The Future of Biology

FSA

Article

Effect of Planting Date and Spraying with Different Potassium Sources on Growth, Productivity and Tuber Quality of Jerusalem Artichoke

Gahwash M.N.[1] and Enas A. Bardisi[2,*]

[1]Veg. Res. Dep., Hort. Res. Inst., Agric. Res. Center, Giza, **Egypt.**
[2]Hort. Dept. Fac. Agric. Zagazig University, **Egypt.**

[*]**Corresponding author:** enasbardisi@gmail.com

CrossMark

Future Science Association

Available online free at
www.futurejournals.org

Print ISSN: 2572-3006

Online ISSN: 2572-3111

DOI:
10.37229/fsa.fjb.2023.05.30

Received: 1 April 2023
Accepted: 10 May 2023
Published: 30 May 2023

Abstract: This experiment was carried out during two successive summer seasons of 2021 and 2022 at the private Farm in Basandela Village, Belqas, Dakahlia Governorate, Egypt (31° 20' 326.7" N and 31° 45' 286.0" E) to study the effect of planting date (planting on 15th April and planting in 15th May) and potassium fertilization sources (five potassium treatments, i.e., 100 % K_2O of the recommended rate (RD) equal 72 kg K_2O /fad. only as soil application (SA), 75 % K_2O RD (equal 54 kg K_2O /fad). and spraying with potassium humate (KH) at 3ml/l, 75 % K_2O RD and spraying with potassium citrate (KCit) at 1 ml /l, 75 % K_2O RD and spraying with potassium silicate (KSil) at 3 ml/l, and 75 % K_2O RD and spraying with thiosulpahte potassium (KTS) at 1 ml /l on plant growth as well as tuber yield and its quality of Jerusalem artichoke Feusa cultivar. Planting date on 15th May condition and fertilization Jerusalem artichoke plants with 75 % K_2O of the recommended rate (equal 54 kg K_2O/faddan) and spraying with KCit at1 ml/l or KSil at3 ml/l significantly increased number of main shoots/ plant, shoot dry weight , total chlorophyll concentration in leaf tissues, K contents and its uptake by shoots, total yield, potassium use efficiency, yield of inilne, P and K contents in tuber, total carbohydrates and dry matter contents, whereas planting date on 15th April and treating plants with the same fertilizers recorded the highest plant height and shoot fresh weight. Planting on 15th May and fertilization Jerusalem artichoke plants with 75 % K_2O of the recommended rate and spraying with KCit at 1 ml /l or KSil at 3 ml/l were the best treatments to increasing the productivity and improving the tuber quality characters, and these treatments recorded increases in total yield about 38.09 and 36.29 % as average two seasons than planting on 15th April and fertilizing with 100% K_2O only.

Key words: Jerusalem artichoke (*Helianthus tuberosus* L.), planting date, potassium sources, potassium use efficiency, tuber yield and inuline.

INTRODUCTION

Jerusalem artichoke (*Helianthus tuberosus* L.) is considered as an important non-traditional vegetable crop. It is a promising crop; It may play an important role in human nutrition as a source of protein, carbohydrates, vitamins, inulin and minerals. It also has a beneficial medical effect, especially for diabetic patients (**Puangbut, *et al*., 2012**). Also, Jerusalem artichoke can be used in food industry and important source for ethanol production. Moreover, the vegetative parts are used as integrated food for farm animals.

Under lengthy days and high temperatures, Jerusalem artichoke plants swiftly expanded vegetatively, but a low temperature and brief daytime harvest period are necessary for the creation of producing tubers (**Arslan, 1985**). Planting date of Jerusalem artichoke is practice which can increase tuber and biomass yield. Furthermore, planting date affects inulin content and yield [**Puangbut, *et al.* 2012**).

There were significant differences between two planting dates on growth , yield and tuber quality (**Arslan,1985, Alian and Attia,2011, Puangbut, *et al*., 2012, Ibrahim , 2017 and Mohamed, 2020**) on Jerusalem artichoke.

Potassium is a crucial nutrient for plant meristematic growth and physiological processes, such as enzyme activation, photosynthesis, protein synthesis and glucose translocation in plants. It also regulates water and gas exchange in plants. According to **Wang *et al*. (2013**), potassium has positive impacts on the metabolism of nucleic acids, proteins, vitamins, and growth factors as well as on energy transfer, phloem transport, cation-anion balance, and the ability of plants to fend off pests and diseases.

Potassium is heavily absorbed by horticultural crops, particularly during tuberlization filing stages. Banding, fertigation, or spraying liquid fertilisers onto the leaves are three methods of applying potassium fertiliser (**Magen, 2004**).

To increase crop production per unit area and make up for K-decreases in the soil brought on by crop uptake, Egyptian farmers utilized enormous quantities of K-chemical fertilisers (such as potassium sulphate or chloride). The high expense of these fertilisers also drives up manufacturing costs and contributes to environmental damage. In place of the pricey applied K-chemical fertilisers, natural potassium fertiliser and/or bio-fertilizer are cheap cost resources for supplying K to plants (**Labib *et al*., 2012**).

Fertilizing with potassium increased the plant growth , plant chemical constituents, yield and tuber quality of Jerusalem artichoke **(Feleafel , 2004, Ghoneim, 2005 , Anwar *et al*., 2011, Abou El-Khair and Mohsen 2016, Moustafa *et al*., 2019, Bogucka *et al*., 2021 and Mansour, and Abd El-Rahman 2021)**.

Due to the high cost of fertilizer materials, concerns over ground water quality, the availability of new formulations of compounds, newer surfactants that increase the efficiency of foliar absorption, etc., there is currently a lot of interest in foliar fertilization for vegetable crops. In addition, foliar feeding is a supplement nutrition with micro and macro elements . Foliar feeding is perfectly suited for situations when production may be constrained and nutrient uptake from the soil is either ineffective or nonexistent (Hiller, 1995). In order to increase crop yield and quality, foliar feeding of nutrients has thus become a standard practise in crop production (**Roemheld and El-Fouly, 1999**). It also minimises environmental pollution and improves nutrient utilisation by using less fertiliser in the soil (**Abou El-Nour, 2002**).

Foliar spray with different potassium sources such as potassium humate , potassium silicate, potassium citrate and potassium thiosulpahte increased plant growth, leaf pigments , K uptake by shoots , productivity and tuber qulity **(Abou El-Nasr and Ibrahim 2011** on carrot**, Salim *et al*., 2014 , Abd El-Gawad *et a*l., 2017** on potato **, Shaban *et al*., 2018** on carrot **, Moon *et al*., 2019** on sweet potato **, Sameh and Shama, 2019, Ewais *et al*., 2020** on potato**, Abo El-Fadel and Shama, 2020** on Jerusalem Artichoke **and Ali *et al*., 2021** on potato .

The aim of this research is to study the most appropriate planting date in light of the current climatic changes with the most suitable potassium fertilization rate and the best source for it in order to obtain a high yield of tubers and the best quality of Jerusalem artichoke.

MATERIAL AND METHODS

This experiment was carried out during two successive summer seasons of 2021 and 2022 at the private Farm in Basandela Village, Belqas, Dakahlia Governorate, Egypt (31° 20' 326.7" N and 31° 45' 286.0" E) to study the effect of planting date and potassium fertilization sources on growth, yield and tuber quality of Jerusalem artichoke cultivation cv. Feusa. The physical and chemical properties of experimental soil in the two seasons showed that it was silt clay in texture which had 1.79 and 1.69 % organic matter, 7.79 and 7.82 pH, 1.72 and 1.69 mmhos/cm EC, 0.89 and 0.86 ppm total N, 8.92 and 9.06 ppm available P and 230 and 242 ppm available K, respectively.

Table (1). Meteorological data at Dakahlia Governorate during the two growing seasons 2021 and 2022 seasons

Month	Temperature (°C)						RH%	
	Max.		Min.		Mean			
	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season
April	28.75	29.85	12.34	13.78	20.55	21.82	52.19	49.06
May	34.93	32.21	17.92	16.80	26.43	24.51	45.73	47.86
June	34.62	36.15	19.28	20.85	26.95	28.50	51.07	49.99
Joule	38.04	37.04	22.42	21.94	30.23	29.49	48.73	49.37
August	38.35	37.03	23.56	23.47	30.96	30.25	49.76	53.78
September	34.56	34.75	21.26	21.70	27.91	28.23	56.64	57.00
October	30.10	29.10	18.65	17.65	24.38	23.38	59.48	61.29
November	24.48	27.38	14.36	15.93	19.42	21.66	60.51	62.30
December	22.15	19.91	10.88	10.14	16.52	15.03	62.79	64.80

These data were obtained from the Central Laboratory for Agricultural Climate (CLAC).

This experiment included 10 treatments were the interaction between 2 planting date (planting on 15th April and planting on 15th May) and five potassium treatments, i.e. 100% K_2O (72 kg /fad. K_2O) as soil application only, 75% K_2O (54 kg /fad. K_2O and spraying with KH at 3 ml/l, 75% K_2O (54 kg /fad. K_2O) and spraying with KCit at 1 ml/l, 75% K_2O (54 kg /fad. K_2O) and spraying with KSil at 3 ml/l, and75% K_2O (54 kg /fad. K_2O) and spraying with KTS) at 1 ml /l.

These treatments were distributed in a split plot design with three replications. Planting dates were distributed in the main plot, while potassium treatments were distributed in the sub plot. The experimental unit area was 21 m^2. It contains three rows with 10 m length each and 70 cm distance between the 2 rows. One row was used to measure the morphological and chemical traits and the other two rows were used for yield determinations. Also, one row was left between each two units experimental as guard area to avoid the overlapping filtration and foliar spraying.

The tuber of Jerusalem artichoke was planted at 50 cm apart. Jerusalem artichoke seeds were obtained from Hort. Res. institute. Potassium sulphate (K_2SO_4) at different rates were added at three portions monthly beginning two months after planting,

Different potassium sources, potassium humate ((12 % K_2O) at 3ml/l, potassium citrate (36.5 %K_2O) at 1 ml/l, potassium silicate (10.6 % K_2O) at 3 ml/l and potassium thiosulpahte (36% K_2O and 25% sulfur) at 1ml/l were added as foliar spray into five times at 60, 80, 100, 120 and 140 days after planting

All the plots were fertilized with 300 kg ammonium sulphate (20.6 % N) and150 kg calcium super phosphate (15.5 % P_2O_5). One quarter of N and all P_2O_5 were added at soil preparation time. The rest of N fertilizer (three quarters) were added monthly at equal doses as soil application, where the first dose was started after two months form planting and was continued till flowering stage.

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

Data recorded

1. Plant growth: Three plants from each experimental unit were taken randomly at 150 days after planting to determine plant height (cm), number of main shoots/ plant, shoot fresh weight, and shoots dry weight (g)/plant was measured using dried fresh shoot/ plant at 70ºC till constant weight.

2. Biochemical characters

2.1. Photosynthetic pigments: Disc samples from the fourth upper leaf of the plant were taken randomly at 150 days after planting from every plot to determine chlorophyll a, b and total chlorophylls (a+b) and in both seasons according to the method described by **Wettestein (1957**).

2.2. According to A.O.A.C. (2000) protocols, potassium contents and uptake were measured in shoots 150 days after planting in both seasons, and potassium uptake (mg/shoot) was computed.

3. **Yield and its components**: At 240 days after planting: Number of tubers per plant, average tuber weight (g), yield per plant (kg), total yield (ton/fad.) were determined, and the yield of the inline/fad. was calculated by multiplied total yield (ton/fad.) x inline tuber percentage

4. Potassium use Efficiency (NUE): It was determined by dividing the yield/fad., by the potassium quantity/fad., and expressed as kg tuber /kg K_2O according to **Clark (1982**).

5. Tuber quality

5.1. Nitrogen, phosphorus, and potassium percentages were calculated in both seasons using the techniques outlined by A.O.A.C. (2000).

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

5.3. Inulin contents: inulin content in tubers was determined according to **Winton and Winton (1958**).

5.4. Carbohydrate percentage in dry tuber*:* It was determined according to A**.O.A.C. (1990**).

Statistical Analysis

The obtained data from this work were subjected to the statistical analysis of variance according to **Snedecor** and **Cochran (1980**), and means separation were done according to **Duncan (1955).**

RESULTS AND DISCUSSION

1- Plant growth

Effect of planting dates

Planting dates of Jerusalem artichoke had a significant effect on plant height, number of main shoots/ plant, fresh and dry weight of shoots at 150 days after planting (DAP) in both seasons (Table 2 to 5). Planting date on 15^{th} April increased plant height and fresh weight of shoots, except fresh weight of shoots in the 2^{nd} season, whereas, planting date on 15^{th} May increased number of main shoots/ plant and dry weight of shoot/ plant.

This means that planting on 15^{th} May increased number of main shoots/ plant (14.79 branches) and shoot dry weight (191.45 g) as average of two seasons.

This superiority may be attributable to the beneficial effects of high temperatures and long days during these times, which simulate plant metabolism and accelerate vegetative development, resulting in the storage of more metabolites in tubers. Such increments in studied morphological characters during early and late planting dates may be due to the suitable and prevalent metrological factors specially temperature (Table 1) which affect positively and increased the vegetative growth phase of plants, photosynthetic assimilation rate and duration of the period of plant growth. According to earlier studies, both temperate (**Kocsis *et al*., 2007a and b**) and tropical (**Pimsaen *et al*., 2010**) locations' temperatures have a significant impact on the growth of Jerusalem artichokes. Similar results were obtained by **Mohamed (2020**) on Jerusalem artichoke.

Effect of potassium sources

Treating with 100 % K_2O of the recommend rate (RD) and 75 % K_2O RD with different sources of potassium as foliar application, i.e., potassium humate (KH) at 3 ml /l , potassium citrate (KCit) at 1 ml/l, potassium silicate (KSil) at 3 ml/l and potassium thiosulpahte (KTS) at 1 ml/l reflect a significant effect on plant height, number of main shoots/ plant, shoot fresh weight and shoot dry weight at 150 DAP in both seasons (Tables 2 to 5). Fertilizing with 75 % K_2O RD with different sources of potassium as foliar application increased plant growth compared to fertilizing with 100 % K_2O (control) and 75 % K_2O with KSil gave the highest values of plant height, number of main shoots/ plant (16.86 branches), shoot fresh weight and shoot dry weight (221.96 g) as average two seasons.

These findings could be attributed to the role of potassium, an element important for numerous metabolic processes, including those that support and encourage vegetative growth and development in plants. The metabolism of carbohydrates and protein molecules, as well as cell division and elongation, are other physiological and biochemical processes that K plays a significant part in (**Marschner, 1995**). Similar results in general were recorded by **Abou El-Nasr and Ibrahim (2011) on** carrot**, Salim *et al*., (2014)** on potato, **Abou El-Khair and Mohsen (2016) and** Abd **El-Gawad et *al.* (2017**) on potato.

Effect of the interaction

Fertilizing Jerusalem artichoke with 75 % K_2O+ spraying with different sources of potassium increased plant growth comparing to 100 % K_2O only under two planting dates and the interaction between planting on 15th April and 75 % K_2O with KSil increased plant height and shoot fresh weight, whereas, the interaction between planting on 15th May and 75 % K_2O with KSil increased number of main shoots/ plant and shoot dry weight at 150 DAP in both seasons (Tables 2, 3, 4 and 5).

Table (2). Effect of planting date, potassium sources and their interactions on plant height (cm) at 150 days after planting of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
	2021 season					
15th April	203.33 e	223.33 c	243.33 a	243.33 a	238.33 b	**230.33 A**
15th May	200.00 f	205.00 e	212.00 d	222.67 c	210.00 d	**209.93 B**
Mean (B)	**201.67 E**	**214.17 D**	**227.67 B**	**233.00 A**	**224.17 C**	
	2022 season					
15th April	222.00 h	235.00 e	262.00 c	285.01 a	270.00 b	**254.80 A**
15th May	217.33 i	229.33 fg	232.00 ef	247.00 d	226.00 gh	**230.33 B**
Mean (B)	**219.67 D**	**232.17 C**	**247.00 B**	**266.01 A**	**248.00 B**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (3). Effect of planting date, potassium sources and their interactions on number of main shoots/ plant at 150 days after planting of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
	2021 season					
15th April	12.33 ef	13.33 d	13.00 de	15.67 ab	14.67 c	**13.80 B**
15th May	12.00 f	15.00 bc	15.67 ab	16.33 a	15.00 bc	**14.80 A**
Mean (B)	**12.16 D**	**14.16 C**	**14.33 BC**	**16.00 A**	**14.83 B**	
	2022 season					
15th April	10.78 f	15.11 c	11.00 f	14.78 cd	16.00 b	**13.53 B**
15th May	12.39 e	14.08 d	15.39 bc	17.03 a	15.09 c	**14.79 A**
Mean (B)	**11.58 D**	**14.59 B**	**13.19 C**	**15.90 A**	**15.54 A**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (4). Effect of planting date, potassium sources and their interactions on fresh weight of shoots / plant at 150 days after planting of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
	2021 season					
15th April	563.64 e	631.85 d	628.03 d	723.75 a	701.27 b	**649.71 A**
15th May	559.08 e	612.44 d	670.74 c	687.54 bc	626.04 d	**631.17 B**
Mean (B)	**561.36 E**	**622.15 D**	**649.39 C**	**705.65 A**	**663.66 B**	
	2022 season					
15th April	472.86 f	543.98 e	587.58 d	713.92 a	698.07 a	**603.28 A**
15th May	498.07 f	557.81 e	618.77 c	663.30 b	635.88 c	**594.77 A**
Mean (B)	**485.47 E**	**550.90 D**	**603.18 C**	**688.61 A**	**666.98 B**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (5). Effect of planting date, potassium sources and their interactions on dry weight of shoots/ plant at 150 days after planting of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
	2021 season					
15th April	133.42 f	161.66 e	207.11 c	212.30 bc	211.84 bc	**185.27 B**
15th May	154.04 e	195.11 d	216.54 ab	223.48 a	193.93 d	**196.62 A**
Mean (B)	**143.73 E**	**178.39 D**	**211.82 B**	**217.89 A**	**202.88 C**	
	2022 season					
15th April	142.03 g	160.48 f	191.07 d	204.82 c	208.70 bc	**181.42 A**
15th May	146.01 g	167.97 f	215.55 ab	220.45 a	181.44 e	**186.28 A**
Mean (B)	**144.02 E**	**164.23 D**	**203.31 B**	**212.64 A**	**195.07 C**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

2. Biochemical characters

Effect of planting dates

There were significant differences between two planting dates in chlorophyll a and total chlorophyll (a+b) in the leaf tissues, K contents and its uptake by shoots at 150 DAP in both seasons (Tables 6, 8, 9 and 10), whereas, there was no significant differences between them in chlorophyll b (Table 7). Planting on 15th May recorded maximum the concentrations of chlorophyll a and total chlorophylls (a+b) in the leaf tissues as well as K content and its uptake by shoots.

The response of plant vegetative development to the planting date was related to the influence of the planting date on K contents and its uptake. The prevailing temperature at the various sowing dates Table (1), which affects nutrient absorption and movement of it to different morphological regions, may be the cause of the variations in the concentration of K in shoot among the studied planting dates.

Effect of potassium sources

Foliar spray with different sources of potassium (KH, KSil, KCit, and KTS) + 75 % K_2O of the recommended rate increased the concentration of chlorophyll a, b and total chlorophyll in the leaf tissues compared to 100 % only and spraying with KCit+75 % K_2O gave the highest values of leaf pigments (chlorophyll a, chlorophyll b and total chlorophyll a+b), K content and its uptake by shoots at 150 DAP in both seasons (Tables, 6, 7 , 8, 9 and 10).

In the plant, potassium plays a number of significant regulatory roles. It is crucial for many processes that are required to support plant growth and reproduction, including protein synthesis, control of the ionic balance, regulation of plant stomata, maintenance of turgor, stress tolerance, water use, activation of plant enzymes, and many others (**Cakmak, 2005**). The effect of silicon on enhancing photosynthetic activity, which was correlated with leaf chlorophyll content, may be responsible for the effects of potassium, citrate, and silicate on chlorophyll concentrations of JA plants (**Adatia and Besford, 1986**). Foliar nutrition is ideally designed to provide many elements in conditions that may be limiting production at a time when nutrient uptake from the soil is inefficient or nonexistent (**Hiller, 1995**). Potassium silicate is considered as a rich source of potassium. Since potassium is directly involved in the nutrients absorption through the process of phloem loading as a counter ion to H^+ (**Komor *et al.*, 1980**) and so enhancing the mineral content of plant foliage. This results are agreement with **Abbass and Hussein (2020**) on Jerusalem artichoke, also, **Ali *et al.* (2021)** found that spraying potato with potassium citrate, gave the highest values of, N, P and K contents in shoot followed by potassium silicate.

Effect of the interaction

The interaction between planting on 15th May and 75 % K_2O with KCit increased chlorophyll a, b and total chlorophyll a+b in the leaf tissues as well as K contents in shoots and its uptake of Jerusalem artichoke at 150 DAP in both seasons (tables 6, 7 , 8, 9 and 10).

Table (6). Effect of planting date, potassium sources and their interactions on chlorophyll a (mg / gm DW) in leaf at 150 days after planting of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	**Mean (A)**
	2021 season					
15th April	2.47 f	2.65 e	2.83 cd	2.72 de	2.74 de	**2.68 B**
15th May	2.55 ef	3.01 bc	3.29 a	3.03 b	3.07 b	**2.99 A**
Mean (B)	**2.51 C**	**2.83 B**	**3.06 A**	**2.87 B**	**2.90 B**	
	2022 season					
15th April	2.66 d	2.76 d	2.77 d	2.66 d	2.78 d	**2.72 B**
15th May	2.63 d	3.12 c	3.53 a	3.27 b	3.22 bc	**3.15 A**
Mean (B)	**2.64 C**	**2.94 B**	**3.15 A**	**2.96 B**	**3.00 B**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (7). Effect of planting date, potassium sources and their interactions on chlorophyll b (mg / gm DW) in leaf at 150 days after planting of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	**Mean (A)**
	2021 season					
15th April	1.55 de	1.62 cd	1.69 abc	1.63 c	1.53 ef	**1.60 A**
15th May	1.46 f	1.75 a	1.73 ab	1.65 c	1.67 bc	**1.65 A**
Mean (B)	**1.50 D**	**1.68 AB**	**1.71 A**	**1.64 BC**	**1.60 C**	
	2022 season					
15th April	1.53 def	1.73 b	1.83 a	1.66 bc	1.48 ef	**1.64 A**
15th May	1.63 bcd	1.67 bc	1.58 cde	1.46 f	1.62 bcd	**1.59 A**
Mean (B)	**1.58 B**	**1.70 A**	**1.70 A**	**1.56 B**	**1.55 B**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (8). Effect of planting date, potassium sources and their interactions on total chlorophyll a+b (mg / gm DW) in leaf at 150 days after planting of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	**Mean (A)**
	2021 season					
15th April	4.02 e	4.27 d	4.52 c	4.35 d	4.27 d	**4.28 B**
15th May	4.01 e	4.76 b	5.02 a	4.68 bc	4.74 b	**4.64 A**
Mean (B)	**4.01 C**	**4.51 B**	**4.77 A**	**4.51 B**	**4.50 B**	
	2022 season					
15th April	4.19 g	4.49 e	4.60 d	4.32 f	4.26 fg	**4.37 B**
15th May	4.26 fg	4.79 bc	5.11 a	4.73 c	4.84 b	**4.74 A**
Mean (B)	**4.22 D**	**4.64 B**	**4.85 A**	**4.52 C**	**4.55 C**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (9). Effect of planting date, potassium sources and their interactions on K contents in shoots at 150 days after planting of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	**Mean (A)**
	2021 season					
15th April	2.42 d	2.43 d	3.70 a	2.82 c	2.84 c	**2.84 B**
15th May	2.26 d	3.27 b	3.82 a	3.37 b	3.23 b	**3.19 A**
Mean (B)	**2.34 D**	**2.85 C**	**3.76 A**	**3.09 B**	**3.03 B**	
	2022 season					
15th April	2.42 d	2.43 d	3.70 a	2.82 c	2.84 c	**2.84 B**
15th May	2.26 d	3.27 b	3.82 a	3.37 b	3.23 b	**3.19 A**
Mean (B)	**2.34 D**	**2.85 C**	**3.76 A**	**3.09 B**	**3.03 B**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (10). Effect of planting date, potassium sources and their interactions on K uptake by shoots at 150 days after planting of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
	2021 season					
15th April	3265 e	3928 d	7663 b	5987 c	6016 c	**5371 B**
15th May	3481 de	6380 c	8272 a	7531 b	6264 c	**6385 A**
Mean (B)	**3373 E**	**5154 D**	**7967 A**	**6759 B**	**6140 C**	
	2022 season					
15th April	3437 g	3900 f	7070 c	5776 d	5927 d	**5222 B**
15th May	3299 g	5493 e	8234 a	7429 b	5861 d	**6063 A**
Mean (B)	**3368 E**	**4696 D**	**7652 A**	**6602 B**	**5894 C**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

3. Yield and its components

Effect of planting date

Data in Tables 11 to 14 show that planting date of Jerusalem artichoke on 15th May recorded higher number of tubers/ plant (44.38), average tuber weight (48.18 g), yield / plant (2.21 kg) and total yield /fad. (24.83 ton) as average two seasons than planting date on 15th April. The increases in total yield due to planting on 15th May were about 13.25 and 3.63 % over planting on 15th April in the 1st and 2nd seasons, respectively.

The increments in total yield during late date may be due to the suitable prevalent metrological factors specially temperature (Table 1) which affect positively and increased the vegetative growth phase of plant. Also, such suitable metrological factors increased the total chlorophyll (Table 8) as well as K content and its uptake (Tables 9 and 10) and in turn increased total yield / fed). Whereas the early planting date on 15th April, resulted in the reduction of number of branches/ plant and dry weight of shoot that it may be due to the highest prevailing temperature during the vegetative growth period which increased the use of assimilated materials in respiration and consequently reduced the anabolic rate of new plant parts and in turn reduced plant growth.

This results were reported by **Arslan (1985), Alian and Attia (2011), Puangbut, *et al*. (2012), Ibrahim (2017) and Mohamed (2020**) on Jerusalem artichoke. They indicated that there were significant differences between planting dates on yield and its components.

Effect of potassium sources

The obtained results in Tables 11 to 14 indicate that fertilizing Jerusalem artichoke plants with 75 % K_2O and foliar spray with KCit or KSil increased number of tubers/ plant, average tuber weight, yield / plant and total yield / faddan compared to other treatments in both seasons and 100 % K_2O only gave the lowest values of yield and its components.

The relative increases in total yield due to fertilizing with 75 % K_2O and spraying with KCit were about 20.34 and 26.95 % and were about due to fertilizing with 75 % K_2O and spraying with KSil over fertilizing with 100 % K_2O only in the 1st and 2nd seasons, respectively.

The role of foliar application of different sources of potassium in increasing the yield and its components might be attributed to its function in plants which includes energy metabolism and enzyme activation that increase exchange rate and nitrogen activity as well as enhance carbohydrates movement from shoots to storage organs. Foliar application of potassium enhanced the stomata resistance coupled with reduced transpiration rate and increased relative water content, thus, may improve water storage capacity of the cells and providing favorable conditions for better yields (**Umar and Bansal 1995**). Foliar feeding of nutrients has become an established procedure in crop production to increase yield of crop products (**Roemheld** and **El-Fouly,1999**). Sprayed plants with potassium minimizes environmental pollution an improves nutrient utilization through reducing the amounts of fertilizers added to the soil (**Abou-El-Nour, 2002**).

Similar conclusions were obtained by **Moon *et al*. (2019)** on sweet potato, Sameh **and Shama (2019), Ewais *et al*. (2020)** on potato**, Abo El-Fadel and Shama, (2020) on** Jerusalem Artichoke and **Ali *et al*. (2021)** on potato. They mentioned that, foliar spray with different potassium sources such as potassium humate, potassium silicate, potassium citrate and potassium thiosulpahte increased yield and its components of sweet potato, potato and Jerusalem Artichoke.

Effect of the interaction

The interaction between planting date on 15th May and 75 % K_2O with KCit or with KSil significantly increased number of tubers/ plant, average tuber weight, yield / plant and total yield /fad. in both seasons (Tables 11, 12, 13 and 14). Fertilizing Jerusalem artichoke with 75 % K_2O with different sources of potassium (KH, KCit, KSil and KTS) increased yield and its components under the two planting dates (15th April and 15th May) compared to 100 % K_2O only under the same planting dates.

Table (11). Effect of planting date, potassium sources and their interactions on number of tuber/ plant at harvesting date of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
	2021 season					
15th April	38.26 f	42.71 d	44.60 abc	44.25 bc	43.69 cd	**42.70 B**
15th May	40.66 e	44.36 bc	45.78 a	45.34 ab	44.69 abc	**44.16 A**
Mean (B)	**39.46 D**	**43.53 C**	**45.19 A**	**44.79 AB**	**44.19 BC**	
	2022 season					
15th April	39.61 f	41.55 e	46.14 bc	47.23 a	44.14 d	**43.73 B**
15th May	41.83 e	42.08 e	46.87 ab	46.50 ab	45.78 c	**44.61 A**
Mean (B)	**40.72 D**	**41.81 C**	**46.50 A**	**46.86 A**	**44.96 B**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (12). Effect of planting date, potassium sources and their interactions on average tuber weight (g) at harvesting date of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
			2021 season			
15th April	40.73 f	45.97 d	47.61 bc	47.33 bcd	46.36 cd	**45.60 B**
15th May	42.87 e	47.34 bcd	51.47 a	52.05 a	48.50 b	**48.44 A**
Mean (B)	**41.80 C**	**46.65 B**	**49.54 A**	**49.69 A**	**47.43 B**	
			2022 season			
15th April	40.25 e	45.99 d	49.80 bc	49.09 bc	46.43 d	**46.31 B**
15th May	42.24 e	46.31 d	52.10 a	51.10 ab	47.93 cd	**47.93 A**
Mean (B)	**41.24 C**	**46.15 B**	**50.95 A**	**50.09 A**	**47.18 B**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (13). Effect of planting date, potassium sources and their interactions on yield / plant (kg) at harvesting date of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
			2021 season			
15th April	1.673 g	1.963 ef	2.079 cd	2.050 de	2.025 def	**1.950 B**
15th May	1.914 f	2.189 bc	2.356 a	2.360 a	2.257 b	**2.210 A**
Mean (B)	**1.793 D**	**2.076 C**	**2.217 A**	**2.205 AB**	**2.141 BC**	
			2022 season			
15th April	1.757 f	2.095 e	2.252 bcd	2.319 abc	2.327 ab	**2.150 A**
15th May	1.851 f	2.180 de	2.442 a	2.376 ab	2.194 cde	**2.208 A**
Mean (B)	**1.804 D**	**2.137 C**	**2.347 A**	**2.347 A**	**2.260 B**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (14). Effect of planting date, potassium sources and their interactions on total yield (ton/fad.) at harvesting date of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
			2021 season			
15th April	19.156 f	21.889 e	23.178 c	22.856 c	22.583 cd	**21.932 B**
15th May	21.938 de	24.506 b	26.273 a	26.312 a	25.164 b	**24.839 A**
Mean (B)	**20.547 D**	**23.198 C**	**24.726 A**	**24.584 A**	**23.874 B**	
			2022 season			
15th April	19.586 f	23.357 d	25.105 c	25.853 b	25.946 b	**23.969 B**
15th May	21.637 e	24.378 c	27.229 a	26.493 b	24.464 c	**24.840 A**
Mean (B)	**20.612 D**	**23.867 C**	**26.167 A**	**26.173 A**	**25.205 B**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

4. Potassium use efficiency (KUE)

Effect of planting date

Data in Table 15 indicate that planting date on 15th May gave higher KUE (439.81 kg tuber /1 kg K_2O as average of the two seasons) than planting date on 15th April.

Effect of potassium sources

Using 75 % K_2O as soil application with KCit or KSil as foliar application were the best treatments for increasing KUE (417.22 kg tuber/1 kg K_2O for KCit and 469.97 kg tuber/ 1 kg K_2O for KSil as average of the two seasons) compared to other treatments and 100 % K_2O only gave the lowest values of KUE (285.82 kg tuber/1 kg K_2O as average of the two seasons) as shown in Table 15.

Effect of the interaction

The highest values of KUE by Jerusalem artichoke plants were obtained from the interaction between planting date on 15th May and 75 % K_2O with KCit or KSil in both seasons (Table 15).

Table (15). Effect of planting date, potassium sources and their interactions on K use efficiency (kg tuber / kg K_2O) of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	**Mean (A)**
	2021 season					
15th April	266.05 f	405.35 d	429.22 c	423.26 c	418.20 c	**388.42 B**
15th May	304.69 e	453.81 b	486.54 a	487.26 a	466.00 b	**439.66 A**
Mean (B)	**285.37 D**	**429.58 C**	**457.88 A**	**455.26 A**	**442.10 B**	
	2022 season					
15th April	272.03 f	432.54 d	464.91 c	478.76 b	480.48b	**425.74B**
15th May	300.51 e	451.40 c	504.24 a	490.61 b	453.04c	**439.97A**
Mean (B)	**286.27 D**	**441.99 C**	**484.57 A**	**484.69 A**	**466.76B**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

5. Inuline content and yield

Effect of planting date

Data in Tables 16 and 17 illustrate that planting date on 15th May increased Inuline contents in tuber and Inuline yield / faddan in both seasons compared to planting date on 15th April. The increases in Inuline yield / fad. due to planting on 15th May was about 17.46 and 5.84 % over planting on 15th May in the 1st and 2nd seasons, respectively.

Planting date of Jerusalem artichoke is practice which can increase tuber and biomass yield. Furthermore, planting date affects inulin content and yield [**Puangbut, *et al*. 2012**). In this regard **Ibrahim (2017)** showed that Inulin contents of Jerusalem artichoke tubers significantly increased as late planting than early planting.

Effect of potassium sources

Potassium at 75 % K_2O of the recommend rate with KCit as foliar spray recorded maximum Inuline content in tuber and Inuline yield /faddan compared to other treatments (Tables 16 and 17).

The increases in Inuline yield / faddan concerning KCit as FA was about 38.74 and 44.69 % over that plants which fertilized with 100 K_2O only in the 1st and 2nd seasons, respectively.

Potassium silicate is considering as significant supplement of K, since potassium plays an important role in water status of plant, promoting the translocation of newly synthesized photosynthetics and mobilization of metabolites as well as promoting the synthesis of sugars and polysaccharides (**Mengel** and **Kirkby, 1982**).

Effect of the interaction

Under the conditions of planting dates on 15th April and 15th May spraying with potassium different sources (KH, KCit, KSil and KTS) with 75 % K_2O improved inuline content and inuline yield /fad. compared to 100 % K_2O only under the same plantings in both seasons (Tables 16 and 17). The increases in Inuline yield / faddan regarding the interaction between planting on 15th May and fertilizing with 75 % K_2O + spraying with KCit was about 61.88 and 62.18 % over that plants which planted on 15th April and fertilized with 100 K_2O only in the 1st and 2nd seasons, respectively.

Table (16). Effect of planting date, potassium sources and their interactions on inuline contents (%) in tuber at harvesting date of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
	2021 season					
15th April	9.53 f	9.83 e	11.23 a	10.30 cd	10.14 d	**10.20 B**
15th May	9.94 e	10.75 b	11.25 a	10.68 b	10.40 c	**10.60 A**
Mean (B)	**9.73 D**	**10.29 C**	**11.24 A**	**10.49 B**	**10.27 C**	
	2022 season					
15th April	9.76 f	9.83 ef	10.99 b	10.59 c	10.04 de	**10.24 B**
15th May	9.88 ef	10.14 d	11.39 a	10.71 c	10.19 d	**10.46 A**
Mean (B)	**9.82 D**	**9.98 C**	**11.19 A**	**10.65 B**	**10.11 C**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (17). Effect of planting date, potassium sources and their interactions on yield of inuline (ton/fad.) at harvesting date of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
	2021 season					
15th April	1.826 f	2.152 e	2.603 c	2.354 d	2.290 d	**2.245 B**
15th May	2.181 e	2.624 c	2.956 a	2.810 b	2.617 c	**2.637 A**
Mean (B)	**2.003 E**	**2.388 D**	**2.779 A**	**2.582 B**	**2.453 C**	
	2022 season					
15th April	1.912 h	2.296 f	2.759 bc	2.738 c	2.605 d	**2.462 B**
15th May	2.138 g	2.465 e	3.101 a	2.837 b	2.493 e	**2.606 A**
Mean (B)	**2.025 E**	**2.380 D**	**2.930 A**	**2.787 B**	**2.549 C**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Tuber quality

Effect of planting date

The obtained results in Tables 18 to 22 show that planting date on 15th May increased P, K, total carbohydrates in tubers as well as dry matter (DM%) compared to planting date in 15th April in both seasons.

This superiority may be attributable to the beneficial effects of high temperatures and long days during these times, which simulate plant metabolism and accelerate vegetative development, resulting in the storage of more metabolites in tubers. Results are harmony with those obtained with **Ibrahim (2017).** They reported that total carbohydrates content of Jerusalem artichoke tubers significantly increased as late planting date than early planting date.

Effect of potassium sources

Spraying Jerusalem artichoke plants which fertilized with 75 % K_2O and KCit or KSil gave the highest values of N, P, K and total carbohydrates as well as DM in tubers compared to the other treatments and 100 % K_2O only gave the lowest values as shown in Tables 18, 19, 20, 21 and 22.

Tuber formation of JA was positively affected by synthesis and accumulation of starch, since K plays a key role in this regard as it influences cell division, tuberous initiation and thickening, photosynthesis, formation of carbohydrates, translocations of sugars, mineral nutrients and photosynthetic matter and it also influences enzyme activity (**Byju and George, 2005**). Also, Potassium activates several enzymes especially in the metabolism of carbohydrates. The main effect of K_2O on carbohydrate, nitrogen and phosphorus percentages confirm that these percentages were raised as K_2O rate increased. Potassium percentage in plant leaves followed similar the above mention trend, but a significant linear relationship between increase in K_2O rate and increase in potassium percentage was detected **(Liu *et al.*, 2010)**.

These results are agreeing with those reported by **Abou El-Nasr and Ibrahim (2011), Shaban *et al.* (2018) on carrot, Moon *et al.* (2019)** on sweet potato and **Abo El-Fadel and Shama (2020) on** Jerusalem Artichoke.

Effect of the interaction

The interaction between 75 % K_2O and spraying with KCit or KSil increased N, P and K, total carbohydrates and DM in tubers in both seasons (Tables 18,19,20, 21 and 22).

Finally it could be concluded that, under planting on 15th May and fertilization Jerusalem artichoke plants with 75 % K_2O of the recommended rate (equal 54 kg K_2O/fad.) and spraying with potassium citrate at 1 ml /l or potassium silicate at 3 ml/l were the best treatments to increasing the growth , productivity and improving the tuber quality characters under the similar conditions of research, and these treatments recorded increases in total yield about 38.09 and 36.29 % as average two seasons than planting on 15th April and fertilizing with 100% K_2O only.

Table (18). Effect of planting date, potassium sources and their interactions on N (%) in tuber at harvesting date of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
	2021 season					
15th April	1.37 c	1.47 abc	1.64 ab	1.56 abc	1.54 abc	**1.51 A**
15th May	1.47 bc	1.53 abc	1.71 a	1.65 ab	1.60 abc	**1.59 A**
Mean (B)	**1.42 C**	**1.50 BC**	**1.67 A**	**1.60 AB**	**1.57 AB**	
	2022 season					
15th April	1.53 e	1.57 cde	1.67 ab	1.63 abcd	1.58 cde	**1.59 A**
15th May	1.55 de	1.59 bcde	1.68 a	1.71 a	1.65 abc	**1.63 A**
Mean (B)	**1.54 D**	**1.58 CD**	**1.67 A**	**1.67 AB**	**1.61 BC**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (19). Effect of planting date, potassium sources and their interactions on P (%) in tuber at harvesting date of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
	2021 season					
15th April	0.352 d	0.353 d	0.368 cd	0.365 cd	0.356 cd	**0.358 B**
15th May	0.361 cd	0.375 bc	0.404 a	0.392 ab	0.365 cd	**0.379 A**
Mean (B)	**0.356 B**	**0.364 B**	**0.386 A**	**0.378 A**	**0.360 B**	
	2022 season					
15th April	0.352 d	0.356 d	0.387 bc	0.385 c	0.355 d	**0.367 B**
15th May	0.356 d	0.364 d	0.401 ab	0.406 a	0.391 bc	**0.383 A**
Mean (B)	**0.354 C**	**0.360 C**	**0.394 A**	**0.395 A**	**0.373 B**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (20). Effect of planting date, potassium sources and their interactions on K (%) in tuber at harvesting date of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
	2021 season					
15th April	2.55 f	2.85 d	3.48 a	3.03 c	3.13 b	**3.00 B**
15th May	2.76 e	3.04 c	3.54 a	3.54 a	3.17 b	**3.21 A**
Mean (B)	**2.65 E**	**2.94 D**	**3.51 A**	**3.28 B**	**3.15 C**	
	2022 season					
15th April	2.71 g	2.89 f	3.33 c	3.13 de	2.81 fg	**2.97 B**
15th May	2.87 f	3.24 cd	4.04 a	3.67 b	3.07 e	**3.37 A**
Mean (B)	**2.79 E**	**3.06 C**	**3.68 A**	**3.40 B**	**2.94 D**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (21). Effect of planting date, potassium sources and their interactions on dry matter (%) in tuber at harvesting date of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	Mean (A)
	2021 season					
15th April	20.98 d	22.65 c	23.24 abc	23.70 a	22.94 bc	**22.70 A**
15th May	21.27 d	22.77 c	23.51 ab	23.89 a	23.34 abc	**22.95 A**
Mean (B)	**21.12 D**	**22.71 C**	**23.37 AB**	**23.79 A**	**23.14 BC**	
	2022 season					
15th April	21.20 c	21.62 c	23.09 b	23.56 ab	21.42 c	**22.17 B**
15th May	21.57 c	21.87 c	23.66 ab	23.91 a	23.45 ab	**22.89 A**
Mean (B)	**21.38 C**	**21.74 C**	**23.37 A**	**23.73 A**	**22.43 B**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Table (22). Effect of planting date, potassium sources and their interactions on total carbohydrates (%) in tuber at harvesting date of Jerusalem artichoke plants during 2021 and 2022 seasons

Planting date (A)	Potassium sources (SA) and (FA) (B)					
	100 % K_2O (SA) Control	75 % K_2O+ KH (FA)	75 % K_2O (SA) + KCit (FA)	75 % K_2O (SA) + KSli (FA)	75 % K_2O (SA)+ KTS (FA)	**Mean (A)**
	2021 season					
15th April	14.34 f	16.78 d	17.22 bcd	17.47 abc	15.79 e	**16.32 B**
15th May	16.88 cd	17.47 bcd	18.26 a	17.74 ab	17.63 ab	**17.59 A**
Mean (B)	**15.61 C**	**17.12 B**	**17.74 A**	**17.60 A**	**16.71 B**	
	2022 season					
15th April	14.83 f	15.96 e	17.07 bcd	16.90 cd	15.79 e	**16.11 B**
15th May	16.83 d	17.45 abc	17.85 a	17.87 a	17.71 ab	**17.54 A**
Mean (B)	**15.83 C**	**16.70 B**	**17.46 A**	**17.38 A**	**16.75 B**	

100 % K_2O= 72 kg /fad. K_2O ,75 % K_2O= 54 kg /fad. K_2O , SA= soil application , FA= foliar application , KH= potassium humate at 3 ml/l , KCit= potassium citrate (36 % K_2O) at 1 ml/l, KSli= potassium silicate 10.6 % K_2O at 3 ml/l and KTS= potassium thiosulphate (36.5 % K_2O) at 1 ml /l

Conclusion

Under Egyptian conditions and during summer plantations, it could be concluded that planting on 15th May and fertilization Jerusalem artichoke plants Feusa cultivar with 75 % K_2O of the recommended rate and spraying with KCit at 1 ml /l or KSil at 3 ml/l were the best treatments to increasing the productivity and improving the tuber quality characters.

REFERNCES

A.O.A.C. Association of Official Agricultural Chemists (2000). Official methods of analysis. 17 ed. Ed. A.O.A.C., Washington, Dc, USA.

Abbass, J. A. and Hussein, Q. M. (2020). Effect of Spraying Organic Fertilizer Extract, Potassium and Zinc Fertilizer on Growth and Yield of Jerusalem Artichoke *Helianthus tuberosus* L. and its Content of Inuline. Plant Archives, 20, 1: 137-149.

Abd El-Gawad, H.G.; Nashwa, A.I.A. and Hikal, M.S. (2017). Effect of Potassium Silicate on Tuber Yield and Biochemical Constituents of Potato Plants Grown Under Drought Stress Conditions. Mid. East J. Agric. Res., 6: 718- 731.

Abo El-Fadel, N. I. and Shama, M. A. (2020). Foliar Application of Glycine Betaine and Potassium Silicate and Its Effect on Growth Performance of Jerusalem Artichoke Grown on Calcareous Soil Under Water Stress Conditions, 25, 1: 14-37.

Abou El-Khair, E. E. and Mohsen, A. A. M. (2016). Effect of Natural Sources of Potassium on Growth, Mineral Uptake and productivity of Jerusalem Artichoke Grown in New Reclaimed Soil conditions. Middle East Journal of Agriculture Research, 5,3 : 367-377.

Abou El-Nasr, M. E. and Ibrahim, E. A. (2011). Effect of Different Potassium Fertilizer Rates and Foliar Application with Some Sources of Potassium on Growth, Yield and Quality of Carrot Plants (*Daucus carota* L.). J. Plant Production, Mansoura Univ., 2,4: 559 – 569.

Abou El-Nour, E.A.A. (2002). Can supplemented potassium foliar feeding reduce the recommended soil potassium? Pak. J. Biol. Sci., 5:259–262.

Adatia, M. H. and Besford, R. T. (1986). The Effects of Silicon on Cucumber Plants Grown in Recirculating Nutrient Solution. Ann. Bot. London, 58:343-51.

Ali, M.M.E.; Petropoulos, S.A.; Selim, D.A.H.; Elbagory, M.; Othman, M.M.; Omara, A.E.D. and Mohamed, M.H. (2021). Plant Growth, Yield and Quality of Potato Crop in Relation to Potassium Fertilization. Agronomy, 11, 675:1-16.

Alian, Fatma S. and Manal M. Attia (2011). Physiological Studies on Jerusalem Artichoke 1- Productivity and Quality of Jerusalem Artichoke in The New Reclaimed Lands. J. Plant Production, Mansoura Univ., 2,12: 1607 – 1617.

Anwar, R.S.M.; Awad, E. M. M. and Al-Easily, I. A. S. (2011). Effect of Different Rates of Nitrogen and Potassium Fertilization on Growth, Yield and Quality of Jerusalem Artichoke Plants Under Sandy Soil Conditions. J. Plant Production, Mansoura Univ., 2, 8: 983 – 993.

Arslan, N., (1985). Influence of Planting Time on The Tuber and Herbage Yield of (Helianthus tuberoses L.) Doga –Bilim – Deryisi, D2 Tarm-Ve- Ormanck, 912: 183-187.

Bogucka, B.; Pszczółkowska, A.; Okorski, A. and Jankowski, K. (2021). The Effects of Potassium Fertilization and Irrigation on the Yield and Health Status of Jerusalem Artichoke (*Helianthus tuberosus* L.). Agronomy, 11, 234: 1-24.

Byju, G. and George, J. (2005). Potassium Nutrition of Sweet Potato. Adv. Hort. Sci., 19:221-239.

Cakmak, I. (2005). The Role of Potassium in Alleviating Detrimental Effects of Abiotic Stresses in Plants. J. Plant Nutr. Soil Sci., 168: 521-530.

Clark, R.B. (1982). Plant Response to Mineral Element Toxicity and Deficiency. pp 71-142 in Breeding Plant for Less Facorable Environments, M.N. Christiansen and C.F. Lewis, Eds. John Wiley & Sons, Inc.

Duncan, D.B. (1955). Multiple rang and multiple F test. Biometrics, 11: 1-42.

Ewais M. A.; Abd El-Rahman, L. A. and Sayed, D. A. (2020). Effect of Foliar Application of Boron and Potassium Sources on Yield and Quality of Potato (*Solanum tuberosum* L.). Middle East J. Appl. Sci., 10,1: 120-137.

Feleafel, M.N. (2004). Effect of Nitrogen and Potassium Fertilization and their Interactions on Growth, Yield and Quality of Jerusalem Artichoke. J. Agric. & Env. Sci. Alex. Univ., Egypt. 3, 1:59-74-.

Ghoneim, I.M. (2005). Effect of Harvesting Dates and Potassium Fertilization Levels on Vegetative Growth Tuber Yield and Quality of Jerusalem Artichoke. J. Agric. Env. Sci., Alex. Univ.,4,2:37-63.

Hiller, K. L. (1995). Foliar Fertilization Bumps Potato Yields in Northwest. Rate and Timing of Application, Plus Host of Other Considerations, are Critical in Applying Foliars to Potatoes. Fluid Journal, 3,3: 29-30.

Ibrahim, N. M. (2017). Influence of Different Planting Dates in Both Summer and Fall Seasons on Growth and Yield on Jerusalem Artichoke Plants. Middle East J. Agric. Res., 6, 2: 252-263.

Kocsis, L.; Kaul, H.P.; Liebhard, P. and Praznik, W. (2007b). Influence of Harvest Date on Shoot and Tuber of Different of Jerusalem Artichoke (*Helianthus tuberosus* L.). Cultivars in the Semiarid Production Area of Austria. Ger. J. Agron., 11: 67-76.

Kocsis, L.; Liebhard, P. and Praznik, W. (2007a). Effect of Seasonal Changes on Content and Profile of Soluble Carbohydrate in Tubers of Different Varieties of Jerusalem Artichoke (*Helianthus tuberosus* L.). J. Agric. Food Chem, 55: 9401-9408.

Komor, E.; Rotter, M.; Waldhauser, J.; Martin, E. and Cho, B. H. (1980). Sucrose Proton Symport for Phloem Loading in The *Ricinus* seedlings. Ber. Deutsh. Bot. Ges., 93: 211-219.

Labib, B.F.; Ghabour, T.K.; Rahim, I.S. and Wahba, M.M. (2012). Effect of Potassium Bearing Rock on the Growth and Quality of Potato Crop (*Solanum tubersoum*). J. Agric. Biotech. and Sustain. Dev., 4,1: 7-15.

Liu, W.; Zhu, D.; Liu, D.; Lu, X. and Geny, M. (2010). Comparative Metabolic Activity Related to Flavonoid Synthesis in Leaves and Flowers of *Chrysanthemum morifolium* in Response to K Deficiency. Plant Soil, 335:325-337.

Magen, H. (2004). Potassium in Fertigation Systems. International Potash Institute (IPI), 5th Fertigation Training Course, Boading, AUH, June 2004

Mansour, F. Y.O. and Abd El-Rahman, L. A. (2021). An Attempt to Reduce the Use of Potassium Fertilization in Jerusalem Artichoke Plants in Clay Soil. J. of Soil Sciences and Agricultural Engineering, Mansoura Univ., 12, 9:603 - 610.

Marschner, H. (1995). Mineral Nutrition of Higher Plants. 2nd ed., Academi Press. Harcourt Brace. Jovanovich Publisher, pp. 674.

Mengel, K. and Kirkby, E. A. (1982). Textbook of Principles of Plant Nutrition. 3rd ed. P. 655. Inter. Potash Inst., Bern, Switzerland.

Mohamed, H.E. (2020). Effect of Tuber Cutting and Planting Date on Yield and Quality of Jerusalem artichoke in New Reclaimed Soil under Upper Egypt Conditions. Middle East J. Agric. Res., 9, 4: 943-947.

Moon, J.; Min, B.; Shin, J.; Choi, Y.; Cho, H.; Lee, Y.; Min, S. and Heo, J. (2019). Influence of Foliar Fertilization with Monopotassium Phosphate on Growth and Yield of Sweet Potato (*Ipomoea batatas* L.). Korean J. Soil Sci. Fert., 52,3: 217-225.

Moustafa, Y. M.M.; Maraei, R.W. and Ezzat, A. S. (2019). Performance, Yield and Sugar Composition of Jerusalem Artichoke (*Helianthus Tuberosus* L.) Grown under the Middle Egypt Conditions. 9th International Conference for Sustainable Agricultural Development 4-6 March 2019 Fayoum J. Agric. Res., & Dev., 33, 1B:801-812.

Pimsean, W.; Jogloy, S.; Surihan, B.; Kesmala, T.; Pensuk, V. and Patanothai, A. (2010). Genotype by Environment (Gxe) Interaction for Yield Components of Jerusalem Artichoke (*Helianthus tuberosus L.)*. Asian Journal of Plant Sciences, 11: 11-19.

Puangbut, D.; Jogloy, S.; Vorasoot, N.; Srijaranai, S.; Kesmala, T.; Holbrook, C.C. and Patanothai, A. (2012). Influence of Planting Date and Temperature on Inulin Content in Jerusalem Artichoke (*Helianthus tuberosus* L.). Australian Journal of Crop Science, 7: 1159-1165.

Puangbut, D.; Jogloy, S.; Vorasoot, N.; Srijaranai, S.; Kesmala, T.; Holbrook, C.C.; Patanothai, A. (2012). Influence of Planting Date and Temperature on Inulin Content in Jerusalem Artichoke (Helianthus tuberosus L.). Aust. J. Crop Sci., 6, 1159–1165.

Roemheld, V. and El-Fouly, M. M. (1999). Foliar Nutrient Application Challenge and Limits in Crop Production. Proceedings of the 2nd International Workshop on Foliar Fertilization, Bangkok, Thailand, 4-10.

Salim, B.B.M.; Abd El-Gawad, H.G. and Abou El-Yazied, A. (2014). Effect of Foliar Spray of Different Potassium Sources on Growth, Yield and Mineral Composition of Potato (*Solanum tuberosum* L.). Middle East J. Appl. Sci., 4,4: 1197-1204.

Sameh A.M.M. and Shama, M. A. (2019). Mitigation the Adverse Effects of Irrigation Water Salinity on Potato Crop Using Potassium Silicate Foliar Application. Middle East J. of App. Sci., 9,3: 804-819.

Shaban, Kh. A.; Mahrous, M. S.; Abdel-Azeem, S. M. and Rashad, R. T. (2018). Effect of Different Sources of Potassium on the Nutrient Status of Saline Calcareous Soil and Carrot (*Daucus carota* L.) Yield and Quality. Asian Journal of Soil Science and Plant Nutrition, 3(3): 1-14.

Snedecor, G.W. and Cochran, W.G. (1980). Statistical Methods.7th ed., Iowa State Univ., Press, Ames., Iowa, U.S.A.

Wang, M.; Zheng, Q.; Shen, Q. and Guo, S. (2013). The Critical Role of Potassium in Plant Stress Response. Inter. J. Molecular Sci., 14, 4:7370–7390.

Wettestein, D. (1957). Chlorophyll. Lethale under submikroskopische formwechsel der plastiden. Exptl. Cell Reso., 12:427-506.

Winton, A. L. and Winton, K. B. (1958). The Analysis of Food. Johan Wiley and Sons, Inc. London, P.857.