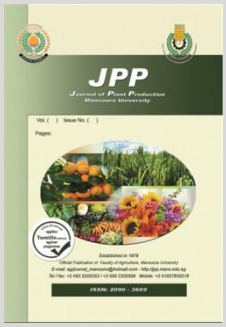
Journal of Plant Production

Journal homepage: www.jpp.mans.edu.eg
Available online at: www.jpp.journals.ekb.eg

Effect of Irrigation Intervals and Foliar Applications with some Nano-Fertilizers on Growth and Productivity of Globe Artichoke Plant: B-Yield and its Quality

Tartoura, E. A.[1]; U. M. Seif El-Deen[2] and A. Y. El-Adawy[2*]

[1] Veg. and Flori. Dept. Fac. Agric., Mansoura. Univ., Egypt.
[2] Horticulture Research Institute, Giza – Egypt



ABSTRACT

Two field experiments were conducted during the seasons of 2017-2018 and 2018-2019 at Baramoon Research Station, Mansoura, Dakahlia Governorate, Egypt, to study the effect of irrigation intervals and foliar application with nano-potassium and boron fertilizers under mineral potassium fertilization on productivity and quality of globe artichoke French Hyrious variety. The experiment divided into 36 treatments, representing the combinations of three irrigation intervals (10, 20 and 30 days) as vertical-plot, three rates of potassium fertilization (50, 75 and 100%) as horizontal plot and four foliar application rates of Nano-fertilizers (without, 3000 ppm K, 50 ppm B and 3000 ppm nano-K + 50 ppm nano-B) as split plot. The design of the experiment was a strip-split plot with three replicates. The results indicated that the fertilization of globe artichoke plants with potassium at 100% (200 kg/fed. potassium sulfate.) or 75% (150 kg/fed. potassium sulfate.) with foliar application by a mixture of 3000 ppm nano-K+ 50 ppm nano-B treatment and irrigation every 20 days to obtain the best yield (early and total) parameters and the highest quality. Therefore, we recommend this treatment because it saves in the amount of potassium and the amount of irrigation water and thus reduces the costs of artichokes production and environmental pollution under the conditions of this study.

Keywords: Globe artichoke, irrigation intervals, nano-fertilizers, nano-K, nano-B, foliar application, yield and its quality

INTRODUCTION

Globe artichoke (*Cynara scolymus* L.) is one of the most important plant belong to Asteraceae family. It is ancient crop and medicinal plant and used worldwide as a fresh canned delicacy or frozen vegetable. 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. In Egypt, the total cultivated area of artichoke reached 16546 ha and the total production exceeded 2968899 ton ha^{-1}.(FAO, 2019).

The proper irrigation interval can play a major role in increasing the water use efficiency and the productivity by applying the required amount of water when it needed. Irrigation scheduling is a critical management input to maximize soil moisture content for proper growth of plant, development, optimum yield, water use efficiency and economic benefits (Himanshu *et al*., 2013). The important use of irrigation can be characterized as the rooting area and avoiding the leaching of nutrients into soil layers (Kruger *et al*., 1999). By increasing irrigation intervals, reducing the amount of water used in each irrigation time or by limiting water consumption to drought-sensitive growth stages, this practice aims to maximize water productivity and to stabilize yields (Fallahi *et al*., 2015). Shafshak *et al.* (2020) showed that application of 80% recommend dose of mineral potassium fertilizers + potassin bio fertilizer (280 kg/fed. potassium sulphate + potassin) then spray the plants with Chelated boron at100 ppm exhibited the highest values in all measured of chemical composition of plant foliage with best fruit quality.

Boron is important for metabolism and growth of higher plants in cell elongation and cell division, protein metabolisms, tissue differentiation, membrane permeability, pollen germination and pollen tube growth (Marschner, 2013). A significant relationship has been found between potassium and boron fertilizers (Hill and Morrill, 1975). Moreover, Woodruff *et al.* (1987) showed that boron may need to be applied to prevent a reduction in plant yield, if the crop is given heavy applications of potassium and other intensive production practices. Shorrocks (1990) reported that effects of B on membrane permeability could lead to association between B and K. The stimulation of K accumulation by the ATPase proton pumps which may account for positive correlations between K and B.

Nanotechnology is a new area of technology in agricultural fields that recently has emerged and could be very useful in designing the new generation of fertilizers with higher efficiency of nutrient use. Nano fertilizers are more effective and efficient than traditional fertilizers because of their positive effects on the quality nutrition of crops and the reduction of stresses in plants and the lack of added quantities and costs for their rapid uptake by the roots and their penetration into cells and transport and representation within the plant tissues. Nano fertilizers are nano-structured formulation of fertilizers that release nutrients into the soil gradually and in a controlled way. (Rameshaiah and Jpallavi, 2015; Morales -Diaz *et al.*, 2017; Singh *et al.*, 2017 and Ali and Al–Juthery, 2017).

The aim of this work was to evaluate the possibility of using nano K and B fertilizers and mineral potassium fertilization under irrigation intervals on the head yield and quality of globe artichoke.

* **Corresponding author.**
E-mail address: aymaneladawygo@gmail.com
DOI: 10.21608/jpp.2021.154344

MATERIALS AND METHODS

In order to obtain the objective of this investigation; two field experiment were undertaken at Baramoon Research Station, Mansoura, Dakahlia Governorate, Egypt, during the winter season of 2017-2018 and 2018-2019, to investigate the effect of irrigation intervals and foliar application with potassium and boron nano fertilizers under mineral potassium fertilization on productivity and quality of globe artichoke French Hyrious variety.

The textural class of soil for experimentation is Clay and, before the start of the experiment, had the following characteristics: EC 1.58 dSm^{-1} , pH 7.78, organic matter% 1.75, available N 74.7; available P 5.2 and available K 370 $mg \cdot kg^{-1}$.

The experiment includes 36 treatments, representing the combinations of three irrigation intervals (10, 20 and 30 days) as vertical-plot, three rates of potassium fertilization (50, 75 and 100%) as horizontal plot and four foliar application of nano-fertilization, treatments (without, 3000 ppm K, 50 ppm B and 3000 ppm K + 50 ppm B) as split plot. The design of the experiment was a strip-split plot with three replicates.

All the experimental units received ammonium sulphate (20.6 % N) at rate of 600 kg/fed. and calcium phosphate super (15.5 % P_2O_5) at rate of 400 kg/fed. For ammonium sulfate was added in 3 batches, super phosphate calcium was added in two batches while potassium sulfate (48 % K_2O) was added in 3 batches depending on the treatments as follows:

-With preparation of soil, the first batch of nitrogen and phosphorus was added with 200 kg of agricultural sulfur.
-After 30 days of planting (complete the germination of the most seeds), the second batch of nitrogen and phosphorus was added and the first batch of potassium was added depending on the treatments.
-After 60 days of planting, the third batch of nitrogen and the second batch of potassium were added.
-After 120 days of planting (in first of mid-December), the last batch of potassium was added according to the treatments (100, 75, 50 % from recommended dose).

As for foliar application: nano-K Fertilizer and nano-Boron powder were obtained from (Nano Fab Technology Company, Cairo, Egypt) and added at rates of K, 3000 ppm nano-K, 50 ppm nano-B, and 3000 nano-K+ 50 nano-B were sprayed at 60 days old three times with 15 days interval.

As for Irrigation: The irrigation treatments began after 30 days from planting. All treatments were received equal amounts of water at the first irrigation. Irrigation was applied at 10, 20 and 30 days intervals but withholding of irrigation was done as defined for the treatments

The French Hyrious cultivar was vegetatively propagated by cutting old grown pieces (stumps). The old pieces were dipped with Rizolex fungicide at 2 g/l for 30 minutes before planting, then planted in mid of August in the first and the second seasons, respectively, with distance of 1.0 m between plants on the ridge and 1.0 meter between the ridges. Each experimental basic unit (sub-plot) included 4 ridges, each one of them of 0.8 m width and 4 m length, resulting an area of 12.8 m^2

Data recorded:

A-Yield parameters:

- **Early heads yield/fed.:** the number and weight of all harvested heads/plot and converted into ton /feddan starting from the beginning of harvest until the end of February were considered.
- **Total heads yield/fed.:** expressed as the number and weight of all harvested heads/plot throughout the entire harvesting season and converted into ton /feddan.

B-Head characteristics and quality:

- Weight of head
- Diameter of head
- Inulin %: It was determined according to Winton and Winton (1958).
- Total sugar %.: It was determined according to the method described by Sadasivam and Manickam (1996).

Statistical analysis:

All obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the strip-split plot design as published by Gomez and Gomez (1984) by using "MSTAT-C" computer software package. Duncan's multiple range test (Duncan, 1955) at 5% level was used to compare the means.

RESULTS AND DISCUSSION

1. Yield parameters:

Effect of irrigation intervals:

Concerning the effect of irrigation intervals (10, 20 and 30 days) on the mean values of heads weight and number of heads for early and total yield /fed. of globe artichoke, data of Table (1) showed a significant increases in all parameters for the plants irrigated with all intervals. The highest values for early yield and total yield in two seasons were realized for the treatment of 20 days followed by 10 days interval, while the lowest one was recorded for the plants irrigated with 30 days. These results are quite expected since prolonging irrigation interval caused water stress which decreased the activity of meristematic tissue and caused a dwarfing in glob artichoke plants and decreased leaves and shoots which decreased the productivity of plant. The higher total heads yield obtained from irrigation the glob artichoke at shorter period, 10 or 20 days intervals may be due to increase in one or more of the estimated attributes either in fresh or dry weight of artichoke plants. So, these increments may be led to the favorable increases in productivity. The obtained results are in good harmony with those to El-Zohiri and Youssef (2015) on Jerusalem artichoke and El-Sharkawy and El-Zohiri (2007), Moursi *et al.* (2010), Salata *et al*. (2016, Yilmaz and YEùø (2016) and Anwar *et al.* (2017) on globe artichoke.

Effect of potassium fertilization:

Data of Table (1) illustrated that glob artichoke plants fertilized with K fertilization significantly effect on early and total yield during both seasons. With increasing rate of K fertilization 50, 75 and 100 % from recommended dose tended to increase the mean values of yield parameters. The heights mean values recorded with plants fertilized by 100% K followed by 75% with high significant at ($p \geq 0.05$) during both seasons. Similar results were recorded by Kasim *et al.* (2007), Aly (2014), Abou El-Khair and Mohsen (2016), Saleh *et al.* (2016) and Anwar *et al.* (2017).

Effect of nano-fertilizers:

Data presented in Table (1) indicated the effect of nano fertilizers in form of K and B or mix together on both weight and number of heads for early and total yield. Increasing nano-fertilizers rates significantly increased on early and total yield during both seasons. The highest

significant values of early yield and total yield, were realized with 3000 ppm nano-K + 50 ppm nano-B treatment followed by 3000 ppm nano-K and then 50 ppm nano-B. These results are in harmony with the findings of Abdel-Aziz *et al.* (2018). Al-Juthery and Saadoun (2018) indicated that nano-micronutrient applied on artichoke was significantly higher in yield. Similar results were recorded by Al-Fahdawi and Allawi (2019) and Shafshak *et al.* (2020).

Table 1. Individual effect of irrigation intervals, potassium fertilization and foliar application of nano-fertilizers on early and total yield during 2017-2018 and 2018-2019 seasons.

Treatments	Early yield				Total yield			
	Heads weight ton/fed.		Number of heads /fed.		Heads weight ton/fed.		Number of heads/fed.	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation intervals								
10 days	1.64^{b}	1.87^{a}	7012.31^{b}	7478.28^{b}	5.71^{a}	5.94^{ab}	33146.61^{b}	33965.69^{b}
20 days	1.67^{a}	1.90^{a}	7086.64^{a}	7568.08^{a}	5.75^{a}	5.99^{a}	33429.83^{a}	34248.25^{a}
30 days	1.61^{c}	1.83^{a}	6936.28^{c}	7443.17^{c}	5.66^{a}	5.89^{b}	32868.83^{c}	33713.00^{c}
Potassium fertilization								
100% K	1.76^{a}	2.00^{a}	7310.36^{a}	7843.64^{a}	5.91^{a}	6.14^{a}	34284.53^{a}	35078.61^{a}
75% K	1.65^{b}	1.88^{b}	7033.58^{b}	7503.44^{b}	5.72^{b}	5.95^{b}	33221.42^{b}	34044.47^{b}
50% K	1.50^{c}	1.72^{c}	6691.28^{c}	7142.44^{c}	5.48^{c}	5.73^{c}	31939.33^{c}	32803.86$_{c}$
Foliar application of Nano-fertilizers								
Without	1.02^{d}	1.18^{d}	5532.15^{d}	5714.26^{d}	4.70^{d}	4.93^{d}	27468.67^{d}	28501.48^{d}
3000 K nano	1.87^{b}	2.13^{b}	7596.07^{b}	8160.37^{b}	6.11^{b}	6.36^{b}	35420.56^{b}	36126.44^{b}
50 B nano	1.28^{c}	1.50^{c}	6189.11^{c}	6582.15^{c}	5.13^{c}	5.41^{c}	30028.48^{c}	30959.48^{c}
3000 K+ 50 B	2.39^{a}	2.65^{a}	8729.63^{a}	9529.26^{a}	6.87^{a}	7.07^{a}	39676.00^{a}	40315.19^{a}

Means followed by the same letter in the same column do not differ significantly by Duncan's multiple range test at 5% level.

Interaction effect between irrigation intervals and K-fertilization:

Regarding the effect between irrigation intervals and K-fertilization on early and total yield, data in Table (2) showed positively effective. The highest early and total yield/fed were recorded when treated plants with 100% K followed by 75% as soil application with significant differences between all treatments of K-fertilization under all intervals days. With a significant increase found highest mean values of early and total yield were recorded with 100% K fertilization from recommended dose under 20 days interval followed by the same rate of K under 10 days during both seasons. The increasing of total yield either per plant or feddan are connected with the increasing in number of heads produced by plant and the increment of average head weight., head diameter and head length. This is explained by potassium consider one of the important nutrient that own effect direct or indirect in vegetative and reproductive growth which reflected positively in yield and head quality directly under irrigation intervals. These results are in harmony with the findings of Anwar *et al.* (2011) on Jerusalem artichoke.

Interaction effect between irrigation intervals and foliar nano-fertilizers:

Regarding the effect of the interaction between irrigation treatments and nano-fertilizers on early and total produced yield, results in Table (3) revealed that all interactive treatments increased significantly early and total yield. The highest average head weight/fed and number of heads for both early and total yield were obtained due to the irrigation after 20 days followed by 10 days interval. Also, these parameters decreased under the treatment every 30 days interval with all foliar application. During the growing seasons, irrigation every 20 days intervals and nano foliar application of potassium fertilization 3000 ppm mix with 50 ppm boron treatment, recorded the highest significant early and total yield.

Interaction effect between K-fertilization and foliar nano-fertilizers:

Concerning with the interaction effect between K-fertilization and foliar nano-fertilizers, data in Table (4) showed that with increasing K fertilization rates with any foliar application increased early and total yield components. The highest values of average heads weight/fed and number of heads/fed for both early and total yield were recorded with 100% K or 75% from recommended dose with significant increase with foliar application of 3000 ppm nano-K and 50 ppm nano-B treatment. The same trend was true in both seasons. These results are in harmony with the findings of Shafshak *et al.* (2020).

Table 2. Interaction effect of irrigation intervals and potassium fertilization on early and total yield during 2017-2018 and 2018-2019 seasons.

Treatments		Early yield				Total yield			
		Heads weight ton/fed.		Number of heads/fed.		Heads weight ton/fed.		Number of heads/ Fed.	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation intervals X Potassium fertilization									
10 days	100% K	1.76^{b}	2.00^{b}	7312.25^{b}	7837.67^{b}	5.90^{a}	6.14^{ab}	34285.58^{b}	35064.08^{b}
	75% K	1.65^{c}	1.88^{e}	7033.58^{e}	7506.58^{e}	5.72^{b}	5.96^{cd}	33219.00^{e}	34022.50^{e}
	50% K	1.50^{g}	1.72^{h}	6691.08^{h}	7090.58^{h}	5.49^{cd}	5.72^{ef}	31935.25^{h}	32810.50^{h}
20 days	100% K	1.79^{a}	2.03^{a}	7384.25^{a}	7934.58^{a}	5.95^{a}	6.19^{a}	34562.08^{a}	35338.92^{a}
	75% K	1.67^{c}	1.91^{d}	7105.50^{d}	7592.42^{d}	5.75^{b}	6.00^{c}	33508.25^{d}	34328.25^{d}
	50% K	1.54^{e}	1.77^{g}	6770.17^{g}	7177.25^{g}	5.54^{c}	5.79^{e}	32219.17^{g}	33077.58^{g}
30 days	100% K	1.74^{b}	1.97^{c}	7234.58^{c}	7758.67^{c}	5.87^{a}	6.10^{b}	34005.92^{c}	34832.83^{c}
	75% K	1.62^{d}	1.85^{f}	6961.67^{f}	7411.33^{f}	5.69^{b}	5.90^{d}	32937.00^{f}	33782.67^{f}
	50% K	1.47^{g}	1.68^{i}	6612.58^{i}	7159.50^{i}	5.42^{d}	5.67^{f}	31663.58^{i}	32523.50^{i}

Means followed by the same letter in the same column do not differ significantly by Duncan's multiple range test at 5% level.

Table 3. Interaction effect of irrigation intervals and nano-fertilizers on early and total yield during 2017-2018 and 2018-2019 seasons.

Treatments		Early yield				Total yield			
		Heads weight ton/fed.		Number of heads /fed.		Heads weight ton/fed.		Number of heads /fed.	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation intervals X Foliar application of Nano-fertilizers									
10 days	Without	1.02^{h}	1.19^{k}	5531.56^{k}	5708.67^{k}	4.71^{de}	4.93^{gh}	27474.44^{k}	28487.22^{k}
	3000 K nano	1.87^{c}	2.13^{e}	7598.00^{e}	8161.00^{e}	6.11^{b}	6.35^{cd}	35424.44^{e}	36123.56^{e}
	50 B nano	1.28^{ef}	1.50^{h}	6191.00^{h}	6512.00^{h}	5.12^{c}	5.41^{ef}	30024.22^{h}	30957.11^{h}
	3000 K+ 50 B	2.38^{b}	2.65^{b}	8728.67^{b}	9531.44^{b}	6.89^{a}	7.07^{ab}	39663.33^{b}	40294.89^{b}
20 days	Without	1.05^{g}	1.22^{j}	5608.33^{j}	5811.22^{j}	4.75^{d}	4.98^{g}	27741.11^{j}	28754.56^{j}
	3000 K nano	1.89^{c}	2.17^{d}	7671.22^{d}	8245.44^{d}	6.15^{b}	6.41^{c}	35702.44^{d}	36392.89^{d}
	50 B nano	1.31^{e}	1.54^{g}	6261.78^{g}	6599.78^{g}	5.17^{c}	5.47^{e}	30323.78^{g}	31254.78^{g}
	3000 K+ 50 B	2.42^{a}	2.68^{a}	8805.22^{a}	9615.89^{a}	6.92^{a}	7.11^{a}	39952.00^{a}	40590.78^{a}
30 days	Without	0.99^{i}	1.15^{l}	5456.56^{l}	5622.89^{l}	4.65^{e}	4.88^{h}	27190.44^{l}	28262.67^{l}
	3000 K nano	1.84^{d}	2.10^{f}	7519.00^{f}	8074.67^{f}	6.07^{b}	6.31^{d}	35134.78^{f}	35862.89^{f}
	50 B nano	1.26^{f}	1.47^{i}	6114.56^{i}	6634.67^{i}	5.10^{c}	5.35^{cd}	29737.44^{i}	30666.56^{i}
	3000 K+ 50 B	2.35^{b}	2.61^{c}	8655.00^{c}	9440.44^{c}	6.82^{a}	7.01^{b}	39412.67^{c}	40059.89^{c}

Means followed by the same letter in the same column do not differ significantly by Duncan's multiple range test at 5% level.

Table 4. Interaction effect of K-fertilization and Nano-fertilizers on early and total yield during 2017-2018 and 2018-2019 seasons.

Treatments		Early yield				Total yield			
		Heads weight ton/fed.		Number of heads /fed.		Heads weight ton/fed.		Number of heads /fed.	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Potassium fertilization X Foliar application of Nano-fertilizers									
100% K	Without	1.09^{j}	1.29^{j}	5750.44^{j}	6000.00^{j}	4.85^{j}	5.10^{j}	28323.00^{j}	29352.78^{j}
	3000 K nano	2.03^{d}	2.29^{d}	7971.33^{d}	8615.33^{d}	6.37^{d}	6.59^{d}	36858.89^{d}	37493.11^{d}
	50 B nano	1.37^{g}	1.60^{g}	6411.00^{g}	6770.78^{g}	5.28^{g}	5.57^{g}	30870.67^{g}	31767.56^{g}
	3000 K+ 50 B	2.55^{a}	2.81^{a}	9108.67^{a}	9988.44^{a}	7.13^{a}	7.31^{a}	41085.56^{a}	41701.00^{a}
75% K	Without	1.02^{k}	1.18^{k}	5542.11^{k}	5717.22^{k}	4.72^{k}	4.93^{k}	27458.78^{k}	28489.78^{k}
	3000 K nano	1.84^{e}	2.11^{e}	7520.56^{e}	8064.33^{e}	6.05^{e}	6.31^{e}	35132.00^{e}	35854.78^{e}
	50 B nano	1.28^{h}	1.51^{h}	6187.67^{h}	6521.00^{h}	5.14^{h}	5.41^{h}	30050.67^{h}	30952.89^{h}
	3000 K+ 50 B	2.46^{ab}	2.72^{ab}	8884.00^{ab}	9711.22^{ab}	6.98^{ab}	7.17^{ab}	40244.22^{ab}	40880.44^{ab}
50% K f	Without	0.94^{l}	1.08^{l}	5303.89^{l}	5425.56^{l}	4.54^{l}	4.77^{l}	26624.22^{l}	27661.89^{l}
	3000 K nano	1.74^{f}	2.00^{f}	7296.33^{f}	7801.44^{f}	5.91^{f}	6.17^{f}	34270.78^{f}	35031.44^{f}
	50 B nano	1.19^{i}	1.40^{i}	5968.67^{i}	6454.67^{i}	4.98^{i}	5.24^{i}	29164.11^{i}	30158.00^{i}
	3000 K+ 50 B	2.15^{c}	2.41^{c}	8196.22^{c}	8888.11^{c}	6.51^{c}	6.72^{c}	37698.22^{c}	38364.11^{c}

Means followed by the same letter in the same column do not differ significantly by Duncan's multiple range test at 5% level.

Triple interaction effect among irrigation intervals, K-fertilization and foliar nano-fertilizers:

The interaction effect among irrigation interval, K-fertilization and foliar application with some nano-fertilization under study are presented in Table (5). It could be observed that; the average values of all yield parameters studied were significantly affected due to the addition of all investigated treatments. Such effect was more pronounced for the treatment of 20 days from irrigation interval with all K-fertilization and foliar with nano-fertilizers rates, whereas the average values of such traits were increased to be approximately around the same levels of irrigation after 10 days. In this connect, the highest mean values of early yield and total yield were recorded for the plants treated with the combination of 100% K or 75% from recommended dose and foliar application by 3000 ppm nano-K + 50 ppm nano-B treatment when irrigated every 20 days. The same trend was true during both seasons. Similar results were recorded by Abou El-Khair and Mohsen (2016), Anwar *et al.* (2017) and Abdel-Aziz *et al.* (2018).

2. Head characteristics and quality:

Effect of irrigation intervals:

Concerning the effect of irrigation intervals, data in Table (6) indicated that increasing irrigation intervals significantly affected in flower head quality. The irrigation every 20 days significantly increased weight of head, head diameter, total sugar concentration and inulin in receptacle followed by irrigation every 10 days. The highest mean values were recorded with treatment of 20 days while, the lowest values were recorded with treatment of irrigation every 30 days during both seasons of the experiments. 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). These results are in the same line with those reported by El-Sharkawy and El-Zohiri (2007), Kolodziej and Winiarska 2010), Zeipiņa *et al.* (2015); Salata *et al*. (2016) and Anwar *et al.* (2017)

Effect of potassium fertilization:

Data in Table (6) indicate that fertilizing glob artichoke plants with different rates of potassium had significant effect on all quality of flower head. However, fertilizing glob artichoke plants with 100 % mineral K gave the highest values of average weight of head, head diameter, total sugar concentration and inulin in receptacle. Treatments of 75% were recorded mean values around 100% K with mentioned parameters with high significant effect during both seasons. The positive effect of high rate of potassium on head quality might be attributed to the role of potassium, in addition, it has activate the enzymes involved in biosynthesis of organic acids (Evans and Sorger, 1996), as well as accelerating translocation of carbohydrate necessary for fruit formation and development, which leads to increase plant growth, head quality and yield. Similar results were recorded by Aly (2014), Saleh *et al.* (2016) and Anwar *et al.* (2017).

Table 5. Triple interaction effect among irrigation intervals, K-fertilization and foliar nano-fertilizers on early and total yield during 2017-2018 and 2018-2019 seasons.

Treatments			Early yield				Total yield			
			Heads weight ton/fed.		Number of heads /fed.		Heads weight ton/fed.		Number of heads /fed.	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd
10 days	100% K f	Without	1.09st	1.29^{tu}	5754.00^{C}	5995.67^{C}	4.84^{kl}	5.11^{klm}	28336.67^{C}	29349.33^{C}
		3000 K nano	2.03^{hi}	2.29^{gh}	7974.00^{k}	8614.00^{k}	6.33^{d}	6.57^{d}	36864.67^{k}	37474.67^{k}
		50 B nano	1.38^{mn}	1.59^{m}	6415.33^{t}	6755.67^{t}	5.26^{gh}	5.55^{gh}	30867.33^{t}	31768.67^{t}
		3000 K+ 50 B 50 B nano	2.49^{cd}	2.74^{c}	8954.67^{d}	9797.00^{d}	7.03^{ab}	7.23^{ab}	40538.00^{d}	41155.00^{d}
	75% K	Without	1.02^{uv}	1.18^{v}	5534.67^{F}	5714.33^{F}	4.74^{lm}	4.95^{no}	27446.00^{F}	28452.33^{F}
		3000 K nano	1.85^{j}	2.11^{i}	7522.67^{n}	8073.67^{n}	6.05^{e}	6.33^{e}	35145.67^{n}	35849.33^{n}
		50 B nano	1.28^{p}	1.51^{op}	6193.00^{w}	6523.67^{w}	5.15^{hi}	5.43^{hi}	30043.00^{w}	30935.33^{w}
		3000 K+ 50 B 50 B nano	2.45^{d}	2.72^{c}	8884.00^{e}	9714.67^{e}	6.96^{b}	7.14^{b}	40241.33^{e}	40853.00^{e}
	50% K	Without	0.94^{wx}	1.09^{w}	5306.00^{I}	5416.00^{I}	4.54^{no}	4.74^{p}	26640.67^{I}	27660.00^{I}
		3000 K nano	1.74^{l}	1.99^{k}	7297.33^{q}	7795.33^{q}	5.93^{ef}	6.15^{f}	34263.00^{q}	35046.67^{q}
		50 B nano	1.18^{r}	1.41^{r}	5964.67^{z}	6256.67^{z}	4.96^{jk}	5.23^{jk}	29162.33^{z}	30167.33^{z}
		3000 K+ 50 B 50 B nano	2.14^{f}	2.41^{e}	8196.33^{h}	8894.33^{h}	6.54^{c}	6.75^{c}	37675.00^{h}	38368.00^{h}
20 days	100% K	Without	1.12^{s}	1.33st	5813.00^{B}	6094.00^{B}	4.86^{kl}	5.13^{kl}	28584.33^{B}	29547.00^{B}
		3000 K nano	2.06^{gh}	2.32^{fg}	8053.67^{j}	8706.00^{j}	6.44^{cd}	6.64^{cd}	37150.00^{j}	37767.33^{j}
		50 B nano	1.40^{m}	1.64^{l}	6484.67^{s}	6863.00^{s}	5.33^{g}	5.63^{g}	31165.67^{s}	32065.00^{s}
		3000 K+ 50 B 50 B nano	2.58^{a}	2.84^{a}	9185.67^{a}	10075.33^{a}	7.17^{a}	7.35^{a}	41348.33^{a}	41976.33^{a}
	75% K	Without	1.04^{tu}	1.20^{v}	5616.67^{E}	5814.33^{E}	4.76^{lm}	4.97^{mno}	27758.00^{E}	28766.00^{E}
		3000 K nano	1.85^{j}	2.14^{i}	7594.33^{m}	8145.67^{m}	6.07^{e}	6.35^{e}	35386.00^{m}	36139.33^{m}
		50 B nano	1.31^{op}	1.54^{no}	6256.33^{v}	6612.67^{v}	5.15^{hi}	5.46^{hi}	30351.00^{v}	31252.67^{v}
		3000 K+ 50 B 50 B nano	2.55^{ab}	2.81^{ab}	9105.67^{ab}	9985.33^{ab}	7.16^{a}	7.33^{a}	41073.67^{ab}	41663.67^{ab}
	50% K	Without	0.98^{vw}	1.12^{w}	5395.33^{H}	5525.33^{H}	4.63^{mn}	4.83^{op}	26881.00^{H}	27950.67^{H}
		3000 K nano	1.76^{kl}	2.04^{j}	7365.67^{p}	7884.67^{p}	5.95^{ef}	6.24^{ef}	34571.33^{p}	35272.00^{p}
		50 B nano	1.21^{qr}	1.45^{q}	6044.33^{y}	6323.67^{y}	5.03^{ij}	5.32^{ij}	29454.67^{y}	30446.67^{y}
		3000 K+ 50 B 50 B nano	2.20^{e}	2.46^{d}	8275.33^{g}	8975.33^{g}	6.55^{c}	6.76^{c}	37969.67^{g}	38641.00^{g}
30 days	100% K	Without	1.08st	1.25^{u}	5684.33^{D}	5910.33^{D}	4.84^{kl}	5.05^{lmn}	28048.00^{D}	29162.00^{D}
		3000 K nano	2.00^{i}	2.27^{h}	7886.33^{l}	8526.00^{l}	6.32^{d}	6.55^{d}	36562.00^{l}	37237.33^{l}
		50 B nano	1.34^{no}	1.58^{mn}	6333.00^{u}	6693.67^{u}	5.24^{gh}	5.54^{gh}	30579.00^{u}	31469.00^{u}
		3000 K+ 50 B 50 B nano	2.53^{bc}	2.78^{b}	9034.67^{c}	9904.67^{c}	7.07^{ab}	7.24^{ab}	40834.67^{c}	41463.00^{c}
	75% K f	Without	0.99^{vw}	1.17^{v}	5475.00^{G}	5623.00^{G}	4.66^{mn}	4.87^{op}	27172.33^{G}	28251.00^{G}
		3000 K nano	1.80^{jk}	2.06^{j}	7444.67^{o}	7973.67^{o}	6.03^{e}	6.26^{ef}	34864.33^{o}	35575.67^{o}
		50 B nano	1.26^{pq}	1.47^{pq}	6113.67^{x}	6426.67^{x}	5.11^{hij}	5.34^{ij}	29758.00^{x}	30670.67^{x}
		3000 K+ 50 B 50 B nano	2.44^{d}	2.70^{c}	8813.33^{f}	9622.00^{f}	6.95^{b}	7.13^{b}	39953.33^{f}	40633.33^{f}
	50% K	Without	0.90^{x}	1.03^{x}	5210.33^{J}	5335.33^{j}	4.44^{o}	4.74^{p}	26351.00^{j}	27375.00^{j}
		3000 K nano	1.71^{l}	1.97^{k}	7226.00^{r}	7724.33^{r}	5.85f	6.13^{f}	33978.00^{r}	34775.67^{r}
		50 B nano	1.17^{r}	1.35^{s}	5897.00^{A}	6783.67^{A}	4.94^{jk}	5.16^{kl}	28875.33^{A}	29860.00^{A}
		3000 K+ 50 B 50 B nano	2.10^{fg}	2.35^{f}	8117.00^{i}	8794.67^{i}	6.45^{cd}	6.66^{cd}	37450.00^{i}	38083.33^{i}

Means followed by the same letter in the same column do not differ significantly by Duncan's multiple range test at 5% level.

Table 6. Individual effect of irrigation intervals, potassium fertilization and foliar application of nano-fertilizers on flower head quality during 2017-2018 and 2018-2019 seasons.

Treatments	Weight of head g		Diameter of head cm		Total sugar %		Inulin %	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation intervals								
10 days	361.28^{b}	378.89^{b}	7.35^{ab}	7.93^{a}	17.23^{b}	19.50^{b}	11.32^{ab}	13.01^{b}
20 days	365.43^{a}	383.06^{a}	7.40^{a}	7.97^{a}	17.42^{a}	19.67^{a}	11.41^{a}	13.10^{a}
30 days	357.47^{c}	374.61^{c}	7.30^{b}	7.90^{a}	17.11^{c}	19.33^{c}	11.23^{b}	12.92^{c}
Potassium fertilization								
100% K	377.38^{a}	395.58^{a}	7.53^{a}	8.10^{a}	17.86^{a}	20.23^{a}	11.64^{a}	13.34^{a}
75% K	362.29^{b}	379.75^{b}	7.38^{b}	7.94^{b}	17.30^{b}	19.55^{b}	11.34^{b}	13.04^{b}
50% K	344.52^{c}	361.23^{c}	7.14^{c}	7.76^{c}	16.59^{c}	18.72^{c}	10.98^{c}	12.65^{c}
Foliar application of Nano-fertilizers								
Without	281.29^{d}	296.82^{d}	6.37^{d}	7.15^{d}	14.10^{d}	15.86^{d}	9.66^{d}	11.36^{d}
3000 K nano	393.77^{b}	411.79^{b}	7.75^{b}	8.23^{b}	18.54^{b}	20.96^{b}	11.98^{b}	13.67^{b}
50 B nano	317.75^{c}	333.66^{c}	6.87^{c}	7.46^{c}	15.52^{c}	17.54^{c}	10.44^{c}	12.13^{c}
3000 K+ 50 B	452.76^{a}	473.15^{a}	8.41^{a}	8.88^{a}	20.85^{a}	23.65^{a}	13.19^{a}	14.88^{a}

Means followed by the same letter in the same column do not differ significantly by Duncan's multiple range test at 5% level.

Effect of nano-fertilizers:

Concerning the effect of nano foliar application, data in the same Table illustrated that nano foliar application with different rates of K and B individually or mixed together significantly affected on average weight of aforementioned traits. The same data revealed that mix of K and B (3000 ppm nano K + 50 ppm nano B) treatment significant high increase on the previous traits than those obtained for the untreated plants, followed by 3000 ppm K then 50 ppm B alone each one with high significant. These results are agree with those reported by Ali and Al-Juthery (2017), Singh *et al.* (2017) and Al-Juthery and Saadoun (2018).

Interaction effect between irrigation intervals and K-fertilization:

It is clear from the data presented in Table (7) that interaction effect between irrigation interval and K-fertilization significantly affected on head quality under investigation. Increasing irrigation interval and K fertilization rates gave a high values for average weight of head, head diameter, total sugar concentration and inulin in receptacle. The highest mean values of head quality were obtained with the treatment of irrigation every 20 days interval followed by the treatment of irrigation at 10 days interval combined with the highest rate of K-fertilization 100% followed by 75 % from recommended dose comparing all treatments during both seasons. These results are in the same line with those reported by Anwar *et al.* (2017).

Interaction effect between irrigation intervals and foliar nano-fertilizers:

Results of the previously mentioned traits in Table (8) indicated that irrigation intervals combined with nano foliar application under investigation gave high significant and best

head quality parameters of glob artichoke plants compared to the untreated plants under all irrigation intervals.

Interaction effect between K-fertilization and foliar nano-fertilizers:

Data in Table (9) showed that the interaction effect between K-fertilization and nano foliar application on quality of heads. It could be observed that; a significant stimulation effect was happened on the mean values of the previously mentioned traits due to an application of K-fertilization rates and studied nano foliar application comparing with the untreated plants. Such effect was more pronounced for the plants treated with 3000 ppm nano K + 50 ppm nano B treatment under all K-rates specially with 100% or 75%, which recorded the highest values during both seasons These results are in harmony with the findings of Qureshi *et al.* (2018) and Shafshak *et al.* (2020).

Table 7. Interaction effect of irrigation intervals and potassium fertilization on flower head quality during 2017-2018 and 2018-2019 seasons.

Treatments		Weight of head g		Diameter of head cm		Total sugar %		Inulin %	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation intervals X Potassium fertilization									
10 days	100% K	377.09^{b}	395.77^{b}	7.54^{ab}	8.10^{a}	17.79^{b}	20.22^{b}	11.65^{b}	13.34^{b}
	75% K	362.07^{e}	379.70^{e}	7.37^{d}	7.93^{b}	17.32^{d}	19.55^{e}	11.33^{e}	13.03^{e}
	50% K	344.69^{h}	361.21^{h}	7.15^{ef}	7.76^{cd}	16.58^{g}	18.72^{h}	10.99^{h}	12.65^{h}
20 days	100% K	381.40^{a}	399.69^{a}	7.59^{a}	8.13^{a}	18.06^{a}	20.41^{a}	11.73^{a}	13.42^{a}
	75% K	366.47^{d}	384.01^{d}	7.43^{bc}	7.98^{b}	17.45^{c}	19.73^{d}	11.42^{d}	13.12^{d}
	50% K	348.43^{g}	365.49^{g}	7.19^{e}	7.81^{c}	16.76^{f}	18.89^{g}	11.07^{g}	12.75^{g}
30 days	100% K	373.65^{c}	391.29^{c}	7.47^{bc}	8.06^{a}	17.75^{b}	20.08^{c}	11.55^{c}	13.26^{c}
	75% K	358.32^{f}	375.55^{f}	7.34^{d}	7.91^{b}	17.14^{e}	19.38^{f}	11.26^{f}	12.96^{f}
	50% K	340.43^{i}	357.00^{i}	7.09^{f}	7.73^{d}	16.43^{h}	18.55^{i}	10.88^{i}	12.55^{i}

Means followed by the same letter in the same column do not differ significantly by Duncan's multiple range test at 5% level.

Table 8. Interaction effect of irrigation intervals and nano-fertilizers on flower head quality during 2017-2018 and 2018-2019 seasons.

Treatments		Weight of head g		Diameter of head cm		Total sugar %		Inulin %	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation intervals X Foliar application of Nano-fertilizers									
10 days	Without	281.21^{k}	296.97^{k}	6.37^{ef}	7.14^{e}	14.10	15.88^{k}	9.66^{i}	11.35^{j}
	3000 K nano	393.84^{e}	411.63^{e}	7.76^{b}	8.24^{c}	18.54	20.94^{e}	11.97^{e}	13.66^{e}
	50 B nano	317.67^{h}	333.83^{h}	6.87^{cd}	7.45^{d}	15.51	17.52^{h}	10.45^{f}	12.12^{g}
	3000 K+ 50 B	452.42^{b}	473.14^{b}	8.41^{a}	8.88^{ab}	20.76	23.65^{b}	13.19^{b}	14.89^{b}
20 days	Without	285.50^{j}	300.85^{i}	6.43^{e}	7.19^{e}	14.27	16.01^{j}	9.77^{h}	11.47^{i}
	3000 K nano	397.67^{d}	416.24^{d}	7.78^{b}	8.27^{c}	18.70	21.13^{d}	12.05^{d}	13.73^{d}
	50 B nano	321.88^{g}	337.76^{g}	6.92^{c}	7.50^{d}	15.67	17.73^{g}	10.51^{f}	12.22^{f}
	3000 K+ 50 B	456.68^{a}	477.40^{a}	8.47^{a}	8.92^{a}	21.04	23.83^{a}	13.28^{a}	14.97^{a}
30 days	Without	277.17^{l}	292.64^{l}	6.31^{f}	7.13^{e}	13.94	15.68^{l}	9.55^{j}	11.26^{k}
	3000 K nano	389.80^{f}	407.49^{f}	7.71^{b}	8.19^{c}	18.38	20.82^{f}	11.91^{e}	13.61^{e}
	50 B nano	313.69^{i}	329.40^{i}	6.82^{d}	7.43^{d}	15.37	17.37^{i}	10.35^{g}	12.04^{h}
	3000 K+ 50 B	449.19^{c}	468.92^{c}	8.37^{a}	8.84^{b}	20.74	23.47^{c}	13.11^{c}	14.79^{c}

Means followed by the same letter in the same column do not differ significantly by Duncan's multiple range test at 5% leve

Table 9. Interaction effect of K-fertilization and nano-fertilizers on flower head quality during 2017-2018 and 2018-2019 seasons.

Treatments		Weight of head g		Diameter of head cm		Total sugar %		Inulin %	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Potassium fertilization X Foliar application of Nano-fertilizers									
100% K	Without	293.42^{j}	309.27^{j}	6.54^{j}	7.24^{i}	14.58^{j}	16.41^{j}	9.93^{j}	11.64^{j}
	3000 K nano	413.48^{d}	432.32^{d}	7.91^{d}	8.45^{d}	19.33^{d}	21.87^{d}	12.36^{d}	14.05^{d}
	50 B nano	329.97^{g}	346.87^{g}	7.01^{g}	7.57^{g}	15.98^{g}	18.08^{g}	10.70^{g}	12.37^{g}
	3000 K+ 50 B	472.65^{a}	493.87^{a}	8.68^{a}	9.12^{a}	21.56^{a}	24.57^{a}	13.58^{a}	15.29^{a}
75% K	Without	281.33^{k}	296.59^{k}	6.37^{k}	7.18^{i}	14.11k	15.86^{k}	9.67^{k}	11.40^{k}
	3000 K nano	389.64^{e}	407.53^{e}	7.75^{e}	8.18^{e}	18.38^{e}	20.79^{e}	11.88^{e}	13.60^{e}
	50 B nano	317.59^{h}	333.43^{h}	6.88^{h}	7.44^{h}	15.51^{h}	17.54^{h}	10.44^{h}	12.11^{h}
	3000 K+ 50 B	460.59^{ab}	481.45^{ab}	8.51^{ab}	8.95^{ab}	21.21^{ab}	24.02^{ab}	13.35^{ab}	15.04^{ab}
50% K	Without	269.13^{l}	284.59^{l}	6.20^{l}	7.04^{j}	13.62^{l}	15.30^{l}	9.38^{l}	11.05^{l}
	3000 K nano	378.19^{f}	395.50^{f}	7.60^{f}	8.07^{f}	17.91^{f}	20.23^{f}	11.69^{f}	13.35^{f}
	50 B nano	305.69^{i}	320.70^{i}	6.71^{i}	7.36^{h}	15.05^{i}	16.98^{i}	10.18^{i}	11.89^{i}
	3000 K+ 50 B	425.05^{c}	444.13^{c}	8.06^{c}	8.58^{c}	19.77^{c}	22.36^{c}	12.65^{c}	14.32^{c}

Means followed by the same letter in the same column do not differ significantly by Duncan's multiple range test at 5% level.

Triple interaction effect among irrigation intervals, K-fertilization and foliar nano-fertilizers:

The combination among irrigation intervals, K-fertilization and nano foliar application under investigation are presented in Table (10). Data clearly showed that; irrigation intervals combination with K-fertilization and nano foliar application has been recorded a significant stimulation effect on the average values of all the aforementioned traits. In addition, the highest mean values were recorded with shorted irrigation intervals and 100% or 75% K and nano foliar application by mix of K and B treatment. So, in this regard the highest mean values of all previous traits were recorded with 100 % K from recommended dose + 3000 ppm nano K+ 50 ppm nano B under irrigation every 20 days during both seasons of the experiments.

Table 10. Triple interaction effect among irrigation intervals, K-fertilization and nano-fertilizers on flower head quality during 2017-2018 and 2018-2019 seasons.

Treatments			Weight of head g		Diameter of head cm		Total sugar %		Inulin %	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd
10 days	100% K	Without	293.47^{C}	309.64^{y}	6.55^{pq}	7.22^{kl}	14.55^{xy}	16.43^{x}	9.92^{vw}	11.64^{uv}
		3000 K nano	413.27^{k}	432.43^{j}	7.92^{efg}	8.48^{e}	19.32^{hi}	21.84^{i}	12.35^{ij}	14.04^{hi}
		50 B nano	329.33^{t}	347.52^{q}	7.02^{kl}	7.55^{hi}	15.96^{p}	18.05^{p}	10.74^{o}	12.36^{no}
		3000 K+ 50 B	464.57^{d}	485.48^{d}	8.55^{bc}	8.97^{bc}	21.35^{bc}	24.19^{c}	13.44^{cd}	15.11^{cd}
	75% K	Without	280.59^{F}	296.67^{B}	6.34^{rs}	7.16^{lm}	14.12^{AB}	15.87^{A}	9.67^{yz}	11.39^{xy}
		3000 K nano	389.65^{n}	407.27^{m}	7.74^{hi}	8.17^{fg}	18.37^{jk}	20.77^{k}	11.85^{kl}	13.59^{jk}
		50 B nano	317.55^{w}	333.52^{t}	6.85^{lmn}	7.43^{ij}	15.53^{rs}	17.53^{r}	10.44^{qr}	12.09^{q}
		3000 K+ 50 B	460.51^{e}	481.32^{e}	8.53^{bc}	8.97^{bc}	21.23^{cd}	24.04^{d}	13.36^{de}	15.04^{de}
	50% K	Without	269.55^{I}	284.59^{E}	6.22st	7.04^{m}	13.62^{D}	15.34^{C}	9.41^{B}	11.03^{A}
		3000 K nano	378.59^{q}	395.18^{o}	7.63^{ij}	8.08^{g}	17.93^{mn}	20.22^{m}	11.71^{mn}	13.36^{lm}
		50 B nano	306.14^{z}	320.46^{w}	6.72^{nop}	7.35^{jk}	15.04^{uv}	16.97^{u}	10.18^{t}	11.91^{s}
		3000 K+ 50 B	424.47^{h}	444.60^{h}	8.03^{de}	8.55^{de}	19.74^{f}	22.36^{g}	12.65^{fg}	14.32^{fg}
20 days	100% K	Without	297.46^{B}	313.36^{x}	6.61^{opq}	7.26^{kl}	14.75^{wx}	16.57^{w}	10.04^{uv}	11.71^{tu}
		3000 K nano	417.50^{j}	436.49^{i}	7.96^{def}	8.46^{e}	19.50^{gh}	22.03^{h}	12.46^{hi}	14.12^{h}
		50 B nano	334.24^{s}	350.62^{q}	7.06^{k}	7.64^{h}	16.16^{o}	18.28^{o}	10.75^{o}	12.46^{n}
		3000 K+ 50 B	476.41^{a}	498.29^{a}	8.74^{no}	9.16^{a}	21.84^{a}	24.75^{a}	13.66^{a}	15.40^{a}
	75% K	Without	285.69^{E}	300.62^{A}	6.43^{qr}	7.24^{kl}	14.25^{zA}	16.03^{z}	9.75^{xy}	11.48^{wx}
		3000 K nano	393.75^{m}	411.52^{l}	7.76^{no}	8.25^{f}	18.54^{j}	20.96^{j}	11.96^{k}	13.66^{j}
		50 B nano	321.85^{v}	338.41^{s}	6.95^{klm}	7.45^{ij}	15.65^{qr}	17.73^{q}	10.54^{pq}	12.21^{p}
		3000 K+ 50 B	472.27^{ab}	493.49^{ab}	8.66^{ab}	9.13^{a}	21.32^{b}	24.55^{ab}	13.57^{ab}	15.30^{ab}
	50% K	Without	273.34^{H}	288.57^{D}	6.25st	7.06^{m}	13.83^{C}	15.44^{C}	9.53^{AB}	11.21^{z}
		3000 K nano	381.77^{p}	400.70^{n}	7.63^{ij}	8.10^{g}	18.06^{lm}	20.40^{l}	11.74^{lmn}	13.40^{l}
		50 B nano	309.56^{y}	324.24^{v}	6.75^{no}	7.42^{ij}	15.21^{tu}	17.16^{t}	10.25st	11.98^{rs}
		3000 K+ 50 B	429.06^{g}	448.44^{g}	8.11^{d}	8.64^{d}	19.94^{e}	22.54^{f}	12.75^{f}	14.40^{f}
30 days	100% K	Without	289.34^{D}	304.82^{z}	6.45^{qr}	7.24^{kl}	14.45^{yz}	16.24^{y}	9.84^{wx}	11.56^{vw}
		3000 K nano	409.66^{l}	428.05^{k}	7.85^{fgh}	8.42^{ij}	19.18^{i}	21.73^{i}	12.26^{j}	14.00^{i}
		50 B nano	326.34^{u}	342.46^{r}	6.96^{klm}	7.53^{hi}	15.84^{pq}	17.92^{p}	10.60^{p}	12.29^{op}
		3000 K+ 50 B	469.28^{c}	489.84^{c}	8.63^{ab}	9.06^{ab}	21.52^{b}	24.42^{b}	13.49^{bc}	15.18^{c}
	75% K	Without	277.69^{G}	292.49^{C}	6.33^{rs}	7.14^{lm}	13.9^{BC}	15.67^{B}	9.60^{zA}	11.32^{y}
		3000 K nano	385.52^{o}	403.80^{n}	7.74^{hi}	8.13^{fg}	18.22^{kl}	20.65^{k}	11.83^{klm}	13.54^{k}
		50 B nano	313.36^{x}	328.36^{u}	6.84^{mn}	7.44^{ij}	15.34st	17.36^{s}	10.33^{rs}	12.03^{qr}
		3000 K+ 50 B	456.69^{f}	477.55^{f}	8.44^{c}	8.91^{c}	21.05^{d}	23.83^{e}	13.27^{e}	14.96^{e}
	50% K	Without	264.49^{J}	280.61^{F}	6.13^{t}	7.02^{m}	13.42^{E}	15.13^{D}	9.22^{C}	10.90^{B}
		3000 K nano	374.22^{r}	390.63^{p}	7.55^{j}	8.03^{g}	17.74^{n}	20.07^{n}	11.63^{n}	13.29^{m}
		50 B nano	301.38^{A}	317.39^{w}	6.65^{op}	7.32^{jk}	14.92^{vw}	16.82^{v}	10.12^{tu}	11.80^{t}
		3000 K+ 50 B	421.61^{i}	439.35^{i}	8.04^{de}	8.53^{de}	19.64^{fg}	22.16^{h}	12.56^{gh}	14.23^{g}
LSD at 5%			2.83	3.40	0.18	0.15	0.20	0.14	0.13	0.10

Means followed by the same letter in the same column do not differ significantly by Duncan's multiple range test at 5% level.

CONCLUSION

Finally, it could be concluded that, potassium fertilization at 100% (200 kg potassium sulfate/fed.) or 75% (150 kg of potassium sulfate/fed.) with foliar application by a mixture of 3000 ppm nano -K+ 50 ppm nano-B treatment and irrigation every 20 days is recommended for globe artichoke to obtain the best yield parameters and the highest quality under the conditions similar to this study.

REFERENCES

Abdel- Wahab, M. M.; A. B. El-attar and A. A. Mahmoud (2017). Economic evaluation of nano and organic fertilizers as an alternative source to chemical fertilizers on *Carum carvi* L. plant yield and components. Agriculture (Pol'nohospodárstvo), 63(1): 33−49.

Abdel-Aziz, H. M. M.; N. A. H. Mohammed and M. O. Aya (2018). Effect of foliar application of nano chitosan NPK fertilizer on the chemical composition of wheat grains. Egypt. J. Bot., 58(1): 87-95.

Abou El-Khair, E. E. and A. A. M. Mohsen (2016). Effect of natural sources of potassium on growth, mineral uptake and productivity of Jerusalem artichoke grown in new reclaimed soil conditions. Middle East J. Agric. Res., 5(3): 367-377.

Al-Fahdawi, A. J. J. and M. M. Allawi (2019). Impact of biofertilizers and nano potassium on growth and yield of eggplant (*Solanum melongena* l.). Plant Archives; 19: 1809-1815.

Ali, N. S. and H. W. A. Al-Juthery (2017). The application of nanotechnology for micronutrient in agricultural production (review article). The Iraq J. Agric. Sci., 9(48): 489-441. (32)

Al-Juthery, H. W. A. and S. F. Saadoun (2018). Impact of foliar application of some micronutrients nano fertilizer on growth and yield of Jerusalem artichoke. Iraqi J. of Agric. Sci., 1028:49(4):755- 787.

Aly, R. G. I. (2014). Effect of planting date and nitrogen and potassium fertilization on some globe artichoke cultivars. M.Sc. Thesis. Zagazig University, Egypt.

Anwar, R. S. M.; E. M. M. Awad and I. A. S. Al-Easily (2011). Effect of different rates of nitrogen and potassium fertilization on growth, yield and quality of Jerusalem artichoke plants under sandy soil conditions. J. Plant Production, Mansoura Univ., 2 (8): 983-993.

Anwar, R. S. M.; M. A. Mahmoud and N. H. Hussien (2017). Effect of irrigation and potassium fertilizer on vegetative growth, yield and quality of globe artichoke plants under sandy soil conditions. J. Plant Production, Mansoura Univ., 8(11): 1275 – 1284.

Duncan, D. B., 1955. "Multiple Range and Multiple F. test. Biometrics, 11: 1-42.

El-Sharkawy, Z. A. and S. S. M. El-Zohiri (2007). Effect of irrigation intervals and potassium fertilization on Jerusalem artichoke. Annals of Agric. Sc., Moshtohor, 45(4): 1635-1649. (12)

El-Zohiri, S. S. M. and M. E. A. Youssef (2015). Response of Jerusalem artichoke to cut off irrigation before harvest and fertilization with Ca, Mg and B. J. Product. & Dev., 20(1): 61-81.

Evans, H. J. and G. J. Sorger (1996). Role of mineral elements with emphasis on the univalent cations. Ann. Rev. Plant Physio., 17, 47-76. http://dx.doi.org/10.1146/annurev.pp. 17.060166.000403.

Fallahi, H.; R. T. Kalantari; M. Aghhavani-Shajari and M. Soltanzadeh (2015). Effect of super absorbent polymer and irrigation deficit on water use efficiency, growth and yield of cotton. Not. Sci. Biol., 7 (3): 338-344.

FAO Statistical Database (FAOSTAT) (2019). http://www.faostat.org.

Gomez, K. A. and A. A. Gomez (1984). "Statistical Procedures for Agricultural Research". John Wiley and Sons, Inc., New York.pp:680.

Hernández-Pérez, V.; M. J. Rodríguez Carrión; A. J. López-Pérez and J. A. Martínez (2013). Effect of polyacrylamines for water saving on three artichoke cultivars. Acta Horti., 983: 289–294.

Hill, W. E. and L.G. Morrill (1975). Boron, calcium and potassium interactions in Spanish peanuts. Soil Sci. Soc. Am. Proc., 39: 80-83.

Himanshu, S. K.; A. K. Singh; S. Kumar and P. Kalura (2013). Response of broccoli to irrigation scheduling and methods under drip, sprinkler and surface irrigation. Inter. J. Eng. Adv. Tech. (IJEAT), 2(4): 777-782.

Kasim, A. T. M.; A. M. Abd-El-Abd and H. M. E. Nadia (2007). A comparison study on the effect of some treatments on earliness, yield and quality of globe artichoke (*Cynara scolymus* L.). Research J. of Agric. and Biological Sci., 3(6):695-700.

Kołodziej, B. and S. Winiarska (2010). The effect of irrigation and fertigation in artichoke (*Cynara cardunculus* L. ssp. flavescens Wikl.) culture. Kerva Polonica, 56 (3): 7-14.

Kruger, E.; G. Schmidt and U. Brucker (1999). Scheduling strawberry irrigation based upon tensiometer measurement and a climatic water balance model. J. Horti. Sci., 81: 409-424.

Marschner, H. (2013). Mineral Nutrition of Higher Plants. 3th Ed. Academic Press, Harcourt Brace and Company, Publishers. London, New York, Tokyo, pp 864.

Morales-Díaz, A. B.; O. O. Hortensia; J. M. Antonio; C. P. Gregorio; G. M. Susana and B. M. Adalberto (2017). Application of nano elements in plant nutrition and its impact in ecosystems. Adv. Nat. Sci.: Nan Osci. Nanotechnol., 8 (013001): 13.

Moursi, E. A.; M. M. Kassab; M. K. M. El-Samanody and M. A. M. Ibrahim (2010). Determining the optimum irrigation intervals and plant densities for sunflower under drip irrigation system. J. Soil Sci. and Agric. Engineering, Mansoura Univ., 1 (5): 487-500.

Mousavi, S. R. and M. Rezaei (2011). Nanotechnology in agriculture and food production. J. Appl. Environ. Biol. Sci., 1(10): 414–419.

Qureshi, A.; D K. Singh and S. Dwivedi (2018). Nano fertilizers: a novel way for enhancing nutrient use efficiency and crop productivity. Int. J. Curr. Microbiol. App. Sci., 7(2): 3325- 3335.

Rameshaiah, G. N. and S. Jpallavi (2015). Nano fertilizers and nano sensors – an attempt for developing smart agriculture. Intl. J. of Eng. Res. and General Sci., 3(1) : 314–320.

Sadasivam, S. and A. Manickam (1996). Biochemical Methods, 2nd Ed. New age inter. India.

Sałata, A.; R. Nurzyńska-Wierdak; R. Stepaniuk and G. Zawiślak (2016). Response of artichoke (*Cynara scolymus* l.) plants to irrigation and harvest date. Acta Sci. Pol. Hortorum Cultus, 15(6): 245-263.

Saleh, S. A.; M. F. Zaki; A. S. Tantawy and Y. A. M. Salama (2016). Response of artichoke productivity to different proportions of nitrogen and potassium fertilizers. Int. J. Chem. Tech. Res., 9 (3): 25-33.

Saleh, S. A. and Z. F. Fawzy (2012). Effect of water amounts on artichoke productivity irrigated with brackish water. Aust. J. Basic Appl. Sci., 6:54–61.

Shafshak, N. S., L. A. Badr; M. H. M. Mohamed and A. S.M. Abd ELAziz (2020). Effect of mineral and bio potassium fertilizer and foliar spray with different sources of boron on productivity and quality of strawberry for exportation. Annals of Agric. Sci., Moshtohor, 58(2): 295 – 304.

Shorrocks, V. M. (1990). Behavior, function and significance of boron in agriculture. Report on an International Workshop at St. John's College, Oxford, England. 23-25 July. Published by Borax Consolidated Limited, London. SW 1P 1H T.

Singh, M. D.; C. Gautam; O. P. Patidar; H. M Meena and G. Prakashaand Vishwajith (2017). Nano-Fertilizers is a new way to increase nutrients use efficiency in crop production. Intl J. Agric. review article. Intl J. Agric. Sci., 9(7): 3831-3833.

Srilatha B. (2011). Nanotechnology in agriculture. J. Nanomed. Nanotechnol. 2: 5-7.

Winton, A. L. and K. B. Winton (1958). The analysis of foods. John Wiley and Sons. Inc .London. 857.

Woodruff, J. R.; F. W. Moore and H. L. Musen (1987). Potassium, boron, nitrogen and lime effects on corn yield and early leaf nutrient concentrations. Agron. J., 79:520-524.

Yilmaz, A. and Y. Ahø (2016). Determination of the yield response to water for two different globe artichoke cultivars (*Cynara scolymus* L. cv. Bayrampaúa and Starline F1) in greenhouse conditions. Horticulture and Landscape Architecture; 37: 11–21.

Zeipiņa, S.; I. Alsiņa and L. Lepse (2015). Influence of agro-ecological factors on artichoke yield and quality: Review Research Rural Dev., 1: 77–81.

تأثير فترات الرى والرش الورقى ببعض أسمدة النانو على النمو والإنتاجية في الخرشوف: ب: المحصول والجوده.

السيد أحمد طرطوره[1]، أسامه محمد سيف الدين[2]و أيمن يوسف العدوي[2]*

[1] قسم الخضر والزينة – كليه الزراعة – جامعه المنصورة - مصر

[2] معهد بحوث البساتين – مركز البحوث الزراعية – الجيزة- مصر

لتحقيق الهدف من هذه الدراسة، تم إجراء تجربتين حقليتين في المزرعة البحثية بالبرامون – محافظة الدقهلية خلال الموسمين الشتويين 2018/2017 و2019/2018 لدراسة تأثير كل من فترات الرى ومعدلات البوتاسيوم والرش الورقى ببعض أسمده النانو مثل البوتاسيوم والبورون على جودة وانتاجية نبات الخرشوف الفرنساوى (هيريوس). اشتملت التجربة على 36 معامله وزعت في ثلاث مكررات خلال تصميم الشرائح المتعامدة في قطع منشقه تتمثل في التفاعلات الممكنة بين 3 فترات الرى كمعاملات في الشرائح الرأسية (10، 20 و 30 يوم)، 3 معدلات من التسميد البوتاسي كمعاملات فى الشرائح الأفقية (50، 75 و 100% من الموصى به) و 4 معدلات من الرش بأسمدة النانو كمعاملات شقية (بدون رش، 3000 جزء في المليون نانو بوتاسيوم، 50 جزء في المليون نانو بورون , خليط من (3000 جزء في المليون نانو بوتاسيوم مع 50 جزء في المليون نانو بورون). وأشارت النتائج إلى أن تسميد نباتات الخرشوف بالبوتاسيوم بمعدل 100٪ (200 كجم/فدان كبريتات البوتاسيوم) او 75٪ (150 كجم/فدان كبريتات البوتاسيوم) مع الرش الورقى بخليط من 3000 جزء في المليون من بوتاسيوم نانو + 50 جزء في المليون بورون نانو والري كل 20 يوما للحصول على أفضل محصول مبكر ومحصول كلى وأعلى جودة. ولذلك ننصح بهذه المعاملة لأنها توفر في كمية البوتاسيوم وكمية مياه الرى وبالتالي تقلل من تكاليف إنتاج الخرشوف وتلوث البيئة في ظل ظروف هذه الدراسة.