J. of Plant Production, Mansoura Univ., Vol. 12 (3):209-216, 2021

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: A-Vegetative Growth and Chemical Content in Leaves

Cross Mark

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 at Baramoon Research Station, Mansoura, Dakahlia Governorate, Egypt, during the two seasons of 2017-2018 and 2018-2019, to investigate the effect of irrigation intervals and foliar application with nano potassium and boron fertilizers under mineral potassium fertilization on plant vegetative growth parameters and mineral content in leaves of globe artichoke, French Hyrious variety. The experiment included 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 K + 50 ppm B) as split plot. The design of the experiment was a strip-split plot with three replicates. The results revealed 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 vegetative growth parameters and the highest nutrient contents.

***Keywords**:* Globe artichoke, irrigation intervals, K-fertilization, nano-fertilizers, nano-K, nano-B and foliar application.

INTRODUCTION

Globe artichoke (*Cynara scolymus* L.) is belong to *Asteraceae* (*Compositae*) family. 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.

In Egypt, the total cultivated area of artichoke reached 16546 ha and the total production exceeded 2968899 ton ha$^{-1.}$ (FAO, 2019). 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.

Water shortage is one of the challenges facing Egypt, the total agriculture land in Egypt is almost entirely dependent on irrigation. This should motivate us to find ways for saving water and use marginal waters, without significant reduction in yield to satisfy the increased rates of population growth requirements. 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). Therefore, predicting the water content in the root zone can be use to helping the farmer decide when, and how much to irrigate. 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). This strategy of deficit irrigation is a successful way of increasing water productivity in different crops without causing a severe decline in growth and yield of the plant.

Potassium (K) is an important nutrient for plant meristematic growth and physiological functions, including regulation of water and gas exchange in plants, protein synthesis, translocation in plants and growth substances, energy transfer, phloem transport, cation - anion balance and enabling their ability to resist pests and diseases (Wang *et al.*, 2013). K is the key for quantity and quality of the product due to its role in stimulating root growth and improving the size of fruits. The formations of carbohydrates and sugars translocation in plant depend on potassium (Imas and Bansal, 19990). The application mode of K (dose, proportion and time) is very important for the adequate nutrients uptake and optimum plant growth resulting maximum yield with good quality. Whereas, potassium enhances the earliness and improves product quality and head characters (Saleh *et al.*, 2016).

Recently, Nano-materials (NMs) can equip one or more nutrients to improve growth and production of plants with better performance and lower amounts of traditional fertilizers and slow nutrient release (Jyothi and Hebsur, 2017). Some studies have demonstrated the importance of active nano-fertilizers in terms of increased nutrient efficiency, higher yield, better quality, and safer environment (Singh *et al.*, 2017).

Boron (B) is essential micronutrients, it is important for metabolism and growth of higher plants through its effect on cell elongation and cell division, protein metabolism, tissue differentiation and membrane permeability

[*] **Corresponding author.**
E-mail address:aymaneladawygo@gmail.com
DOI: 10.21608/jpp.2021.154341

(Marschner, 2013). The affected curds have deformities in shape, size, bitter in taste and less productive which adversely affects the market value. It was seen that boron increased growth and yield of the crops as it helps in cell wall development, cell division, cell extension and pollen tube growth (Tandon, 1991).

The main objective of this study is to define the optimum schedule irrigation and water requirements and evaluate the effects of foliar application with some nano-fertilizers (Nano K and Nano B) on vegetative growth parameters, nutrition values of globe artichoke under mineral potassium fertilization.

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 vegetative growth parameters and leaf mineral content 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:

After 135 days from planting, samples of globe artichoke were taken randomly from each experimental plot to measure the following parameters:

1-Vegetative growth parameters:

Number of leaves/plant,

Number of branches/plant,

Dry weight of /leaves,

Leaf area /plant: It was calculated according to Koller (1972).

2-Mineral content in leaves:

The sample of artichoke leaves were taken and dried then thoroughly ground and stored for determination of chemical constituents in the leaves. N was determined as described by Jones *et al.* (1991), P and K % were determined according to Peters *et al.* (2003).

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. Vegetative growth parameters:

Effect of irrigation intervals:

Data presented in Table (1) showed the individual effect of irrigation intervals (10, 20 and 30 days) on plant growth parameters as (number of leaves/plant, number of branches/plant, dry weight and leaf area) during two seasons. There were a significant differences in all vegetative growth parameters in both seasons except no. of leaves. In this respect, irrigation interval of 20 days recorded the highest values for all measured growth parameters, followed by irrigation every 10 days during both seasons. Such increment in plant morphological parameters due to the reduction of irrigation interval may be due to the main role of irrigation water in increasing the availability and diffusion as well as the uptake of macro and micro- nutrients by plant which affect greatly on plant growth. Such response might be attributed to lake of water absorbed, inhibition of meristemic activity and reduction in photosynthetic efficiency under the prolonged irrigation interval. Similar results were recorded by El-Sharkawy and El-Zohiri (2007); Zeipiņa *et al.* (2015) and Anwar *et al.* (2017).

Effect of potassium fertilization:

Data in Table (1) showed the effect of potassium fertilization rate on above mentioned vegetative growth parameters. The differences were significant in both seasons. In this regard, an increase was found in all vegetative growth parameters with increasing rates of potassium from 50 % up to 100% of recommended dose. Treatment of 100% K from recommended dose recorded the highest significant values of all vegetative growth parameters in both seasons. K plays an important role in many metabolic processes such as photosynthesis, use of water and synthesis of amino acids and protein as well as translocation of sugars and assimilates within the plant and the accumulation of high molecular carbohydrates which necessary for head formation and development which leads to increase of plant growth (Yildirim *et al.* 2009). 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-hormones, regulation of cellular pH, enhancing N uptake, and acting as an activator to enzymatic systems (Marschner, 2013). These results are in harmony with the findings of El-Sharkawy and El-Zohiri (2007), Kasim *et al.* (2007) and Anwar *et al.* (2017) on globe artichoke

Table 1. Individual effect of irrigation intervals, potassium fertilization and foliar application of nano-fertilizers on vegetative growth parameters during 2017-2018 and 2018-2019 seasons.

Treatments	No. of leaves/plant		No. of branches/plant		Dry weight /plant g		Leaf area /plant cm^2	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation intervals								
10 days	18.08^{a}	20.00^{a}	6.75^{b}	7.56^{b}	143.56^{b}	152.50^{b}	461.98^{b}	482.31^{b}
20 days	18.67^{a}	20.39^{a}	7.08^{a}	8.31^{a}	144.79^{a}	154.09^{a}	465.08^{a}	485.05^{a}
30 days	17.72^{a}	19.67^{a}	6.36^{c}	7.42^{b}	142.18^{c}	150.70^{c}	460.29^{c}	479.99^{c}
Potassium fertilization								
100% K	19.25^{a}	21.47^{a}	7.06^{a}	8.08^{a}	148.00^{a}	159.63^{a}	471.23^{a}	492.55^{a}
75% K	18.42^{a}	20.08^{a}	6.83^{a}	7.78^{ab}	143.74^{b}	152.62^{b}	463.75^{b}	483.47^{b}
50% K	16.81^{b}	18.50^{b}	6.31^{b}	7.42^{b}	138.80^{c}	145.04^{c}	452.38^{c}	471.34^{c}
Foliar application of Nano-fertilizers								
Without	11.74^{d}	13.78^{d}	4.37^{d}	5.44^{d}	121.34^{d}	116.10^{d}	414.85^{d}	431.26^{d}
3000 K nano	21.63^{b}	22.33^{b}	7.33^{b}	8.37^{b}	152.61^{b}	167.19^{b}	482.04^{b}	502.39^{b}
50 B nano	15.00^{c}	16.74^{c}	6.33^{c}	7.37^{c}	131.30^{c}	132.41^{c}	435.41^{c}	454.44^{c}
3000 K+ 50 B nano	24.26^{a}	27.22^{a}	8.89^{a}	9.85^{a}	168.79^{a}	194.01^{a}	517.51^{a}	541.72^{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:

Data in Table (1) stated that the significant effect of foliar application of treatments with different concentration by K and B in nano-fertilization forms on all parameters of vegetative growth parameters. The highest mean values of mentioned parameters were achieved in 3000 ppm K + 50 ppm B treatment followed by 3000 ppm K then 50 ppm B comparing with the control treatment (without) in both seasons. Al-Juthery and Saadoun (2018) indicated that nano-micronutrient applied on artichoke plants achieved significantly higher vegetative growth. These results are in agreement with those obtained by Nassef and Nabeel (2012), Al-Fahdawi and Allawi (2019) and Shafshak *et al.* (2020).

Interaction effect between irrigation intervals and K-fertilization:

Data illustrated in Table (2) showed the effect of irrigation intervals (10, 20 and 30 days) and K-fertilization rates (50, 75 and 100% from recommended dose). All treatments significantly affected previous traits. It could be observed that globe artichoke supplied with 100 % potassium fertilization gave the highest values under all intervals days under (10 and 20 days) followed by 75 % but with 20 days irrigation interval gave the highest significant values of number of leaves/plant, number of branches/plant, dry weight and leaf area in both seasons. The reduction in vegetative growth caused by increasing the irrigation intervals is mainly due to limiting the plant ability to absorb nutrients needed for optimal growth and development of plant. Also, it is well recognized that water is not only required for different biochemical activities of all cells, but also awakes generated turgor pressure a driving force of cell (Xiong and Zhu, 2002). Therefore, water deficit disturbs normal cellular activities and restricts plant growth. Whereas using potassium application on artichoke encourage this mainly due to its vital role in regulating of many physiological processes (potassium regulates the opening and closing of stomata, and therefore regulates CO_2 uptake). The obtained results are in accordance with those of Leskovar and Xu (2013) and Anwar *et al.* (2017).

Table 2. Interaction effect of irrigation intervals and potassium fertilization on vegetative growth parameters during 2017-2018 and 2018-2019 seasons.

Treatments		No. of leaves /plant		No. of branches /plant		Dry weight /plant g		Leaf area /plant cm^2	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation intervals X Potassium fertilization									
10 days	100% K	19.25^{ab}	21.50^{ab}	7.08^{abc}	8.00^{abc}	148.08^{b}	159.81^{b}	469.54^{b}	492.48^{b}
	75% K	18.17^{a-d}	20.00^{a-d}	6.83^{a-d}	7.33^{de}	143.72^{e}	152.45^{e}	463.93^{d}	483.25^{e}
	50% K	16.83^{cd}	18.50^{d}	6.33^{de}	7.33^{de}	138.89^{h}	145.23^{h}	452.47^{g}	471.20^{h}
20 days	100% K	19.58^{a}	21.75^{a}	7.42^{a}	8.58^{a}	149.50^{a}	161.30^{a}	474.44^{a}	495.15^{a}
	75% K	19.25^{ab}	20.58^{abc}	7.17^{ab}	8.42^{ab}	144.78^{d}	154.49^{d}	465.86^{c}	485.67^{d}
	50% K	17.17^{bcd}	18.83^{cd}	6.67^{bcd}	7.92^{bcd}	140.08^{g}	146.48^{g}	454.96^{f}	474.35^{g}
30 days	100% K	18.92^{abc}	21.17^{ab}	6.67^{bcd}	7.67^{cd}	146.41^{c}	157.78^{c}	469.71^{b}	490.03^{c}
	75% K	17.83^{a-d}	19.67^{bcd}	6.50^{cde}	7.58^{cde}	142.72^{f}	150.91^{f}	461.46^{e}	481.48^{f}
	50% K	16.42^{d}	18.17^{d}	5.92^{e}	7.00^{e}	137.42^{i}	143.41^{i}	449.71^{h}	468.47^{i}

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 foliar nano-fertilizers:

As for the effect of interaction between irrigation intervals and foliar application by nano-fertilizers on vegetative growth parameters were revealed in Table (3). All treatments significantly affected vegetative growth parameters. Data showed that foliar with 3000 ppm K+ 50 ppm B under 10 or 20 days intervals recorded the highest values from number of leaves, number of branches/plant, dry weight and leaf area in both seasons. Nano-fertilizers have been used to improve plant growth due their ability to move across seed teguments where they can increase water and oxygen uptake, as well as develop resistance against different stresses that affect early plant growth (Ismail *et al.*, 2017). Therefore, foliar-applied nanoparticles only have the phloem system option for uptake and translocation from leaves to roots to compensate the loss of water by long irrigation intervals.

Table 3. Interaction effect of irrigation intervals and nano-fertilizers on vegetative growth parameters during 2017-2018 and 2018-2019 seasons.

Treatments		No. of leaves /plant		No. of branches /plant		Dry weight /plant g		Leaf area /plant cm^2	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Irrigation intervals X Foliar application of Nano-fertilizers									
10 days	Without	11.67^{e}	13.78^{d}	4.33^{h}	5.33^{ef}	121.52^{k}	116.10^{k}	414.80^{j}	431.25^{k}
	3000 K nano	21.44^{b}	22.22^{b}	7.33^{de}	8.11^{c}	152.74^{e}	167.43^{e}	482.50^{e}	502.30^{e}
	50 B nano	15.00^{c}	16.78^{c}	6.33^{fg}	7.00^{d}	131.18^{h}	132.43^{h}	433.17^{h}	454.17^{h}
	3000 K+ 50 B	24.22^{a}	27.22^{a}	9.00^{ab}	9.78^{a}	168.81^{b}	194.02^{b}	517.44^{b}	541.53^{b}
20 days	Without	12.33^{de}	14.22^{d}	4.67^{h}	6.00^{e}	122.52^{j}	117.71^{j}	417.41^{i}	433.98^{j}
	3000 K nano	22.33^{ab}	22.78^{b}	7.67^{cd}	9.00^{b}	153.87^{d}	168.68^{d}	484.22^{d}	504.98^{d}
	50 B nano	15.44^{c}	17.00^{c}	6.67^{efg}	8.00^{c}	132.64^{g}	134.36^{g}	438.86^{g}	457.23^{g}
	3000 K+ 50 B	24.56^{a}	27.56^{a}	9.33^{a}	10.22^{a}	170.11^{a}	195.61^{a}	519.84^{a}	544.02^{a}
30 days	Without	11.22^{e}	13.33^{d}	4.11^{h}	5.00^{f}	119.98^{l}	114.49^{l}	412.33^{k}	428.54^{l}
	3000 K nano	21.11^{b}	22.00^{b}	7.00^{def}	8.00^{c}	151.22^{f}	165.46^{f}	479.40^{f}	499.89^{f}
	50 B nano	14.56^{cd}	16.44^{c}	6.00^{g}	7.11^{d}	130.09^{i}	130.46^{i}	434.20^{h}	451.91^{i}
	3000 K+ 50 B	24.00^{a}	26.89^{a}	8.33^{bc}	9.56^{ab}	167.43^{c}	192.40^{c}	515.25^{cs}	539.62^{c}

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 K-fertilization and foliar nano-fertilizers:

Data illustrated in Table (4) showed the effect of potassium fertilization at different rates and foliar application with nano K and B fertilizers on vegetative growth parameters during 2017-2018 and 2018-2019. A stimulation significant effect in all plant growth parameters as result of application of K-fertilization and nano foliar application, since it recorded the highest significant values for aforementioned traits when using 100% or 75 % from recommended dose with foliar application of 3000 ppm K + 50 ppm B, while the lowest values were realized with only 50% K. This trend was true during both seasons. This increase is due to the role of K fertilizer in promoting vegetative growth, increasing the process of representation and nutrient transport. As for nano-fertilizers, it is due to reasons related to the nature of nano-materials, such as their small size and large surface area that help them to penetrate the plant tissue and increase their absorption rates to a very large extent. The obtained results are in accordance with those of Shafshak *et al.* (2020)

Table 4. Interaction effect of K-fertilization and nano-fertilizers on vegetative growth parameters during 2017-2018 and 2018-2019 seasons.

Treatments		No. of leaves /plant		No. of branches /plant		Dry weight /plant g		Leaf area /plant cm^2	
		1st	2nd	1st	2nd	1st	2nd	1st	2nd
Potassium fertilization X Foliar application of Nano-fertilizers									
100% K	Without	12.67^{efg}	15.00^{ef}	4.33^{hi}	5.44^{g}	124.56^{j}	121.54^{j}	421.78^{j}	438.84^{j}
	3000 K nano	22.67^{bc}	24.22^{b}	7.67^{cd}	8.78^{cd}	158.17^{d}	176.16^{d}	494.16^{d}	515.15^{d}
	50 B nano	16.33^{d}	17.67^{d}	6.67^{efg}	7.78^{ef}	134.79^{g}	138.12^{g}	440.15^{g}	462.10^{g}
	3000 K+ 50 B	25.33^{a}	29.00^{a}	9.56^{a}	10.33^{a}	174.48^{a}	202.70^{a}	528.82^{a}	554.11^{a}
75% K	Without	12.00^{fg}	14.00^{fg}	4.78^{h}	5.78^{g}	121.52^{k}	115.70^{k}	415.39^{k}	431.38^{k}
	3000 K nano	21.89^{c}	22.00^{c}	7.33^{de}	8.22^{de}	151.57^{e}	165.30^{e}	479.92^{e}	499.92^{e}
	50 B nano	15.00^{de}	16.67^{de}	6.33^{fg}	7.22^{f}	131.34^{h}	132.12^{h}	437.19^{h}	454.33^{h}
	3000 K+ 50 B	24.78^{ab}	27.67^{a}	8.89^{ab}	9.89^{ab}	170.51^{ab}	197.34^{ab}	522.49^{ab}	548.23^{ab}
50% K	Without	10.56^{g}	12.33^{g}	4.00^{i}	5.11^{g}	117.94^{l}	111.06^{l}	407.38^{l}	423.55^{l}
	3000 K nano	20.33^{c}	20.78^{c}	7.00^{def}	8.11^{de}	148.10^{f}	160.11^{f}	472.04^{f}	492.10^{f}
	50 B nano	13.67^{ef}	15.89^{def}	6.00^{g}	7.11^{f}	127.78^{i}	127.00^{i}	428.89^{i}	446.88^{i}
	3000 K+ 50 B	22.67^{bc}	25.00^{b}	8.22^{bc}	9.33^{bc}	161.37^{c}	181.99^{c}	501.21^{c}	522.83^{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:

Concerning to the triple interaction effect among all treatments, data in Table (5) indicated that all fertilization whether K or foliar with nano significantly increased all vegetative growth parameters under all irrigation intervals. The suitable treatments which recorded the highest mean values for all mentioned parameters were 100% or 75 % K combined with 3000 ppm K+ 50 ppm B under 20 days irrigation intervals during both seasons, which reach approximately around the same treatments under 10 days intervals with no significant effect. While the lowest significant values recorded with plants fertilized with 50% K under irrigation after 30 days. Similar results in other crops, were reported by El-Sharkawy and El-Zohiri (2007) on Jerusalem artichoke.

2. Chemical constituents and quality:

Effect of irrigation intervals:

Results of Table (6) demonstrated that individual effect of irrigation intervals significantly increased the mean values of all nutritional elements (N, P and K in leaves). Such effects were noticed that increasing irrigation interval increased all mentioned parameters until irrigation every 20 days. The highest mean values were recorded with irrigation every 20 days followed by irrigation every 10 days then decreased with irrigation at 30 days during both seasons. These increments could be attributed to increasing water quantity applied by shortage on the irrigation period, giving a good opportunity to increase nutrients movement in the soil solution, which raised the availability to plant roots absorption and the translocation through plant tissues and consequently reflect on plant growth, development and chemical constituents. These results are in harmony with those obtained by El-Sharkawy and El-Zohiri (2007) and Saleh *et al.* (2012)

Table 5. Triple interaction effect among irrigation intervals, K-fertilization and foliar nano-fertilizers on vegetative growth parameters during 2017-2018 and 2018-2019 seasons.

Treatments			No. of leaves /plant		No. of branches /plant		Dry weight /plant g		Leaf area /plant cm^2	
			1st	2nd	1st	2nd	1st	2nd	1st	2nd
10 days	100 % K	Without	12.67^{i-n}	15.00^{n-s}	4.33^{no}	5.33^{nop}	124.80^{yz}	121.67^{t}	421.66^{u}	438.57^{xy}
		3000 K nano	22.67^{a-e}	24.33^{d-i}	7.67^{e-h}	8.67^{d-g}	158.50^{i}	176.67^{g}	494.57^{h}	515.48^{hi}
		50 B nano	16.33^{g-j}	17.67^{k-o}	6.67^{h-k}	7.67^{g-j}	134.57^{q}	138.47^{o}	433.47^{qr}	461.40^{p}
		3000 K+ 50 B	25.33^{ab}	29.00^{ab}	9.67^{ab}	10.33^{ab}	171.50^{cd}	199.13^{c}	524.63^{cd}	549.50^{cd}
	75 % K	Without	11.67^{k-n}	14.00^{o-s}	4.67^{mno}	5.67^{m-p}	121.43^{BC}	115.53^{vw}	415.35^{wx}	431.55^{AB}
		3000 K nano	21.33^{cde}	21.67^{f-j}	7.33^{f-i}	7.67^{g-j}	151.53^{kl}	165.27^{j}	480.63^{j}	499.60^{k}
		50 B nano	15.00^{i-l}	16.67^{n-q}	6.33^{ijk}	6.33^{k-n}	131.33st	131.57^{q}	437.38^{p}	454.44^{rs}
		3000 K+ 50 B	24.67^{a-d}	27.67^{a-e}	9.00^{a-d}	9.67^{a-d}	170.57^{de}	197.43^{c}	522.34^{de}	547.42^{d}
	50 % K	Without	10.67^{mn}	12.33^{rs}	4.00^{no}	5.00^{op}	118.33^{E}	111.10^{yz}	407.40^{z}	423.62^{D}
		3000 K nano	20.33^{efg}	20.67^{i-m}	7.00^{g-j}	8.00^{f-i}	148.20^{no}	160.37^{l}	472.30^{l}	491.81^{mn}
		50 B nano	13.67^{i-n}	16.00^{n-r}	6.00^{jkl}	7.00^{i-l}	127.63^{vw}	127.27^{rs}	428.67^{s}	446.66^{uv}
		3000 K+ 50 B	22.67^{a-e}	25.00^{c-g}	8.33^{c-f}	9.33^{b-e}	161.40^{fg}	182.20^{e}	501.50f	522.70^{f}
20 days	100 % K	Without	13.00^{i-n}	15.33^{n-s}	4.67^{mno}	6.00^{l-o}	125.53^{xy}	123.30^{t}	424.26st	441.63^{wx}
		3000 K nano	23.00^{a-e}	24.33^{d-i}	8.00^{d-g}	9.33^{b-e}	159.37^{hi}	177.20^{g}	496.53^{gh}	517.34^{gh}
		50 B nano	16.67^{f-i}	18.00^{j-n}	7.00^{g-j}	8.33^{e-h}	136.50^{p}	140.50^{n}	445.56^{n}	465.49^{o}
		3000 K+ 50 B	25.67^{a}	29.33^{a}	10.00^{a}	10.67^{a}	176.60^{a}	204.20^{a}	531.40^{a}	556.12^{a}
	75 % K	Without	13.00^{i-n}	14.33^{n-s}	5.00^{lmn}	6.33^{k-n}	122.63^{AB}	117.23^{v}	417.61^{vw}	433.60^{zA}
		3000 K nano	23.33^{a-e}	23.00^{f-i}	7.67^{e-h}	9.00^{c-f}	152.70^{k}	167.23^{i}	481.62^{j}	502.90^{j}
		50 B nano	15.67^{ijk}	17.00^{m-p}	6.67^{h-k}	8.00^{f-i}	132.27^{rs}	134.37^{p}	439.57^{op}	456.69^{qr}
		3000 K+ 50 B	25.00^{a-c}	28.00^{a-d}	9.33^{a-c}	10.33^{ab}	174.47^{b}	202.43^{ab}	528.46^{ab}	554.46^{ab}
	50 % K	Without	11.00^{lmn}	13.00^{qrs}	4.33^{no}	5.67^{m-p}	119.40^{DE}	112.60^{xy}	410.37^{y}	426.70^{CD}
		3000 K nano	20.67^{def}	21.00^{h-l}	7.33^{f-i}	8.67^{d-g}	149.53^{mn}	161.60^{l}	474.53^{l}	494.70^{lm}
		50 B nano	14.00^{i-n}	16.00^{n-r}	6.33^{ijk}	7.67^{g-j}	129.17^{uv}	128.20^{l}	431.45^{r}	449.52^{tu}
		3000 K+ 50 B	23.00^{a-e}	25.33^{b-f}	8.67^{b-e}	9.67^{a-d}	162.23^{f}	183.50^{e}	503.49^{f}	526.46^{e}
30 days	100 % K	Without	12.33^{j-n}	14.67^{n-s}	4.00^{no}	5.00^{op}	123.33^{zA}	119.67^{u}	419.43^{uv}	436.31^{yz}
		3000 K nano	22.33^{a-e}	24.00^{d-i}	7.33^{f-i}	8.33^{e-h}	156.63^{j}	174.60^{h}	491.38^{i}	512.62^{i}
		50 B nano	16.00^{hij}	17.33^{l-p}	6.33^{ijk}	7.33^{h-k}	133.30^{qr}	135.40^{p}	441.44^{o}	459.42^{pq}
		3000 K+ 50 B	25.00^{abc}	28.67^{abc}	9.00^{a-d}	10.00^{abc}	172.37^{c}	201.47^{b}	526.60^{bc}	551.75st
	75 % K	Without	11.33^{lmn}	13.67^{p-s}	4.67^{mno}	5.33^{nop}	120.50^{CD}	114.33^{wx}	413.21^{x}	428.99^{BC}
		3000 K nano	21.00^{cde}	21.33^{g-k}	7.00^{g-j}	8.00^{f-i}	150.47^{lm}	163.40^{k}	477.51^{k}	497.26^{kl}
		50 B nano	14.33^{i-m}	16.33^{n-q}	6.00^{jkl}	7.33^{h-k}	130.43^{tu}	130.43^{q}	434.61^{q}	451.87st
		3000 K+ 50 B	24.67^{a-d}	27.33^{a-e}	8.33^{c-f}	9.67^{a-d}	169.47^{e}	195.47^{d}	520.50^{e}	547.79^{d}
	50 % K	Without	10.00^{n}	11.67^{s}	3.67^{o}	4.67^{p}	116.10^{F}	109.47^{z}	404.36^{A}	420.32^{E}
		3000 K nano	20.00^{e-h}	20.67^{i-m}	6.67^{h-k}	7.67^{g-j}	146.57^{o}	158.37^{m}	469.30^{m}	489.78^{n}
		50 B nano	13.33^{i-n}	15.67^{n-r}	5.67^{klm}	6.67^{j-m}	126.53^{wx}	125.53^{s}	426.55st	444.44^{vw}
		3000 K+ 50 B	22.33^{a-e}	24.67^{d-h}	7.67^{e-h}	9.00^{c-f}	160.47^{gh}	180.27^{f}	498.64^{g}	519.32^{g}

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 potassium fertilization:

Data tabulated in Table (6) indicated that the average values of N, P and K% in leaves of globe artichoke were significantly increased as a result of fertilizing plants with different rates of K-fertilization (50, 75 and 100% K from recommended dose). The highest mean values for N, P and K% in leaves were found to be associated with the addition of 100% K, while such effect was realized for the treatment of 75% K during both seasons. Similar results were reported by El-Sharkawy and El-Zohiri (2007), Kasim *et al.* (2007), Anwar *et al.* (2017) and Shafshak *et al.* (2020).

Effect of nano-fertilizers:

Data illustrated in Table (6) clear that using foliar application of nano K, B and mix together were significantly affected N, P and K% in leaves of artichoke. The highest mean values of mentioned parameters were recorded with 3000 ppm K + 50 ppm B followed by 3000 ppm K then 50 ppm B while, the lowest values were recorded with control treatment. The same trend was true during both seasons. The obtained results are in accordance with those of Samy *et al.* (2015) and Shafshak *et al.* (2020).

Interaction effect between irrigation intervals and K-fertilization:

It is clear from the data presented in Table (7) that combination between irrigation intervals and K fertilization significantly affected N, P and K% in leaves of artichoke. With increasing K fertilization rates under any level of irrigation, found an increase in all mentioned parameters. The highest mean values were obtained with the treatment of 100% K from recommended dose, which appeared to be approximately near to that of 75% treatment under all irrigation intervals especially irrigation every 20 days during the two seasons. In this concern, it was found that root growth rate, length and surface had been associated with K acquisition efficiency of root system, consequently improved nutrient absorption. Similar results were reported by Anwar *et al.* (2017)

Table 6. Individual effect of irrigation intervals, potassium fertilization and foliar application of nano-fertilizers on N, P and K % in leaves during 2017-2018 and 2018-2019 seasons.

Treatments	N %		P %		K %	
	1st	2nd	1st	2nd	1st	2nd
Irrigation intervals						
10 days	2.75^{b}	2.87^{b}	0.324^{b}	0.339^{b}	2.18^{b}	2.65^{b}
20 days	2.79^{a}	2.91^{a}	0.326^{a}	0.343^{a}	2.21^{a}	2.69^{a}
30 days	2.72^{c}	2.84^{c}	0.320^{c}	0.335^{c}	2.14^{c}	2.61^{c}
Potassium fertilization						
100% K	2.90^{a}	3.03^{a}	0.336^{a}	0.353^{a}	2.32^{a}	2.82^{a}
75% K	2.76^{b}	2.89^{b}	0.324^{b}	0.340^{b}	2.18^{b}	2.67^{b}
50% K	2.60^{c}	2.70^{c}	0.310^{c}	0.325^{c}	2.02^{c}	2.47^{c}
Foliar application of Nano-fertilizers						
Without	2.01^{d}	2.07^{d}	0.259^{d}	0.270^{d}	1.46^{d}	1.82^{d}
3000 K nano	3.06^{b}	3.20^{b}	0.350^{b}	0.367^{b}	2.46^{b}	2.98^{b}
50 B nano	2.32^{c}	2.42^{c}	0.289^{c}	0.300^{c}	1.79^{c}	2.21^{c}
3000 K+ 50 B	3.63^{a}	3.81^{a}	0.396^{a}	0.419^{a}	3.00^{a}	3.60^{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 foliar nano-fertilizers:

Data in Table (8) clear that interaction effect between irrigation intervals and foliar nano-fertilizers on chemical constituents of leaves. The data reflected that all treatments under investigation significantly affected the mentioned parameters.

The highest values of N, P and K%, of artichoke leaves were realized for the treatments of 3000 ppm nano K +50 ppm nano B combined with the treatment of irrigation at 20 days intervals followed by the same foliar under irrigation every 10 days intervals during both seasons**.**

Table 7. Interaction effect of irrigation intervals and potassium fertilization on N, P and K% in leaves during 2017-2018 and 2018-2019 seasons.

Treatments		N %		P %		K %	
		1st	2nd	1st	2nd	1st	2nd
Irrigation intervals X Potassium fertilization							
10 days	100% K	2.90^{b}	3.03^{b}	0.336^{b}	0.353^{b}	2.32^{b}	2.82^{b}
	75% K	2.76^{e}	2.88^{e}	0.324^{e}	0.339^{e}	2.18^{e}	2.67^{e}
	50% K	2.60^{h}	2.70^{h}	0.311^{h}	0.325^{h}	2.03^{h}	2.47^{h}
20 days	100% K	2.94^{a}	3.07^{a}	0.339^{a}	0.356^{a}	2.36^{a}	2.86^{a}
	75% K	2.80^{d}	2.93^{d}	0.327^{d}	0.344^{d}	2.21^{d}	2.71^{d}
	50% K	2.64^{g}	2.74^{g}	0.313^{g}	0.329^{g}	2.05^{g}	2.52^{g}
30 days	100% K	2.86^{c}	3.00^{c}	0.333^{c}	0.349^{c}	2.28^{c}	2.78^{c}
	75% K	2.73^{f}	2.85^{f}	0.321^{f}	0.337^{f}	2.15^{f}	2.63^{f}
	50% K	2.56^{i}	2.66^{i}	0.306^{i}	0.320^{i}	1.99^{i}	2.42^{i}

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 K-fertilization and foliar nano-fertilizers:

Data in Table (9) reflects that all treatments under investigation significantly affect the mentioned parameters. Treating the plants of artichoke with the different rates of K fertilization and various concentration of nano K and B increased all traits. The highest values for all the aforementioned traits compared to the untreated plants were recorded with the treatment of 100% or 75% K with foliar application of 3000 ppm K + 50 ppm B. An increase in nutrients might be due to the role of K in nutrients uptake and nutritional balance, which increased the biosynthesis of photosynthesis (Salami and Saadat, 2013). Similar results were reported by Abdel-Aziz *et al.* (2018) on artichoke.

Table 8. Interaction effect of irrigation intervals and nano-fertilizers on N, P and K% in leaves during 2017-2018 and 2018-2019 seasons.

Treatments		N %		P %		K %	
		1st	2nd	1st	2nd	1st	2nd
Irrigation intervals X Foliar application of Nano-fertilizers							
10 days	Without	2.01^{k}	2.06^{k}	0.260^{iab}	0.269^{k}	1.46^{k}	1.82^{k}
	3000 K nano	3.06^{e}	3.20^{e}	0.350^{d}	0.367^{e}	2.46^{e}	2.98^{e}
	50 B nano	2.32^{h}	2.42^{h}	0.288^{g}	0.300^{h}	1.78^{h}	2.21^{h}
	3000 K+ 50 B	3.63^{b}	3.80^{b}	0.396^{ab}	0.419^{b}	3.00^{b}	3.60^{b}
20 days	Without	2.04^{j}	2.11^{j}	0.262^{i}	0.274^{j}	1.49^{j}	1.87^{j}
	3000 K nano	3.10^{d}	3.24^{d}	0.353^{c}	0.371^{d}	2.50^{d}	3.01^{d}
	50 B nano	2.36^{g}	2.45^{g}	0.292^{f}	0.303^{h}	1.82^{g}	2.25^{g}
	3000 K+ 50 B	3.67^{a}	3.85^{a}	0.398^{a}	0.423^{a}	3.03^{a}	3.64^{a}
30 days	Without	1.97^{l}	2.02^{l}	0.254^{j}	0.266^{l}	1.42^{l}	1.77^{l}
	3000 K nano	3.03^{f}	3.16^{f}	0.348^{e}	0.364^{f}	2.42^{f}	2.94^{f}
	50 B nano	2.29^{i}	2.39^{i}	0.286^{h}	0.296^{i}	1.76^{i}	2.17^{i}
	3000 K+ 50 B	3.59^{c}	3.76^{c}	0.393^{b}	0.416^{c}	2.96^{c}	3.56^{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 9. Interaction effect of K-fertilization and nano-fertilizers on N, P and K% in leaves during 2017-2018 and 2018-2019 seasons.

Treatments		N %		P %		K %	
		1st	2nd	1st	2nd	1st	2nd
Potassium fertilization X Foliar application of Nano-fertilizers							
100% K	Without	2.11^{j}	2.18^{j}	0.266^{j}	0.279^{j}	1.56^{j}	1.96^{j}
	3000 K nano	3.26^{d}	3.38^{d}	0.366^{d}	0.386^{d}	2.64^{d}	3.20^{d}
	50 B nano	2.43^{g}	2.55^{g}	0.301^{g}	0.310^{g}	1.91^{g}	2.32^{g}
	3000 K+ 50 B	3.81^{a}	4.02^{a}	0.411^{a}	0.436^{a}	3.18^{a}	3.80^{a}
75% K	Without	2.01^{k}	2.07^{k}	0.260^{k}	0.270^{k}	1.45^{k}	1.82^{k}
	3000 K nano	3.02^{e}	3.17^{e}	0.347^{e}	0.363^{e}	2.42^{e}	2.94^{e}
	50 B nano	2.32^{h}	2.41^{h}	0.288^{h}	0.300^{h}	1.78^{h}	2.23^{h}
	3000 K+ 50 B	3.70^{ab}	3.89^{ab}	0.402^{ab}	0.425^{ab}	3.07^{ab}	3.68^{ab}
50% K	Without	1.90^{l}	1.94^{l}	0.249^{l}	0.261^{l}	1.35^{l}	1.67^{l}
	3000 K nano	2.90^{f}	3.05^{f}	0.339^{f}	0.352^{f}	2.33^{f}	2.80^{f}
	50 B nano	2.23^{i}	2.31^{i}	0.276^{i}	0.289^{i}	1.67^{i}	2.09^{i}
	3000 K+ 50 B	3.37^{c}	3.50^{c}	0.375^{c}	0.396^{c}	2.74^{c}	3.32^{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:

Nutritional elements concentrations in leaves of artichoke as affected by the interaction among all treatments under study are tabulated in Table (10). The most suitable treatment which realized the highest values N, P and K% in leaves were connected with 100 or 75 % K from recommended dose with 3000 K+ 50 ppm B as foliar application under irrigation every 20 days during 2017-2018 and 2018-2019. In addition, these mean values tended to be significantly and near of the same treatments with irrigation every 10 days. These results are in harmony with those obtained by El-Sharkawy and El-Zohiri (2007), Zain *et al.* (2015) and Qureshi *et al.* (2018).

Table 10. Interaction effect of irrigation intervals, K-fertilization and nano-fertilizers on N, P and K % in leaves during 2017-2018 and 2018-2019 seasons.

Treatments			N%		P%		K%	
			1st	2nd	1st	2nd	1st	2nd
10 days	100% K	Without	2.11^{u}	2.17^{s}	0.267^{s}	0.279^{s}	1.56^{t}	1.97^{t}
		3000 K nano	3.26^{i}	3.37^{h}	0.366^{gh}	0.385^{h}	2.65^{i}	3.21^{gh}
		50 B nano	2.43^{o}	2.55^{mn}	0.301^{mn}	0.311^{n}	1.90^{p}	2.33^{n}
		3000 K+ 50 B	3.74^{cd}	3.94^{c}	0.404^{cd}	0.429^{c}	3.10^{cd}	3.73^{c}
	75% K	Without	2.01^{wx}	2.07^{t}	0.261^{uv}	0.267^{t}	1.45^{vw}	1.82^{vw}
		3000 K nano	3.01^{k}	3.17^{j}	0.346^{ij}	0.363^{j}	2.42^{l}	2.94^{j}
		50 B nano	2.32^{qr}	2.41^{op}	0.288^{op}	0.300^{p}	1.77^{q}	2.22^{pq}
		3000 K+ 50 B	3.71^{d}	3.88^{d}	0.401^{d}	0.425^{d}	3.07^{de}	3.68^{d}
	50% K	Without	1.90^{y}	1.94^{v}	0.252^{x}	0.262^{v}	1.36^{x}	1.67^{y}
		3000 K nano	2.90^{lm}	3.05^{kl}	0.339^{kl}	0.353^{l}	2.33^{mn}	2.80^{l}
		50 B nano	2.23st	2.31^{q}	0.276^{qr}	0.290^{q}	1.68^{r}	2.07^{s}
		3000 K+ 50 B	3.37^{g}	3.51^{f}	0.375^{e}	0.395^{f}	2.75^{fg}	3.32^{ef}
20 days	100% K	Without	2.15^{u}	2.24^{r}	0.269^{s}	0.282^{s}	1.61^{s}	2.00^{t}
		3000 K nano	3.30^{h}	3.43^{g}	0.369^{fg}	0.389^{g}	2.68^{hi}	3.23^{pq}
		50 B nano	2.47^{n}	2.57^{m}	0.304^{m}	0.313^{n}	1.95^{o}	2.36^{n}
		3000 K+ 50 B	3.86^{a}	4.06^{a}	0.414^{a}	0.439^{a}	3.21^{a}	3.83^{a}
	75% K	Without	2.04^{vw}	2.10^{t}	0.262^{tu}	0.275^{t}	1.48^{uv}	1.86^{v}
		3000 K nano	3.06^{j}	3.21^{i}	0.349^{i}	0.366^{i}	2.47^{k}	2.98^{i}
		50 B nano	2.35^{q}	2.44^{o}	0.293^{o}	0.304^{o}	1.80^{q}	2.26^{o}
		3000 K+ 50 B	3.81^{ab}	4.02^{ab}	0.411^{ab}	0.436^{ab}	3.17^{ab}	3.79^{ab}
	50% K	Without	1.94^{y}	2.00^{u}	0.255^{wx}	0.265^{u}	1.38^{x}	1.74^{x}
		3000 K nano	2.93^{l}	3.08^{k}	0.342^{jk}	0.357^{k}	2.35^{m}	2.83^{l}
		50 B nano	2.26^{s}	2.34^{q}	0.279^{q}	0.293^{q}	1.71^{r}	2.15^{r}
		3000 K+ 50 B	3.42^{f}	3.54^{f}	0.377^{e}	0.399^{e}	2.77^{f}	3.35^{e}
30 days	100% K	Without	2.07^{v}	2.14^{s}	0.263^{tu}	0.275^{t}	1.52^{u}	1.90^{u}
		3000 K nano	3.22^{i}	3.34^{h}	0.362^{h}	0.382^{h}	2.60^{j}	3.17^{h}
		50 B nano	2.39^{p}	2.52^{n}	0.299^{n}	0.306^{o}	1.87^{p}	2.27^{o}
		3000 K+ 50 B	3.76^{c}	3.99^{b}	0.408^{bc}	0.432^{c}	3.14^{bc}	3.76^{bc}
	75% K	Without	1.99^{x}	2.03^{u}	0.257^{vw}	0.267^{u}	1.42^{w}	1.79^{w}
		3000 K nano	2.98^{k}	3.13^{j}	0.344^{ij}	0.361^{j}	2.37^{m}	2.89^{k}
		50 B nano	2.30^{r}	2.38^{p}	0.285^{p}	0.297^{p}	1.78^{q}	2.20^{q}
		3000 K+ 50 B	3.66^{e}	3.84^{e}	0.400^{d}	0.422^{d}	3.04^{e}	3.64^{d}
	50% K	Control	1.85^{z}	1.89^{w}	0.241^{y}	0.256^{w}	1.31^{y}	1.61^{z}
		3000 K nano	2.87^{m}	3.02^{l}	0.336^{l}	0.348^{m}	2.30^{n}	2.76^{m}
		50 B nano	2.20^{t}	2.27^{r}	0.274^{r}	0.286^{r}	1.63^{s}	2.04^{s}
		3000 K+ 50 B	3.33^{gh}	3.46^{g}	0.372^{ef}	0.392^{f}	2.71^{gh}	3.28^{f}

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.) followed by 75% (150 kg of potassium sulfate/fed.) with foliar application by a mixture of 3000 ppm nano-K+ 50 ppm nano-B and irrigation every 20 days is recommended for globe artichoke plants grown under field conditions to obtain the best vegetative growth and the best contents of leaves under the conditions similar to this study.

REFERENCES

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.

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.

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

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)

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.

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.

Imas, P. and S. K. Bansal (1999). Potassium and integrated nutrient management in potato. 12Presented at the global conference on potato, December 6-11, New Delhi, India.

Ismail, M.; R. Prasad; A. I. M. Ibrahim and A. I. S. Ahmed (2017). Modern Prospects of Nanotechnology in Plant. Pathology; Springer Science and Business Media LLC: Singapore, pp: 305–317.

Jones, J.; B. J. B. Wolf and H. A. Mills, (1991). Plant analysis Handbook: A Practical Sampling, Preparation, Analysis, and Interpretative Guide. Micro-Macro Publishing, Athens, Ga.

Jyothi, T. V. and N. S. Hebsur (2017). Effect of nano-fertilizers on growth and yield of selected cereals - A review. Agric. Res. Communication Centre, 38(2): 112-120. www.arccjournals.com

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.

Koller, H. R. (1972). Leaf Area-Leaf Weight Relationships in the Soybean Canopy. Biology Crop Sci., 12: 180-183.

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.

Leskovar, D. and C. Xu (2013). Irrigation strategies and water use efficiency of globe artichoke. Acta. Hort., 983: 261-268.

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

Merghany, M. M.; M. M. Shahein; Mahmoud A. Sliem; K. F. Abdelgawad and A. F. Radwan (2019). Effect of nano-fertilizers on cucumber plant growth, fruit yield and it's quality. Plant Archives, 19 (2): 165-172.

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.

Nassef, D. M. T. and A. H. M. Nabeel (2012). Response of two broccoli cultivars to foliar application of Lithovit fertilizer under two planting methods. Assiut J. Agric. Sci., 43 (6): 27-45.

Peters, I. S.; B. Combs; I. Hoskins; I. Iarman; M. Kover Watson and N. Wolf (2003). Recommended Methods of Manure Analysis. Univ. of Wisconsin, Cooperative extension Publ., Madison.

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.

Rai, G. K.; M. M. Verma and J. Singh (2002). Nitrogen and potassium interaction effect on yield attributes of potato. J. Indian Potato Association, 9(34): 153-154.

Salami, M. and S. Saadat (2013). Study of potassium and nitrogen fertilizer levels on the yield of sugar beet in jolge cultivar. J. of Novel Applied Sciences, 2(4):94-100.

Saleh, S. A.; Z. S. El-Shal; Z. F. Fawzy and A. M. El-Bassiony (2012). Effect of water amounts on artichoke productivity irrigated with brackish water. Aust. J. Basic Appl. Sci., 6(5): 54–61.

Samy, M. M.; N. A. Mohamed and M. G. Abd El-Aziz (2015). Effect of boron, copper and humic acid treatments on vegetative growth, yield and storability of Jerusalem artichoke tubers. J. Product. & Dev., 20(3): 325 – 342.

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.

Shelp, B. J. and L. Liu (1992). Nutrient uptake by field-grown broccoli and net nutrient mobilization during inflorescence development. Pl. Soil, 140:151-55.

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.

Tandon, H. L. S. (1991). Secondary and Micronutrients in Agriculture. Fertilizer Development and Consultation Organization, New Delhi.

Wang, M.; Q. Zheng; Q. Shen and S. Guo (2013). The critical role of potassium in plant stress response. Inter. J. Molecular Sci., 14(4):7370– 7390.

Xiong, L. and J. K. Zhu (2002). Molecular and genetic aspects of plant responses to osmotic stress. Plant, Cell and Environment, 25: 131-139.

Yildirim, E.; H. Karlidag and M. Turan (2009). Mitigation of salt stress in strawberry by foliar K, Ca and Mg nutrient supply. Plant Soil Environ; 55(5): 213-221.

Zain, M.; I. Khan; R. W. K. Qadri; U. Ashraf; S. Hussain; S. Minhas; A. Siddique; M. Jahangir and M. Bashir (2015). Foliar application of micronutrients enhances wheat growth, yield and related attributes. American J. Plant Sci., 6: 864- 869.

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:
أ: النمو الخضرى ومحتوى الأوراق من العناصر

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 و2018/ 2019 لدراسة تأثير كل من فترات الرى ومعدلات البوتاسيوم والرش الورقى ببعض أسمده النانو مثل البوتاسيوم و البورون على النمو الخضرى والتحليل الكيماوى لأوراق 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). أوضحت النتائج أن تسميد نباتات الخرشوف بمعدل 100% (200كجم/ فدان سلفات البوتاسيوم) او 75 % (150 كجم/فدان سلفات البوتاسيوم) مع الرى كل 20 يوم مع الرش الورقى لخليط من 3000 جزء في المليون نانو بوتاسيوم مع 50 جزء في المليون نانو بورون للحصول على أفضل نمو خضرى وأعلى محتوى كيماوى.