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An Attempt to Reduce the Use of Potassium Fertilization in Jerusalem Artichoke Plants in Clay Soil

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ABSTRACT

A field experiment was carried out at the Experimental Farm of El-Gemmeiza, Agric. Res. Station, El-Gharbeya Governorate, Egypt , during 2019 and 2020 summer seasons,to study the effects of different rates of potassium treatments at 48, 72 and 96 kg/fad. K_2O as soil application and K_2O concentration treatments at 0,0.5 and 1.0% as foliar application and their interactions on growth, yield and tuber quality of Jerusalem artichoke Fuseau cultivar under clay soil**.**The interaction treatments of fertilizing Jerusalem artichoke with K_2O at 72 kg /fad. as soil application (SA) and spraying plants with K_2O at 1 % four times at 75, 90,105 and 120 days after planting had significantly increased on plant height , number of branches /plant,both fresh and dry weight of shoots/plant, N,P and K contents in shoots and its uptake, average tuber weight , yield / plant and total yield/faddan .While,the interaction treatment between K_2O at 96 kg /fad. as soil application and spraying plants with K_2O at 1% reflected a significant effect and increased total carbohydrates , inulin,K and dry matter percentages in tuber at harvest time compared with plants received K_2O at 48 kg /fad. as SA only in both seasons. Finally, under the same conditions, fertilizing Jerusalem artichoke with K_2O at72 kg/fad. as soil application and spraying plants with K_2O at 1% reduced the using of potassium fertilizer by 25% and increases in total yield about 9.89 and 6.91 % over fertilizing with 96 kg /fad. K_2O only in the 1^{st} and 2^{nd} seasons, respectively.

Keywords: Jerusalem artichoke, potassium soil and foliar application, yield and tuber quality

INTRODUCTION

The Jerusalem artichoke (Helianthus tuberosus L.) is a North American native that has been transferred to several nations for immediate usage and development, especially in terms of lower production costs and drought tolerance (Denoroy et al., 1996). The Jerusalem artichoke is utilized in a range of applications, including human nutrition, animal feed, and ethanol production.

Egypt's agriculture is largely reliant on high usage of chemical fertilizers, with much of it imported, resulting in daily increases in fertilizer costs, as well as the government's decision to stop subsidies on domestic fertilizers for farmers. Chemical fertilizer overuse, on the other hand, has detrimental effects on the agroecosystem and soil health, as well as human welfare, by diminishing productivity and raising environmental concerns. (El-Ramady *et al.*, 2018). Furthermore, excessive use of K chemical fertilizers has been found to be exceedingly inefficient, with potassium usage ranging from 70 to 80 percent. [Mani and Mondal , 2016).

Potassium is required for the creation and function of proteins, lipids, carbohydrates, and chlorophyll, as well as the maintenance of the salt-water balance in plant cells. (Marschner, 1995). Potassium improves the quality of many fruits' production properties such as colour, taste, consistency, and preservation by activating a variety of enzymes involved in plant development and vigour (Dhillon et al., 1999).

Fertilizing plants with potassium gave the highest values of plant growth, yield and quality (Mansour *et al.*, 2001, Tawfik *et al.*, 2003, Feleafel , 2004, Abd El – Rehim *et al.*, 2005, Ghoneim, 2005, El-Sharkawy, and El-Zohiri, 2007, Anwar *et al.* 2011, Abou El-Khair and Mohsen 2016, Moustafa *et al.* 2019, Abbass and Hussein 2020. Bogucka *et al.* 2021).

Foliar nutrients are ideally intended to provide a wide range of nutrients in instances where production is limited or non-existent due to inefficient or non-existent nutrient uptake from the soil. (Hiller, 1995). Heavy metal accumulation in tubers may result from the use of large amounts of fertilizers and soil amendments in Jerusalem artichoke production, which can later become hazardous in the soil environment. Most foliar deficits can be treated with foliar sprays, but if the nutrient is not mobile in the phloem, foliar sprays are ineffective in fixing tuber nutritional abnormalities. (Westennann, 2005). As a result, foliar nutrient feeding has become a standard practise in crop production to boost output and product quality (Roemheld and El-Fouly, 1999) In addition, by minimising the amount of fertiliser given to the soil, it reduces pollution and enhances nutrient use. (Abou-El-nour, 2002). In addition, foliar K treatments can boost output and tuber quality, especially in heavy clay soils where K is scarce. (Marchand and Bourrie, 1999)

Foliar spray of potassium caused significant increases in plant growth ,N,P and K contents and its uptake, yield and its quality than unsprayed (El-Bassiony 2006 on onion , Gomaa , 2007, El-Sirafy *et al.*, 2008,

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Hussein *et al.* 2012 on pepper, Salim *et al.* , 2014 on potato , Amjad *et al*. 2014 on tomato , Ismail *et al*. 2014 on garlic , Afzal *et al*., 2015 on tomato , Arisha *et al*., 2017 on garlic, Abd El-Gawad *et al*., 2017, Ewais *et al*., 2020 on potato and Goud and Kumar (2021) on strawberry.

The goal of this study is to see if foliar spraying with potassium sulphate can partially replace expensive potassium chemical fertilizer (potassium sulphate) and achieve high growth, best tuber yield, and quality in Jerusalem artichoke cultivated in clay soil.

MATERIALS AND METHODS

During two consecutive seasons of 2019 and 2020, a field experiment was conducted at El-Gemmeiza, Agric. Res. Station, El-Gharbeya Governorate, Egypt, to investigate the effects of different potassium rates (soil and foliar applications) on growth, yield, and tuber quality of Jerusalem artichoke Fuseau cultivar.

Some physical and chemical parameters of the experimental soil are presented in Table (1).

Table 1. shows the physical and chemical parameters of the experimental soil in 2019 and 2020 seasons

Season	OM (%)	Clay (%)	Silt (%)	Sand (%)	Texture class	E.C ds/m	pH	Available (mg/kg)		
								N	P	K
2019 season	1.52	50.58	37.82	11.60	Clay loam	1.77	7.82	38.82	6.30	354.1
2020 season	1.54	51.19	36.70	12.11		1.79	7.90	39.02	7.29	362.1

This experiment included nine treatments, which were the combinations between three rates of potassium as soil application (48, 72 and 96 kg K_2O/fad. and three levels of potassium as foliar application (spraying plants with water, 0.5 and 1.0 % K_2O). These treatments were arranged in a split plot design with three replicates, potassium soil application treatments were randomly assigned in the main plots, while potassium foliar application treatments were randomly distributed in the sub-plots

Tuber seed of Jerusalem artichoke cultivar (Fuseau) was obtained from Hort. Res. Instit. and sown on 17th and 21st April in the 1st and 2nd seasons , respectively at 50 cm apart. The experiment plot area was 18.9 m^2. It contains three ridges with 9 m in long and 70cm distance between each two rows ridge.

Potassium rates as soil application were added at 60, 90 and 120 days after planting , while potassium concentrations as foliar application were sprayed at 75, 90, 105 and 120 days after planting).

One ridge was used to measure the vegetative growth parameters and the other two ridges were leaved for yield determination and tuber quality. In addition, one row was left between each two experimental plots as a guard area to avoid the overlapping infiltration of soil or spraying application.

All the experimental units received 300 kg ammonium sulphate (20.6 % N) and 150 kg calcium super phosphate (15.5 % P_2O_5).One third of N and all P_2O_5 were added at soil preparation time. The rest of nitrogen fertilizers (two thirds) were applied at 45 and 70 days after planting.

The agricultural practices were carried out in accordance with the Ministry of Agriculture's advice for commercial production of Jerusalem artichoke.

Data recorded

1. **Plant growth**: Three plants from each experimental unit were taken randomly at 135 days after planting to determine plant height (cm) , number of branches per plant and shoot fresh weight (g) , also shoots dry weight (g)/plant was measured using dried fresh shoot/ plant at 70ºC till constant weight.
2. **Nitrogen, phosphorus and potassium contents:** N,P and K contents were determined in shoots in both seasons according to the methods described by A.O.A.C.(2016). Nitrogen, phosphorus and potassium uptake (mg/shoot) were calculated**.**
3. **Yield and its components:** At harvest time, 180 days after planting , number of tuber roots/ plant, average tuber root weight (g), tuber roots yield per plant (kg) and total yield (ton/ fad.).

4. Potassium use efficiency

$$\mathbf{KUE} = \frac{Y_k}{K_R} = \text{"kg tuber roots/one kg } K_2O\text{"}$$ (Janssen, 1998)

Where:

Y_k is yield as the particular K level , and K_R is the particular K rate.

5. Tuber quality:

Percentage of potassium was determined in both seasons according to the methods described by A.O.A.C. (2016).

Dry matter (%): it was determined by drying 100 g of grated tuber tissues at 105 ºC till constant weight, and then DM (%) was calculated.

Inulin contents: Tuber concentration of inulin was determined according to Winton and Winton (1985).

Carbohydrate percentage*:* It was determined colorimetrically in dry tuber following the methods described by A.O.A.C. (2016).

Statistical Analysis: Recorded data were subjected to the statistical analysis of variance according to Snedecor and Cochran (1980), and means separation were done according to Duncan (1958).

RESULTS AND DISCUSSION

Plant Growth

Effect of potassium rates as soil application (SA)

Results in Table 2 show that potassium application at 72 kg K_2O /fad., had a significant effect on plant height , number of branches /plant , both fresh and dry weight of shoots/ plant, followed by fertilizing with 96 kg K_2O/fad. of Jerusalem artichoke at 135 days after planting under clay soil in both seasons. On the contrary, fertilized plants with 48 kg K_2O/fad. gave the lowest values of abovementioned parameters of Jerusalem artichoke in both seasons .

The increases in dry weight of shoot/ plant were about 93.21 and 71.20.5% for K_2O treatment at 72 kg /fad. and 28.33 and 22.07 % compared with the treatments of 48 and 96 kg K_2O/fad. in the 1st and 2nd seasons, respectively.

These findings could be explained by the role of potassium in metabolism and a variety of other activities required to maintain and stimulate plant vegetative growth and development. Furthermore, K is involved in a variety of physiological and biochemical activities, including cell division and elongation, as well as the metabolism of carbohydrates and protein molecules. (Marschner, 1995).

These results are agree with those reported with Mansour, 2001, Tawfik *et al*., 2003, Anwar *et al.* 2011, Abou El-Khair and Mohsen 2016 and Moustafa *et al.* 2019 all on Jerusalem artichoke.

Table 2. Effect of potassium rates as soil and foliar application on plant growth of Jerusalem artichoke at 135 days after planting under clay soil in 2019 and 2020 seasons

Treatments	Plant height (cm)		Number of branches / plant		Fresh weight of shoots (g)		Dry weight of shoots (g)	
	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
SA	Effect of potassium rates as SA (kg K_2O /fad.)							
48	112.24 c	117.04 c	7.220 c	6.58 c	429.57 c	441.98 c	144.29 c	147.69 c
72	187.62 a	190.87 a	11.153 a	11.25 a	775.83 a	763.75 a	278.78 a	252.87 a
96	153.89 b	152.16 b	10.113 b	9.45 b	615.54 b	600.64 b	217.23 b	207.14 b
	Effect of potassium concentration as FA							
0	136.42 b	140.07 c	8.81 b	8.37 b	533.22 c	529.43 c	187.97 c	178.66 c
0.5 %	155.66 a	152.72 b	9.80 a	9.05 b	598.45 b	599.43 b	212.56 b	204.04 b
1.0 %	161.67 a	167.28 a	9.86 a	9.86 a	689.27 a	677.51 a	239.77 a	225.01 a

SA=Soil application , FA= foliar application
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.

Effect of K_2O concentration as foliar application (FA)

Different concentrations of K_2O at 0.5 or 1% as foliar application had significant effect on plant height , number of branches /plant , both fresh and dry weight of shoots/plant of Jerusalem artichoke than unsprayed plants at 135 days after planting in both seasons (Table 2).

Spraying plants with K_2O at 1 % significantly increased plant height, number of branches /plant, both fresh and dry weight of shoots/plant without any significant differences with 0.5% as for plant height and number of branches / plant in the 1st season.

The increases in shoot dry weight due to K_2O at 1% were about 27.56 and 25.54%, 13.08 and 14.20 % for K_2O at 0.5% compared with unsprayed plants in the 1st and 2nd seasons, respectively.

Foliar sprays with element nutrients have the following advantages: (1) application rates are much lower than for soil application, (2) uniform application is easy to achieve, and (3) response to the applied nutrient is almost instantaneous, allowing deficiencies to be corrected during the growing season. (Mortvedt *et al*., 1991).

These results were in coinciding with that obtained by El-Bassiony 2006 on onion , El-Sirafy *et al*., 2008, Salim *et al.* , 2014 Abd El-Gawad *et al*. 2017 and Ewais *et al*. 2020 on potato.

Effect of the interaction treatment

The interaction between K_2O as SA and K_2O as FA reflected a significant effect on all plant growth of Jerusalem artichoke in both seasons (Table 3). Treated plants with K_2O at 72 Kg/fad. and sprayed plants with K_2O at 1% recorded the highest values of each of plant height , number of branches /plant , both fresh and dry weight of shoots/plant of Jerusalem artichoke. These increases in shoot dry weight were about 123.81 and 98.28% for the interaction between K_2O at 72 kg/fad. as SA and K_2O at 1% as FA compared with fertilized plant with 48 kg K_2O only in the 1st and 2nd seasons, respectively.

The results are harmony with Ismail *et al.* (2014) who indicated that fertilization of garlic plants with 90 kg K_2O/ fed. as soil application and spraying with K at 3 cm^3/ L recorded the highest values of plant height, number of leaves and total dry weight/ plant than 120 kg K_2O only.

Table 3. Effect of interaction between potassium rates as soil and foliar application on plant growth of Jerusalem artichoke at 135 days after planting under clay soil in 2019 and 2020 seasons

Treatments		Plant height (cm)		Number of branches / plant		Fresh weight of shoots (g)		Dry weight of shoots (g)	
K_2O (kg /fad.) SA	K_2O (%) FA	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
48	0	106.82 e	108.78 e	6.90 c	6.58 cd	352.80 g	364.56 g	123.48 e	137.30 f
	0.5%	112.70 de	115.35 de	6.92 c	6.00 d	411.60 f	465.50 f	135.93 e	143.96 f
	1.0%	117.20 de	127.00 d	7.84 bc	7.84 c	524.30 e	495.88 e	173.46 d	161.80 e
72	0	121.90 d	130.14 d	8.82 b	7.18 cd	525.57 e	503.43 e	173.17 d	163.27 e
	0.5%	163.37 c	149.94 c	10.72 a	9.80 b	595.84 d	591.92 d	209.03 c	217.17 d
	1.0%	191.41 a	198.45 a	11.02 a	11.70 a	818.30 a	830.06 a	276.36 b	272.24 a
96	0	180.55 ab	181.30 b	10.74 a	10.72 ab	721.28 c	720.30 bc	267.25 b	235.40 c
	0.5%	190.90 a	192.86 ab	11.72 a	11.36 a	787.92 b	740.88 b	292.73 a	250.98 b
	1.0%	176.40 b	176.40 b	10.78 a	10.70 ab	725.20 c	706.58 c	269.50 b	240.98 bc

SA=Soil application , FA= foliar application
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.

N, P and K Contents and its Uptake by Shoots

Effect of potassium rates as SA

Treated Jerusalem artichoke plants with K_2O at 72 kg/ fad., as soil application under clay soil had significant effect on mineral contents in shoots, *i.e.*, N, P and K as well as N,P and K uptake by shoots at 135 after planting in both seasons, except P content in shoots in the 1st season, with no significant differences with the treatment of 96 kg K_2O /fad. respecting N and P in the 2nd season and K in both seasons (Table 4). N, P and K contents as well as N, P and K uptake by shoots were the highest with the treatment of K_2O as SA at 72 kg /fad. in both seasons. On the other hand, fertilizing plants with 48 kg K_2O/fad. only gave the lowest values of three mineral contents and its uptake by shoots in both seasons.

The increases in K uptake by shoots due to application of 72 kg K_2O/fad. were about 132.33 and 96.58 % than 48 Kg K_2O/fad. and 33.13 and 23.35 % compared with the application of 96 kg K_2O/fad. in the 1st and 2nd seasons, respectively.

Soil condition inducing K deficiency in crop plants are sandy, organic, leached and eroded soils (Fageria *et al*., 1997). Furthermore, K leaching, particularly in sandy soils, is a major contributor to poor K-use efficiency in farming systems. (Kayser and Isselstein, 2005). Foliar feeding is ideally suited to give several components in settings when nutrient uptake from the soil is inefficient or nonexistent, restricting productivity. (Hiller, 1995). Potassium, as a counter ion to H^+, is directly engaged in nutrient absorption through the process of phloem loading, therefore increasing the mineral content of plant leaf. (Marschner, 1995) .

These results are harmony with Abbass and Hussein (2020) who indicated that increasing K_2O fertilizer as soil application gave the highest percentage of potassium in leaves compared with control treatment.

Table 4. Effect of potassium rates as soil and foliar application on N,P and K contents and its uptake of Jerusalem artichoke shoots at 135 days after planting under clay soil in 2019 and 2020 seasons

	Contents (%)						Uptake (mg / shoots)					
Treatments	N		P		K		N		P		K	
	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
	Effect of potassium rates as SA (kg K_2O /fad.)											
48	2.19 c	2.30 b	0.342 a	0.341 b	1.63 b	1.70 b	3186.1 c	3418.7 c	495.79 c	505.80 c	2381.0 c	2528.4 c
72	2.59 a	2.52 a	0.358 a	0.361 a	1.98 a	1.96 a	7249.1 a	6387.9 a	998.00 a	914.67 a	5531.7 a	4970.5 a
96	2.36 b	2.43 a	0.347 a	0.357 a	1.90 a	1.93 a	5158.1 b	5057.4 b	760.27 b	742.57 b	4155.2 b	4029.3 b
	Effect of potassium concentration as FA											
0	2.20 c	2.33 b	0.339 b	0.344 b	1.75 b	1.75 c	4161.4 c	4201.3 c	643.59 c	619.43 c	3406.7 c	3189.1 c
0.5 %	2.42 b	2.38 b	0.347 ab	0.355 a	1.85 a	1.89 b	5282.0 b	4909.7 b	741.20 b	728.53 b	4029.6 b	3921.0 b
1.0 %	2.53 a	2.53 a	0.361 a	0.360 a	1.90 a	1.95 a	6149.7 a	5752.9 a	869.27 a	815.07 a	4631.5 a	4418.2 a

SA=Soil application , FA= foliar application

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.

Effect of K_2O concentration as FA

Spraying Jerusalem artichoke plants with K_2O at 0.5 or 1.0 % had significant effect on N, P, and K contents and its uptake in Jerusalem artichoke shoot compared to unsprayed plants in both seasons (Table 4).

The highest values of three mineral contents and its uptake by shoots were obtained by spraying plants with 1.0 % with no significant differences with 0.5 % as for P contents in both seasons and K content in the 1st season.

The increases in K uptake by shoot were about 35.96 and 38.54% for sprayed plants with K_2O at 1% and 18.28 and 22.95 % with K_2O at 0.5% compared with unsprayed plants in the 1st and 2nd seasons, respectively.

These results are agreement with those reported by Gomaa (2007) and El-Sirafy *et al.,* 2008) on potato. Which found that, N, P and K contents in shoots were significantly increased by foliar spray with K_2O than unsprayed plants.

Effect of the interaction treatments

The interaction between K_2O as SA and K_2O at FA reflected significant effect on of N,P and K contents and its uptake by shoot compared with treated plants with 48 kg/fad. K2O only in the two season (Table 5).

Table 5. Effect of interaction between potassium rates as soil and foliar application on N,P and K contents and its uptake of Jerusalem artichoke shoots at 135 days after planting under clay soil in 2019 and 2020 seasons

		Contents (%)						Uptake (mg / shoots)					
Treatments		N		P		K		N		P		K	
K_2O (kg /fad.) SA	K_2O (%) FA	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
48	0	2.08 d	2.25 d	0.332 b	0.329 d	1.51 e	1.54 e	2568.4 g	3117.6 e	410.0 f	455.0 f	1910.5 e	2130.3 f
	0.5 %	2.30 c	2.25 d	0.335 b	0.352 a-c	1.82 bcd	1.83 c	3017.6 f	3239.1 e	470.3 e	501.0 f	2283.6 e	2461.7 e
	1.0 %	2.22 cd	2.41 bc	0.352 ab	0.352 a-c	1.93 ab	1.89 bc	3972.2 e	3899.4 d	607.1 d	561.4 e	2948.8 d	2993.3 d
72	0	2.22 c	2.35 cd	0.346 ab	0.348 bc	1.68 de	1.71 d	3982.9 e	3836.8 d	580.1 d	574.7 e	3151.7 d	2987.8 d
	0.5 %	2.30 c	2.39 cd	0.343 ab	0.355 a-c	1.89 abc	1.96 ab	4807.7 d	5190.4 c	717.0 c	771.0 d	3950.7 c	4256.5 c
	1.0 %	2.82 a	2.65 a	0.368 a	0.368 a	2.02 a	2.01 a	7793.4 a	7214.4 a	1017.0 a	001.8 a	5582.5ab	5417.6 a
96	0	2.29 c	2.40 b-d	0.350 ab	0.347 c	1.99 ab	1.99 a	5933.0 c	5649.6 c	940.7 b	828.6 cd	5157.9 b	4449.1 c
	0.5 %	2.48 b	2.51 abc	0.365 a	0.366 ab	2.00 ab	2.01 a	8020.8 a	6299.6 b	1036.3 a	913.6 b	5854.6 a	5044.7 b
	1.0 %	2.74 a	2.55 ab	0.354 ab	0.364 a-c	1.70 cd	1.85 c	6683.6 b	6145.0 b	983.7 ab	882.0 bc	5363.1 b	4843.7 b

SA=Soil application , FA= foliar application

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.

The best interaction treatment for increasing N,P and K contents and its uptake by shoot were recorded with the interaction between fertilizing plants with 72 kg K_2O as SA and spraying plants with 1% K_2O in both seasons .

The increases in K uptake by shoot were about 192.20 and 154.30% for the interaction between K_2O at 72 kg /fad . as SA and sprayed plants with 1% K_2O compared with treatment of 48 kg /fad. as SA only in the 1st and 2nd seasons, respectively.

The results are harmony with Arisha *et al.* (2017) who showed that the interaction between potassium at 125 kg K_2O/fed. as soil application and spraying with K_2O at 0.5 % was the best treatment for enhancing N,P and K uptake of garlic plants.

Yield and its Components

Effect of potassium rates as SA

It is obvious from results presented in Table 6 that K_2O rates as SA had significant effect on yield and its components of Jerusalem artichoke in both season. Number of tuber / plant , average tuber weight, yield/ plant and total yield/fad. were increased by application of K_2O at 72 kg /fad., followed by 96 kg K_2O/fad. , while fertilizing plants with 48 kg /fad. K_2O gave the lowest values of all yield components' of Jerusalem artichoke and recorded the highest values of potassium use efficiency under clay soil conditions.

The increases in total yield were about 9.49 and 7.26 % for treatment of K_2O at 72 kg /fad. compared with fertilized plants with 96 kg /fad. as SA in the 1st and 2nd seasons, respectively.

The increase in total yield was directly due to the increase in plant growth (Table 2), high mineral uptake (Table 4) and high average tuber weight (Table 6). These gains could be attributed to the beneficial effect of potassium in pigment creation, photosynthetic activation, and carbohydrates assimilation in the tuber, which was the plant's most profitable component. (Hilman and Asandhi, 1987).

These results are similar with El-Sharkawy, and El-Zohiri (2007), Anwar *et al.* (2011), Abou El-Khair and Mohsen (2016), Moustafa *et al.* (2019) and Bogucka *et al.* (2021) on Jerusalem artichoke .

Table 6. Effect of potassium rates as soil and foliar application on yield and its components and potassium use efficiency of Jerusalem artichoke under clay soil in 2019 and 2020 seasons

Treatments	Number of tuber/ plant		Average tuber weight (g)		Yield / plant (kg)		Total yield (ton /fad.)		Potassium use efficiency (kg tuber / kg K_2O)	
	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
	Effect of potassium rates as SA (kg K_2O /fad.)									
48	37.48 b	38.02 c	48.70 c	47.96 c	1.824 c	1.822 c	21.836 c	21.565 c	455.06 a	449.26 a
72	39.94 a	40.99 a	52.50 a	52.30 a	2.097 a	2.144 a	24.795 a	25.367 a	326.72 b	335.61 b
96	37.82 b	39.24 b	50.56 b	50.37 b	1.912 b	1.973 b	22.644 b	23.649 b	249.11 c	258.87 c
	Effect of potassium concentration as FA									
0	37.84 b	38.68 b	49.60 c	48.91 c	1.877 b	1.888 b	22.323 c	22.563 c	332.09b	333.83b
0.5 %	38.72 a	39.82 a	50.56 b	49.96 b	1.960 a	1.992 a	23.222 b	23.706 b	344.51a	349.81a
1.0 %	38.67 ab	39.74 a	51.60 a	51.76 a	1.997 a	2.059 a	23.729 a	24.311 a	354.16a	360.11a

SA=Soil application , FA= foliar application

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.

Effect of K_2O concentration as FA

Presented results in Table 6 show that, spraying Jerusalem artichoke plants which grown in clay soil with K_2O at different concentrations had significant effect on number of tuber / plant , average tuber weight, yield / plant and total yield/fad. as well as potassium use efficiency than unsprayed plants in the both seasons.

Spraying plants with K_2O at 1 % significantly increased all yield and its components as well as potassium use efficiency with no significant differences with K_2O at 0.5% regarding number of tubers/ plant , yield / plant and potassium use efficiency in both seasons.

The increases in total yield were about 6.30 and 7.74 % for K_2O at 1% as FA and 4.03 and 5.06 % for K_2O at 0.5 % as FA compared with unsprayed plants in the 1st and 2nd seasons, respectively.

As for potassium use efficiency , the increases were about 6.65 and 7.87 % for K_2O at 1% as FA and 3.74 and 4.78 % for K_2O at 0.5 % as FA than unsprayed plants in the 1st and 2nd seasons, respectively.

The formation of Jerusalem artichoke tubers is influenced by the synthesis and accumulation of starch, because K influences cell division, tuberous root initiation and thickening, photosynthesis, carbohydrate formation, sugar translocations, mineral nutrients, and photosynthetic matter, as well as enzyme activity. (Byju and George, 2005).

These results are accordance with those reported with Hussein *et al.* (2012) on pepper, Salim *et al.* (2014) on potato , Amjad *et al.* (2014) on tomato, Afzal *et al.* (2015) on tomato, Abd El-Gawad *et al.* (2017), Ewais *et al.* (2020) on potato. They indicated that foliar spray of potassium caused significant increases in yield and its quality than unsprayed plants.

Effect of the interaction treatment

The interaction between the application of K_2O as SA at 72 Kg/fad. and K_2O as foliar spray at 1% had significantly increased yield and its components' , i.e., number of tubers / plant, average tuber weight, yield / plant and total yields/ fad in both seasons (Table 7).

The increases in total yield were about 9.89 and 6.91 % for the interaction between K_2O at 72 kg/fad as SA and sprayed plants with K_2O at 1 % over than fertilizing with 96 kg /fad. K_2O as SA only in the 1st and 2nd seasons, respectively.

Regarding potassium use efficiency , the same data in Table 7 indicate that, the maximum potassium use efficiency 462.65 and 459.14 kg / one unit K_2O were obtained with the interaction treatment between 48 kg /fad. K_2O as SA and spraying with K_2O at 1 % in the 1st and 2nd seasons, respectively.

Table 7. Effect of interaction between potassium rates as soil and foliar application on yield and its components and potassium use efficiency of Jerusalem artichoke under clay soil in 2019 and 2020 seasons

Treatments		Number of tuber/ plant		Average tuber weight (g)		Yield / plant (kg)		Total yield (ton /fad.)		Potassium use efficiency (kg tuber / kg K_2O	
K_2O (kg /fad.) SA	K_2O (%) FA	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
48	0	37.48 cde	38.58 cd	47.50 e	46.00 e	1.780 d	1.775 c	21.264 e	21.096 e	443.00a	439.50a
	0.5 %	38.02 cde	38.58 cd	48.30 e	47.00 e	1.836 cd	1.813 c	22.036 d	21.559 de	459.08ab	449.15a
	1.0 %	36.94 e	36.90 e	50.30 cd	50.90 c	1.858 cd	1.878 c	22.207 d	22.039 d	462.65a	459.14a
72	0	37.24 de	37.38 de	50.00 d	49.53 d	1.862 cd	1.839 c	22.221 d	22.069 d	308.63d	306.52d
	0.5 %	37.38 cde	39.86 bc	50.70 bcd	50.60 c	1.895 bc	2.017 b	22.542 d	24.203 c	313.08d	336.15c
	1.0 %	40.24 ab	41.86 a	53.50 a	53.40 a	2.153 a	2.235 a	25.810 a	26.220 a	358.47c	364.17b
96	0	38.80 bcd	40.08 bc	51.30 b	51.20 c	1.990 b	2.052 b	23.485 c	24.525 c	244.64ef	255.47e
	0.5 %	40.78 a	41.04 ab	52.70 a	52.30 b	2.149 a	2.146 ab	25.089 b	25.357 b	261.35e	264.14e
	1.0 %	38.84 bc	40.48 ab	51.00 bc	51.00 c	1.981 b	2.064 b	23.170 c	24.674 bc	241.36f	257.02e

SA=Soil application , FA= foliar application
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.

Tuber Quality

Effect of potassium rates as SA

The obtained results in Table 8 show that fertilizing Jerusalem artichoke plants with K_2O at 72 or 96 kg /fad. under clay soil had significant effect on total carbohydrates, inulin, K and dry matter percentages in tuber at harvest time than the treatment of K_2O at 48 kg /fad. in both seasons. Treated plants with K_2O at 96 kg /fad. significantly increased all tuber quality in both seasons with no significant differences with 72 kg /fad. as for K content and dry matter percentage in the 2nd season.

The increases in inulin contents in tuber were about 13.07 and 11.94 % for K_2O at 96 kg /fad. and 6.24 and 8.18 % for K_2O at 72 kg /fad. as compared to treated plants with K_2O at 48 kg /fad. in the 1st and 2nd seasons, respectively.

Potassium is the most abundant cation in plants, and it may play a role in cell ionic homeostasis. It also binds ionically to the enzyme pyruvate kinase, which is required for respiration and glucose metabolism. As a result, potassium plays a critical role in the plant's entire metabolism. In addition, Evans and Wildes (1971) reported that potassium is involved in a number of steps in protein synthesis.

These results are harmony with those reported by Tawfik *et al.* (2003) which found that the application of 96 kg K_2O / fed. increased, dry matter, tuber inulin and total carbohydrate. Also, Abbass and Hussein (2020) and Bogucka *et al.* (2021) came to similar results.

Table 8. Effect of potassium rates as soil and foliar application on tuber quality at harvesting time of Jerusalem artichoke in under clay soil 2019 and 2020 seasons

Treatments	Total carbohydrates(%)		Inulin(%)		K(%)		Dry matter(%)	
	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
Effect of potassium rates as SA (kg K_2O /fad.)								
48	16.60 c	16.70 b	10.10 c	10.38 c	1.87 b	1.95 b	19.47 c	19.66 b
72	17.23 b	17.08 b	10.73 b	11.23 b	2.01 b	2.06 a	22.36 b	22.62 a
96	18.36 a	18.18 a	11.42 a	11.62 a	2.20 a	2.14 a	24.06 a	23.17 a
Effect of potassium concentration as FA								
0	16.87 b	16.83 b	10.44 b	10.70 c	1.87 b	1.98 b	21.44 b	21.28 b
0.5 %	17.55 a	17.42 a	10.79 a	11.11 b	2.06 a	2.02 b	22.10 a	21.91 a
1.0 %	17.77 a	17.72 a	11.02 a	11.43 a	2.15 a	2.15 a	22.35 a	22.26 a

SA=Soil application , FA= foliar application
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.

Effect of K_2O concentration as FA

The obtained results in Table 8 indicate that spraying plants with K_2O at 0.5 or 1 % reflect a significant effect on total carbohydrates, inulin , K and dry matter percentages in tuber at harvest time compared to unsprayed plants in both seasons. However, spraying with 1 % significantly increased all above-mentioned parameters without any significant differences with K_2O at 0.5 % concerning total carbohydrates and dry matter in both seasons and inulin and K percentages in the 1st season .

The increases in inulin contents in tuber were about 3.35 and 3.83 % for K_2O at 0.5 % and 5.56 and 6.82 % for K_2O at 1.0 % as FA as compared to unsprayed plants in the 1st and 2nd seasons, respectively.

Potassium helps sugars and carbohydrates to translocate from leaves to tuber (George *et al.* ,2002).

These results are harmony with those obtained with Hussein *et al.* (2012) on pepper, Amjad *et al.* (2014) , Afzal *et al.* (2015) on tomato and Goud and Kumar (2021) on strawberry. They showed that the best quality was obtained by spraying with K_2O than unsprayed plants.

Effect of the interaction treatment

The obtained results in Table 9 indicate that the interaction treatment between K_2O at 96 kg /fad. as SA and K_2O at 1% as FA reflected a significant effect and increased total carbohydrates , inulin, K and dry matter percentages in tuber roots at harvest time than plants received K_2O at 48 kg /fad. as SA only in both seasons.

The increases in inulin contents in tuber were about 31.20 and 23.52 % for the interaction treatment between K_2O at 96 kg /fad. as SA and K_2O at 1% as FA compared with plants received 48 kg /fad. only in the 1st and 2nd seasons, respectively.

Table 9. Effect of the interaction between potassium rates as soil and foliar application on tuber quality at harvesting time of Jerusalem artichoke under clay soil in 2019 and 2020 seasons

Treatments		Total carbohydrates(%)		Inulin (%)		K (%)		Dry matter(%)	
K_2O (kg /fad.)SA	K_2O (%) FA	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season	2019 season	2020 season
48	0	16.16 d	16.14 d	9.85 e	9.86 f	1.77 d	1.91 d	18.56 d	18.92 d
	0.5%	16.70 cd	16.64 cd	9.97 e	10.43 e	1.89 cd	1.91 d	19.66 c	19.78 c
	1.0%	16.95 bc	17.33 bc	10.49 cd	10.85 d	1.95 cd	2.05 bcd	20.20 c	20.29 c
72	0	16.92 bc	16.79 bcd	10.45 d	11.02 cd	1.96 cd	2.00 cd	22.09 b	22.04 b
	0.5%	17.33 bc	17.02 bc	10.87 bcd	11.17 c	1.96 cd	2.03 bcd	22.50 b	22.90 a
	1.0%	17.44 bc	17.44 bc	10.88 bc	11.51 b	2.11 bc	2.17 ab	22.51 b	22.72 ab
96	0	17.55 b	17.56 b	11.03 b	11.22 c	1.89 cd	2.04 bcd	23.69 a	23.25 a
	0.5%	18.63 a	18.61 a	11.53 a	11.73 ab	2.33 ab	2.13 abc	24.16 a	23.12 a
	1.0%	18.92 a	18.39 a	11.71 a	11.93 a	2.40 a	2.25 a	24.35 a	23.37 a

SA=Soil application , FA= foliar application
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.

Similar findings were reported by Abou El-Khair *et al.* (2011) who indicated that fertilization of sweet potato with 100 % of recommended rate of K_2O as soil application or with 50 % recommended rate of K_2O as soil application combined with 3 % K_2O as foliar spray significantly increased N,P, K, starch, total sugars and TSS (%)in tuber roots compared to other treatments.

Generally, it could be concluded that under the same conditions, fertilized Jerusalem artichoke plants with potassium at 72 kg/fad. as soil application and sprayed with K_2O at 1% recorded the maximum yield and best quality of tuber.

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محاولة لتقليل استخدام التسميد البوتاسى فى نباتات الطرطوفة فى الارض الطينية

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أجريت تجربة حقلية خلال موسمي الصيف المتتاليين لعامى 2019 و 2020 بمزرعة الجميزة للبحوث الزراعية ، بمحافظة الغربية، مصر. لدراسة تأثير المعدلات المختلفة من التسميد البوتاسى عند 48 ، 72 ، 96 كجم / فدان بو2أ كإضافة أرضية والرش الورقى باستخدام بو2أ بتركيز 0, 0.5 و 1٪ على النمو الخضرى والمحصول وجودة الدرنات تابنلا الطرطوفة صنف فيوزا تحت ظروف الأرض الطينية. سجلت معاملة التفاعل بين تسميد نباتات الطرطوفة بـ بو2أ بمعدل 72 كجم / فدان كإضافة أرضية والرش الورقى بـ بو2أ بتركيز 1٪ أربع مرات بعد 75 ، 90 ، 105 ، 120 يومًا من الزراعة إلى زيادة معنوية في إرتفاع النبات وعدد الأفرع / النبات والوزن الطازج والجاف للمجموع الخضرى / النبات ومحتوي المجموع الخضرى من النيتروجين والفوسفور والبوتاسيوم والممتص منهم ، ومتوسط وزن الدرنات ، ومحصول النبات ، والمحصول الكلى للفدان من الدرنات . بينما سجلت معاملة التفاعل بين بو2أ عند 96 كجم / فدان كإضافة أرضية والرش الورقى بتركيز 1٪ من بو2أ تأثيرًا معنويًا وزيادة فى نسب الكربوهيدرات والأنيولين والبوتاسيوم والمادة الجافة في الدرنات عند الحصاد مقارنة بالنباتات التي تم تسميدها بمعدل 48 كجم / فدان من بو2أ فقط في كلا الموسمين. أخيرًا ، تحت نفس الظروف يمكن التوصية بالتسميد بـ بو2أ بمعدل 72 كجم / فدان كإضافة أرضية والرش منه بتركيز 1٪ حيث يؤدى الى تقليل استخدام سماد البوتاسيوم بنسبة 25٪ وزيادة في المحصول الكلي بحوالي 9.89 و 6.91٪ عن التسميد بـ بو2أ بمعدل 96 كجم / فدان فقط في الموسمين الأول والثاني ، على التوالي.