Effect of Calcium Chloride, Potassium Humate and Fulvic Acid on Growth and Productivity of Jerusalem Artichoke (*Helianthus tuberosus* L.) under Water Stress.

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ABSTRACT

This study was carried out to investigate the impact of adding potassium humate and fulvic acid to the soil and spraying calcium chloride under various irrigation levels on the growth,productivity and the chemical content of Jerusalem artichoke tubers during the two successive summers of 2020 and 2021 at a private farm in El-Kaluobia Governorate, Egypt. This study included three irrigation treatments (100 %, 80 % and 60 % of evapotranspiration (ETp) in the main plots), adding potassium humate (2000 and 3000 ppm) and fulvic acid (2000 and 3000 ppm) to the soil and foliar application of calcium chloride (500 and 1000 ppm) to the plantsin the sub plots. The results showed that irrigation levels of 100% followed by 60% (ETp) increased growth and yield. Furthermore, the soil addition of potassium humate at 3000 ppm and fulvic acid at 2000 ppm produced the highest plant height, number of lateral shoots, fresh and dry weight, total yield, average tuber weight, dry matter and inulin content. The best interaction resulted in significantly increased growth, yield, and its components when fulvic acid was present at 2000 ppm under 60% (ETp) and potassium humate at 3000 ppm under 100% (ETp). The study recommended the ground application of fulvic acid at 2000 ppm under 60% (ETp) since, it significantly improved the studied traits and was effective in saving water consumption by 40% of the recommended amount, when planting Jerusalem artichoke.

Key words: Jerusalem artichoke, Potassium Humate, Fulvic acid,Calcium Chloride,Tuber yield.

INTRODUCTION

Jerusalem artichoke (*Helianthus tuberosus* L.) originally belongs to the Astreacea family. Whereas an important tuberous plant for healthy food, the tubers are used for a variety of uses, including human feeding, medical, and industrial (Meijer and Mathijssen 1993). It is suitable for diabetics because it strengthens immunity, lowers blood cholesterol, and improves calcium absorption (Panchev et al., 2011).

Water stress is the most significant biotic environmental stress that the main problem affecting agricultural production in these circumstances is the loss of irrigation water, which has a significant negative impact on crop water use efficiency and crop water content, resulting in low net photosynthesis, slowing growth, and reduced yield of stored roots in sweet potatoe (Van Heeden and Laurie, 2008 and Yooyongwech et al., 2016).

The positive effects of potassium humate on plant growth may be attributed to either their direct or indirect improvements in plant biomass and fertilizer efficacy. Potassium humate raises plant and product quality as well as their resistance to pests, disease, salinity, heat, and drought stress (Khordhidi et al., 2009).Eid (2013) and Samy et al., (2015) observes that humic acid increased the yield of tubers and the weight of the fresh and dry Jerusalem artichoke shoots. An alternative strategy for increasing crop production and maintaining soil fertility is the beneficial effects of organic amendments or plant biostimulants based on humic substances (Canellas et al., 2015). Morever, Fahmi et al., (2020) on wheat showed that irrigation level at 100% (ETc.) potassium humate treatment recorded the highest values of plant growth and yield.

Fulvic acid catch water molecules, keeping the soil moist and facilitating nutrient uptake by plant roots.Fulvic acid can directly deliver these nutrients to plants, making it easy for it to bind or chelate minerals like iron, calcium, copper, zinc and magnesium (Yamauchi et al., 1984). Additionally, it increased photosynthesis, decreased stomata opening status and transpirations, which stimulated growth and decreased water loss (Li et al., 2005). Moreover, it increased soil microbial activity, plant growth, yield quantity, quality, controlled powdery and downy mildews on cucumber plants (Kamel et al., 2014). According to Aggag et al., (2015) and El-Helaly (2018) fulvic acid effectively increases the physiological activities and yield production of tomato plants by acting as antitranspirants and conserving soil water, which lowers the applied water by 25% of irrigation water. Furthermore, Abd El-Baky (2020) demonstrated that the application of fulvic acid significantly affected the fresh and dry weight of Okra leaves. Decreased irrigation intervals from 7 to 3 days significantly increased root fresh weight/plant of Sugar Beet

Calcium signaling also regulates stomatal closure by triggering ion outflow from guard cells and lowering the volume of the guard cells (Roelfsema et al., 2012). Undoubtedly, CaCl2 has been shown to improve stress tolerance in numerous reviews (Upadhyaya et al., 2011; Xu et al., 2013). Plants with calcium deficiencies are therefore more susceptible to pathogens and osmotic stress; calcium status influences plant profitability and tolerance to both biotic and abiotic stresses (Knight, 2000). According to Suejin et al., findings.'s in 2020, viola's stomata closed as a result of osmotic treatment with a high concentration of CaCl2, reducing water loss and extending shelf life under water deficit stress.

The purpose of this study was to evaluate the applying of potassium humate, fulvic acid, and calcium chloride under irrigation at 100%, 80%, and 60% (ETp) on Jerusalem artichoke growth, productivity, quality characteristics of tubers and inulin content in sandy soil.

MATERIALS AND METHODS

This work was carried out on Jerusalem artichoke (*Helianthus tuberosus* L.), at the Orabi Association Farm in the El-Kaluobia Governorate, (private farm). Tubers from a local cultivar were used during the two growing seasons in 2020 and 2021, to investigate how different irrigation levels affect tuber growth, yield and its components as well as chemical composition, the study used potassium humate, fulvic acid and calcium chloride.The physical and chemical characteristic of the soil are shown in Table (1).

Table (1).Physical properties of the experiment soil.

Parameter	**Value**
Particle size distribution (%):	
Clay %	4.43
Silt %	6.82
Fine sand %	38.75
Coarse sand %	50.0
Texture class	**Sandy**

Water parameters and bulk density

Depth	**Field capacity (FC)**		**Wilting Point (WP)**		**Available water (AW)**		**Bulk density (BD) gm./cm^3**
	% by weight	**cm**	**% by weight**	**cm**	**% by weight**	**cm**	
0-15	12.2	28.7	2.3	5.4	9.9	23.3	1.57
15-30	11.1	26.6	2.2	5.3	8.9	21.4	1.60
30-45	10.3	25.0	2.5	6.1	7.8	19.0	1.62
45-60	8.2	20.4	2.7	6.7	5.5	13.7	1.66
		100.8		**23.5**	**23.5**	**77.3**	

Table (2).Meteorological data for the experimental site during 2020 and 2021 seasons.

Month \ Season	T. max.	T. min.	WS	RH	R. F	Epan
	2020					
Apr.	**26.9**	**11.8**	**2.8**	**57.2**	**76.1**	**4.2**
May	**32.6**	**15.8**	**3.2**	**50.8**	**0.2**	**7.1**
Jun.	**36.5**	**19.1**	**3.2**	**41.5**	**0.0**	**7.6**
Jul.	**38.8**	**21.6**	**3.1**	**42.9**	**0.0**	**7.5**
Aug.	**38.9**	**22.0**	**2.8**	**45.3**	**0.0**	**6.7**
Sep.	**38.2**	**21.8**	**3.2**	**50.6**	**0.0**	**5.5**
Oct.	**33.3**	**19.1**	**3.0**	**57.3**	**0.7**	**4.5**
Nov.	**24.6**	**13.6**	**2.4**	**63.4**	**10.9**	**3.2**
Dec.	**22.6**	**10.5**	**2.3**	**60.6**	**0.6**	**2.0**
	2021					
Apr.	**29.4**	**11.7**	**3.2**	**50.2**	**4.0**	**5.1**
May	**36.8**	**17.9**	**3.1**	**36.6**	**0.0**	**6.3**
Jun.	**36.9**	**19.5**	**3.5**	**41.4**	**0.0**	**7.5**
Jul.	**39.3**	**22.5**	**3.0**	**41.1**	**0.0**	**6.7**
Aug.	**39.7**	**22.9**	**2.8**	**42.8**	**0.0**	**7.8**
Sep.	**35.9**	**20.8**	**3.2**	**51.0**	**0.0**	**7.4**
Oct.	**31.5**	**17.7**	**3.0**	**55.2**	**1.3**	**4.4**
Nov.	**27.7**	**15.1**	**2.3**	**61.7**	**20.0**	**3.2**
Dec.	**19.4**	**8.9**	**2.6**	**68.4**	**10.3**	**1.9**

T. max,T. min = maximum and minimum temperatures °C. **WS** = wind speed (m / sec^{-1}). **RH** = relative humidity (%). **RF** = rainfall (mm/$month^{-1}$). **Epan** = evaporation (ETp) by class A pan.

The experiment included twenty-one treatments which were as follows:

Irrigation treatments (main plots).

Irrigation treatments as a percentage of crops Evapotranspiration (ETp %) were applied at the following 3 levels:

1. I_1 = Irrigation with amount of water equals 100 % of potential evapotranspiration (ETp) determined by class A pan,
2. I_2 = irrigation with amount of water equals 80 % of (ETp).
3. I_3 = irrigation with amount of water equals 60 % of (ETp) beside the control (Irrigation with amount of water equals 100 % of requirement (farmer practices).

Organic soil conditioner and calcium chloride treatments (sub-plots):

1- Without treatment (Control)

2- Potassium Humate (2000ppm)

3- Potassium Humate (3000ppm)

4- Fulvic acid (2000ppm)

5- Fulvic acid (3000ppm)

6- Calcium chloride (500ppm)

7- Calcium chloride (1000ppm)

Calculation of irrigation water requirements (IR)

Potential evapotranspiration (ETp) values were obtained by class A pan (Doorenbos and Priutt, 1984) and were calculated by the following equation:

$$ETp = E\,pan \times K\,pan$$

Where:

E pan = measured pan evaporation daily values, mm day^{-1}

K pan = pan coefficient. Kpan values depended on the relative humidity, wind speed and the site conditions (bare or cultivated). Kpan value of 0.75 was used at the experimental site (FAO, 1979).

The amount of gross irrigation requirements (IRg) calculated according to the following equation (FAO, 1984).

IRg = A ETpKc +Lr /Ea

Where:

IRg = gross irrigation requirements (ld^{-1})
A= total area allocated (m^2).
ETp= potential evapotranspiration (mmd^{-1}) Table (3).
Kc = K_C is the crop coefficient. Crop coefficients values used for Jerusalem artichoke for growth stages initial, development, mid, and end, respectively as suggested by Abo El-Fadeland Shama (2020)Table (3).

Ea = the irrigation application efficiency (%) Ea of 90 % of drip irrigation method was used.
Lr = extra amount of water needed for leaching. It was calculated according to FAO (1985) as follows:
Lr = ECw/ maximum ECe, where ECw = salinity of applied irrigation water (dS m^{-1}) and ECe= average soil salinity tolerated by the crop as measured on soil saturated extract.

Table (3): Pan evaporation formulae in 2020 and 2021 seasons.

Season		Evapotranspiration ETp			
		2020		2021	
Month	Kc	mm/day	mm/month	mm/day	mm/month
April (15 days)	0.40	3.2	47.3	3.83	57.4
May	0.44	5.3	165.1	4.73	146.5
June	0.58	5.7	171.0	5.63	168.8
July	0.99	5.6	174.4	5.03	155.8
August	1.19	5.0	155.8	5.85	181.4
September	1.18	4.1	123.8	5.55	166.5
October	0.79	3.4	104.6	3.30	102.3
November (15 days)	0.44	2.4	36.0	2.40	36.0
Seasonal (mm)			**978**		**1015**

Potassium humate and fulvic acid were added to the soil after 30, 60, and 90 days from planting, A foliar application of calcium chloride compound was sprayed in three times at 30, 60, and 90 days after planting.

Three replicates of each treatment were set up in a split-plot design system. In the first and second seasons, the whole seed tubers were planted on April 15 and April 11, respectively and were harvested after 240 days from planting on the two growing seasons. Each plot had 5 rows, each measuring 5 m long and 70 cm wide. Plant distinctions were 50 cm. The experimental plot had a surface area of about 17.5m^2. Jerusalem artichoke plants were supplied with farmyard manure at 40 m^3/fed. and mineral fertilizers as Ministry of Agriculture recommendation under sandy soil conditions.

Data recorded:-

A- Vegetative growth characteristics:-

Three plants from each plot were randomly taken at 120 days from planting in summer season for recording the following measurements:-

1- Plant height (cm).
2- Number of lateral shoots /plant.
3- Fresh weight (kg /plant) and dry weight (%).

B- Yield and its component:-

1-**Total tuber yield (kg/plant) and (ton/fed.):-**

All tubers were harvested 240 days after planting at the end of each experimental summer season. The total tuber yield (kg/ plant) and (ton/fed.) were calculated after determining the number of collected tubers per plot.

2- **Average tuber weight (g):** Five random tubers were weighed and average tuber weight was calculated.

C- Chemical components:-

1-**Dry matter (%)**
2- **Inulin content of tubers:** Inulin content was determined in tubers according to the method of Winton and Winton (1958).
3- **Determination of calcium content of leaves:-**

Calcium content of Jerusalem artichoke leaves samples was determined with an Inductively-Coupled Plasma (ICP) spectrometer according to Stefanssn et al., (2007).

D- Irrigation data recorded:

1-Water utilization efficiency (W.U.E)

The relationship between production and irrigation water applied is defined as applied irrigation water. According to Jensen, (1983) it was decided. The equation used was as follows:

W.U. E = yield (kg/fed)/seasonal AIW (m^3 water applied/fed.)

E- Statistical and analysis:-Data were statistically analyzed and means were compared using Duncan,s multiple range tested as described by Snedecor and Cochran (1989).

RESULTS AND DISCUSSION

1- Vegetative growth:-

The findings in (Table 4) show that potassium humate, fulvic acid and calcium chloride applications under irrigation levels have an impact on plant height and the quantity of lateral shoots. In the first season, Jerusalem artichoke plants were the tallest with irrigation at 80% (ETp) than with irrigation at 100% (ETp) and 60% (ETp). Moreover, in the second season, irrigation at 100% (ETp) and 80% (ETp) resulted in the highest significant increase in plant height. While, in the first season, irrigation at 100% (ETp) and 60% (ETp) produced the highest number of lateral shoots of Jerusalem artichoke plant. On the other hand, the three irrigation levels did not significantly differed from each other in the second season. Results are in harmony with those obtained by Abo El-Fadel and Shama (2020) who found that plant height was significantly affected by irrigation 100% ETc treatment.

In the two tested seasons, it was observed that treatments with potassium humate at 3000 ppm and fulvic acid at 2000 ppm significantly increased the plant height of Jerusalem artichokes. The highest numbers of lateral shoots were produced in the first season by the application of fulvic acid at 2000 ppm.

Moreover, the application of 3000 ppm of potassium humate and 2000 ppm of fulvic acid treatments produced the highest number of lateral shoots in the second growing season. Additional to, in comparison to the other treatments in both of the tested seasons, the application of fulvic acid at 2000 ppm in soil under 60% (ETp) irrigation level and potassium humate at 3000 ppm in soil under 100% (ETp) irrigation levels increased the plant height and number of lateral shoots of Jerusalem artichoke plant. The findings of Li et al., (2005) on wheat, folvic acid increased photosynthesis, decreased stomata opening status and transpirations, which stimulated growth and decreased water loss. Also, Awwad et al. (2015) on maize, AbdElghany (2019) on carrot, Fahmi et al. (2020) on wheat and Abd El-Baky (2020) on okra. Due to the fact that fulvic acid application to plants affects cell membranes, which enhances the transport of minerals, improves protein synthesis, and plant growth under both well-watered and dry conditions (Li et al., 2005).

Table (4): Effect of potassium humate, fulvic acid and calcium chloride under different irrigation levels on plant height and number of lateral shoots of Jerusalem artichoke plants in 2020 and 2021 seasons.

Treatments	plant height (cm)				Number of lateral shoots /plant			
	100% ETp	80% ETp	60% ETp	Mean	100%ETp	80% ETp	60% ETp	Mean
				2020				
Without-treatment (Control)	160.67d	154.33d-f	138.00g	151.00D	21.67j	47.00 b	25.00g-i	31.22D
Potassium humate 2000ppm	156.67de	187.33ab	145.00e-g	163.00C	39.00c	29.67 e-g	25.00g-i	31.22D
Potassium humate 3000ppm	191.33ab	184.67ab	179.33bc	185.11A	61.67a	26.67 f-h	36.00cd	41.44B
Fulvic acid 2000ppm	168.33cd	188.33ab	187.33ab	181.33AB	46.00 b	33.10 de	58.00 a	45.70A
Fulvic acid 3000ppm	146.00e-g	190.67ab	185.00ab	173.89 B	31.00ef	23.67 hi	62.00a	39.67BC
Calcium chloride 500ppm	145.00e-g	146.00e-g	177.00bc	156.00CD	26.85f-h	12.33 j	34.00 de	24.44 E
Calcium chloride 1000ppm	142.33fg	195.33a	145.00e-g	160.89 C	33.33 de	50.00 b	28.00f-h	37.11 C
Mean	158.62 B	178.10 A	165.24 B		37.07 A	31.78 B	38.62 A	
				2021				
Without-treatment (Control)	265.00cd	230.00ef	175.00 i	223.33B	47.17efg	49.67 d-f	28.00ij	41.61 C
Potassium humate 2000ppm	273.08bc	285.00bc	187.33hi	248.47A	55.83cd	51.33 c-e	35.00h	47.17 B
Potassium humate 3000ppm	314.33 a	250.00de	201.67h	255.33A	61.00 ab	50.17c-f	41.33g	50.83 A
Fulvic acid 2000ppm	183.33hi	267.50cd	292.00ab	247.61A	47.50efg	46.67e-g	66.00a	53.39 A
Fulvic acid 3000ppm	186.67hi	225.00fg	205.00gh	205.56C	29.00h-j	55.83 bc	33.67hi	39.50 C
Calcium chloride 500ppm	203.67gh	195.00hi	245.00d-f	214.56BC	27.00 j	33.50hi	62.33 a	41.06 C
Calcium chloride 1000ppm	175.00 i	178.33i	185.00hi	179.44 D	27.00 j	26.67 j	44.67 fg	32.78 D
Mean	228.73 A	232.98 A	213.00 B		42.03 A	44.83 A	44.43 A	

Values within the column or rows followed by the same capital or small letters do not significantly differ from each other according to Duncan's multiple range test at 5% level.

2- Fresh and dry weight:

Results in table (5) show that irrigation at 100% (ETp) produced the highest fresh and dry weight values during the two tested seasons. Although there were no significant differences between irrigation at 100% (ETp) and 60% (ETp) compared with irrigation at 80% (ETp), they recorded the highest values of dry weight percentage in the second season. Table (5) clear that in both tested seasons, the addition of potassium humate at a concentration of 3000 ppm and fulvic acid at a concentration of 2000 ppm produced the highest fresh weight (kg) per plant. Also, potassium humate at 3000 ppm, fulvic acid at 2000 ppm and calcium chloride at 1000 ppm all significantly increased the dry weight percentage during the two tested seasons. Results are in harmony with those obtained by Abd El- Haleim (2020), decreased irrigation intervals from 7 to 3 days significantly increased root fresh weight/plant of Sugar Beet.

The addition of Potassium humate 3000 ppm under 100% (ETp), fulvic acid 2000 ppm and calcium chloride 500 ppm under 60% (ETp) in the two tested seasons resulted in the highest values of fresh weight per plant. The first and second seasons had the highest fresh weight values, 3.17 and 6.23 kg/plant, respectively. Referring to dry weight percentage, the treatments of fulvic acid at 2000 ppm under 60% (ETp) and potassium humate at 3000 ppm under 100% (ETp) yielded the highest values of dry weight percentage in both seasons. These results are similar with those of Abd El-Baky (2020) onOkra.

The application of a high rate of potassium humate and a lot of water quantities had resulted in a significant increase in fresh and dry weight of Jerusalem artichoke(Eid, 2013), fulvic acid increased chlorophyll, photosynthesis, decreased stomata opening status, and decreased transpiration, which stimulated growth and decreased water loss (Lotfi et al., 2015).

Table (5): Effect of potassium humate, fulvic acid and calcium chloride under irrigation levels on fresh and dry weight of Jerusalem artichoke plant in 2020 and 2021 seasons.

Treatments	Fresh weight (Kg /plant)				Dry weight %			
	100% ETp	80% ETp	60% ETp	Mean	100% ETp	80% ETp	60% ETp	Mean
				2020				
Without-treatment (Control)	2.01de	2.20d	2.17de	2.12BC	37.00ef	37.13ef	32.17hij	35.43 B
Potassium humate 2000ppm	2.68bc	2.77bc	1.32g	2.23B	36.00efg	24.25k	32.53 hi	30.93 C
Potassium humate 3000ppm	2.93ab	2.23d	2.04de	2.40A	44.60a	38.55de	30.07 ij	37.74 A
Fulvic acid 2000ppm	2.76bc	1.83ef	2.82abc	2.47A	41.34bc	30.09 ij	43.05ab	38.16 A
Fulvic acid 3000ppm	2.08de	1.87ef	2.70bc	2.22B	35.47fg	33.25gh	38.09def	35.61 B
Calcium chloride 500ppm	1.60f	1.23g	3.17a	1.96C	40.03cd	29.43 j	23.61k	31.03 C
Calcium chloride 1000ppm	2.027de	2.60c	1.24g	1.95C	35.75fg	44.65a	31.95hij	37.45 A
Mean	2.38A	2.14C	2.28B		38.69A	33.91B	33.17B	
				2021				
Without-treatment (Control)	5.30b	3.22de	2.63efgh	3.72C	35.41efg	36.53defg	34.75efg	35.57BC
Potassium humate 2000ppm	5.47ab	5.50ab	1.73i	4.23B	36.23defg	34.08 g	35.55efg	35.28BC
Potassium humate 3000ppm	6.23a	5.77ab	3.08def	5.03A	43.33a	37.13defg	35.67efg	38.71 A
Fulvic acid 2000ppm	5.23b	2.97defg	5.60ab	4.60AB	38.24cde	35.44efg	42.82ab	38.83 A
Fulvic acid 3000ppm	3.78cd	4.20c	2.23ghi	3.41C	35.48efg	34.69efg	34.55fg	34.88 C
Calcium chloride 500ppm	1.97hi	2.43fghi	5.57ab	3.32CD	39.49bcd	35.14efg	36.63defg	37.09AB
Calcium chloride 1000ppm	2.73efgh	2.33fghi	3.73cd	2.93D	38.04cdef	36.77defg	41.13abc	38.65 A
Mean	4.48 A	3.78 B	3.51 B		38.03 A	35.67 B	37.30 A	

Values within the column or rows followed by the same capital or small letters do not significantly differ from each other according to Duncan·s multiple range test at 5% level.

3- Total tuber yield:

The results in Table (6) demonstrate that in the first season, irrigation at 100% (ETp) and 60% (ETp) produced the highest tuber yield (kg) per plant of Jerusalem artichoke. Although, there were no significant differences in irrigation levels during the second season. The highest tuber yield (ton/fed.) was produced by plants that were irrigated at 100% (ETp) in the first season.

Data in Table (6) clearly show that potassium humate application in the soil at a concentration of 3000 ppm resulted in the highest tuber yield per plant of Jerusalem artichoke during the two growing seasons. However, the addition of 3000 ppm of potassium humate and 2000 ppm of fulvic acid produced the highest values of total tuber yield (ton/fed.) in the two seasons.

Additionally, in the same table, there were significant increases in the total tuber yield (kg /plant) by the application of potassium humate at 3000 ppm under 100% (ETp) and Fulvic acid at 2000 ppm under 60% (ETp,) in the first and second seasons,

As well as, in the second season, the plants that received irrigation at 100% (ETp) and 60% (ETp) produced the highest tuber yield (ton/fed.) values compared with 80% (ETp). Results are in harmony with those obtained by **Abo El-Fadel and Shama (2020)** the highest average values were recorded for yield of Jerusalem artichoke at 100% ETC followed by75% ETC.

respectively. Moreover, the addition of potassium humate at 3000 ppm and Fulvic acid at 2000 ppm in soil under100% (ETp) and the application of fulvic acid at 2000 ppm in soil under 60% (ETp) recorded the highest of total yield per fed. in the two tested seasons.

The Jerusalem artichoke's total yield (ton/fed.) was the highest (29.51 and 19.23 ton /fed.) with the application of potassium humate at 3000 ppm under100% (ETp). However, the lowest total yield (ton/fed.) values were obtained with the treatment that received calcium chloride at 500 ppm under 80% (ETp) in the first season and those received potassium humate at 2000 ppm at under 60% (ETp) in the second season. These findings concur with those of Awwad et al., (2015) on maize, AbdElghany et al., (2019) on carrot, Abd El- Haleim (2020) on sugar beet and Fahmi et al., (2020) on wheat.

The increase of yield due to the role of potassium humate may be related to which affect plant cell membranes, increasing the availability of micronutrients like Fe and Zn from sparingly soluble hydroxides (Stevenson, 1994). Fulvic acid application also improves protein synthesis, increases plant hormone-like activity, promotes photosynthesis, modifies enzyme activities and solubilizes micro and macro elements (Aggag et al., 2015 and El-Helaly, 2018).

Table (6): Effect of potassium Humate, fulvic acid and calcium chloride under irrigation levels on total yield of Jerusalem artichoke in 2020 and 2021 seasons.

Treatments	Yield (kg / plant)				Yield (ton / fed.)			
	100% ETp	80% ETp	60% ETp	Mean	100% ETp	80% ETp	60% ETp	Mean
					2020			
Without-treatment (Control)	3.08 efg	2.35 jk	2.30 k	2.58 D	24.63 cdefg	24.63 cdefg	24.62 cdefg	24.63 B
Potassium humate 2000ppm	3.58 bc	3.18 de	3.38 cd	3.38 A	26.10 bcd	24.69 cdefg	26.28 bc	25.68 B
Potassium humate 3000ppm	3.96 a	2.48 ijk	3.39 cd	3.28 A	29.51 a	24.67 cdefg	29.66 a	27.94 A
Fulvic acid 2000ppm	2.56 ij	2.66 hi	3.83 ab	3.02 B	28.07 ab	25.59 cde	29.21 a	27.62 A
Fulvic acid 3000ppm	2.88 fgh	2.67 hi	2.87 gh	2.81 C	26.40 bc	23.83 defg	22.43 g	24.22 B
Calcium chloride 500ppm	2.25 k	2.31 jk	3.08 ef	2.55 D	25.68 bcde	16.53 h	25.30 cdef	22.50 C
Calcium chloride 1000ppm	2.02 i	3.22 de	2.48 ijk	2.58 D	23.40 efg	26.26 bcd	22.93 fg	24.27 B
Mean	2.91 A	2.79 B	3.05 A		26.25 A	23.74 C	25.78 B	
					2021			
Without-treatment (Control)	1.08 ij	1.16 ghij	1.30defgh	1.18 C	13.37 fgh	13.43 fgh	16.38 cd	14.39 CD
Potassium humate 2000ppm	1.55 bc	1.22efghi	1.33 defg	1.37 B	17.55 abc	13.23 fgh	12.02 h	14.27 D
Potassium humate 3000ppm	1.78 a	1.37 cdef	1.48 bcd	1.54 A	19.23 a	15.22 def	16.45 bcd	16.97 A
Fulvic acid 2000ppm	1.17 ghij	1.39 cde	1.63 ab	1.49 B	17.43 abc	12.93 gh	18.50 ab	16.29 AB
Fulvic acid 3000ppm	1.39 cde	1.33 defg	1.49 cde	1.37 B	15.80 cde	14.42 defg	16.41 cd	15.54 BC
Calcium chloride 500ppm	1.18 fghi	1.11 hij	1.18 fghi	1.16 C	14.67 defg	14.17 efg	14.89 defg	14.58 CD
Calcium chloride 1000ppm	0.98 J	1.35 defg	1.11 hij	1.15 C	13.17 fgh	15.78 cde	13.85 efgh	14.27 D
Mean	1.30 A	1.27 A	1.35 A		15.89 A	14.17 B	15.50 A	

Values within the column or rows followed by the same capital or small letters do not significantly differ from each other according to Duncan's multiple range test at 5% level.

4- Average tuber weight (g):-

Table (7) demonstrated that the irrigation level of 100% (ETp) followed by 60% (ETp) gave a significant positive correlation with the average tuber weight in both seasons. In contrast, soil addition of 3000 ppm potassium humate resulted in the highest tuber weight over the course of the two tested seasons. Regarding the interaction effects, the highest average tuber weight were recorded during the first and second seasons when potassium humate at 3000ppm was applied at an irrigation level of 100% (ETp). In the first and second seasons, the in average tuber weight register values were 84.72 to 93.05, respectively. This result is in the line that found by Abo El-Fadel and Shama (2020).

5- Chemical characters of tubers:

5.1- Dry matter %:

It could be noted in Table (7) that the highest dry matter % of tubers was obtained when irrigated plants with 100% (ETp) and 60% (ETp) in the first season. Moreover, in the second season, the highest value of dry matter of tubers was recorded when plants irrigated with 100% (ETp).However, in the two tested seasons, adding 3000 ppm of potassium humate to the soil resulted in a noticeable increase in the dry matter of the tubers. Furthermore, in both growing seasons, the highest amount of dry matter in tubers was produced by the interaction between 100% (ETp) irrigation of plants and the addition of 3000 ppm of potassium humate to the soil. The results are consistent with those of **EL Komy*et al.*, (2021),** who mentioned that the application of compost tea, fulvic acid and humic acid significantly increased of dry matter of potato.

Table (7): Effect of potassium humate, fulvic acid and calcium chloride under irrigation levels on average tuber weight and dry matter of Jerusalem artichoke tubers in 2020 and 2021 seasons.

Treatments	Average tuber weight (g)				Dry matter (%)			
	100% ETp	80% ETp	60% ETp	Mean	100% ETp	80% ETp	60% ETp	Mean
					2020			
Without-treatment (Control)	68.10 fg	65.83 f-h	64.82 gh	66.25 CD	28.71 e	27.52 g	26.76 i	27.33 D
Potassium humate 2000ppm	70.62 ef	74.62 de	60.93 hi	68.73 C	28.77 e	29.71 c	26.07 hi	28.18 C
Potassium humate 3000ppm	84.72 ab	67.25 fg	79.43bcd	77.13 A	32.20 a	29.56 cd	31.48 b	31.08 A
Fulvic acid 2000ppm	75.37 de	67.57 fg	77.72 cd	73.56 B	29.61 cd	29.25 d	29.56 cd	29.47 B
Fulvic acid 3000ppm	82.74 a-c	58.98 i	87.35 a	76.36 AB	27.60 g	25.77 i	31.36 b	28.24 C
Calcium chloride 500ppm	77.07 d	85.45 a	63.01ghi	75.17 AB	28.51 ef	27.60 g	32.32 a	29.48 B
Calcium chloride 1000ppm	67.69 fg	65.90 f-h	62.99 g-i	65.53 D	27.64 g	28.25 f	26.43 h	27.44 D
Mean	75.19 A	69.37 B	70.89 B		29.01 A	28.24 B	29.17 A	
					2021			
Without-treatment (Control)	56.41 k	55.00 kl	80.53 d-g	63.98 D	30.01 de	27.35 gh	26.62 hi	27.99 D
Potassium humate 2000ppm	83.05 dei	80.94 d-f	56.27 k	73.65 C	34.21 b	29.42 ef	26.07 hi	29.90 B
Potassium humate 3000ppm	93.05 ab	85.39 cd	74.89 f-h	84.44 A	37.27 a	31.33 cd	26.38 hi	31.66 A
Fulvic acid 2000ppm	67.23 j	58.61 k	98.44 a	74.76 C	25.88 ij	28.87 ef	31.02 cd	28.57 CD
Fulvic acid 3000ppm	78.90 e-g	67.96 ij	91.58 bc	79.48 B	26.43 hi	28.71 ef	24.76 j	26.63 E
Calcium chloride 500ppm	75.95 f-h	44.91m	48.68 lm	56.51 E	28.83 ef	26.64 hi	31.38 c	28.95 C
Calcium chloride 1000ppm	58.65 k	69.64 h-j	73.96 g-i	67.42 D	25.58 ij	25.98 ij	28.69 fg	26.72 E
Mean	73.42 A	66.06 B	74.91 A		29.74 A	28.32 B	27.83 B	

Values within the column or rows followed by the same capital or small letters do not significantly differ from each other according to Duncan's multiple range test at 5% level.

5.2- Inulin content (g/100g):

The findings demonstrated that plants irrigated with 60% (ETp) experienced a significant increase in inulin content during the first growing season. On the other hand, there were no significant differences in the inulin content of Jerusalem artichoke tubers in the second season among the three irrigation levels (Fig. 1). Adding to the soil potassium humateat 3000 ppm, fulvic acid at levels of 2000 and 3000 ppm, as well as spraying calcium chloride at a concentration of 1000 ppm significantly increased the inulin content of Jerusalem artichoke tubers during the two tested growing seasons. The findings of Abo El-Fadel and Shama (2020).

Data in Fig. (1) illustrated a clear relationship between the application of potassium humate at a concentration of 3000 ppm, fulvic acid at a concentration of 3000 ppm, or calcium chloride at a concentration of 1000 ppm under 100% (ETp) and fulvic acid at a concentration of 2000 and 3000 ppm and calcium chloride at a concentration of 1000 ppm under 60% (ETp) gave significant increases in inulin content in tubers as compared to the other treatments in both tested seasons. This may be explained by the possibility that humic substances exhibit anti-stress properties under abiotic stress conditions. As a result of drought stress, inulin level increased, and the addition of potassium humate may have considerably contributed to the increase in cytoplasmic osmotic pressure **(**Arulbalchandran et al., 2009 and Samy et al., 2015). Also, Abd El-Haleim (2020) on sugar beet.

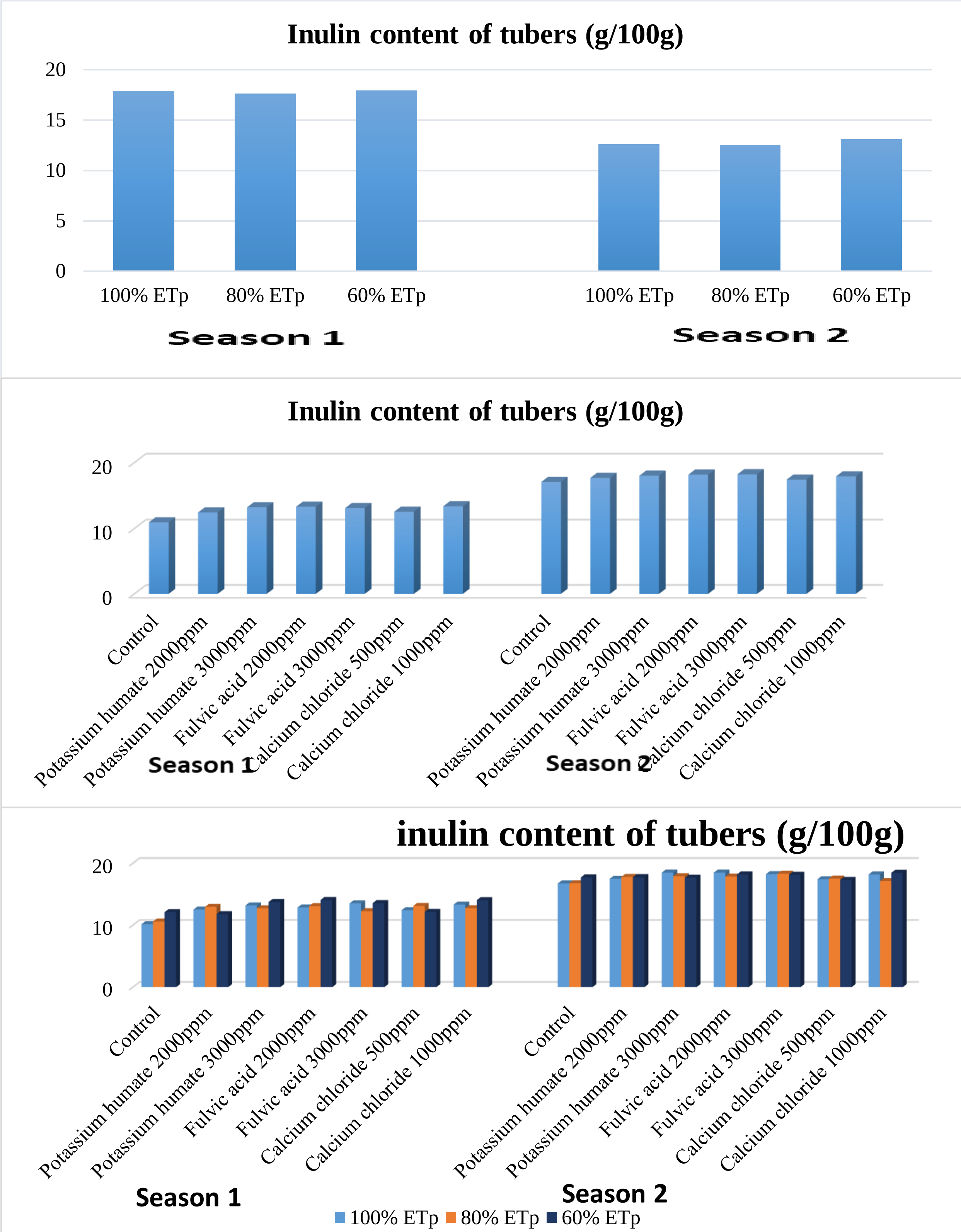
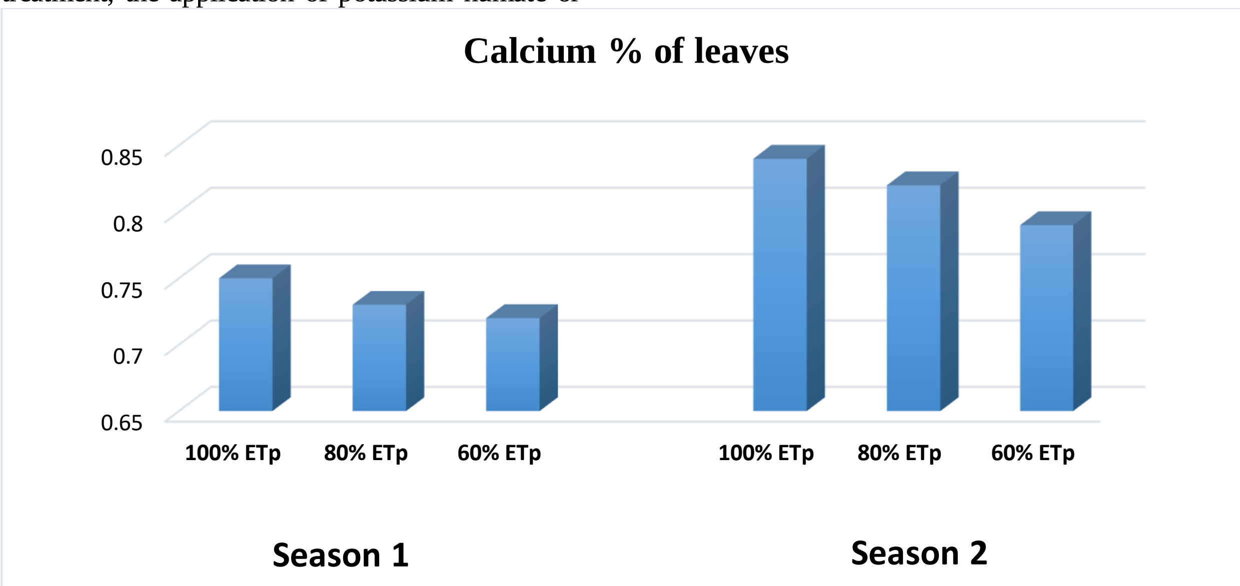
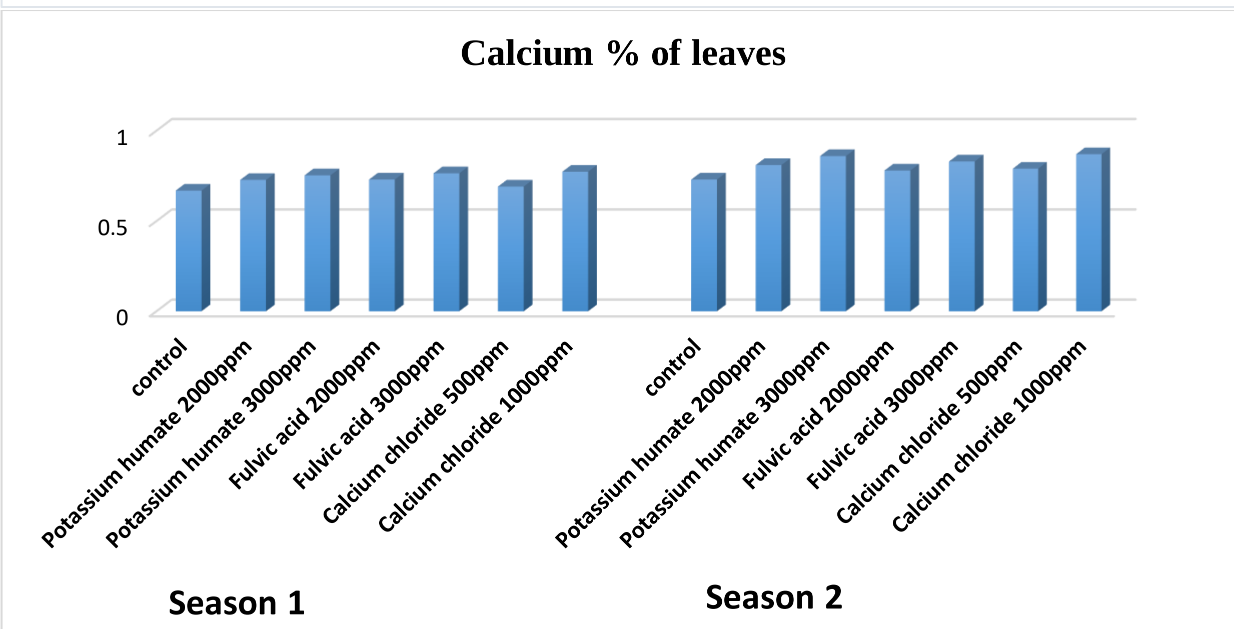


Fig. (1). Effect of potassium humate, fulvic acid and calcium chloride under irrigation levels on inulin content of Jerusalem artichoke tubers in 2020 and 2021 seasons.

5.3-Calcium contents of leaves:

It is clear from Fig. (2) that during the two seasons of testing, the irrigated plants with 100% (ETp) significantly increased the calcium content of Jerusalem artichoke leaves followed by irrigated plants with 80 % (ETp). Additionally, compared to the other treatments, a significant increase in the calcium content of the leaves was seen with the addition of potassium humate (3000 ppm) and calcium chloride (1000 ppm) spraying in both seasons. However, compared to the control treatment, the application of potassium humate or fulvic acid at a concentration of 3000 ppm under 100% (ETp) and foliar spraying of calcium chloride at a concentration of 1000 ppm under 60% (ETp) resulted in the highest calcium content values in the two growing seasons. The obtained results are in agreement with those reported bySamy et al., (2015) and El Komy et al., (2021)the results revealed that, individually application of fulvic acid was more efficient to promote the potato plants growth and macronutrient uptake by shoots and tubers.





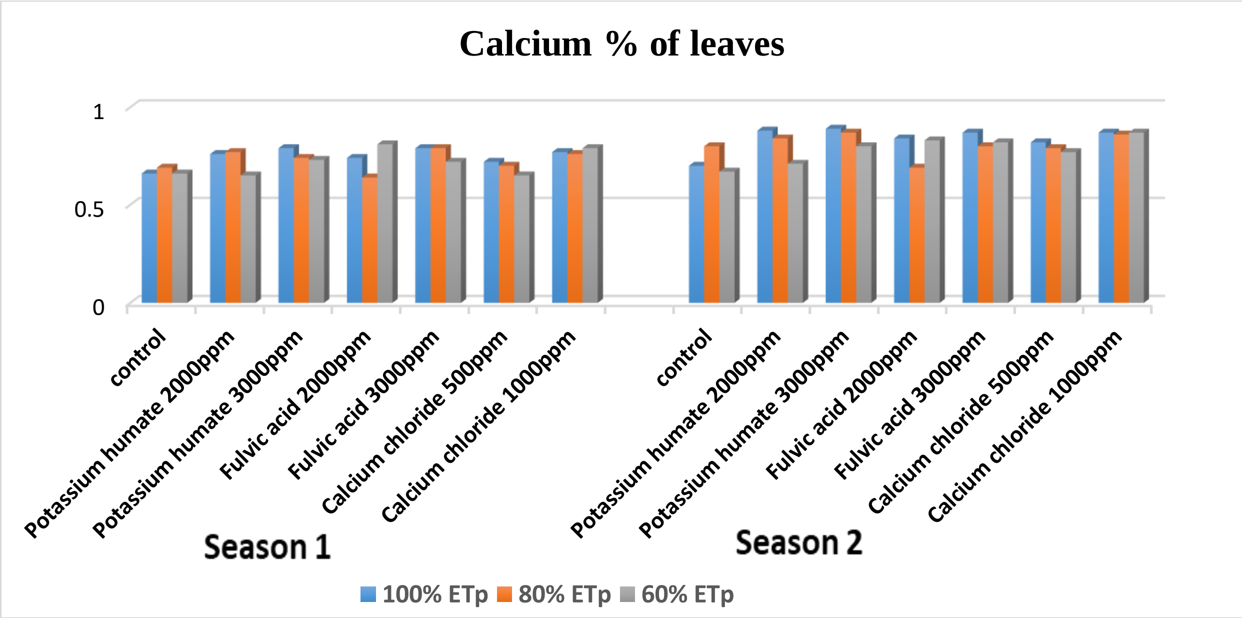


Fig. (2). Effect of potassium humate, fulvic acid and calcium chloride under irrigation levels on calcium content of Jerusalem artichoke leaves in 2020 and 2021 seasons.

6- Soil water relations:-

6.1- Water requirements for Jerusalem artichoke:

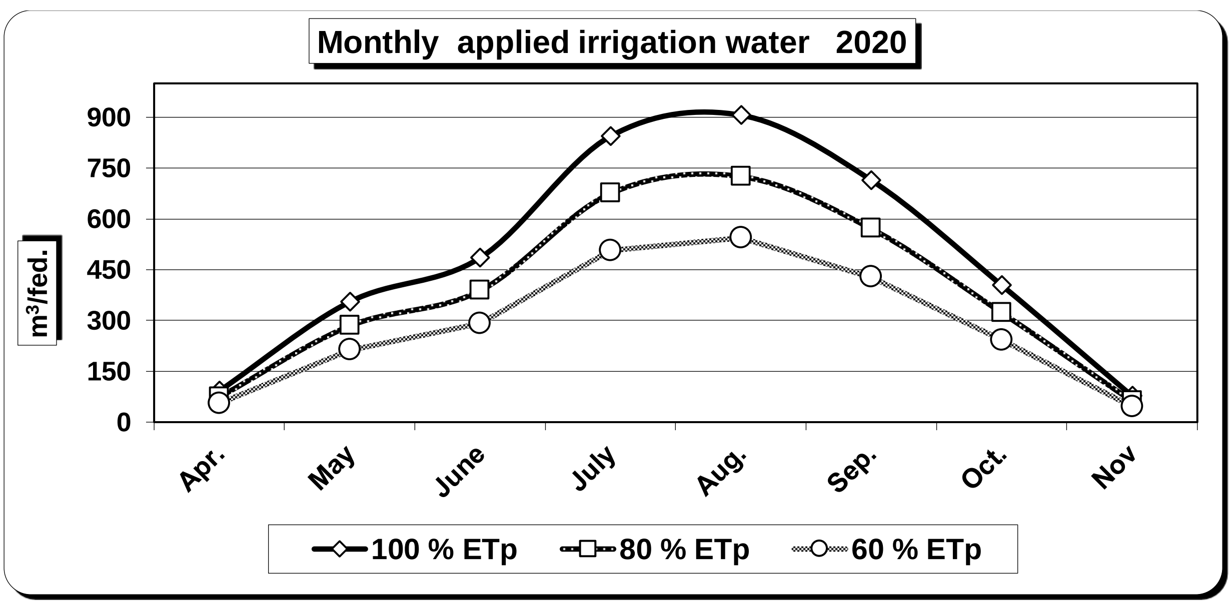
The amounts of irrigation used for Jerusalem artichoke during the growing seasons of 2020 and 2021 are shown in Table (8). The applied amounts were given in terms of m^3/fed. per day, m^3/fed. per month, and m^3/fed. per year. In the first season, irrigation water applications equal to 60, 80, and 100% of (ETp) were 2327, 3102, and 3878 m^3/fed/year, whereas applications in the second season were 2489, 3318, and 4148 m^3/fed/year, respectively. Due to the Jerusalem artichoke plants' increasing vegetative growth, the amount of applied fertilizer started out low and gradually increased throughout the season. At maturity, irrigation water application then decreased. In all irrigation methods, the highest applied water values for Jerusalem artichoke plants occurred in July and August. The study's findings and those reported by **Abo El-Fadel and Shama(2020)**were very similar.

6.2- Monthly applied irrigation water:-

Results in Table (8) and Fig. (3) demonstrate that under drip irrigation systems, monthly applied water values started to rise in May, increased gradually, and peaked in July and August in both growing seasons. The plant reached its full development in July and August, and as a result, August shows a greater reduction in soil moisture than the other months.The monthly water consumption increased gradually over the course of the two seasons as plants grew larger, peaking in August primarily as a result of increased plant water demand. So, the coverage of the plants can be used to explain the rise in evapotranspiration from the start of the growth season until harvesting maturity.

Table (8): Monthly and seasonal applied irrigation water to Jerusalem artichoke plant by drip irrigation system in 2020 and 2021 growing seasons.

Month	Irrigation treatment					
	100 (%)ETp		80 (%)ETp		60 (%)ETp	
	m^3/fed./ day	m^3/fed./ month	m^3/fed./ day	m^3/fed./ month	m^3/fed./ day	m^3/fed. /month
2020						
April (15 days)	6.2	92	4.9	74	3.7	55
May	11.5	355	9.2	284	6.9	213
June	16.2	485	12.9	388	9.7	291
July	27.2	844	21.8	675	16.3	506
August	29.2	906	23.4	725	17.5	544
September	23.8	714	19.0	571	14.3	428
October	13.0	404	10.4	323	7.8	242
November (15 days)	5.2	77	4.1	62	3.1	46
Seasonal (m^3/fed.)		**3878**		**3102**		**2327**
2021						
April (15 days)	7.5	112	6.0	90	4.5	67
May	10.2	315	8.1	252	6.1	189
June	16.0	479	12.8	383	9.6	287
July	24.3	754	19.5	603	14.6	452
August	34.0	1055	27.2	844	20.4	633
September	32.0	961	25.6	768	19.2	576
October	12.7	395	10.2	316	7.6	237
November (15 days)	5.2	77	4.1	62	3.1	46
Seasonal (m^3/fed.)		**4148**		**3318**		**2489**



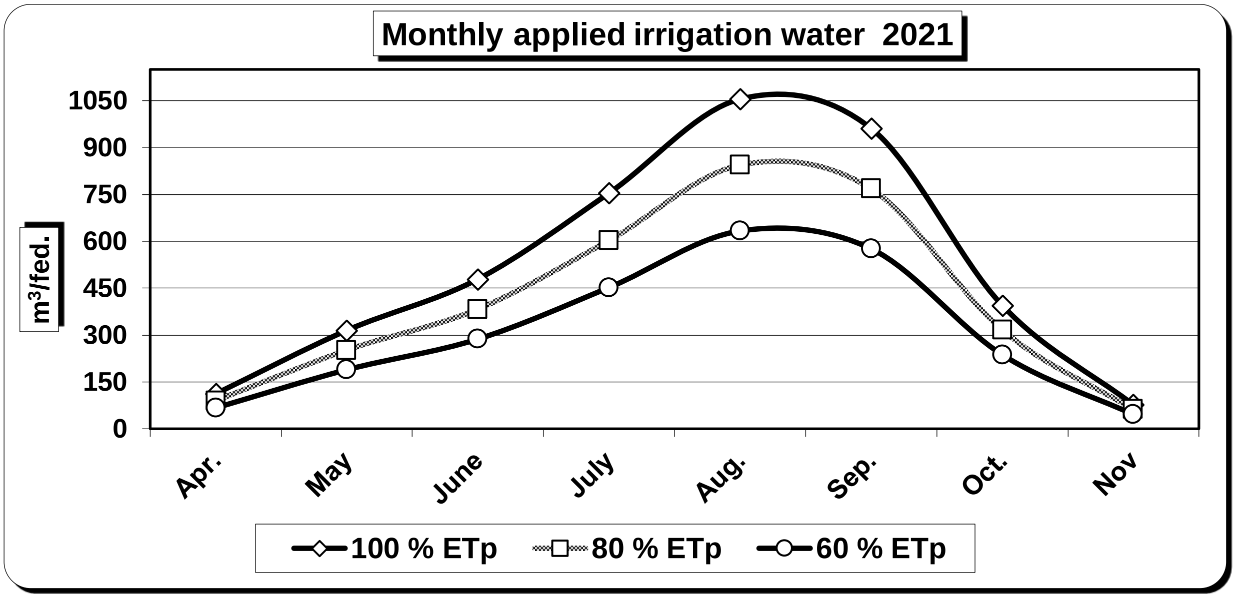


Fig. (3). Monthly applied irrigation water (m^3/fed.) by Jerusalem artichoke plants under different water regime levels.

6.3-Water utilization efficiency (W.U.E):

Theamount of yield produced by one cubic meter of irrigation water consumed by crop is used to represent water utilization efficiency (Fig. 4). When plants were irrigated with 100% and 80% (ETp) compared to 60% (ETp) in both seasons, water utilization efficiency was significantly lower.The primary outcome of irrigation treatments demonstrates that 60% (ETp) provided the highest W.U.E and the following values were obtained: (Means of the 2 Seasons) 60% (ETp) = 8.33, 80% (ETp) = 5.71, and 100% (ETp) = 5.24 kg tuber / m^3 water (means of the two seasons). The current findings are consistent with those mentioned by Ritchie (1974) who showed that allowing plants to experience mild water stress can have positive effects on water conservation. According to Lotfi et al., (2015) on Brassica napus subjected to fulvic acid application under water stress discovered that fulvic acid application improved plants' performance index (PI) in both well-watered and limited-water situations.

The main impact of the calcium chloride and organic soil conditioner treatments demonstrates that all treatments increased W.U.E in comparison to the untreated (control) treatment. Potassium humate had the highest W.U.E treatments, while calcium chloride had the lowest. The two seasons mean values for potassium humate, fulvic acid, and calcium chloride were 8.57, 6.44, and 6.0 kg tuber/m^3 water, respectively.The current findings are consistent with those reported by Mei and Yang (1983)who found that humic substances may reduce stomatal conductance and transpiration, according to recent reports. However,Awwad et al., (2015), demonstrated the benefits of irrigation levels of 100% ETc and adding of potassium humate the W.U.E, yield, and yield attributes were the highest after treatment with potassium humate.Aggag et al., (2015) and El-Helaly (2018) found that, fulvic acid effectively increases the physiological activities and yield production of tomato plants by acting as antitranspirants and conserving soil water, which lowers the applied 25% of irrigation.

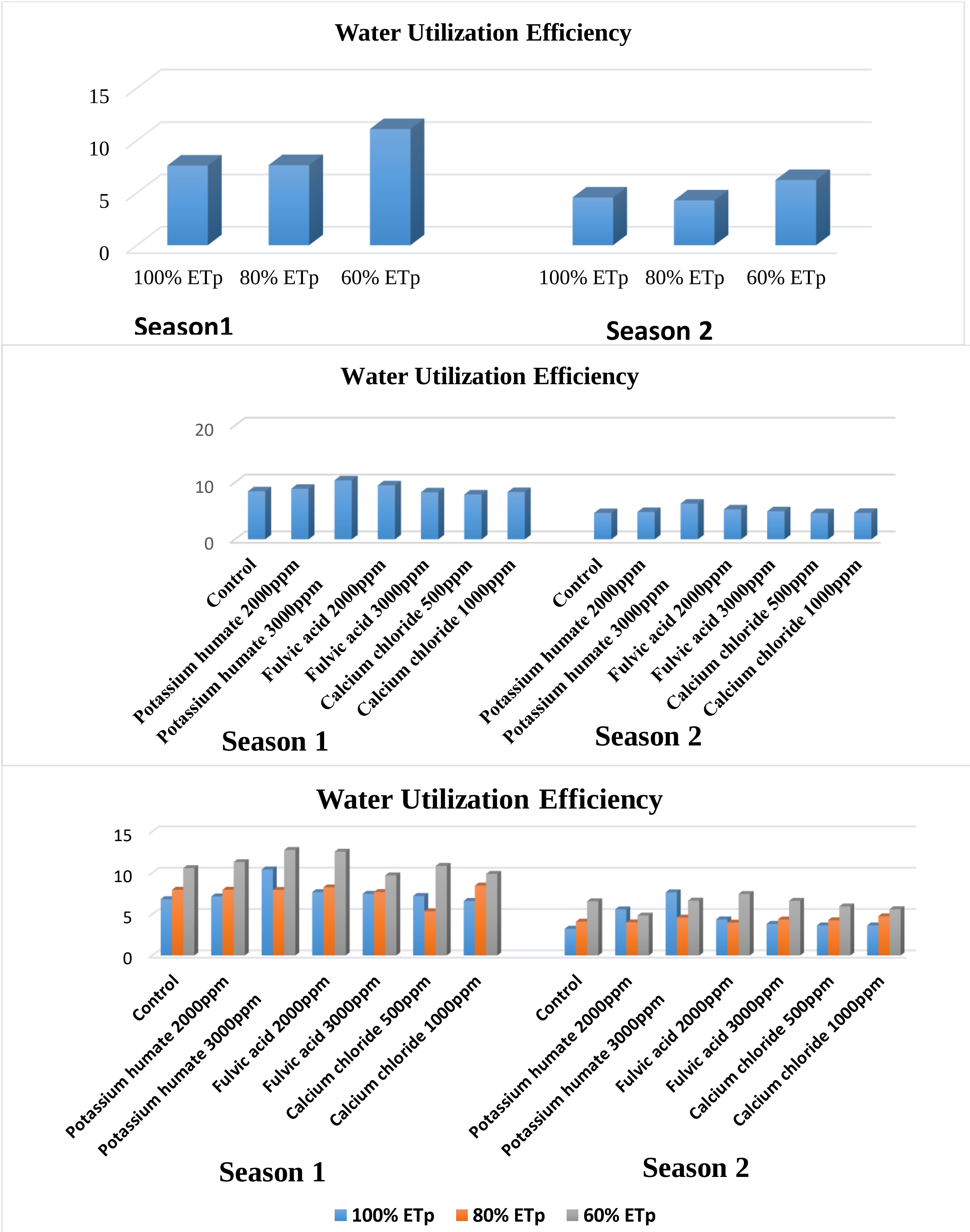


Fig. (4). Effect of potassium humate, fulvic acid and calcium chloride under irrigation levels on water utilization efficiency of Jerusalem artichoke in 2020 and 2021 seasons

Conclusion

The study recommends the addition of fulvic acid at 2000 ppm in soil under 60 % (ETp.) works to save 40% of irrigation water, with high productivity and quality of Jerusalem artichoke tubers.

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تاثير كلوريد الكالسيوم وهيومات البوتاسيوم وحمض الفولفيك علي نمو وانتاجية الطرطوفة تحت الاجهاد المائي

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***قسم البطاطس والتكاثر الخضري معهد بحوث البساتين-مركز البحوث الزراعية**

**** قسم النبات الزراعي- كلية زراعة- جامعة عين شمس**

*****معهد بحوث الاراضي والمياه –معهد بحوث البيئة- مركز البحوث الزراعية**

أجريت هذه الدراسة لمعرفة تأثير إضافة هيومات البوتاسيوم وحمض الفولفيك إلي التربة ورش كلوريد الكالسيوم تحت مستويات ري مختلفة علي النمو والإنتاجية والمحتوي الكيميائي لدرنات الطرطوفة خلال موسمي 2020 و2021 بمزرعة خاصة في محافظة القليوبية- مصر.

واشتملت هذه الدراسة علىثلاث معاملات ري (100 % و80 % و60 %) من البخر نتح في القطع الرئيسية وتم إضافة هيومات البوتاسيوم وحمض الفولفيك كلا منهما بتركيزات (2000 و3000 جزء في المليون) للتربة ورش كلوريد الكالسيوم بتركيزات (500 و1000 جزء في المليون) علي النباتات في القطع الفرعية.

أظهرت نتائج الدراسة أن مستويات الري 100% تليها 60% أدت إلي زيادة النمو والمحصول؛ وكذلك أدت الإضافة الأرضية لكلا من هيومات البوتاسيوم 3000 جزء في المليون وحمض الفولفيك 2000 جزء في المليون إلي أعلي أرتفاع للنبات وزيادة عدد السيقان الجانبية والوزن الطازج والجاف للنبات والمحصول الكلي للدرنات ومتوسط وزن الدرنة والمادة الجافة للدرنات ومحتوي الانيولين في الدرنات؛وأظهرت أفضل نتائج التفاعل عند المعاملة بحمض الفولفك 2000 جزء في المليون عند الري 60% من البخر نتح والمعاملة بهيومات البوتاسيوم 3000 جزء في المليون عند الري 100% من البخر نتح التي أدت أعلي نموخضري وإنتاجية وزيادة في صفات الجودة لدرنات الطرطوفة.

هذه الدراسة توصي بالإضافة الأرضية لحمض الفولفيك بتركيز2000 جزء في المليون والري بـ60% حيث كانت أفضل معاملات التفاعل التي أدت لزيادة معنوية في الصفات المدروسة وكانت فعالة في توفير أستهلاك المياه بنسبة 40 % من الكمية الموصي بها عند زراعة الطرطوفة.