Schwartz and Mohan, 1995).

Furthermore, the interaction between different irrigation treatments with onion cultivars was not significant.

Effect of irrigation and some onion cultivars on seasonal amount of applied water (cm & m3/fed.) in the two growing seasons:

**Table 4 :** Macro-elements content as affected by the different irrigation treatments on the cultivated cultivars and their interactions for the two growing seasons (2016/2017 and 2017/2018).

| Treatment | | 2016/2017 | | | 2017/2018 | | |
|---|---|---|---|---|---|---|---|
| | | Total nitrogen (%) | Phosphorus (ppm) | Potassium (ppm) | Total nitrogen (%) | Phosphorus (ppm) | Potassium (ppm) |
| Irrigation treatments (I) | | | | | | | |
| $I_0$-Farmers practice | | 2.98 | 0.47 | 1.66 | 3.08 | 0.28 | 1.89 |
| $I_1$-Fixed furrow | | 2.33 | 0.28 | 1.34 | 2.28 | 0.25 | 1.39 |
| $I_2$-Alternativefurrow | | 3.10 | 0.54 | 1.82 | 3.21 | 0.29 | 2.04 |
| $I_3$-Cut-off | | 2.58 | 0.34 | 1.63 | 2.73 | 0.27 | 1.74 |
| LSD $_{(0.05)}$ | | 0.42 | 0.05 | 0.14 | 0.32 | 0.02 | 0.16 |
| Cultivars (V) | | | | | | | |
| $V_1$- Giza 20 | | 2.93 | 0.48 | 1.77 | 3.04 | 0.29 | 1.96 |
| $V_2$- Giza white | | 2.51 | 0.35 | 1.47 | 2.63 | 0.26 | 1.63 |
| $V_3$-Giza red | | 2.81 | 0.40 | 1.60 | 2.82 | 0.27 | 1.71 |
| LSD $_{(0.05)}$ | | N.S | 0.03 | 0.10 | 0.24 | 0.01 | 0.09 |
| Interaction (I x V) | | | | | | | |
| $I_0$ | Giza 20 | 3.14 | 0.58 | 1.77 | 3.32 | 0.29 | 2.09 |
| | Giza white | 2.73 | 0.38 | 1.56 | 2.94 | 0.27 | 1.72 |
| | Giza red | 3.07 | 0.44 | 1.65 | 3.00 | 0.28 | 1.86 |
| $I_1$ | Giza 20 | 2.47 | 0.34 | 1.54 | 2.55 | 0.27 | 1.59 |
| | Giza white | 2.12 | 0.26 | 1.17 | 1.89 | 0.23 | 1.27 |
| | Giza red | 2.42 | 0.25 | 1.30 | 2.41 | 0.25 | 1.32 |
| $I_2$ | Giza 20 | 3.47 | 0.61 | 2.06 | 3.45 | 0.31 | 2.26 |
| | Giza white | 2.77 | 0.44 | 1.61 | 3.03 | 0.28 | 1.93 |
| | Giza red | 3.08 | 0.57 | 1.79 | 3.15 | 0.28 | 1.94 |
| $I_3$ | Giza 20 | 2.64 | 0.39 | 1.72 | 2.83 | 0.28 | 1.89 |
| | Giza white | 2.43 | 0.31 | 1.53 | 2.65 | 0.26 | 1.60 |
| | Giza red | 2.67 | 0.34 | 1.65 | 2.71 | 0.27 | 1.72 |
| LSD $_{(0.05)}$ | | N.S | 0.06 | N.S | N.S | N.S | N.S |

LSD(0.05): Least significant difference and N.S indicate not significant at P: 0.05 probability.

**Table 5 :** Storage losses in the different onion cultivars after 180 days of storage under different irrigation treatments for the two growing seasons (2016/2017 and 2017/2018).

| | | 2016/2017 | | | | 2017/2018 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Rotted onion% | Sprouted onion% | Physiological wt loss% | Total weight loss(%) | Rotted onion% | Sprouted onion% | Physiological wt loss% | Total weight loss(%) |
| Irrigation treatments (I) | | | | | | | | | |
| $I_0$-Farmers practice | | 6.33 | 12.10 | 18.65 | 37.07 | 5.99 | 10.48 | 17.19 | 33.67 |
| $I_1$-Fixed furrow | | 5.93 | 10.02 | 16.18 | 32.13 | 5.22 | 9.51 | 15.77 | 30.49 |
| $I_2$-lternative furrow | | 4.99 | 9.68 | 15.34 | 30.01 | 4.27 | 7.95 | 14.29 | 26.51 |
| $I_3$-Cut-off | | 6.12 | 12.15 | 18.18 | 36.45 | 5.43 | 10.02 | 16.63 | 32.07 |
| LSD $_{(0.05)}$ | | 0.87 | 0.92 | 1.23 | 2.10 | N.S | 1.44 | 1.96 | 4.35 |
| Cultivars (V) | | | | | | | | | |
| Giza 20 | | 5.85 | 11.07 | 16.44 | 33.35 | 4.99 | 9.10 | 14.32 | 28.42 |
| Giza white | | 6.25 | 11.32 | 17.93 | 35.49 | 5.96 | 10.43 | 18.62 | 35.00 |
| Giza red | | 5.42 | 10.58 | 16.89 | 32.89 | 4.73 | 8.94 | 14.96 | 28.64 |
| LSD $_{(0.05)}$ | | 0.42 | 0.22 | 0.26 | 0.61 | 0.29 | 0.64 | 1.45 | 2.02 |
| Interaction (I x V) | | | | | | | | | |
| $I_0$ | Giza 20 | 6.14 | 12.15 | 17.89 | 36.18 | 5.67 | 10.22 | 15.64 | 31.52 |
| | Giza white | 7.10 | 12.56 | 19.77 | 39.43 | 6.84 | 11.55 | 19.89 | 38.28 |
| | Giza red | 5.76 | 11.58 | 18.28 | 35.62 | 5.47 | 9.70 | 16.05 | 31.22 |
| $I_1$ | Giza 20 | 6.03 | 9.95 | 15.42 | 31.39 | 4.97 | 8.96 | 14.54 | 28.47 |
| | Giza white | 6.07 | 10.51 | 17.04 | 33.62 | 5.82 | 10.36 | 18.30 | 34.47 |
| | Giza red | 5.67 | 9.62 | 16.08 | 31.37 | 4.87 | 9.20 | 14.47 | 28.54 |
| $I_2$ | Giza 20 | 5.02 | 9.79 | 14.76 | 29.56 | 4.14 | 7.64 | 12.02 | 23.80 |
| | Giza white | 5.32 | 9.93 | 16.06 | 31.31 | 4.96 | 8.77 | 16.97 | 30.70 |
| | Giza red | 4.62 | 9.31 | 15.22 | 29.15 | 3.71 | 7.44 | 13.87 | 25.03 |
| $I_3$ | Giza 20 | 6.20 | 12.39 | 17.70 | 36.29 | 5.18 | 9.58 | 15.10 | 29.87 |
| | Giza white | 6.51 | 12.26 | 18.86 | 37.63 | 6.23 | 11.04 | 19.30 | 36.57 |
| | Giza red | 5.64 | 11.80 | 17.99 | 35.42 | 4.87 | 9.43 | 15.47 | 29.78 |
| LSD $_{(0.05)}$ | | N.S | N.S | N.S | N.S | N.S | N.S | N.S | N.S |

LSD$_{(0.05)}$: Least significant difference and N.S indicate not significant at P: 0.05 probability.

**Table 6:** Effect of irrigation treatment and some onion cultivars on seasonal amount of applied in the two-growing seasons.

| Irrigation Treatment (I) | Onion cultivars (v) | 1st growing seasons | | 2nd growing seasons | | The overall mean values through the two growing seasons | |
|---|---|---|---|---|---|---|---|
| | | cm | $m^3$/fed. | cm | $m^3$/fed. | cm | $m^3$/fed. |
| $I_0$ Farmers practice | Giza 20 | 56.60 | 2377.20 | 57.94 | 2433.68 | 57.27 | 2405.44 |
| | Giza white | 56.60 | 2377.20 | 57.94 | 2433.68 | 57.27 | 2405.44 |
| | Giza red | 56.60 | 2377.20 | 57.94 | 2433.68 | 57.27 | 2405.44 |
| | Mean | 56.60 | 2377.20 | 57.94 | 2433.68 | 57.27 | 2405.44 |
| $I_1$ Fixed furrow | Giza 20 | 52.55 | 2207.07 | 53.51 | 2247.43 | 53.03 | 2227.25 |
| | Giza white | 52.55 | 2207.07 | 53.51 | 2247.43 | 53.03 | 2227.25 |
| | Giza red | 52.55 | 2207.07 | 53.51 | 2247.43 | 53.03 | 2227.25 |
| | Mean | 52.55 | 2207.07 | 53.51 | 2247.43 | 53.03 | 2227.25 |
| $I_2$ Alternative furrow | Giza 20 | 48.58 | 2040.4 | 49.86 | 2094.1 | 49.22 | 2067.25 |
| | Giza white | 48.58 | 2040.4 | 49.86 | 2094.1 | 49.22 | 2067.25 |
| | Giza red | 48.58 | 2040.4 | 49.86 | 2094.1 | 49.22 | 2067.25 |
| | Mean | 48.58 | 2040.40 | 49.86 | 2094.10 | 49.22 | 2067.25 |
| $I_3$ Cut-off | Giza 20 | 54.53 | 2290.23 | 55.16 | 2316.83 | 54.85 | 2303.53 |
| | Giza white | 54.53 | 2290.23 | 55.16 | 2316.83 | 54.85 | 2303.53 |
| | Giza red | 54.53 | 2290.23 | 55.16 | 2316.83 | 54.85 | 2303.53 |
| | Mean | 54.53 | 2290.23 | 55.16 | 2316.83 | 54.85 | 2303.53 |

**Table 7:** Effect of irrigation treatment and some onion cultivars on seasonal amount of applied in the two-growing season.

| Onion cultivars (v) | 1st growing seasons | | 2nd growing seasons | | The overall mean values through the two growing seasons | |
|---|---|---|---|---|---|---|
| | cm | $m^3$/fed. | cm | $m^3$/fed. | cm | $m^3$/fed. |
| Giza 20 | 53.08 | 2257.88 | 55.31 | 2323.18 | 54.54 | 2290.53 |
| Giza white | 53.07 | 2080.38 | 49.59 | 2082.82 | 49.56 | 2081.60 |
| Giza red | 53.07 | 2347.92 | 57.45 | 2413.03 | 56.68 | 2380.48 |

**Table 8:** Effect of irrigation treatments on productivity of irrigation water (PIW, Kg/$m^3$) for some onion cultivars in the two-growing season.

| Irrigation treatments (I) | 1 st growing Season | 2nd growing season | The overall mean values through the two growing seasons |
|---|---|---|---|
| $I_0$-Farmers practice | 5.12 | 5.3 | 5.21 |
| $I_1$-Fixed furrow | 6.45 | 6.71 | 6.58 |
| $I_2$-Alternative furrow | 7.53 | 7.73 | 7.63 |
| $I_3$-Cut-off | 5.58 | 5.77 | 5.68 |

**Table 9:** Effect of some onion cultivars on productivity of irrigation water (PIW, Kg/$m^3$) in the two-growing season.

| Onion cultivars | 1 st growing seasons | 2 nd growing seasons | the overall mean values through the two growing seasons |
|---|---|---|---|
| Giza 20 | 5.91 | 6.10 | 6.01 |
| Giza white | 4.85 | 5.25 | 5.05 |
| Giza red | 7.44 | 7.48 | 7.46 |

Concerning the effect of irrigation treatments on applied water data in Table (6) clearly indicated that, the highest overall mean values for applied water were recorded under traditional irrigation like practice by local farmers in the studied region, (I0) and the values are (56.60 cm, 2377.20 m3/fed.) and (57.94 cm, 2433.68 m3/fed.) in the first and second growing seasons, respectively. On the other hand, the lowest values were recorded under irrigation treatment I2 (changing alternative irrigation) and the values are (48.58 cm, 2040.40 m3/fed.) and (49.86 cm, 2094.10 m3/fed.) in the first and second growing seasons, respectively. Generally, the overall mean values for seasonal amount of applied water can be descended in order Io >I3 >I1 >I2. Increasing the overall mean values for seasonal amount of applied water under irrigation treatment Io comparing with other irrigation treatments I1, I2 and I3 might be attributed to increasing number of watering's under traditional practices by local farmers in the investigated area and hence, increasing amount of applied water. Also, under this traditional condition of irrigation the wetted area increases and hence increasing time of irrigation process also, increasing amount of losses by evaporation. So, increasing the values of water consumptive use and hence increasing the amount of applied water in comparison with other irrigation treatments. These results are in some line with those reported by Rashed and Moursi (2012) and Geries et al. (2015).

Date in Table, 7 indicated that the highest overall mean values for seasonal amount of applied water was recorded with onion cultivar Giza red and the value is 56.68 cm, 2380.48 m3/fed. On the other hand, the lowest overall mean value was recorded with onion cultivar Giza white and the value is 49.56 cm, 2081.6 m3/fed. Generally, the overall mean values for seasonal amount of applied water can be descended in order Giza red >Giza 20 >Giza white and the values are (56.68 cm, 2380.48 m3/fed.), (54.54 cm, 2290.53 m3/fed.) and (49.56 cm, 2081.6 m3/fed.), respectively. Increasing the values of seasonal amount of applied water under onion cultivar Giza red comparing with other onion cultivars, might be due to increasing vegetative cover for this crop and hence increasing exposed area for the sunlight and increasing the rate of losses by transpiration from plant surfaces. So, to compensate these losses, amount of applied water should be increased to protect plants from the bad effects which resulted from water stress which may be affected badly on growing plants.

Tabulated data in Tables (8 and 9) showed that the productivity of irrigation water (PIW, Kg/m3) were clearly affected by both irrigation treatment and the studied onion cultivars. Concerning, the effect of irrigation treatments the overall mean values for PIW can be descended in order I2 >I1 >I3 >I0 and the values are 7.63, 6.58, 5.68 and 5.21 Kg/m3, respectively. Increasing the values of PIW under irrigation treatment I2 comparing with other irrigation treatments might be attributed to decreasing the amount of applied water under the conditions of this treatment as shown in Table (7) the lowest overall mean values were recorded under irrigation treatment Io might be increasing the amount of applied water. So, decreasing the values of productivity of irrigation water. These results agree with those reported by Rashed and Moursi (2012) and Geries et al. (2015). Gelu (2018) concluded that the alternative furrow irrigation treatment-controlled stress irrigation without the risk reduced economic yield and total yield of yield of onion increase production and productivity of the society. Moreover, it increased the water use efficiency and saved irrigation water. Besides it also saves the energy and time for farmers to irrigate the whole land in turn it saves the cost for water of irrigation.

Regarding the effect of the studied onion cultivars, the highest overall mean values were recorded under onion cultivar Giza red and the value is 7.46 Kg/m3 in comparison with other onion cultivars. Generally, the overall mean values for PIW can be descended in order Giza red >Giza 20 >Giza white and the values are 7.46, 6.01 and 5.05 Kg/m3, respectively.

## Conclusion

From the findings of the study it is concluded that alternative furrow irrigation at vegetative and late growth stages of onions produce higher yield with high quality together with a somewhat best chemical composition of bulbs at harvest and during storage. Also, Giza red or Giza 20 the best cultivar for storage ability under North Delta with deficit irrigation conditions.

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