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Effect of Irrigation and Potassium Fertilizer on Vegetative Growth, Yield and Quality of Globe Artichoke Plants under Sandy Soil Conditions

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ABSTRACT

A field experiment was carried out during 2014/2015 and 2015/2016 seasons at El-Kassasin Horticulture Research Station, Ismailia governorate, Egypt, to study the effect of irrigation and potassium fertilizer treatments on vegetative growth, yield and quality of globe artichoke plants under drip irrigation system in sandy soil. The experiment was designed as split plot. Main plots devoted to irrigation treatments which included irrigation with 100% of ET_c (I_1), 80% of ET_c (I_2) and 60% of ET_c (I_3). While potassium fertilizer treatments were in the sub-plot. Potassium fertilizer treatments were 100% of recommended potassium fertilizer dose (K_1), application of 75% and 50% from recommended potassium fertilizer dose plus 1% foliar potassium citrate (K_2 and K_3 respectively). Results indicated that the highest values of plant height, leaf fresh and dry weight, number of offshoots plant^{-1}, flower heads fresh weight and diameter, fresh weight and diameter as well as thickness of receptacle, number of early and total flower heads plant^{-1} and total yield fed^{-1} were obtained from I_1 and K_1, while the lowest values resulted from I_3 and K_3. There were no significant differences between K_1 and K_2 potassium treatments for all characteristics, as well as between $I_1 \times K_1$ and $I_1 \times K_2$ interactions in the two growing seasons. Seasonal applied water was 39.32, 31.63 and 23.97 cm when globe artichoke plants were irrigated with 100, 80 and 60% of ET_c respectively. The highest values of productivity of irrigation water (PIW) resulted from irrigation with 60% of ET_c. At the same time, potassium treatments of K_1 and K_2 not only resulted in higher yield but also increased the PIW. Generally, it could be concluded that under study condition irrigation with 100 ET_c and application of 75% from recommended potassium fertilizer dose plus 1% foliar potassium citrate was the best combination for globe artichoke yield and its quality. When water becomes limiting factor, the treatment of I_3 x K_2 could be recommended.

Keywords: Globe artichoke; Irrigation; Potassium fertilizer, Vegetative growth, Flower head quality.

INTRODUCTION

Globe artichoke (*Cynara scolymus* L.) is belongs to *Asteraceae* (*Compositae*) family. It is ancient crop and medicinal plant, the therapeutic potential of which was known to the ancient Egyptians, Greeks and Romans. It is commonly distributed all over the world, especially in the Mediterranean Basin, South America, United States and China. The production of artichokes in the world has tendency to increase by years (Pandino *et al.,* 2013). The edible part of the plant is the enlarged receptacle and the tender thickened bracts bases of the head *(capitula),* which is the immature inflorescence. It is used worldwide as a fresh canned delicacy or frozen vegetable (Gebhardt, 1997; Brown and Rice-Evans, 1998). Recently, the consumer demand for artichoke has increased because of their reputation as health food due to their nutritional and phytochemical composition (Lattanzio *et al.*, 2009; Guida *et al.*, 2013). Artichoke heads are characterized by high content of vitamins, minerals, carbohydrates, inulin, polyphenolic compounds and low protein and fat (Kołodziej and Winiarska, 2010; Pandino *et al.*, 2013; Zeipiņa *et al.*, 2015). Artichoke leaves also, are used as a herbal medicine and have been recognized since ancient times for their beneficial and therapeutic effects (Gebhardt, 1997; Llorach *et al.*, 2002; Lattanzio *et al.*, 2009). Also, leaves, stems and industry residues are used for cattle feed and insert the artichoke byproducts in sheep ration improve animal performance. (Hammouda *et al.*, 1993 and Salman *et al* 2014).

Egypt has the potential to develop an excellent export industry in artichoke (Schrader, 2001). Artichoke heads production is widely distributed all over world (1,634,219 ton). Egypt is ranked the first world producer of artichoke in 2012 with a total production of 387,704 ton with an area 17895 ha. In 2014, Egypt is ranked the second producer in the world after Italy with an area of 12647 ha and total yield of 266196 ton year^{-1}. Moreover, Egypt has the highest yield of the unit area with 21.0482 ton ha^{-1} (FAO, 2015). Recently, the government is paying more attention to promote artichoke production especially in the newly reclaimed areas to satisfy the increasing demand for both local consumption and exportation.

Artichokes has a deep rooted system (Schrader and Mayberry, 1997). It can be grown on a wide range of soil types (Ryder *et al.*, 1983). Artichoke is a higher water requirement crop compared to other vegetables crops may be due to large foliage biomass and long production cycle, so artichoke productivity strongly influenced by irrigation amount. The bud yield increase with increasing irrigation water (Garnica *et al.*, 2004; Macua *et al.*, 2005; Leskovar *et al.*, 2011; Boari *et al.*, 2012; Saleh and Fawzy, 2012; Leskovar and Xu, 2013).The highest yield were obtained when applying 100% of maximum evapotranspiration compared with applying 33% and 66% of maximum evapotranspiration (Litrico *et al.*, 1998). The greateast plant growth, bud yield and product quality were recorded when irrigation water applied at 75-100% cumulated pan evaporation compared to other treatmentsand there was no further increases when applied 125% of pan evaporation (Saleh, 2003). Many studies around the world indicated that the marketable yield of artichoke significantly increased when applying irrigation regime of 100 ET_c compared to the treatments of 50 % and 75% ET_c (Pomares *et al.,* 2004; Shinohara, 2008; Leskovar *et al.*, 2011; Shinohara *et al.*, 2011 and Hernández-Pérez *et al.*, 2013). There were no significant differences on yield between irrigation with 100% and 125% ET_c (Pomares *et al.,* 2004). Provide artichoke plant by regular irrigation with 85-100% of the crop evapotranspiration resulted the highest plant growth and development (Zeipiņa *et al.*, 2015). While drought or deficit irrigation significantly decreased marketable yield and yield attributes, as head number and head weight (Saleh, 2003; Garnica *et al.*, 2004; Pomares *et al.*, 2004; Macua *et al.*, 2005; Shinohara, 2008; Leskovar *et al.*, 2011; Shinohara *et al.*, 2011; Boari *et al.*, 2012; Saleh and Fawzy, 2012; Hernández-Pérez *et al.*, 2013; Leskovar and Xu, 2013). However, water use efficiency significantly increased with decreasing the irrigation water (Garnica *et al.*, 2004; Pomares *et al.*, 2004; Macua *et al.*, 2005; Saleh and Fawzy, 2012; Leskovar and Xu, 2013). In Egypt, the growth characters, total sugar and inulin significantly increased when water quantity increased from 2850 m^3ha^{-1} to 5700 m^3ha^{-1}. The water application of 4300 m^3ha^{-1} with using 30 m^3 farmyard manure and kaolin at 6 % as antitranspirants was the best combination for globe artichoke production which resulted in maximum water use efficiency (Saif El-Din and Abd El-Hamed, 2010).

Potassium has a crucial role in enhancement of tissue water relation, plant energy status, translocation and storage of assimilates. It is also involved in stomatal regulation of transpiration and photosynthesis, photophosphorylation, transportation of photo assimilates from source tissues via the phloem to sink tissues, enzyme activation, and maintenance of tissue water relation and stress tolerance (Marschner, 2012). It also plays a key role of crop quality through its importance for carbohydrate formation and sugar translocation. Moreover, K provides resistance against drought, frost stresses, diseases and pests (Imas and Bansal, 1999). It is a mineral nutrient required in a large amount to plants. It is an essential mineral element for plants as it involved in many biochemical and physiological processes vital to plant growth, yield, quality and stress (Aown *et al.*, 2012). Potassium enhances the earliness and improves product quality and head characters(Foti *et al.*, 2000 and Saleh, 2003).

Balanced fertilizer beside appropriated irrigation regime is very essential to obtain the highest yield as quantity and quality. In Egypt, the highest early and total yield, large head diameter were found with application of K at rate of 115 kg K_2O ha^{-1} compared to 0 and 57 kg K_2O ha^{-1} rates. However these potassium rates did not reflect any significant effect on plant vegetative growth. (El-Shal *et al.*, 1993). The application of 286 kg N ×179 kg K_2O ha^{-1} recorded the highest plant growth, number of flower heads/plant, average head weight and total yield/ha with no significant difference when compared to the rates of 286 kg N × 357 kg K_2O, 381 kg N × 179 kg K_2O and 381 kg N × 357 kg K_2O kg ha^{-1} (Aly, 2014).

Egypt is one of countries that facing water scarcity problem and there are many projections indicating that this scarcity will grow in future due to expected impacts of climate change and rapid population increase. In water scarcity areas, there are essential guidelines to determine irrigation schedules that maximize water productivity and farm profitability (Alromeed *et al.*, 2015).

The main objective of this study is to define the optimum schedule irrigation and water requirements and evaluate the effects of various rates of potassium on vegetative growth parameters, yield and its component of globe artichoke in sandy soils.

MATERIALS AND METHODS

Experimental site:

Tow Field Experiment Were Conducted During two seasons of 2014/2015 and 2015/2016, at the Experimental Farm of El-Kassasin Horticultural Research Station, Ismailia governorate, Egypt. The average climatic data were collected from Ismailia Agro-metrological Station (30° 36 'N latitude, 32° 14 'E longitude and 10 m above sea level) of 2000 - 2014 as shown in Table (1).

Table 1. Monthly average climatic parameters for Ismailia governorate in 2000- 2014.

Months	Mean air temperature			Mean relative humidity (%)	Mean wind Speed (km d^{-1})	Rain full (mm\ month)	possible Sunshine (hrs)	Radiation (Mj m^{-2} d^{-1})	Et_o (mm d^{-1})
	Max. (^oC)	Min. (^oC)	Mean (^oC)						
January	19.57	8.074	13.82	61.85	176	2.84	10.30	15.80	2.45
February	21.51	9.045	15.28	59.86	201	2.07	10.90	19.10	3.24
March	24.29	11.5	17.89	57.55	225	1.10	11.90	23.70	4.45
April	27.3	13.97	20.64	54.2	214	1.36	12.80	27.60	5.61
May	31.39	17.38	24.38	53.56	202	0.73	13.60	30.10	6.63
June	33.71	20.64	27.17	55.86	181	0.00	14.00	31.00	7.05
July	35.87	23.44	29.66	58.43	197	0.00	13.70	30.30	7.44
August	36.00	23.46	29.73	58.72	185	0.00	13.10	28.40	7.02
September	33.93	21.52	27.73	58.99	172	0.00	12.20	24.90	5.91
October	30.54	18.03	24.29	60.35	162	0.11	11.40	20.60	4.49
November	26.39	13.32	19.86	61.93	142	0.43	10.60	16.70	3.10
December	22.16	9.895	16.03	62.83	159	3.66	10.10	14.80	2.46

Soil properties of the experimental site were determined before cultivation process. Soil chemical properties were determined according to Page *et al.*, (1982). Soil physical properties, i.e., particle-size distribution, bulk density, total porosity, soil field capacity and permanent welting point were determined according to Klute, (1986) as shown in Table (2).

Table 2. Mean values of some physical and chemical soil properties of the experimental site as an average of the two growing seasons.

Properties	Values	Properties	Values
Sand (%)	95.85	Total porosity (%)	36.22
Silt (%)	1.68	Soil organic matter (%)	0.06
Clay (%)	2.47	Ec_e (ds m^{-1}) 1:5 extraction	0.61
Texture	Sandy soil	pH in 1:2.5 suspension	7.90
Calcium carbonate (%)	0.23	Available N (ppm)	5.20
Field capacity (%)	6.53	Available P (ppm)	4.76
Wilting point (%)	2.21	Available K (ppm)	56
Available water (%)	4.32	Ec_i (ds m^{-1}) Irrigation water	0.43
Bulk density (Mg m^{-3})	1.69		

Experimental design and treatments:

A split- plot design arrangement with three replications was used. The main plots were assigned for the irrigation treatments, meanwhile the sub-plots were allocated to potassium fertilizer treatments.

Irrigation treatments (I):

Irrigation with 100% of ET_c (I_1) , irrigation with 80% of ET_c (I_2) and irrigation with 60% of ET_c (I_3).

Potassium fertilizer treatments (K):

Potassium fertilizer was added in the amount of 100% of the recommended dosage (250 kg.fed^{-1}) (K_1) , 75% of the recommended dosage plus spraying with potassium citrate with concentration of 1% (K_2) and 50% of the recommended dosage plus spraying with potassium citrate with concentration of 1% (K_3).

The used drip irrigation system was consisted of normal polyethylene pipes of 16 mm diameter as laterals with line dripper of 4 L/h at 50 cm apart. The laterals were located 100 cm apart, one lateral for each plant row. Irrigation water was filtered through gravel filters and refiltered through screen filters.

The French cultivar "Herious" was vegetatively propagated by offshoots and cutting stumps. The old pieces were treated with fungicides for 30 minutes before planting, then planted in 4^{th} and 6^{th} of September in the first and the second seasons, respectively, with 1.0 m between each two plants on the ridge and 1.0 m between the ridges and the plot area was 40.0 m^2 (20.0 m length x 2.0 m width).

Globe artichoke plants were subjected to foliar spray with potassium citrate at three times started after 75 days from planting, with two weeks interval, during the two growing seasons. Potassium was added in the form of potassium sulphate (48% K_2O), twenty five percent of potassium sulphate was applied before planting and the rest were divided into three equal portions and added to the soil at 45, 90 and 120 days after planting . All other agricultural practices were followed according to recommendations of Ministry of Agriculture, Egypt.

Crop evapotranspiration (ET_c), was calculated using the following equation:

$ET_c = ET_o \times k_c$.......[1]

Where, ET_o refers to reference evapotranspiration and K_c refers to crop co-efficient values which quoted from Doorenbos *et al.*, (1979). Reference evapotranspiration was calculated according to Penman Monteith equation (Allen *et al.*, 1998) using FAO-CROP WAT 8.0 software (Smith, 1992).

Irrigation water applied (IWA)

The amount of applied water at each irrigation is mainly based on term of ET_c whether it is 100%, 80% or 60% which calculated from reference evapotranspiration (ET_o) multiplied by crop coefficient (K_c) as shown in equation (1). To ensure that the various percentage of the crop evapotranspiration (ET_c) of each treatment has been properly added, the applied irrigation water (IWA) was calculated, as shown in equation (2), according to (Habib, 1991):

$$IWA = \frac{ETo.\,Kc.\,Kr.\,Ii. + LR}{Ea} \quad ....[2]$$

Where:

IWA is the irrigation water applied (mm), ETo is a reference evapotranspiration (mm/day), Kc is a crop coefficient, Kr is a reduction factor (Keller and Karmeli, 1974), Ii is an irrigation interval (days), Ea is an irrigation efficiency (85%). Ea is estimated from emitter uniformity coefficient (0.95) multiplied in drip irrigation efficiency coefficient (0.90), and LR is leaching requirement percent.

Productivity of irrigation water (PIW)

The Productivity of irrigation water in kg economic yield m^{-3} was calculated according to Ali *et al.*, (2007), as follows:

PIW (kg m^{-3}) =

$$\frac{\text{Economic yield (heads yield) in kg fed}^{-1}}{\text{Amount of irrigation water applied m}^{3}\,\text{fed}^{-1}}$$

Data recorded:

Growth characters:

Random samples from each plot were chosen at150 days after planting in two seasons and the flowing measurements were recorded:

1-Plant height (cm): The height of plants was measured from the soil surface up to the tip of the height leaf.
2-Leaf fresh weight (g): representative samples from fourth leaf.
3-Leaf dry weight (g): after drying to a constant weight at 70^0 C.
4-Number of offshoots / plant at the end of harvesting.

Yield and its component:

The early yield was calculated from the beginning of harvest till the end of February and many parameters were evaluated in both seasons of the study as number of early and total flower heads /plant, total yield /plant and total yield (ton/ fed). Random samples of five flower heads were taken from each plot in both seasons for measuring the physical head characters, including flower head diameter (cm) and fresh weight (g), receptacle fresh weight (g), diameter (cm) and thickness (cm).

Chemical analyses*:*

Representative samples of flower heads (edible part) were dried in an electric oven at 70°C to constant weight. In addition, the digested dry matter was taken for chemical determinations. Total and reducing sugars were determined according to Dubois *et al.,* (1956), and Inulin concentration was determined according to Winton and Winton (1958).

Economic feasibility:

Economic analysis was calculated according to Heady and Dillon (1961) as following:

Gross income (L.E. fed^{-1}) = total yield (flower heads fed^{-1}) × price of flower head (L.E.)

Net return (L.E. fed^{-1}) = gross income – total cost of production.

Profit margin = net return/ Gross income

Return of Pound= net return/ total cost of production

Benefit/cost ratio =gross income / total cost

Statistical analysis:

Data obtained from experimental treatments were subjected to analysis of variance by using COSTAT software and treatments means were compared using Duncan's multiple range test (Duncan, 1955) at 5% level of significance (p= 0.05) which was used for means comparison according to Snedecor and Cochran, (1980).

RESULTS AND DISCUSSION

1. Vegetative growth parameters:

Data presented in Table (3) shows the effect of irrigation and potassium fertilizer treatments and their interaction on vegetative growth parameters of globe artichoke plants that including plant height (cm), Leaf fresh weight (g), leaf dray weight (%) and number offshoots/plant during the 2014/2015 and 2015/2016 growing seasons. There were significant differences in all vegetative growth parameters in both seasons. In this respect, irrigation treatment of I_1 (100% of ET_c) recorded the highest values in all measured growth parameters, followed by irrigation treatments of I_2 (80% of ET_c) and I_3 (60% of ET_c) in descending order. This may be due to the decrease of shoot and/ or root growth by lowering photosynthetic rates with decrease of irrigation treatments (Pomares *et al.*, 2004; Shinohara 2008; Leskovar *et al*., 2011; Shinohara *et al*., 2011; Leskovar and Xu, 2013 and Zeipiņa *et al*., 2015).

There were significant differences between potassium treatments for plant height and offshoots number per plant traits in both season. While there were no significant differences in leaf dry weight in the two seasons and leaf fresh weight in the second season. In this regard, treatment of K_1 (100% of recommended dosage) exhibited the highest values of all vegetative growth parameters in both seasons. This might be due to that the potassium affects photosynthesis at various levels. The enhancing effect of potassium on plant growth might be attributed to its association with the efficiency of leaf as an assimilator to Co_2 (Rai *et al.,* 2002), activating phyto-hormone, regulation of cellular PH, enhancing N uptake, and acting as an activator to enzymatic systems (Marschner, 2012). In this respect, Zewail *et al.* (2011) found that foliar application of potassium citrate increased plant height, number of branches, and dry weight of leaf and stems of faba bean plants. Also, these results were in somewhat in harmony with the findings of Hagag *et al.* (2000) who found that the highest values of number of branches growth and fruiting of olive seedlings were produced by foliar spray with potassium citrate.

Table 3. Effect of irrigation, potassium treatments and their interaction on vegetative growth traits of artichoke plants during 2014/2015 and 2015/2016 growing seasons.

Treatments			Plant height(cm)		Leaf fresh weight(g)		Leaf dry weight (g)		Offshoots no. plant^{-1}	
			1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation		I_1	84.22 a	73.22 a	47.00 a	32.11 a	13.37 a	8.43 a	3.27 a	3.60 a
		I_2	63.11 b	60.00 b	42.22 b	31.33 a	10.64 b	7.51 a	2.59 b	2.58 b
		I_3	53.66 b	51.22 c	35.56 c	26.22 b	8.99 b	6.25 b	2.01 c	1.72 c
Potassium		K_1	73.44 a	64.00 a	44.77 a	30.33 a	11.82 a	7.81 a	2.93 a	3.09 a
		K_2	67.56 b	62.44 a	40.56 b	29.78 a	11.29 a	7.32 a	2.68 a	2.72 a
		K_3	60.00 c	58.00 b	39.44 b	29.56 a	9.90 a	7.06 a	2.26 b	2.09 b
Interaction	I_1	K_1	88.33 a	75.67 a	51.33 a	28.33 abc	14.00 a	9.25 a	3.67 a	4.20 a
		K_2	84.33 ab	73.33 a	45.33 ab	33.33 ab	11.69 ab	7.70 a-d	3.13 b	3.40 b
		K_3	80.00 b	70.67 a	43.33 ab	29.33 abc	9.77 ab	6.48 bcd	3.00 b	3.20 b
	I_2	K_1	69.67 c	61.67 b	45.67 ab	31.67 ab	13.44 a	8.23 ab	2.78 bc	2.86 bc
		K_2	65.33 cd	60.33 b	41.67 bc	31.67 ab	10.84 ab	7.44 bcd	2.75 bc	2.83 bc
		K_3	62.33 d	58.00 bc	40.00 bcd	26.00 bc	9.58 ab	6.29 cd	2.22 d	2.03 cd
	I_3	K_1	54.33 e	54.67 c	38.30 bcd	34.00 a	12.68 a	7.80 abc	2.33 cd	2.20 d
		K_2	53.00 e	53.67 c	35.00 cd	31.33 ab	9.40 ab	7.40 bcd	2.15 d	1.93 d
		K_3	45.67 f	45.33 d	33.33 d	23.33 c	7.63 b	5.98 d	1.55 e	1.03 e

Means of each factor within each column, values followed by the same letters are not significantly different at 5% level, using Duncan's Multiple Range Test.

I_1= irrigation with 100% of ET_C **K_1=100% of recommended dosage.**

I_2= irrigation with 80% of ET_C **K_2= 75% of recommended dosage + spraying with potassium citrate (1%).**

I_3= irrigation with 60% of ET_C **K_3= 50% of recommended dosage + spraying with potassium citrate (1%).**

The highest values of plant height, leaf fresh weight and leaf dry weight were obtained from $I_1 \times K_1$ and $I_1 \times K_2$ interactions without any significant differences between them, but the highest number of offshoots/plant resulted from $I_1 \times K_1$ in two seasons. On the other hand, the lowest values of these plant growth characters were observed from $I_3 \times K_3$ interaction in the two growing seasons as shown in Table (3).

2. Yield and its components

Yield

Data in Table (4) showed that all the flower heads yield treats of artichoke plants decreased significantly with decreasing the amount of irrigation water applied and with decreasing the rate of K fertilizer in the two growing seasons. These results agree with those obtained by Litrico *et al*., (1998); Saleh (2003), Pomares *et al*., (2004) and Leskovar *et al*., (2011) who reported that theearly yield and total yield of artichoke were associated with 100% ET_c.The reduction of total heads number / plant and total yield for irrigation treatments of I_2 and I_3 were 9.3% and 16 %, 11.8% and 19.7% respectively compared to irrigation treatments of I_1 as the mean of two growing seasons. These results agree with those obtained by Shinohara *et al*., (2011) who reported that artichoke yield reduced by 20% and 35% when irrigated applied with 75% ET_c and 50% ET_c, respectively compared to 100% ET_c, this reduction may be due to the decrease of head number/plant and head weight (Garnica *et al.,* 2004; Macua *et al*., 2005 and Leskovar and Xu, 2013).

Concerning the potassium fertilizer, K_1 and K_2 treatments had the highest values, while the lowest one were obtained under K_3 treatment in the two growing seasons. This could be attributed to the importance of potassium for many biochemical and physiological process vital to plant growth, yield , quality and plant water stress tolerance (Aown *et al*., 2012). These results similar to those obtained by Zewail *et al.,* (2011) found that foliar application of potassium citrate increased yield and yield components of faba bean plants.

Table 4. Effect of irrigation, potassium fertilizer treatments and their interaction on yield traits of artichoke plants during 2014/2015 and 2015/2016 growing seasons.

Treatments		No. of early heads plant^{-1}		No. of total heads plant^{-1}		Total yield plant^{-1} (kg)		Total yield (ton fed^{-1})	
		1st season	2nd season	1st season	2nd season	1st season	2nd Season	1st season	2nd season
Irrigation	I_1	1.583 a	1.24 a	9.25 a	8.67 a	2.07 a	1.95 a	8.28 a	7.81 a
	I_2	1.48 ab	1.167 ab	8.46 b	7.80 b	1.82 b	1.72 b	7.30 b	6.89 b
	I_3	1.39 b	1.10 b	7.66 c	7.39 c	1.66 c	1.57 c	6.64 c	6.27 c
Potassium	K_1	1.58 a	1.27 a	8.67 a	8.22 a	2.00 a	1.89 a	8.02 a	7.56 a
	K_2	1.46 b	1.17 b	8.62 a	8.06 ab	1.92 a	1.82 a	7.69 a	7.26 a
	K_3	1.42 b	1.08 c	8.11 b	7.57 b	1.63 b	1.53 b	6.51 b	6.13 b
Interaction I_1	K_1	1.68 a	1.31 a	9.52 a	8.96 a	2.21 a	2.08 a	8.83 a	8.33 a
	K_2	1.57 ab	1.22 ab	9.41 a	8.85 a	2.18 a	2.06 a	8.72 a	8.23 a
	K_3	1.50 abc	1.20 ab	8.85 ab	8.18 ab	1.82 b	1.72 b	7.27 b	6.86 b
Interaction I_2	K_1	1.58 ab	1.29 a	9.04 ab	8.18 ab	2.08 a	1.96 a	8.32 a	7.84 a
	K_2	1.45 bc	1.11 b	8.62 abc	7.84 bc	1.87 b	1.76 b	7.46 b	7.04 b
	K_3	1.40 bc	1.10 b	8.18 bcd	7.39 bc	1.53 c	1.44 c	6.13 c	5.78 c
Interaction I_3	K_1	1.47 bc	1.20 ab	7.90 cd	7.50 bc	1.73 b	1.63 bc	6.90 b	6.51 b
	K_2	1.35 c	1.18 ab	7.84 cd	7.43 bc	1.73 b	1.63 bc	6.90 b	6.51 b
	K_3	1.35 c	0.93 c	7.28 d	7.28 c	1.53 c	1.44 c	6.12 c	5.78 c

Means of each factor within each column, values followed by the same letters are not significantly different at 5% level, using Duncan's Multiple Range Test

I_1= irrigation with 100% of ET_C K_1=100% of recommended dosage.

I_2= irrigation with 80% of ET_C K_2= 75% of recommended dosage + spraying with potassium citrate (1%).

I_3= irrigation with 60% of ET_C K_3= 50% of recommended dosage + spraying with potassium citrate (1%).

Application of 100 of ET_c combined with K_1 and K_2 potassium were the most favorable treatments for increasing early and total flower heads number / plant as well as total yield/plant and total yield/ha (Table, 4). There were no significant differences of yield and its parameters between $I_1 \times K_1$, $I_1 \times K_2$ and $I_2 \times K_1$, but the lowest values of flower heads parameters were associated with $I_3 \times K_3$ interaction in the two growing seasons. This may be due to suitable plant growth , increase number of heads/plant and head weight (Leskovar *et al*., 2011; Boari e*t al*., 2012; Leskovar and Xu, 2013 and Aly, 2014)

2. Flower Head Quality

As shown in Table (5) mean values of flower head quality, i.e. head fresh weight (g), head diameter (cm), receptacle fresh weight (g), receptacle diameter (cm) and receptacle thickness (cm) decreased significantly with decreasing the irrigation water amount and with decreasing the rate of K fertilizer in two growing seasons, except for the receptacle thickness which was not significantly affected in the second season. The highest values of the flower heads quality traits were achieved with the treatment of I_1 (100% of ET_c) and with K_1 (100% of recommended dose). The lowest values were obtained under I_3 and K_3 in both seasons. This mean that quality traits of artichoke plant decreased with decreasing the applied irrigation amount and with the decreasing of potassium fertilizer applied dose than the recommended one. These results agree with Saleh (2003) and Saleh and Fawzy (2012). This may be due to the positive correlation between increasing water amount and vegetative growth characters, total yield and bud productivity of artichoke plants (Saleh and Fawzy 2012). However, there were reduction of head quality when drought applied (Hernández-Pérez et al., 2013).

As for potassium treatments. Generally, the highest values of above mentioned parameters were observed with K_1 and K_2 treatments in both seasons. These may be due the importance of potassium on performance of multiple plant enzyme functions, and its regulation the metabolite pattern of higher plants, ultimately changing metabolite concentrations (Mengel, 2001 and Marschner 2012). In addition to, the importance of potassium in increasing marketable yield and bud yield quality (Imas and Bansal 1999 and Saleh 2003).

Table 5. Effect of irrigation, potassium fertilizer treatments and their interaction on flower heads quality traits of artichoke plants during 2014/2015 and 2015/2016 growing seasons.

Treatments		Heads Fresh weight (g)		Heads Diameter (cm)		Receptacle Fresh weight (g)		Receptacle Diameter (cm)		Receptacle Thickness (cm)	
		1st season	2nd season	1st season	2nd season	1st season	2nd eason	1st season	2nd season	1st season	2nd eason
Irrigation	I_1	363.3a	318.8a	8.79a	8.39a	52.13a	43.46a	5.70a	5.07a	3.03a	2.68a
	I_2	290.7ab	300.4b	8.17ab	8.14ab	35.66ab	38.56b	4.89ab	4.98a	2.49ab	2.48ab
	I_3	266.9b	288.7b	7.77b	7.93b	27.38b	34.95b	4.34b	4.81a	2.14b	2.33b
Potassium	K_1	320.7a	309.9a	8.44a	8.28a	42.30a	41.02a	5.22a	5.01a	2.69a	2.56a
	K_2	316.2a	304.7ab	8.32a	8.20ab	41.35a	39.32a	5.09a	4.98a	2.63a	2.56a
	K_3	284.0b	293.3b	7.96b	7.99b	31.53b	36.63a	4.62b	4.87b	2.34b	2.39a
Interaction I_1	K_1	392.7a	329.7a	9.07a	8.53a	60.56a	46.00a	6.13a	5.17a	3.27a	2.70ab
	K_2	386.0a	323.3ab	8.90ab	8.46ab	59.68a	43.85a	6.03a	5.13ab	3.20a	2.80a
	K_3	311.3b	303.3abc	8.40bc	8.17abc	36.16bc	40.53ab	4.93bc	4.90cd	2.63b	2.53abc
Interaction I_2	K_1	297.3bc	304.3abc	8.23c	8.20abc	37.51b	39.90ab	4.97b	5.00bc	2.60b	2.53abc
	K_2	294.7bcd	300.3bc	8.20c	8.17abc	37.35b	38.17ab	4.93bc	5.00bc	2.57b	2.50abc
	K_3	280.0bcd	296.7bc	8.07c	8.07bcd	32.13bc	37.62ab	4.7bc	4.93cd	2.30bc	2.43bc
Interaction I_3	K_1	272.0cd	295.7bc	8.03cd	8.10bcd	28.83bc	37.16ab	4.57cd	4.87cd	2.20c	2.43bc
	K_2	268.0cd	290.3c	7.87cd	7.97cd	27.02bc	35.93ab	4.30de	4.80d	2.13c	2.37bc
	K_3	260.7d	280.0c	7.40d	7.73 d	26.31c	31.75b	4.17e	4.77d	2.10c	2.20c

Means of each factor within each column, values followed by the same letters are not significantly different at 5% level, using Duncan's Multiple Range Test

I_1= irrigation with 100% of ET_C K_1=100% of recommended dosage.
I_2= irrigation with 80% of ET_C K_2= 75% of recommended dosage + spraying with potassium citrate (1%).
I_3= irrigation with 60% of ET_C K_3= 50% of recommended dosage + spraying with potassium citrate (1%).

As for interaction, treatments of $I_1\times K_1$ and $I_1\times K_2$ gave the highest values of flower head fresh weight and diameter moreover, receptacle fresh weight, diameter and thickness without any significant differences between them, while the lowest values of these parameters resulted from the interaction between $I_3 \times K_3$ in the two growing seasons.

3. **Chemical characteristics:**

Data in Table (6) revealed that all chemical parameters of the receptacle; total and reducing sugar as well as inulin of edible part, differed significantly under the effect of irrigation and K fertilizer treatments in the two growing seasons. Irrigation treatment I_1 reflected the highest value of all measured chemical parameters, followed by I_2 irrigation treatment, while the lowest ones were obtained under the I_3 irrigation treatment. These results agree with those obtained by Saif El-Din and Abd El-Hamed, (2010).

Table 6. Effect of irrigation, potassium fertilizer treatments and interaction on chemical analysis of artichoke receptacle during 2014/2015 and 2015/2016 growing seasons.

Treatments		Total sugar(%)		Reduce sugar(%)		Inulin(%)	
		1st season	2nd season	1st season	2nd season	1st season	2nd season
Irrigation	I_1	5.22 a	4.32 a	3.10a	3.08 a	2.09 a	2.01 a
	I_2	4.41 b	3.51 b	2.86 a	2.51 ab	1.73 b	1.66 b
	I_3	4.19 b	3.29 b	2.54 b	2.21 b	1.36 c	1.31 c
Potassium	K_1	5.70 a	4.80 a	3.42 a	3.07 a	1.88 a	1.81 a
	K_2	4.50 b	3.59 b	2.66 b	2.54 ab	1.82 a	1.74 a
	K_3	3.63 b	2.73 c	2.42 b	2.18 b	1.49 b	1.42 b
Interaction I_1	K_1	6.07 a	5.17 a	3.05 bc	3.76 a	2.10 ab	2.01 ab
	K_2	5.07ab	4.16 b	2.33 de	2.95 ab	1.54 d	1.48 d
	K_3	4.52 cd	3.62 cd	2.23 e	2.54 bc	2.01 b	1.93 b
Interaction I_2	K_1	5.33 abe	4.43 abc	3.46 ab	2.90 b	2.14 a	2.06 a
	K_2	4.09 de	3.19 de	2.82 cd	2.62 bc	1.50 d	1.44 d
	K_3	3.16 e	2.26 e	2.30 e	2.00 c	1.81 c	1.73 c
Interaction I_3	K_1	5.71 ab	4.81 ab	3.74 a	2.55 bc	2.04 ab	1.96 b
	K_2	4.34 cd	3.44 cd	2.83 cd	2.06 c	1.04 f	1.00 f
	K_3	3.19 e	2.29 e	2.73 cde	2.00 c	1.37 e	1.32 e

Means of each factor within each column, values followed by the same letters are not significantly different at 5% level, using Duncan's Multiple Range Test

I_1= irrigation with 100% of ET_C K_1=100% of recommended dosage.
I_2= irrigation with 80% of ET_C K_2= 75% of recommended dosage + spraying with potassium citrate (1%).
I_3= irrigation with 60% of ET_C K_3= 50% of recommended dosage + spraying with potassium citrate (1%).

A similar trend was observed in respect to potassium treatments, treatment of K_1 that received 100% of the recommended dosage gave the highest values for all measured chemical parameters, followed by treated plants with 75% of the recommended dosage plus 1.0% of potassium citrate.The highest values of total sugar were observed from $I_1\times K_1$ interaction in the two growing seasons and reduce sugar in second season only. On the other hand, the lowest values were obtained from the interactions of $I_2\times K_3$ for total and reduce sugar as well as $I_3\times K_2$ for inulin in both seasons. These results may be due to the physiological roles of potassium on increased metabolic processes rate, in addition to the role of potassium compounds in improving plant growth which reflected on carbohydrates storage and increased total and reduce sugar contents and inulin (Chaliakhyan, 1957).

4. Water relations

Applied irrigation water

The highest values of applied irrigation water amount were obtained for irrigation treatment of I_1 to be 39.32 cm (1651 m^3fed^{-1}). The lowest ones of irrigation water applied were resulted from irrigation treatment of I_3 to be 23.97 (1007 m^3fed^{-1}) as the mean of two growing seasons (Table, 7). It is obvious that amount of irrigation water applied was gradually increased as a result of growing up of a vegetative growth that required higher amount of irrigation to meet its water requirements. It means that growth stages and meteorological variables affected irrigation water applied

Irrigation treatment of I_3 saves about 24 % and 39% compared to irrigation treatments of I_2 and I_1 respectively as the mean of two growing seasons. These results are agree with those obtained by Saleh (2003); Pomares *et al.*, (2004); Saif El-Din and Abd El-Hamed, (2010). There are no differences of irrigation water applied between all potassium fertilizer treatments as shown in Table (7).

Table 7. Monthly and seasonal applied irrigation water as influenced by irrigation and potassium fertilizer and their interaction during the two growing seasons under drip irrigation.

Treatments		Monthly rates (cm)								Seasonal IWA (cm)
		Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	
100% ET_C	K_1	0.96	0.98	1.86	3.15	4.39	6.37	9.64	11.97	39.32
	K_2	0.96	0.98	1.86	3.15	4.39	6.37	9.64	11.97	39.32
	K_3	0.96	0.98	1.86	3.15	4.39	6.37	9.64	11.97	39.32
80% ET_C	K_1	0.96	0.78	1.48	2.52	3.51	5.10	7.71	9.57	31.63
	K_2	0.96	0.78	1.48	2.52	3.51	5.10	7.71	9.57	31.63
	K_3	0.96	0.78	1.48	2.52	3.51	5.10	7.71	9.57	31.63
60% ET_C	K_1	0.96	0.59	1.11	1.89	2.64	3.82	5.78	7.18	23.97
	K_2	0.96	0.59	1.11	1.89	2.64	3.82	5.78	7.18	23.97
	K_3	0.96	0.59	1.11	1.89	2.64	3.82	5.78	7.18	23.97

I_1= irrigation with 100% of ET_C **K_1=100% of recommended dosage.**
I_2= irrigation with 80% of ET_C **K_2= 75% of recommended dosage + spraying with potassium citrate (1%).**
I_3= irrigation with 60% of ET_C **K_3= 50% of recommended dosage + spraying with potassium citrate (1%).**

Productivity of irrigation water

Irrigation water productivity differed significantly between irrigation, potassium fertilizer and the interaction between these treatments in the two growing seasons (Fig 1). The highest productivity of irrigation water was observed with irrigation treatment of I_3 compared to irrigation treatments of I_1 and I_2 as the mean of the two growing seasons. These results were in harmony with previous reported by Garnica *et al.*, (2004); Pomares *et al.*, (2004); Macua *et al.*, (2005); Saif El-Din and Abd El-Hamed, (2010) and Leskovar and Xu, (2013), who indicated that productivity of irrigation water decrease with the increase of the applied irrigation water. The lowest values of productivity of irrigation water were recorded under K_3, but there are no significant differences between potassium treatments of K_1 and K_2 in the two growing seasons.

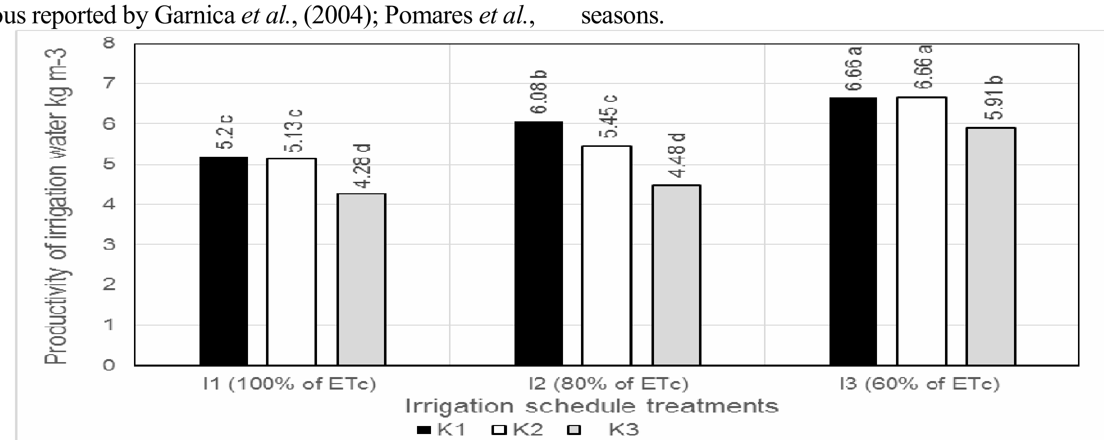

Fig 1. Productivity of irrigation water as affected by irrigation and potassium fertilizer treatments as mean of the two growing seasons.

Concerning the interaction between I and K, the obtained results showed that the highest values of productivity of irrigation water was observed with the interactions of $I_3 \times K_1$, $I_3 \times K_2$ without any significant differences between them, while the lowest values of productivity of irrigation water were resulted from the interaction between $I_1 \times K_3$ as the mean of the two growing seasons..

5. Economic feasibility:

Data in table (9) shows the details of economic analysis containing average of total cost production including fixed and variable costs like land preparation, sowing, irrigation, fertilization, insect and weed control, harvesting (LE.fed.$^{-1}$), average of gross income (LE.fed.$^{-1}$), net return (LE.fed.$^{-1}$), profit margin (LE. flower head^{-1}), return of pound and benefit/ cost ratio.

The total cost production ranged from16623 to 18814 L.E./fed. among all treatments. The highest values of average gross income occurred with I_1X K_1 and I_1 X K_2 treatments (31046 and 30670 L.E.) respectively. Regarding the net return, profit margin, return of pound and B/C ratio the $I_1 \times K_2$ Treatment gave the highest values (12607, 0.411, 0.698 and 1.698) respectively, meanwhile the $I_3 \times K_3$ treatment gave the lowest values (7650, 0.315, 0.460, 1.460) respectively. The variations occurred due to the cost of irrigation and potassium fertilizer treatments. Artichoke prices vary substantially from month-to-month. The highest prices usually occur from December to February, when the quality of fresh artichokes is relatively high, but volume is low. The lowest prices occur during March, April, and May (Bertelsen. *et al.,*1995).

Table 9. Effect of irrigation and potassium fertilizer treatments on economic costs for production of globe artichoke (average 2014/2015 and 2015/2016 seasons).

Treatments		Average of Total cost production (L.E/fed)	Average of Gross income (L.E/fed)	Net return (L.E/fed)	Profit margin (L.E.flower^{-1})	Return of Pound	B/C Ratio
	K_1	18814	31046	12232	0.394	0.650	1.650
I_1	K_2	18063	30670	12607	0.411	0.698	1.698
	K_3	17310	28600	11290	0.395	0.652	1.652
	K_1	18513	28930	10417	0.360	0.563	1.563
I_2	K_2	17763	27660	9897	0.358	0.557	1.557
	K_3	17013	26154	9141	0.350	0.537	1.537
	K_1	18123	25884	7761	0.300	0.428	1.428
I_3	K_2	17373	25660	8287	0.323	0.577	1.477
	K_3	16623	24273	7650	0.315	0.460	1.460

CONCLUSION

It could be concluded that under the current study condition, economically globe artichoke plant should irrigate with 100% of ET_c (I_1) and application of 75% from recommended potassium fertilizer dose plus spraying with concentration of 1.0 % of potassium citrate (K_2) this will promote highest values of yield, yield characters, yield quality, gross income, net return, profit margin, return of pound and B/C ratio compared to all studied treatments.

But under shortage condition of water, irrigation with 80% of ET_c (I_2) and add 100% of the recommended potassium fertilizer dose(K_1) could be recommended for globe artichoke production because 19.6% of irrigation water could be saved and increase productivity of irrigation water by 16.9% compared to $I_1 \times K_2$ interaction. With the continuous increase in water shortage, in such cases, irrigation with 60% of ET_c (I_3) and application of 75% from recommended potassium fertilizer dose plus spraying with concentration of 1.0 % of potassium citrate (K_2) could be applied because it produced higher PIW, saved 39% of irrigation against 21% of the yield reduction compared to $I_1 \times K_2$ interaction.

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تاثير الرى والتسميد البوتاسي على النمو الخضرى والمحصول والجودة لنباتات الخرشوف تحت ظروف الأراضى الرملية.

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أجريت هذه الدراسه خلال موسمى الزراعة ٢٠١٥/٢٠١٤ و ٢٠١٦/٢٠١٥ بمحطة بحوث البساتين بالقصاصين - محافظة الاسماعيلية – مصر وذلك لدراسة تأثير الرى ومستويات التسميد البوتاسى على النموالخضرى والمحصول والجوده لنورات الخرشوف تحت نظام الرى بالتنقيط بالأراضى الرملية . حيث صممت التجربة فى قطع منشقة مرة واحدة حيث وضعت معاملات الرى فى القطع الرئيسية وهى الرى بتطبيق ١٠٠% من البخرنتح للمحصول (I_1) و ٨٠% من البخرنتح للمحصول (I_2) و٦٠ % من البخرنتح للمحصول (I_3) بينما وضعت مستويات التسميد البوتاسى فى القطع تحت الرئيسية وهى التسميد بمعدل ١٠٠% من المعدل الموصى بة (K_1) والتسميد بمعدل ٧٥% من المعدل الموصى بة مع الرش الورقى بسترات البوتاسيوم ١% (K_2) والتسميد بمعدل ٥٠% من التسميد البوتاسى الموصى بة مع الرش بسترات البوتاسيوم ١%(K_3)أوضحت النتائج أن اعلى القيم لطول النبات والوزن الطازج والجاف للورقة وعدد الخلفات/ نبات ومتوسط الوزن الطازج وقطر النوره والوزن الطازج وقطر وسمك التخت وعدد النورات المبكرة والكليه /نبات كذلك وزن المحصول الكلى / نبات و الوزن الكلى للمحصول/فدان سجلت باستخدام المعاملة I_1 بينما سجلت اقل القيم للصفات المدروسة بعد المعاملة I_3 خلال موسمى الزراعة .لايوجد فروق معنوية لكل من طول النبات والوزن الطازج والجاف للورقة وعدد الخلفات/ نبات والوزن الطازج وقطر النوره والوزن الطازج وقطر وسمك التخت وعدد النورات المبكرة والكليه /نبات والمحصول الكلى / نبات كذلك المحصول الكلى للفدان بين معاملات التسميد K_1 و K_2 وكذلك بين التفاعلات $I_1 \times K_1$ و $I_1 \times K_2$ خلال موسمى الزراعة سجلت كمية مياه الرى المضافة خلال الموسم القيم ٣٩.٣٢ و ٣١.٦٣ و ٢٣.٩٧ سم عند رى نبات الخرشوف بتطبيق المعاملات ١٠٠% و ٨٠% و ٦٠% من البخرنتح للمحصول على الترتيب. وكانت اعلى القيم لانتاجية مياه الرى لمعاملة الرى ٦٠% من البخرنتح للمحصول . ادت معاملات التسميد البوتاسى K_1 وK_2 الى زيادة انتاجية الخرشوف وكذلك انتاجية مياه الرى.لذلك توصى الدراسة بانة تحت ظروف الاراضى الرمليه يمكن الرى ب ١٠٠% من البخرنتح للمحصول مع التسميد البوتاسى بمعدل ٧٥% من المعدل الموصى بة مع الرش بسترات البوتاسيوم ١% حيت ان هذة المعاملة تعطى أفضل قيم للمحصول وصفات الجودة. ولكن عندما تصبح الماء العامل المحدد للانتاج فانة يمكن تطبيق معاملة الرى ب ٦٠% من البخرنتح مع التسميد البوتاسى بمعدل ٧٥% من المعدل الموصى بة مع الرش بسترات البوتاسيوم ١%.