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EFFECT OF ADDING BIOCHAR AND DIFFERENT RATES OF CHEMICAL FERTILIZATION ON GROWTH AND YIELD OF GLOBE ARTICHOKE PLANTS GROWN IN SANDY SOIL

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ABSTRACT

A field experiment was carried out during two successive winter seasons of 2017/2018 and 2018/2019 at the Experimental Farm of El-Kassasin Horticultural Research Station, Ismailia Governorate, Egypt, to study the effect of different rates of mineral NPK (100, 75, 50 and 25 % of the recommended rates) and biochar (0, 1, 2 and 4 m^3/fad.) on growth, yield and head quality of globe artichoke plants grown in sandy soil.

Results showed that , the interaction between fertilizing globe artichoke plants with NPK at 100 % of recommended rates (RR) and treating with biochar at 4 m^3/fed, significantly increased plant height , leaf fresh weight and offshoots number / plant, highest number ofearly heads/ plant , number of total heads/ plant , total yield / plant , total yield /fed. and total sugars (%) in receptacle in both seasons. While, the interaction between fertilizing globe artichoke plants with NP K at 75 % of RR and treating with biochar at 4 m^3/fed. significantly enhanced leaf dry weight and all flower head quality such as head fresh weight, head diameter, receptacle fresh weight, receptacle diameter and receptacle thickness, with no significant differences between the interaction treatment between fertilizing with NP K at 100 % RR and treating with biochar at 4 m^3/fed. in both seasons. However, reducing sugars and inulin (%) significantly enhanced with the interaction treatments between NPK at 100 or 75% of RR and treating with biochar at 4 or 2m^3/fed. in both seasons . On the other hand, the lowest values of all plant growth parameter, yield and its components, head quality and chemical constituents of receptacles were obtained from the plants which received 25 % of the recommended rate of NPK in without biochar both seasons.

***Conclusively,** it could be concluded that, fertilizing globe artichoke plant with NPK at 100% from recommended rate which equal 120 kg N, 62.0 Kg P_2O_5 and 120 kg K_2O and treated with 4 m^3/fed. was the best treatment for recorded the highest values of yield characters, and head*

quality under the similar conditions compared to the other studied treatments.

Key words: Globe artichoke , NPK , biochar , growth, yield, head quality.

INTRODUCTION

The globe artichoke (*Cynara scolymus* L.) is a herbaceous plant grown all over the world for its large and fleshy heads. Most of the farming areas in the Mediterranean countries. Artichoke is an important vegetable crop in Egypt because of its nutritive and medical values. The immature flower bud (head) is the edible part of the crop which includes the fleshy receptacle and fleshy tender basis of bracts. Artichoke is widely used in human diet, characterized by low protein and fat, high content of minerals, fibers, vitamins, inulin, carbohydrates and polyphenolic compounds. The edible flower buds and other artichoke plant extracts are rich in polyphenols and have high levels of antioxidant activity (Liorach *et al*., 2002). Moreover, it gained a highly exportable importance to the European markets. It is well known that high productivity of any crop is the final goal of many factors and operations. In addition, the pronounced role of the agronomical processes such as N, P and K fertilization treatments has very important effect on productivity and quality of artichoke crop.

Mineral fertilizers in developing nations such as Egypt are not only in restricted supply, but also costly. Chemical fertilizer prices are growing day by day, and the continued use of these fertilizers has an adverse effect on soil health, which is of great concern to farmers. Modern nutrient management approach has changed its focus to sustainable and environmentally friendly concepts. Intensive use of only chemical fertilizers to achieve high production has created various problems. The continued use of high doses of chemical fertilizers has resulted in a deterioration of soil health in terms of soil physical and chemical properties, a decline in soil microbial activity, a decrease in soil humus, enhanced soil, water and air pollution (George and Michael, 2002).

The application of N P and K is very important for the adequate nutrients uptake and optimum plant growth resulting maximum yield with good quality. Whereas, nitrogen results in the highest vegetative growth characters and increases head yield. Potassium enhances the earliness and improves product quality and head characters (Saleh, 2003) .The excess nutrient fertilizers are not recommended due to economic and environmental issues. Also, the little application of nutrient fertilizers will not be enough to satisfy plant requirements in the long run during plant growth cycle (Shaheen *et al*., 2007).

Many previous studied that increasing the amount of N , P and K as mineral fertilizers recorded the best results for increasing productivity and enhancing quality globe artichoke (Foti *et al*., 2005, Ierna *et al*., 2006 , Elia and Conversa, 2007, Paradiso *et al.,* 2007, Shaheen *et al*., 2007, Ezz El-Din *et al*., 2010, Shinohara *et al*., 2011, Anita and Mauro 2012, Allahdadi *et al*., 2016, Saleh *et al*., 2016, Mohamed *et al*., 2017 and Allahdadi and Farzane 2018).

Biochar is a carbon-rich material obtained from the rmochemical conversion (slow, intermediate, and fast pyrolysis or gasification) of biomass in an oxygen-limited environment. It can be produced from a range of feedstock, including forest and agriculture residues, such as straw, nut shells, rice hulls, wood chips/pellets, tree bark, and switch grass (Sohi *et al*.,2009).Biochar has been described as a possible tool for soil fertility improvement, potential toxic element adsorption, and climate change mitigation (Ennis *et al*., 2012).

Indeed, several studies have shown that biochar application to soil can improve soil physical and chemical properties (Mukherjee and Lal, 2013), enhance plant nutrient availability and correlated growth and yield (Biederman and Harpole, 2013), increase microbial population and activities (Jaafar *et al.,* 2014), and reduce greenhouse gas emissions through C sequestration (Crombie, *et al.,* 2015).

The beneficial effects of biochar on plant productivity and soil microbial population are related to the improvement of specific surface area, cation exchange capacity, bulk density, pH, water, and nutrients within the soil matrix (Thies and Rillig, 2009). Beside the generally positive plant growth responses to biochar amendment, especially in acidic coarse texture soil, negligible or negative effects also occur due to types of feedstock and pyrolysis process, biochar application rate, plant species, and soil characteristics (Spokas *et al.,* 2012). Furthermore, in most cases, biochar does not provide high amounts of nutrients (Glaser *et al*., 2002).

In this regard , treated plants with biochar increased plant growth , yield and quality (Graber *et al.* , 2010 on tomato , Carter *et al*., 2013 on lettuce and cabbage , El-Shimi and Byan, 2015 on eggplant, Vaccari *et al*., 2015 on tomato, Paneque *et al*., 2016 on sunflower Silva *et al.* , 2017 on common bean, Trupiano *et al*., 2017 on lettuce , Tahir *et al*., 2018 on spinach, Hameeda *et al.* (2019) on tomato and Mostafa and Shaban (2019) on faba bean.

Therefore, the objective of this study was to determine the suitable rates of mineral NPK and biochar to obtain high head yield with good quality of globe artichoke under sandy soil conditions.

MATERIALS AND METHODS

A field experiment was carried out during the two successive winter seasons of 2017/2018 and 2018/2019 at the Experimental Farm of El-Kassasin Horticultural Research Station, Ismailia Governorate, Egypt, to study the effect of different rates of mineral NPK and biochar on growth, yield and head quality of globe artichoke plants grown in sandy soil . Random samples were collected from the experimental soil field location and used biochar at the beginning of the experiment in the two seasons to determine physical and chemical properties according to the methods described by Jakson (1970) as shown in Table A.

Table A: The physical and chemical properties of the experimental soil and used biochar.

	Season				Season	
Soil	**2017/2018**	**2018/2098**	**Biochar**		**2017/2018**	**2018/2019**
Physical Properties(%)			**Chemical properties**			
Sand(%)	**94.11**	**93.17**	**Total %(DW)**	**C**	**31.08**	**31.25**
Silt(%)	**2.68**	**2.75**		**N**	**0.80**	**0.72**
Clay(%)	**3.21**	**4.08**	**Mg/kg**	**S**	**0.09**	**0.08**
O.M (%)	**0.06**	**0.07**		**P**	**17.85**	**17.75**
Texture	**sandy**	**sandy**		**K**	**310.5**	**301.5**
Chemical Properties				**Ca**	**676.5**	**664**
PH	**7.94**	**7.51**		**Mg**	**189.5**	**178**
Available N(ppm	**5.20**	**5.78**		**Na**	**880.5**	**925.5**
Available P(ppm)	**4.62**	**4.71**		**Fe**	**76.68**	**71.2**
Available K(ppm	**58**	**61**		**Mn**	**166.5**	**155.5**
				Zn	**12.78**	**12.8**
				Cu	**9.80**	**9.03**
				PH	**9.76**	**9.60**
				m^3	**735 kg**	**750 kg**

This experiment included 16 treatments, which were the combinations between four rates of mineral NPK and four rates of biochar as follows: NPK at rates of 100, 75, 50 and 25 % of the recommended rates (RR), and biochar at the rates of 0,1,2 and 4 m^3/feddan.

Nitrogen ,phosphorus and potassium rates were added in the form of ammonium sulphate, calcium super phosphate and potassium sulphate, respectively as shown in Schedule 1.

These treatments were arranged in a split plot design with 3 replications. The rates of N,P and K were arranged in the main plots and the rates of biochar were assigned in the sub plots**.** The French cultivar "Herious" was vegetatively propagated by offshoots and cutting stumps.

Schedule 1: Quantities and sources of N,P and K fertilizers

NPK rates(100%)	Nitrogen		Phospours		Potassium	
	N (kg/fed)	Ammonium sulphate (20.5%) kg/fed	P_2O_5 (kg/fed)	Calcium superphosphate (15.5 % P_2O_5kg/fed)	K_2O (kg/fed)	Potassium sulphate (48 % K_2O kg/fed)
100	120	600	62.0	400	120	250
75	90	450	46.5	300	90	187.5
50	60	300	31.0	200	60	125
25	30	150	15.5	100	30	62.5

The old pieces were treated with fungicides for 30 minutes before planting, then planted in 6th and 9th of September in the 1st and 2nd seasons, respectively, with 1.0 m between each two plants on the ridge and 1.0 m between the ridges . The plot area was 40.0 m^2 (20.0 m length x 2.0 m width).

Seventy five percent of different rates of P_2O_5, 25% of different rates of N and K_2O were applied during soil preparation. The rest quantity of N,P and K were divided into three equal portions and added at 45 , 90 and 120 days after planting as soil application. Different rates of biochar were added during the soil preparation in the center of row and covered by sand. All other agricultural practices were followed according to recommendations of Ministry of Agriculture, Egypt.

Data recorded:

Growth characters:

Random sample of three plants from each plot was taken at 150 days after planting in two seasons and the flowing measurements were recorded:

1- Plant height (cm): The height of plants was measured from the soil surface up to the tip of the height leaf.

2- Leaf fresh weight (g): representative samples from fourth leaf.

3- Leaf dry weight (g): after drying to a constant weight at 70 C.

4- Number of offshoots / plant at the end of harvesting.

Yield and its component:

Number of early heads / plant was calculated from the beginning of harvest till the end of February and many parameters were evaluated in both seasons of the study as number of early heads /plant, number of total heads /plant, total yield /plant and total yield (ton/ fed). Random sample of five flower heads was taken from each plot in both seasons for measuring the physical head

characters, including flower head diameter (cm) and fresh weight (g), receptacle fresh weight (g), diameter (cm) and thickness (cm).

Chemical analyses:

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

Statistical analysis:

The data of the experiment were subjected to proper statistical analysis of variance according to Snedecor and Cochran, (1982) and means were compared using Duncan's multiple range test (Duncan, 1955) at 5% level of significance.

RESULTS AND DISCUSSION

Plant growth

1. Effect of mineral fertilizers

Fertilization of globe artichoke plants with different rates of NPK as mineral fertilizers had significant effect on vegetative growth at 150 days after planting during 2017/2018 and 2018/2019 seasons (Table 1). Plant height, fresh weight of leaf and offshoots number /plant significantly increased with increasing NPK rates up to 100 % of the recommended rate of RR with no significant differences with NPK at 75 % of RR for leaf fresh weight in the 2nd season. However, leaf dry weight significantly increased with 75 % NPK of RR in both seasons. On the other hand, fertilizing plants with 25 % NPK of RR gave the lowest values of all vegetative growth parameters in both growing seasons.

The necessity of nitrogen, phosphorus and potassium for growth has been demonstrated by several investigators, since nitrogen supply was desirable for vegetative growth, dry matter accumulation as well as nutrient uptake by plant. The rise in plant growth can be ascribed to N positive impacts on stimulating aerostatic activity to produce more tissues and bodies, as N plays significant roles in the synthesis of structural enzymes and several other macromolecules, as well as, its essential contribution to several growth-related biochemical procedures in the plant (Marschner, 1995).

Table 1. Effect of mineral fertilizers and biochar rates on vegetative growth parameters of globe artichoke plants during 2017/2018 and 2018/ 2019 seasons

Treatments	Plant height (cm)		Leaf fresh weight (g)		Leaf dry weight (g)		Offshoots No/ plant	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
	Effect of mineral fertilizer rates							
100 % of RR	81.82a	89.17a	65.68a	67.69a	9.86a	10.85b	3.66a	3.58a
75 % of RR	78.32b	84.92b	63.65b	66.86a	9.72a	11.38a	3.25 b	3.33b
50 %of RR	67.25c	75.07c	53.16c	56.04b	9.03b	10.10c	3.08 c	3.08c
25 % of RR	54.77d	63.50d	46.84d	51.41c	9.00 b	9.54 d	2.41 d	2.50d
(m^3/fed.)	***Effect of biochar rates***							
0	63.80d	70.75d	51.05d	53.72d	7.96 d	9.33c	2.75 d	2.91c
1	69.20c	76.42c	56.39c	58.66c	9.35 c	10.23b	3.00 c	2.99bc
2	72.37b	80.75b	59.43b	63.43b	9.97 b	11.10a	3.16 b	3.16b
4	76.80a	84.75a	62.46a	66.19a	10.34a	11.22a	3.50 a	3.41a

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.
RR: Recommended rates of N, P_2o5 and K_2o were 120, 62 and 120 kg /fed., respectively.

Besides, Nitrogen is an significant protoplasm component. Enzymes, the biological catalytic agents that accelerate life processes, also have N as their main components (Mengel and Kirkby, 1978). Moreover, Potassium component is very essential in plant enzyme activity general metabolism, it has been discovered to serve a crucial function in photosynthesis by directly growing growth and leaf region. Potassium also has a positive impact on water use (Gardener *et al.*, 1985).

These results are harmony with those reported with Shaheen *et al*. (2007), Ezz El-Din *et al*. (2010), Allahdadi and Farzane (2018). They showed that nitrogen application in higher levels improved the growth of artichoke such as leaf length, number of leaves per plant, plant fresh weight and dry weight**.**

2. *Effect of biochar*

Treated globe artichoke plants with biochar at different rates had significant effect on all plant growth parameters compared to untreated

plants at 150 days after planting in both seasons (Table 1). The highest values of plant height, both fresh and dry weight of leaf and offshoots number /plant were recorded by 4 m^3/fed. of biochar, followed by treated plants with biochar at 2m^3/fed. of biochar in both seasons.

Biochar induced stimulation of plant growth and this can be ascribed to a change in microbial communities to positive plant growth supporting rhizobacteria or fungi as a consequence of either the biochar's chemical or physical characteristics (Elad *et al*., 2011). Also, biochar enhanced the dry weight of plants and this can be ascribed to the immediate impacts of the nutrients provided by biochar (Silber *et al*., 2010). These results are agree with Graber *et al*. (2010) on tomato , Carter *et al*. (2013) on lettuce and cabbage and Tahir *et al*. (2018) on spinach. They found that treating plants with biochar increased plant growth than untreated plants.

3. *Effect of the interaction*

The interaction between fertilizing globe artichoke plants with different rates of NPK as mineral fertilizers and treating with biochar had significant effect on all plant growth parameters at 150 days after planting in both seasons (Table 2).

Fertilizing plants with NPK at 100 % of RR and treated with biochar at 4 m^3/fed significantly increased plant height , leaf fresh weight and offshoots number / plant, in both seasons. Leaf dry weight significantly increased with NPK at 75 % of RR and biochar at 4 m^3/fed. in the 1st season and with 75 % of RR and 2m^3/fed. in the 2nd season.

The lowest values of all plant growth traits were recorded by NPK at 25 % of RR only in both seasons. These results are harmony with those reported with Hossain *et al*., (2020) on tomato. They showed that the interaction between biochar and NP and K recorded the highest values of plant height, number of branches and leaves / plant than NPK only.

Table 2. Effect of interaction between mineral fertilizers and biochar rates on vegetative growth parameters of globe artichoke plants during 2017/2018 and 2018/ 2019 seasons

Treatments		Plant height (cm)		Leaf fresh weight (g)		Leaf dry weight (g)		Offshoots No/ plant	
NPK rates	**Biochar m^3/ fed**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**	**1st season**	**2nd season**
100 % of RR	0	75.70e	81.30 d	59.93 e	61.34 e	8.98 gh	9.81 hi	3.33 c	3.33 bc
	1	80.00c	87.70 c	63.40 d	65.87 c	9.51d-g	10.59d-f	3.67 b	3.33 bc
	2	84.30b	92.00 b	68.79 b	70.20 b	10.38bc	11.23 c	3.67 b	3.67 ab
	4	87.30a	95.70 a	70.61 a	73.37 a	10.59ab	11.79 b	4.00 a	4.00 a
75 % of RR	0	71.50f	77.70 e	57.33 f	59.89 e	7.33 j	10.18f-h	3.00 d	3.00 cd
	1	77.60de	80.70 d	61.95 d	63.86 d	9.91 cd	10.86c-e	3.00 d	3.33 bc
	2	79.50cd	88.30 c	66.45 c	70.98 b	10.63ab	12.66 a	3.33 c	3.33 bc
	4	84.70b	93.00 b	68.90 b	72.73 a	11.02 a	11.83 b	3.67 b	3.67 ab
50% Of RR	0	62.30i	69.70 h	48.63 i	50.72 h	8.26 i	9.19 j	2.67 e	3.00 cd
	1	65.50h	74.30g	51.39 h	54.94 g	8.73 hi	9.89 g-i	3.00 d	3.00 cd
	2	68.70g	76.00 f	54.65 g	57.52 f	9.29 e-h	10.36e-g	3.00 d	3.00 cd
	4	72.50f	80.30d	57.98 f	60.98 e	9.87c-f	10.98cd	3.67 b	3.33 bc
25% of RR	0	45.70l	54.30k	38.33 j	42.95 i	7.28 j	8.16 k	2.00 g	2.33 e
	1	53.70k	63.00 j	48.83 i	50.00 h	9.27f-h	9.58 ij	2.33 f	2.33 e
	2	57.00j	66.70i	47.85 i	55.02 g	9.59 d-f	10.15f-h	2.67 e	2.67 de
	4	62.70i	70.00h	52.38h	57.70 f	9.88 c-e	10.30f-h	2.67 e	2.67 de

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.
RR: Recommended rates of N, P_2o_5 and K_2o were 120, 62 and 120 kg /fed., respectively.

Yield and its components

1. Effect of mineral fertilizers

The current data in Table 3 show that fertilizing globe artichoke plants with different NPK rates had significant effect on all yield and its components parameters in both seasons.

The maximum values of number of early heads/ plant, number of total heads/ plant, total yield / plant and total yield /fed. were obtained by the plants, which fertilized with NPK at 100 % of RR , followed by the plants which fertilized with NPK at 75 % of RR in both seasons. On the other hand, fertilizing plants with NPK at 25 % of RR recorded the minimum values of all yield parameters in both seasons. The increase in total yield was directly due to

Table 3. Effect of mineral fertilizers and biochar rates on yield parameters of globe artichoke plants during 2017/2018 and 2018/ 2019 seasons

Treatments	Number of early heads/ plant		No of total heads/ plant		Total yield / plant (kg)		Total yield (ton/fed.)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
	Effect of mineral fertilizer rates							
100 % of RR	3.20a	3.31a	10.33a	10.48 a	3.011 a	3.058a	11.842 a	12.235a
75 % of RR	2.99 b	3.14b	9.79b	9.93 b	2.866 b	2.875b	11.520 b	11.510b
50 % of RR	2.73 c	2.88c	7.59c	7.70 c	2.022 c	2.042c	8.100c	8.170c
25 % of RR	1.45 d	1.60d	7.42c	7.56 c	1.613 d	1.657d	6.515 d	6.630d
(m^3/fed.)	*Effect of biochar rates*							
0	2.28d	2.37d	7.86 d	8.00 d	2.046d	2.078d	8.185 d	8.315d
1	2.59c	2.72c	8.64 c	8.76 c	2.331 c	2.347c	9.258 c	9.390c
2	2.65 b	2.85b	8.92 b	9.08 b	2.435b	2.473b	9.525 b	9.895b
4	2.85a	2.99a	9.71a	9.83a	2.701a	2.733a	11.010a	10.945a

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.
RR: Recommended rates of N, P_2o_5 and K_2o were 120, 62 and 120 kg /fed., respectively.

the increase in plant growth (Tables 1), high head weight (Table 3) and then increased yield per plant and total yield /feddan.

The application of N P and K is very important for the adequate nutrients uptake and optimum plant growth resulting maximum yield with good quality. Whereas, nitrogen results in the highest vegetative growth characters and increases head yield. Potassium enhances the earliness and improves product quality and head characters (Saleh, 2003). These above results coincided with those found by Foti *et al*. (2005) ; Ezz El-Din *et al*. (2010) ; Saleh *et al*. (2016), Mohamed *et al*. (2017); Allahdadi and Farzane (2018). They showed that increasing N, P and K up to the highest rate recorded the highest yield and its components of globe artichoke**.**

2. Effect of biochar

It is clear from the data in Table 3 that treating globe artichoke plants with biochar at different rates had significant effect on yield and its components than untreated plants in both seasons. Number of early heads/ plant, number of

total heads/ plant, total yield/plant and total yield /fed. were significantly increased with increasing biochar application up to the highest rates ($4m^3$/fed.), followed by that plants which treated with $2m^3$ biochar/fed. While, untreated plants recorded the minimum values of all above parameters of yield in both seasons. The increases in total yield /fed. due to treated with $4m^3$/fed. biochar were about 34.51 and 31.62 than zero biochar in the 1st and 2nd seasons, respectively. The beneficial effects of biochar on plant productivity are related to the improvement of specific surface area, cation exchange capacity, bulk density, pH, water, and nutrients within the soil matrix (Thies and Rillig, 2009)

These results are in accordance with those reported by Vaccari *et al*. (2015) on tomato, Silva *et al*. (2017) on common bean, Trupiano *et al*., (2017) on lettuce Mostafa and Shaban (2019) on faba bean.

3.Effect of the interaction

It is evident from data presented in Table 4 that the interaction treatment between mineral NPK fertilizer rates and treating globe artichoke plants with biochar had significant effect on the components of yield in both seasons. The interaction between fertilizing plants with NPK at 100 % of RR and treating with biochar at 4 m^3/fed. gave the highest values of number of early heads/ plant , number of total heads/ plant , total yield / plant and total yield /fed. in both seasons , followed by the interaction between fertilizing plants with NPK at 75 % of RR and application with biochar at 4 m^3/fed. In both seasons. On the other hand the lowest values of all yield and its components parameters were recorded with fertilizing plants with 25 % NPK of RR only in both seasons.

The increase in total yield/fed., were about 45.45 and 41.46 % for the interaction between fertilizing with NP and K at 100 % of RR and fertilizing with biochar at $4m^3$/fed. and were about 34.54 and 31.34% for the interaction between 75 % of RR of NPK and fertilizing with biochar at $4m^3$/fed. over mineral NPK at 100 RR only in the 1st and 2nd seasons, respectively.

These results are harmony with those reported by Hossain *et al*., (2020) on tomato. They showed that, the interaction between biochar and NPK recorded the highest values of umber of flower clusters per plant, number of fruits per cluster, number of fruits per plant, the weight of individual fruit and yield per plant than the plants which treated with NPK mineral only.

Flower head quality

1. Effect of mineral fertilizers

Data presented in Table 5 show that, flower head quality, *i.e*. head fresh weight, head diameter, receptacle fresh weight, receptacle diameter and

Table 4. Effect of interaction between mineral fertilizers and biochar rates on yield parameters of globe artichoke during 2017/2018 and 2018/ 2019 seasons**.**

Treatments		No of early heads/ plant		No of total heads/ plant		Total yield / plant (kg)		Total yield (ton/fed.)	
NPK rates	Biochar m3/ fed	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
100 % Of RR	0	2.75e	2.80f	8.85e	9.06e	2.475e	2.520f	9.900e	10.080f
	1	3.18bc	3.25c	10.23cd	10.35cd	2.980cd	3.000d	11.070d	12.000d
	2	3.23b	3.42b	10.50bc	10.66bc	3.065c	3.150c	12.000c	12.600c
	4	3.66a	3.78a	11.75a	11.88a	3.525a	3.565a	14.400a	14.260a
75 % Of RR	0	2.63f	2.71f	8.46ef	8.58ef	2.370e	2.410g	9.480e	9.640f
	1	3.00d	3.12d	9.85d	10.00d	2.860d	2.850e	11.680c	11.400e
	2	3.11c	3.40b	9.98cd	10.14cd	2.945cd	2.940d	11.600c	11.760de
	4	3.24b	3.36bc	10.90b	11.00b	3.290b	3.300b	13.320b	13.240b
50% Of RR	0	2.39g	2.48g	7.15i	7.22i	1.860g	1.880j	7.440h	7.520h
	1	2.80e	2.95e	7.28i	7.36i	1.930g	1.950i	7.840gh	7.800h
	2	2.80e	2.99e	7.84gh	7.98gh	2.110f	2.140h	8.200g	8.560g
	4	2.95d	3.10d	8.11fg	8.27fg	2.190f	2.200h	8.920f	8.800g
25% Of RR	0	1.35j	1.50j	7.00i	7.16i	1.480h	1.505m	5.920j	6.020j
	1	1.40ij	1.59ij	7.22i	7.35i	1.555h	1.590l	6.440i	6.360ij
	2	1.47i	1.62hi	7.39hi	7.55hi	1.620h	1.665k	6.300ij	6.660i
	4	1.58h	1.72h	8.08fg	8.20fg	1.800g	1.870j	7.400h	7.480h

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

RR: Recommended rates of N, P_2o_5 and K_2o were 120, 62 and 120 kg /fed., respectively.

Table 5. Effect of mineral fertilizers and biochar rates on flower head quality parameters of globe artichoke during 2017/2018 and 2018/ 2019 seasons.

Treatments	Head				Receptacle					
	Fresh weight (g)		Diameter (cm)		Fresh weight (g)		Diameter (cm)		Thickness (cm)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
	Effect of mineral fertilizer rates									
100 %ofRR	290.7a	290.8a	9.23a	9.17a	55.98a	56.41a	6.13a	6.19a	3.08a	3.10a
75 %ofRR	291.8a	289.1a	9.19a	9.12a	55.91a	55.90a	6.10a	6.11a	3.06a	3.06a
50 %ofRR	266.0b	264.7b	8.45b	8.35b	51.02b	50.64b	5.56b	5.53b	2.82b	2.79b
25 %0fRR	217.1c	218.7c	6.83c	6.90c	41.65c	41.80c	4.53c	4.54c	2.32c	2.32c
(m^3/fed)	Effect of biochar rates									
0	257.8c	257.4c	8.12d	8.06d	49.27d	48.98d	5.36d	5.33d	2.67c	2.65d
1	265.5b	263.9bc	8.59b	8.32c	50.97c	50.78c	5.57c	5.56c	2.83b	2.80c
2	268.8ab	268.5ab	8.23c	8.49b	51.63b	51.96b	5.64b	5.68b	2.86b	2.88b
4	273.6a	273.7a	8.77a	8.66a	52.69a	53.02a	5.75a	5.80a	2.92a	2.95a

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.
RR: Recommended rates of N, P_2O_5 and K_2O were 120, 62 and 120 kg /fed., respectively.

receptacle thickness of globe artichoke plants significantly affected by different NPK rates than unfertilized plants in both seasons.

All flower head quality such as head fresh weight , head diameter , receptacle fresh weight, receptacle diameter and receptacle thickness significantly increased with increasing NPK up to the highest levels 100 % of RR, with no significant differences between 75 % NPK in both growing season, while fertilizing plants with the lowest level 25% NPK of RR recorded the lowest values of all flower head quality parameters in both seasons.

This mean that quality traits of globe artichoke plant increased with increasing the applied of NPK at the highest rates. These may be due to the importance of N,P and K on performance of multiple plant

enzyme functions, and its regulation the metabolite pattern of higher plants, ultimately changing metabolite concentrations (Marschner 2012).

These results are in a harmony with those of Ghoneim (2005), Allahdadi *et al.* (2016) and Mohamed and Ali (2016) on globe artichoke.

2. Effect of biochar

The data in Table 5 show that treating globe artichoke plants with biochar had a significant effect on all flower head quality traits than untreated plants in both seasons.

Treating plants with biochar at 4 m^3/fed. recorded the highest values of head fresh weight, head diameter, receptacle fresh weight, receptacle diameter and receptacle thickness, with no significant differences with biochar at 2m^3/fed. as for head fresh weight in both seasons. While, untreated plants with biochar gave the lowest values of all flower head quality parameters in both seasons.

In this respect, Lehmann *et al*. (2006) found that biochar addition may enhance the productivity of plants directly due to their nutrient content and release features or indirectly due to enhanced nutrient retention. In addition, biochar's ability to enhance the accessibility of water and soil retention characteristics (Sun and Lu, 2014).

These results are in harmony with those reported by Akhtar *et al*. (2014), Vaccari *et al*. (2015) on tomato, Paneque *et al*., 2016 on sunflower and Silva *et al*. (2017) on common bean and Hameeda *et al.* (2019) on tomato.

3. *Effect of the interaction*

It is clear from the data in Table 6 that, the interaction between fertilizing globe artichoke plants with NPK at 75 % of RR and treating with biochar at 4 m^3/fed. significantly enhanced all flower head quality such as head fresh weight, head diameter, receptacle fresh weight, receptacle diameter and receptacle thickness with no significant differences with the interaction treatment between fertilizing with NP and K at 100 % of RR and treating with biochar at 4 m^3/fed. in both seasons. On the contrary, the lowest values of all flower head quality were obtained by the interaction between 25 %NPK of RR and zero biochar in both seasons.

Table 6. Effect of interaction between mineral fertilizers and biochar rates on flower head quality parameters of globe artichoke during 2017/2018 and 2018/ 2019 seasons.

Treatments		Head				Receptacle					
		Fresh weight (g)		Diameter (cm)		Fresh weight (g)		Diameter (cm)		Thickness (cm)	
NPK rates	Biocharm3/ fed	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season	1st season	2nd season
100% OfRR	0	279.7bc	278.1ce	88.5cd	87.1ef	537.4c	531.7e	58.7c	58.1e	29.0c	28.7e
	1	291.3ab	289.8ac	93.6b	91.4bc	558.0b	559.4cd	61.2b	61.7cd	30.9b	30.5d
	2	291.9ab	295.5ab	90.0c	93.5ab	563.5b	578.2ab	61.7b	63.4ac	31.2b	32.0ab
	4	300.0a	300.1a	97.2a	95.0a	581.8a	587.2a	63.6a	64.4a	32.2a	32.8a
75% OfRR	0	280.1bc	280.9be	88.6cd	88.0de	535.5c	540.9e	58.2cd	57.9e	28.3d	28.1e
	1	290.3ab	285.0ad	93.0b	89.9cd	560.4b	555.6d	61.3b	60.6d	31.0b	30.7cd
	2	295.1a	289.9ac	90.0c	91.8bc	562.6b	567.3bc	61.5b	62.2bd	31.1b	31.5bc
	4	301.8a	300.9a	96.2a	95.3a	578.1a	584.5a	63.2a	63.9ab	32.0a	32.4a
50% OfRR	0	260.1d	260.4f	81.5f	81.6h	495.4e	496.0g	54.0g	54.0g	26.7e	26.8f
	1	265.1d	264.6ef	87.2de	83.5gh	510.8d	510.4fg	55.5f	55.1fg	26.6cd	28.0e
	2	269.1cd	268.1df	83.0f	84.8fg	515.5d	511.6f	56.3ef	55.9f	26.6cd	28.4e
	4	270.0cd	266.0ef	86.4e	84.2g	521.2d	513.5f	56.9de	56.6ef	28.9c	28.6e
25% OfRR	0	211.4e	210.2h	66.3h	66.0k	402.7h	400.8j	43.7j	43.5j	22.8g	22.4i
	1	215.3e	216.3gh	69.8g	69.2jk	411.6gh	413.7j	44.8j	45.0j	22.9g	23.0hi
	2	219.2e	220.5gh	66.3h	69.8j	423.6fg	421.6i	46.1hi	45.9hi	23.5f	23.4gh
	4	222.8e	228.0g	71.0g	72.1i	428.1f	433.9h	46.6h	47.5h	23.8f	24.2g

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

RR: Recommended rates of N, P_2O_5 and K_2O were 120, 62 and 120 kg /fed., respectively.

Chemical constituents

1. Effect of mineral fertilizers

Data in Table (7) revealed that, all chemical parameters of the receptacle; total and reducing sugars as well as inulin of edible part of globe artichoke differed significantly under the effect of NP and K treatments in the two growing seasons. Fertilizing plants with 100 % NPK of RR reflected the highest values of all measured chemical parameters, with no significant differences with NPK at 75 % of RR regarding reducing sugars in both seasons and inulin content in the 2nd season. While, the lowest values of all chemical constituents parameters were obtained by 25 % NPK of RR in both season. These results agree with those obtained by Mohamed *et al.* (2017) on globe artichoke.

2. *Effect of biochar*

Fertilizing globe artichoke plants with biochar at different rates had significant effect on all chemical parameters of the receptacle than untreated plants in both seasons (Table 7).

Fertilizing plants with biochar at 4 m^3/ fed. significantly increased total and reducing sugars percentage of edible part in both seasons as well as inulin percentage in the 1st season only, with no significant differences with biochar at 2 m^3/fed. as for reducing sugars (%) in both seasons and inulin content (%) in the 1st season.

On the other hand, untreated plants with biochar gave the lowest values of all chemical parameters of the receptacle in both seasons. Biochar may increase the quality by increasing photosynthesis and translocation of sucrose and organic acid to the receptacle that may contribute to a higher concentration gradient of sucrose in receptacle (Wang *et al*., 2014).

3. *Effect of the interaction*

Data in Table 8 show that, the interaction treatments between mineral NPK rates and biochar had significant effect on chemical parameters of the receptacle in both seasons.

Total sugars significantly increased with the interaction treatment between NPK at 100 % of RR and treated with biochar at 4 m^3/fed in both growing seasons. Reducing sugars and inulin (%) significantly enhanced with the interaction treatments between NP and K at 100 or 75% of RR and treated with biochar at 4 or 2m^3/fed. in both seasons.

Table 7. Effect of mineral fertilizers and biochar rates on chemical constituents of globe artichoke during 2017/2018 and 2018/ 2019 seasons.

Treatments	Total sugars (%)		Reducing sugars (%)		Inulin (%)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
	Effect of mineral fertilizer rates					
100 % of RR	5.90 a	4.98 a	3.55 a	3.41 a	2.03 a	1.89 a
75 % of RR	5.08 b	4.49 b	3.48 a	3.38 ab	1.93 b	1.83 a
50 % of RR	4.39 c	4.32 c	3.36 b	3.34 b	1.83 c	1.72 b
25 % of RR	3.80 d	3.38 d	2.79 c	2.80 c	1.73 d	1.66 b
(m^3/fed.)	Effect of biochar rates					
0	4.41 c	4.23 b	3.18 b	3.19 c	1.83 c	1.75 a
1	4.46 c	4.16 c	3.23 b	3.22 bc	1.86 bc	1.76 a
2	4.96 b	4.30 b	3.35 a	3.25 ab	1.90 ab	1.79 a
4	5.35 a	4.47 a	3.43 a	3.27 a	1.93 a	1.81 a

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.

RR: Recommended rates of N, P_2O_5 and K_2o were 120, 62 and 120 kg /fed., respectively.

Table 8. Effect of interaction between mineral fertilizers and biochar rates on chemical constituents of globe artichoke during 2017/2018 and 2018/ 2019 seasons.

Treatments		Total sugars (%)		Reducing sugars (%)		Inulin (%)	
NPK rates	Biocharm3/ fed	1st season	2nd season	1st season	2nd season	1st season	2nd season
100 % of RR	0	5.05 e	4.88 cd	3.41 bc	3.37 a-e	2.01 ab	1.87 ab
	1	5.62 d	4.92 bc	3.43 bc	3.40 a-e	2.03 ab	1.89 a
	2	6.20 b	5.02 ab	3.67 a	3.42 a-c	2.05 a	1.90 a
	4	6.74 a	5.12 a	3.71 a	3.45 a	2.06 a	1.93 a
75 % of RR	0	4.44 f	4.30 gh	3.37 c	3.34 c-e	1.89 de	1.80 a-d
	1	4.47 f	4.35 g	3.39 bc	3.36 b-e	1.90 c-e	1.82 a-c
	2	5.55 d	4.56 f	3.56 ab	3.41 a-d	1.95 b-d	1.85 ab
	4	5.87 c	4.75 de	3.62 a	3.43 ab	1.98 a-c	1.86 ab
50%of RR	0	4.11 h	4.65 ef	3.33 c	3.32 e	1.77 g-i	1.70 c-e
	1	4.20 gh	4.15 i	3.35 c	3.33 de	1.82 e-h	1.71 c-e
	2	4.33 fg	4.20 hi	3.37 c	3.35 b-e	1.85 e-g	1.74 b-e
	4	4.95 e	4.28 gh	3.41 bc	3.36 b-e	1.88 d-f	1.75 b-e
25% of RR	0	4.05 h	3.12 m	2.63 f	2.75 g	1.65 j	1.63 e
	1	3.56 j	3.25 l	2.75 ef	2.79 fg	1.71 ij	1.65 e
	2	3.77 i	3.42 k	2.82 de	2.82 fg	1.76 hi	1.67 de
	4	3.85 i	3.75 j	2.98 d	2.87 f	1.80 f-h	1.70 c-e

Values having the same alphabetical letter(s) did not significantly differ at the 0.05 level of significance, according to Duncan's multiple range test.
RR: Recommended rates of N, P_2o_5 and K_2o were 120, 62 and 120 kg /fed., respectively.

The interaction between NPK at 25 % of RR and untreated with biochar recorded the lowest values of total sugars , reducing sugars and inulin contents of the receptacle in both seasons.

Conclusively, it could be concluded that, under the same study condition, fertilizing globe artichoke plant with NPK at 100% of recommended rate equal 120 kg N, 62. Kg P_2O_5 and 120 kg K_2O respectively, and treating with biochar at 4 m^3/ fed. was the best treatment for enhancing growth characters and head quality under the same conditions when compared to the other studied treatments.

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تاثير إضافه الفحم النباتى ومعدلات مختلفه من التسميد الكيماوى على نمو ومحصول نباتات الخرشوف المنزرعة فى أرض رملية

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قسم بحوث البطاطس والخضر خضرية التكاثر – معهد بحوث البساتين- مركز البحوث الزراعية- جيزة - مصر.

أجريت تجربة حقلية خلال موسمى شتاء 2018/2017و2019-2018 بالمزرعة البحثية لمحطة بحوث البساتين بالقصاصين – محافظة الاسماعيلية – مصر وذلك لدراسة تأثير مستويات مختلفه من النيتروجين والفوسفور والبوتاسيوم (100، 75، 50 ، 25 %) من الموصى به والبيوشار بمعدل (0 ، 1، 2، 4 م^3/فدان) على النمو ، المحصول ، وجوده النورات للخرشوف النامى فى أراضى رملية.

اوضحت النتائج ان التفاعل بين تسميد نباتات الخرشوف بالنيتروجين والفوسفور والبوتاسيوم عند 100 % من الموصى به والبيوشار بمعدل 4 م^3/ فدان سجل زيادة معنوية فى إرتفاع النبات ، الوزن الطازج للورقة ، عدد الخلفات/نبات، أعلى القيم لعدد النورات المبكره / نبات ، عدد النورات الكلى / النبات ، محصول النبات الكلى ، المحصول الكلى للفدان ، نسبه السكريات الكليه فى التخت فى كلا الموسمين. بينما سجلت معامله التفاعل بين التسميد بالنيتروجين والفوسفور والبوتاسيوم عند 75 % من الموصى به والبيوشار بمعدل 4 م^3/ فدان زياده معنويه للوزن الجاف للورقه ، كل صفات الجوده فى النورات متمثلا فى الوزن الطازج للرأس، قطر النورة، الوزن الطازج للتخت، قطر وسمك التخت وبدون فروق معنويه مع معامله التفاعل بين التسميد بالنيتروجين والفوسفور والبوتاسيوم عند 100 % من الموصى به والبيوشار بمعدل 4 م^3/ فدان فى كلا الموسمين. علاوه على ذلك فقد ازداد معنويا كل من نسبه السكريات المختزله والانيولين بمعامله التفاعل بين التسميد بالنيتروجين والفوسفور والبوتاسيوم عند 100 أو 75 % من الموصى به والبيوشار بمعدل 2 أو 4 م^3/ فدان فى كلا الموسمين. على النقيض من ذلك ، فقد لوحظت أقل القيم لكل من صفات نمو النبات ، المحصول ومكوناته ، جوده النورات المكونات الكيمائيه فى تخت النباتات التى سمدت ب 25 % من الموصى به من النيتروجين والفوسفور والبوتاسيوم فى كلا الموسمين بدون اضافة بيوشار.

التوصية : من خلال هذه الدراسة نستخلص ان تسميد نباتات الخرشوف بمعدل 100 % من الموصى به والتى تعادل 120 كجم نيتروجين ، 62 كجم خامس أكسيد ا لفوسفور ، 120 كجم أكسيد بوتاسيوم ،على التوالى مع استخدام 4 م3/ فدان بيوشار كانت المعامله الافضل لزياده صفات المحصول وجوده النورات تحت الظروف المشابهه مقارنه بباقى المعاملات الاخرى.