

## Effect of some mineral nutrients on productivity, tuber seed quality and storability of Jerusalem artichoke

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### ABSTRACT

This investigation was carried out to determine the effect of some macro elements with calcium (Ca) at 10 kg/feddan and magnesium (Mg) at 5 kg/feddan as well as foliar spraying with micro elements (boron and silicon at a concentration of 100 ppm for each one) and, their combinations on vegetative growth, yield and its components, tuber quality (chemical constituents) and tubers storability of Jerusalem artichoke (*Helianthus tuberosus* L.), cv. Fuseau. The experiment was conducted during both summer seasons of 2015 and 2016, on clay loam soil at Kaha Vegetables Research Farm, Horticulture Research Institute, Agriculture Research Centre, Egypt. The obtained results showed that, the best positive effect was obtained for the treatments of mixing between each of the major elements (calcium and magnesium) as well as the micro-elements (silicon and boron) and the increase was represented by average plant length, number of main stems per plant and both fresh and dry weight of the total plant foliage as well as both weight and number of tubers in addition to increasing productivity and total yield per feddan, while the control recorded the lowest obtained values compared to the rest of the other treatments. Also, a mixture of spraying with microelements (silicon and boron) with the ground addition of both calcium and magnesium significantly increased the chemical content of tubers, *i.e.*, nitrogen, phosphorus, potassium, calcium and magnesium as macro-elements as well as silicon and boron as micro-elements. It appears that the increase in this chemical content and its accumulation in tubers through treatment had a positive effect on the storability of the tubers as the percentage of weight loss and decomposition during the storage process, which lasted for three months, decreased when storing at 5°C and 85-95% relative humidity. This may be due to the treatment with the important and necessary elements for the formation of plant cellular walls, which support the plant against external influences, such as loss of internal contents.

**Keywords:** Jerusalem artichoke, Tubers, Calcium, Magnesium, Storability, Tuber decay.

### Introduction

Jerusalem artichoke crop is grown in many types of land where they are grown in order to obtain tubers of high nutritional value, especially carbohydrates in the form of naturally inulin sugar (instead of starch) within the tubers raised (Chubey and Dorrell, 1974) which, is of great importance to diabetics as well as heart patients and is also used in the diet (Ozgen *et al.*, 2003). It has been found that the plants of Jerusalem artichoke respond to the good nutrition of the major elements where researches had proved that macronutrients have an effective role in crop yielding (Ashour *et al.*, 1997). The magnesium element plays an important role in the process of oxidation and reduction, exchange of carbohydrates and participates in the movement of phosphorus (Marschner, 1995 and Reddy and Reddi, 2002). As for the calcium, it has been found that it enters the formation of the central of the cell walls of the plant and therefore plays an important role in the hardness of plant tissues and this leads to an increase in storage capacity of the plant and can reduce post-harvest losses (Bangerth, 1979). Also, micronutrients play an important role in growth, yield, quality and storage capacity. Boron has been found to have an active and vital role in metabolism as well as growth process such as structure cellular wells and protein composition and has a role in membrane permeability (Marschner, 2013). However, it has been found that foliar spray of plants by boron at 1.0 kg/ha leads to high significantly increment in both number and weight of tubers per plant and average tuber weight (Marie and Toma, 2011) as well as foliar spray of B-levels significantly affected potato growth parameters and all of total tuber yield, dry shoot yield and average weight of tubers significantly increased (El-Dissoky and Abdel-Kadar, 2013). Silicon has an effective role in plant resistance to fungal and bacterial diseases, works to increase sugar glucose in plant cells. Also, rapid

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water loss after harvesting of tubers occurs due to the thinness of the skin and its sensitivity (Danilcenko *et al.*, 2008). Therefore, the present study aimed to find out the effect of some macro- (Ca, Mg) and micro- nutrients (boron and silicon) on the quantity, quality and high storage capacity of Jerusalem artichoke through spraying system with magnesium, calcium, boron and silicon.

## Materials and Methods

Two field experiments were carried out at Kaha Vegetables Research Farm, Horticulture Research Institute, Agriculture Research Centre, Giza, Egypt during both summer seasons of 2015 and 2016 under clay loam soil to study the effect of soil application of both calcium (Ca) and magnesium (Mg) with foliar spray of both boron (B) and silicon (Si) and their interactions on production, quality and storability of Jerusalem artichoke.

### 1. Experimental Design:

The experiments were carried out in a Randomized Complete Block Design (RCBD) with three replicates in split plots. Each plot consisted of five ridges (4m length × 0.75 m wide), so the plot area was 15 m<sup>2</sup>, whereas; one ridge was left without planting as a guard ridge between plots to avoid the interference of various treatments. The tuber seeds of cv. Fuseau (obtained from the potatoes and vegetable vegetative reproduction Research Department, Horticulture Research Institute, Ministry of Agriculture, Dokki, Giza.) were planted in hills 40 cm apart and 5 cm depth on 1<sup>st</sup> April and 29<sup>th</sup> March in the first and the second seasons, respectively. Macro nutrients occupied the main plots which were subdivided to 4 sub plots each contained one of the micronutrients treatment. The experiments included 16 treatments (4 macro x 4 micro treatments including the corresponding control treatment). The treatments were arranged as follow:

#### a- Macro nutrients (soil application):

1. Control treatment (untreated).
2. Ca: 10 kg/fed calcium element (Ca)
3. Mg: 5 kg/fed magnesium element (Mg)
4. Ca + Mg

#### b- Micro nutrients (foliar spray):

1. Control treatment (untreated)
2. Si: Silicon at 100 ppm (as Potassium silicate, 25% SiO<sub>2</sub>)
3. B: Boron at 100 ppm (as Borax, 10.5% boron)
4. Si + B (100+100 ppm)

Due to the large number of substances that provide a specific element and their difference in the content of this element according to the source, purity and moisture of these materials, therefore it should be taken into consideration that about 60 kg/fed calcium nitrate (CaNO<sub>3</sub>, 17% Ca) and 50 kg/fed magnesium sulfate (MgSO<sub>4</sub>, 10% Mg) were supplied in 4 monthly split applications during weeks 11- 23 giving a total of 10 kg/fed calcium (Ca) and 5 kg/fed magnesium (Mg). Concerning Boron and Silicon foliar spraying treatment, single biweekly foliar application for boron and/or silicon (100ppm each) foliar spray treatments were made during weeks 17-23 giving a total of 4 applications.

All the treatments were fertilized with the recommendation rates of NPK, *i.e.*, 100 units N/fed, 30 units P<sub>2</sub>O<sub>5</sub>/fed and 50 units K<sub>2</sub>O/fed. Calcium superphosphate (15.5% P<sub>2</sub>O<sub>5</sub>) was added once before planting as a source of phosphorus. Both ammonium nitrate (33.5% N, as nitrogen source) and potassium sulfate (48% K<sub>2</sub>O, as a source of potassium) were applied (broadcast) in five constant doses (20% for each), at one-month intervals, starting on the first of May (the extra nitrogen applied in the Ca treatment was balanced by reducing the ammonium nitrate application at side dressing). The other cultural practices were applied according to the instructions laid down by the Ministry of Agriculture, Egypt. Soil samples analyses were carried out according to the procedures described by Jackson (1973) and the average of the obtained data are shown in Table 1.

**Table 1:** Physical and chemical properties of the experimental soil.

Physical properties			Chemical properties		
Items	2015	2016	Items	2015	2016
Sand %	19.55	19.37	Available N (ppm)	95.56	92.77
Silt %	18.65	19.33	Available P (ppm)	5.54	4.63
Clay %	61.80	60.18	Available K (ppm)	209.44	211.36
			pH	7.6	7.2

## 2. Recorded data:

### 2.1. Vegetative growth parameters:

Measurements of the vegetative growth were carried out after 150 days of planting. Five plants were randomly selected to determine the average plant length, number of main stems per plant, and number of side branches per plant as well as both fresh and dry weight of the total plant foliage.

### 2.2. Yield and its component at harvest time:

- Number of tubers/plant .
- Weight of tubers /plant (kg).
- Total yield (tons per feddan). Tuber yield per plot in (kg) was determined and then it was calculated in ton/feddan.
- Dry matter percentage of tubers: a sample of 100 g from fresh weight of tubers were taken from each experimental plot and dried in an electric oven to constant weight at 65 °C and the dry matter percentage was calculated.
- Specific gravity was calculated as average of three grades for each treatment according to the methods of Murphy and Goven (1959) by the following formula:

$$\text{Specific gravity} = \frac{\text{Weight in air}}{\text{Weight in air} - \text{Weight in water}}$$

### 2.3. Chemical constituents:

- Total nitrogen was determined according to a modified method of Kjeldahl by Horneck and Miller (1998).
- Phosphorus was determined according to the method of Watanabe and Olsen (1965).
- Potassium percentage was determined by using Flame photometer according to Brown and Lilleland (1946).
- Ca, Mg and B were determined using atomic absorption spectrophotometer according to A.O.A.C. (1990).

### 2.4. Tubers storability:

At harvesting times, Yield of 5 plants (It ranges from 7 to 15 kg depending on its treatment) from each treatment were taken after the complete cleaning of the suspended soil (all the defected tubers were discarded), taken a statement of fresh weight immediately after the harvest and packaged in perforated bags (15µm) and numbered each bag with the number of treatment (in a randomised complete block design with three replicates) and put all the bags of one treatment within a special carton. All Packets were stored in the refrigerator at (5°C) degree and a relative humidity of 85-95%. All replicates were examined every month for weight loss and decay percentage for three months (90 days). The percentage of weight loss and decay of stored tubers were recorded after 30, 60 and 90 days from storage in both seasons according to Youssef (2007), as follows:

- Weight loss percentage was estimated according to the following equation:

$$\text{Weight loss}\% = \frac{\text{Initial tuber weight} - \text{tuber weight at sampling date}}{\text{Initial tuber weight}} \times 100$$

-The percentage of decayed tubers was calculated in relation to the total number of tubers according to the following formula:

$$\text{Decayed tubers\%} = \frac{\text{Number of decayed tubers}}{\text{Total numbers of tubers}} \times 100$$

#### **Statistical analysis:**

All recorded data were subjected to the analysis of variance procedures and treatment means were compared using the L.S.D. as described by Gomez and Gomez (1984). The statistical analysis was done by using the computer program MSTATC software version 4.

### **Results and Discussion**

#### **1. Vegetative growth parameters:**

Results in Table 2 show that the characteristics of vegetative growth, i.e., plant height, number of branches, and both fresh and dry weight of the plant, recorded the highest significant values when treated with a mixture of macro-fertilizers (Mg+Ca) followed by a single Mg element in both seasons except foliage dry weight in the 2<sup>nd</sup> season, where the single Mg treatment was exceeded without significant. The rest of the treatments in which one single element was used, whether calcium or magnesium, were significantly superiority in all abovementioned traits except foliage fresh weight in both seasons over the control treatment, which recorded the lowest values obtained in all the studied vegetative growth characteristics. Data in Table 2, also clarified that the use of spraying on leaves with both boron and silicon elements in a texture treatment (B+Si), or if both were single in alone treatment (B or Si) lead to significant differences between these treatments and between each other in all vegetative traits in both seasons except weight of both fresh and dry foliage which did not show any significant differences between spraying silicon (Si) and control treatments in both seasons and the 2<sup>nd</sup> season, respectively.

However, spraying with a mixture of boron and silicon (B+Si) treatment was superiority the rest of the treatments that contained only one element in all studied vegetative growth characteristics (plant height, number of branches and both fresh and dry weight of the plant). The results presented in the Table 2 show that the combination of (Mg+Ca) and spraying with some of the micro- elements (boron and/or silicon) in one treatment led to a positive reaction in most of the studied vegetative growth characteristics. Significant increment and clear superiority were recorded with soil application of Mg+Ca with spraying B+Si treatments over the rest of the other treatments in all vegetative traits during both studied seasons except foliage dry weight in 2<sup>nd</sup> season where the interaction of Mg soil application with B+Si foliar spray treatments show the significant higher effect followed by Mg+Ca with B+Si interaction. Table 2, also shows the presence of significant differences when treatment with fertilization with one element of calcium or magnesium and spray with one component also of boron or silicon compared to the control treatment in all the studied characteristics except foliage fresh weight. On the other hand, data shows that the least affected treatment by this reaction was the control, where the lowest values obtained were recorded in these tested characters compared to other treatments during both seasons. This increase may be caused to the important and multiple physiological functions of these elements intra the plant cell. These results are in agreement with the results obtained by El-Zohiri and Youssef (2015) who stated that treatment of Jerusalem artichoke with magnesium, calcium and boron resulted in a significant increase in all studied traits compared with control. In similar results, Nadia *et al.*, (2017) found that the treatment with the calcium element gave the highest values of tuber fresh weight and foliage fresh weight in both seasons of the study. These results are also in harmony with Mengel and Kirkby (1978) and Samy *et al.* (2015) who they found that boron has a positive role in cell division and development.

**Table 2.** Vegetative growth characters of Jerusalem artichoke plants as affected by macro and micro-nutrients as well as their interactions.

Treatments	Plant height (cm)		N0 of mean stems/plant		Foliage fresh weight(kg)		Foliage Dry weight%		
	2015	2016	2015	2016	2015	2016	2015	2016	
<b>Macro-nutrients</b>									
Control	215.75	204.75	55.99	55.48	1.4	1.37	24.35	25.13	
Ca	253.25	237.75	63.1	63.82	1.43	1.46	27.06	27.9	
Mg	246	227.75	68.1	71.07	1.46	1.54	29.03	29.52	
Mg+Ca	258	242.5	74.84	74.03	1.57	1.7	30.16	28.31	
LSD at 5%	8.03	8.44	6.78	2.82	0.11	0.16	1.45	1.24	
<b>Micro-nutrients foliar spray</b>									
Control	225.5	212.5	59.76	59.87	1.37	1.43	25.93	26.73	
Si	245.25	230	65.84	66.85	1.44	1.49	28.14	26.75	
B	247.5	233	65.95	66.88	1.5	1.53	26.54	27.65	
B+Si	254.75	237.25	70.48	70.78	1.57	1.61	29.99	29.73	
LSD at 5%	9.21	8.28	3.95	2.65	0.13	0.14	2.08	1.69	
<b>Interactions:</b>									
<b>Macro* Micro**</b>									
Control	Control	175	171	50.44	48.81	1.35	1.32	23.24	23.42
	Si	220	210	55.37	54.29	1.39	1.31	24.55	24.71
	B	223	215	56.08	58.3	1.41	1.4	23.23	25.7
	B+Si	245	223	62.08	60.5	1.45	1.43	26.38	26.68
Ca	Control	241	228	55.44	54.85	1.4	1.41	25.077	25.92
	Si	257	241	64.84	65.34	1.4	1.45	28.21	28.77
	B	256	240	64.81	66.31	1.45	1.45	26.38	28.15
	B+Si	259	242	67.31	68.77	1.47	1.52	28.57	28.75
Mg	Control	238	220	65.02	68.55	1.36	1.42	26.78	27.98
	Si	243	224	69.75	76.18	1.51	1.53	30.62	29.84
	B	251	231	67.18	68.13	1.42	1.56	27.38	28.15
	B+Si	252	236	70.44	71.41	1.56	1.63	31.35	32.12
Mg+Ca	Control	248	231	68.15	67.27	1.35	1.55	28.62	29.61
	Si	261	245	73.41	71.6	1.44	1.68	29.19	23.68
	B	260	246	75.72	74.78	1.71	1.72	29.18	28.61
	B+Si	263	248	82.08	82.45	1.78	1.85	33.66	31.35
L.S.D. at 5%	17.83	16.5	3.2	5.3	0.25	0.3	2.89	2.475	

\*: Macro-nutrients as ground application (Ca: Calcium nitrate at 60kg/fed., Mg: magnesium sulfate at 50kg/fed.)

\*\* : Micro-nutrients as foliar spray (Si: Silicon at 100 ppm. B: Boron at 100 ppm)

## 2. Yield and its components at harvest time:

As for the effect of macronutrients on yield and its components, data presented in Table 3 show clearly that a single (Ca or Mg) and mixture (Mg+Ca) treatments, significantly increased all studied yield parameters compared to the control treatment during the two studied seasons. However, the highest tubers number/plant, total yield /fed, dry matter (g/100g) and specific gravity of tubers in both seasons and tubers weight/plant in 2<sup>nd</sup> season were recorded with the mixture of calcium nitrate and magnesium sulfate (Mg+Ca) treatment, followed by a single Mg treatment in case of number of tubers/plant and total yield /feddan in both seasons and both dry matter and tubers weight/plant in 1<sup>st</sup> and 2<sup>nd</sup> seasons, respectively as well as a single Ca treatment in case of dry matter (2<sup>nd</sup> season) and specific gravity (both seasons) compared to the other tested treatments. On the contrary, the lowest weight of tubers (kg /plant), tubers number/plant, total yield (ton/fed.), dry matter (g/100g) and specific gravity were obtained in untreated control. Obtained results are similar in potato tuber yield to those reported by Talukder *et al.* (2009), who reported that Magnesium increased tuber yield of potato by 18 and 31% when magnesium was applied at 5 and 10 kg/ha, respectively. The same Table (3), also clarifies the spraying of boron and silicon elements (macronutrients) in a single (B or Si) or mixture (B+Si) treatments. A single (B or Si) and mixture (B+Si) treatments, significantly increased tubers weight/plant, tubers number/plant, total yield /fed and specific gravity of tubers in both seasons comparing to the control treatment during the two studied seasons. No significant

differences between a single Si treatment and the corresponding control were observed for dry matter in both seasons. However, the highest weight and number of tubers/plant, total yield /feddan, dry matter (g/100g) and specific gravity of tubers were recorded with the mixture of boron and silicon (B+Si) foliar spray treatment, followed by a single B treatment in both studied seasons.

**Table 3:** Jerusalem artichoke yield and its components as affected by macro and micro-nutrients as well as their interactions.

Treatments	Weight of tubers (kg /plant)		Tubers number/plant		Total yield (ton/fed.)		Dry matter (%)		Specific gravity (g/cm <sup>3</sup> )		
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	
<b>Macro-nutrients</b>											
Control	2.21	2.13	49.35	51.74	21.050	19.28	22.33	23.41	0.89	0.85	
Ca	2.51	2.78	52.51	54.75	25.097	22.38	23.95	26.12	0.93	0.92	
Mg	2.80	2.89	54.47	58.88	25.983	22.70	24.02	24.58	0.92	0.91	
Mg+Ca	2.78	3.13	57.86	62.95	27.325	26.00	25.25	26.81	0.95	0.94	
LSD at 5%	0.016	0.014	2.39	1.66	0.962	0.73	0.725	1.77	0.01	0.01	
<b>Micro-nutrients foliar spray</b>											
Control	2.09	2.26	44.92	50.96	21.808	19.66	22.37	23.16	0.90	0.87	
Si	2.46	2.56	52.28	53.99	24.790	22.92	22.89	24.11	0.91	0.90	
B	2.62	2.78	54.08	59.28	25.627	23.00	24.59	26.01	0.93	0.92	
B+Si	3.14	3.31	62.91	64.10	27.231	24.78	25.70	27.65	0.95	0.94	
LSD at 5%	0.01	0.019	1.52	2.04	0.835	0.98	0.70	1.33	0.008	0.009	
<b>Interactions:</b>											
<b>Macro* Micro**</b>											
Control	Control	1.85	1.99	40.13	50.04	18.58	16.35	21.21	22.13	0.87	0.81
	Si	2.28	2.06	50.04	51.15	20.51	18.67	21.23	23.24	0.88	0.82
	B	2.21	2.12	52.15	52.96	21.50	19.59	23.07	23.56	0.91	0.87
	B+Si	2.53	2.34	55.08	52.83	23.61	22.51	23.84	24.74	0.92	0.92
Ca	Control	2.03	2.31	41.09	50.14	20.83	18.00	24.65	22.14	0.92	0.90
	Si	2.30	2.46	52.99	54.81	25.96	23.16	22.11	26.22	0.93	0.93
	B	2.50	2.75	53.78	52.84	25.37	23.18	23.01	27.61	0.94	0.93
	B+Si	3.20	3.61	62.18	61.22	28.23	25.19	24.31	28.53	0.96	0.95
Mg	Control	2.21	2.2	49.34	50.35	22.54	19.62	20.77	21.86	0.89	0.87
	Si	2.63	2.59	51.81	54.81	25.53	23.47	23.66	22.54	0.91	0.93
	B	2.73	2.95	53.49	61.18	27.32	23.50	25.17	25.73	0.93	0.93
	B+Si	3.63	3.80	63.26	69.17	28.54	24.23	26.50	28.22	0.95	0.94
Mg+Ca	Control	2.25	2.54	49.11	53.31	25.28	24.68	22.87	26.52	0.92	0.90
	Si	2.62	3.16	54.29	55.17	27.16	26.39	23.37	24.45	0.95	0.93
	B	3.07	3.32	56.89	70.15	28.32	25.73	26.61	27.17	0.97	0.96
	B+Si	3.21	3.51	71.14	73.18	28.54	27.21	28.16	29.12	0.98	0.97
L.S.D. at 5%	0.03	0.038	3.04	4.08	1.67	1.96	1.41	2.67	0.01	0.01	

\*: Macro-nutrients as ground application (Ca: Calcium nitrate at 60kg/fed., Mg: magnesium sulfate at 50kg/fed.)

\*\* : Micro-nutrients as foliar spray (Si: Silicon at 100 ppm., B: Boron at 100 ppm)

Marie and Toma (2011) reported that, foliar application of boron with 1 kg/ha caused significant effects on tuber weight per plant with 60 and 59.4%, number of tubers per plant with 21.87 and 22.97%, average tuber weight with 33 and 31%, in both growing season, respectively, as compared with control. Regarding the effect of the interaction between macro nutrients soil application and micro spray, results in Table 3 show that there were significant effects on total produced yield and its components. In this regards, soil application of the mixture Mg+Ca treatment interacted with foliar spray with mixture (B+Si), significantly increased number of tubers/plant, total yield /fed, dry matter and specific gravity of tubers. However, the combination of a single Mg with mixture B+Si exhibited the significant heaviest weight per plant comparing to all other tested treatments. In the same time, no significant differences were observed between this combination (a single Mg with B+Si treatment) and the above combination (Mg+Ca treatment interacted with B+Si) for total yield/fed (1<sup>st</sup> season) and both tubers number and dry matter (2<sup>nd</sup> season). On the contrary, the lowest weight of tubers (kg

/plant), tubers number/plant, total yield (ton/fed.) and specific gravity were obtained in untreated control. The positive effect of Ca, Mg and B and its combination treatments on Jerusalem artichoke tubers yield components could be interpreted by multiple physiological functions to each element (El-Zohiri and Youssef, 2015). Whereas, Bari *et al.* (2001) found that the combination between B, Mg, S and Zn gave the highest number of tubers/plant and the high tuber weight. Obtained results are similar to those reported by Harris (1992); Zolotareva *et al.*, (2002), Trehan and Sharma (2003), White *et al.* (2005) and Zidan and Dauob (2005). They stated that foliar spraying of the mixture of CN at 2% + Potassium sulphate 2% or MS at 1.5% + Potassium nitrate 2% gave the highest yield/plant and per fed. of the largest tubers and reported that the application of mineral fertilizers to potato crop accelerates plant growth and increases tubers yield.

### 3. Tubers constituents:

Data presented in Table 4 show clearly that the tested macro and micro-nutrients significantly affected the tuber chemical constituents, i.e., N, P, K, Mg, Ca, B and Si contents. In this regard, data show clearly that applying mixture macronutrients (Mg+Ca) treatment to soil or spraying plants with mixture micronutrients (B+Si) treatment significantly increased all assayed mineral content of produced tubers during both seasons of study except nitrogen and boron contents in the 2<sup>nd</sup> season for spray of micro-nutrients and macro application, respectively comparing with other corresponding tested nutrients and the control treatment. However, no significant differences were found within the macronutrient treatments as well as within the micronutrient treatments for tuber phosphorus element in 2<sup>nd</sup> and both seasons, respectively.

Also, no significant differences were observed between soil application of Ca and Mg in a single nutrient for the tuber constituents of nitrogen, phosphorus and boron in both seasons as well as silicon in 1<sup>st</sup> one where Ca nutrient application had the greatest effect on tuber calcium and silicon constituents than Mg nutrient. Reverse trend was found in potassium, Magnesium and boron constituents in tuber at both seasons. As for the effect of the interaction, data in the same Table 4 indicate that no significant differences were observed for nitrogen, phosphorus and potassium in all treatments. Moreover, Mg+Ca combination with B+Si increased most mineral content of produced tubers, however no significant differences were observed between any combinations contain Mg macronutrient (Mg or Mg+Ca interact with B and/or Si) in tuber magnesium constituent. Also, the same trend with any combination contain Ca macronutrient (Ca or Mg+Ca interact with B and/or Si) in tuber Ca constituent. Moreover, the calcium component, which is an important element in the construction of cellular walls, makes cells strong and cohered, leading to the safety and stability of the cell. It has been observed that the treatment of plants with spraying by the calcium element led to a significant increase in tubers content of this element compared to the rest of the treatments, particularly in control treatment, which recorded the lowest values. and these results agree with Silva *et al.*, 1991; Locascio *et al.*, 1992; Karlsson *et al.*, 2001; Ozgen *et al.*, 2003; El-Zohiri and Youssef, 2015 and Hamdi *et al.*, 2015. Generally, the results show that the treatment of plants with a mixture of some macro- elements (calcium and magnesium) and spraying with some minor elements (boron and silicon with a concentration of 100 ppm/ each) led to a positive reaction and a significant increase in the chemical content of some mineral elements in tubers, i.e., nitrogen, phosphorus, potassium, calcium, magnesium, boron and silicon, where it recorded a noticeable superiority over corresponding control treatments during the studied seasons. Moreover, it was found that the boron affects the absorption of calcium and this is of great importance as it leads to balance between the elements involved in the composition of cellular walls and makes cellular walls able to resist the external effects of the causes of diseases and weather factors. These results are consistent with Spillman (2003) and Samy *et al.* (2015) who found that spraying of Jerusalem artichoke plants with boron at a concentration of 140 ppm gave the highest significant increase in boron content of tubers compared to other treatments in each of the study seasons. Adding a mixture of magnesium, calcium, boron and silicon with a concentration of 100 ppm for both boron and silicon, resulted in a significant increase in all vegetative and crop as well as increased chemical content in the chemical analysis compared to the other studied treatments. Most of these characteristic are presented in both study seasons and agree with Bari *et al.* (2001). They found that spraying mixture of calcium, magnesium and boron resulted in a high yield of Jerusalem artichoke tubers (9.30 t / ha) and the application of mineral fertilizers

leads to increased growth and productivity of tubers (Harris, 1992; Trehan and Sharma, 2003 and White *et al.*, 2005).

**Table 4:** Mineral contents of Jerusalem artichoke tubers as affected by macro and micro-nutrients as well as their interactions.

Treatments	N%		P%		K%		Mg%		Ca%		B (mg/kg)		Si (mg/kg)		
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	
<b>Macro-nutrients</b>															
Control	1.25	1.38	0.23	0.24	2.6	2.44	0.81	0.85	0.71	0.72	8.3	8.17	0.375	0.364	
Ca	1.41	1.46	0.26	0.25	2.69	2.63	0.82	0.86	0.91	0.92	8.5	8.44	0.441	0.434	
Mg	1.42	1.52	0.24	0.26	2.74	2.68	1.1	1.12	0.83	0.83	8.53	8.49	0.438	0.421	
Mg+Ca	1.55	1.53	0.32	0.27	2.81	2.77	1.13	1.14	0.91	0.93	8.66	8.43	0.449	0.425	
L.S.D. at 0.05	0.17	0.1	0.05	NS	0.07	0.04	0.03	0.02	0.03	0.01	0.14	0.11	0.008	0.013	
<b>Micro-nutrients foliar spray</b>															
Control	1.37	1.42	0.24	0.25	2.67	2.54	0.94	0.97	0.8	0.81	8.13	8.07	0.349	0.339	
Si	1.4	1.45	0.31	0.26	2.68	2.62	0.96	0.98	0.84	0.84	8.24	8.16	0.479	0.464	
B	1.43	1.52	0.25	0.26	2.7	2.67	0.98	0.99	0.84	0.86	8.78	8.55	0.395	0.381	
B+Si	1.44	1.5	0.26	0.26	2.77	2.7	0.99	1.02	0.86	0.88	8.83	8.75	0.480	0.462	
L.S.D. at 0.05	NS	0.01	N.S.	NS	0.06	0.04	0.03	0.04	0.01	0.02	0.14	0.15	0.006	0.022	
<b>Interactions:</b>															
Macro*	Micro**														
Control	0	1.26	1.4	0.21	0.23	2.51	2.31	0.78	0.8	0.7	0.71	7.97	7.75	0.304	0.305
	Si	1.27	1.4	0.24	0.25	2.58	2.43	0.8	0.85	0.7	0.73	8.1	8	0.411	0.401
	B	1.31	1.5	0.24	0.25	2.66	2.5	0.83	0.87	0.71	0.73	8.46	8.34	0.371	0.351
	B+Si	1.15	1.24	0.25	0.25	2.64	2.53	0.84	0.88	0.73	0.74	8.68	8.6	0.414	0.401
Ca	0	1.38	1.4	0.27	0.25	2.67	2.52	0.8	0.82	0.86	0.86	8.06	8	0.361	0.367
	Si	1.4	1.4	0.25	0.26	2.66	2.61	0.82	0.84	0.9	0.91	8.21	8.11	0.511	0.492
	B	1.4	1.46	0.25	0.26	2.63	2.66	0.82	0.87	0.92	0.94	8.89	8.81	0.393	0.373
	B+Si	1.47	1.58	0.26	0.26	2.79	2.74	0.86	0.91	0.95	0.97	8.85	8.84	0.501	0.503
Mg	0	1.4	1.42	0.23	0.26	2.74	2.61	1.03	1.11	0.82	0.81	8.16	8.18	0.361	0.335
	Si	1.41	1.5	0.24	0.27	2.71	2.68	1.11	1.11	0.83	0.82	8.28	8.22	0.482	0.464
	B	1.41	1.57	0.25	0.27	2.72	2.74	1.15	1.12	0.82	0.83	8.83	8.78	0.409	0.403
	B+Si	1.48	1.59	0.26	0.26	2.78	2.71	1.12	1.14	0.84	0.85	8.85	8.78	0.499	0.482
Mg+Ca	0	1.45	1.47	0.25	0.26	2.77	2.74	1.14	1.14	0.85	0.87	8.34	8.34	0.371	0.347
	Si	1.52	1.52	0.25	0.25	2.79	2.75	1.13	1.12	0.92	0.92	8.38	8.33	0.515	0.500
	B	1.6	1.54	0.26	0.28	2.81	2.77	1.12	1.13	0.93	0.96	8.95	8.27	0.407	0.394
	B+Si	1.64	1.6	0.27	0.28	2.87	2.84	1.13	1.17	0.94	0.98	8.96	8.79	0.508	0.460
L.S.D. at 0.05	0.17	0.07	NS	NS	N.S	N.S	0.06	0.04	0.07	0.07	0.22	0.19	0.019	0.027	

\*: Macro-nutrients as ground application (Ca: Calcium nitrate at 60kg/fed., Mg: magnesium sulfate at 50kg/fed.)

\*\* : Micro-nutrients as foliar spray (Si: Silicon at 100 ppm., B: Boron at 100 ppm)

#### 4. Tubers storability:

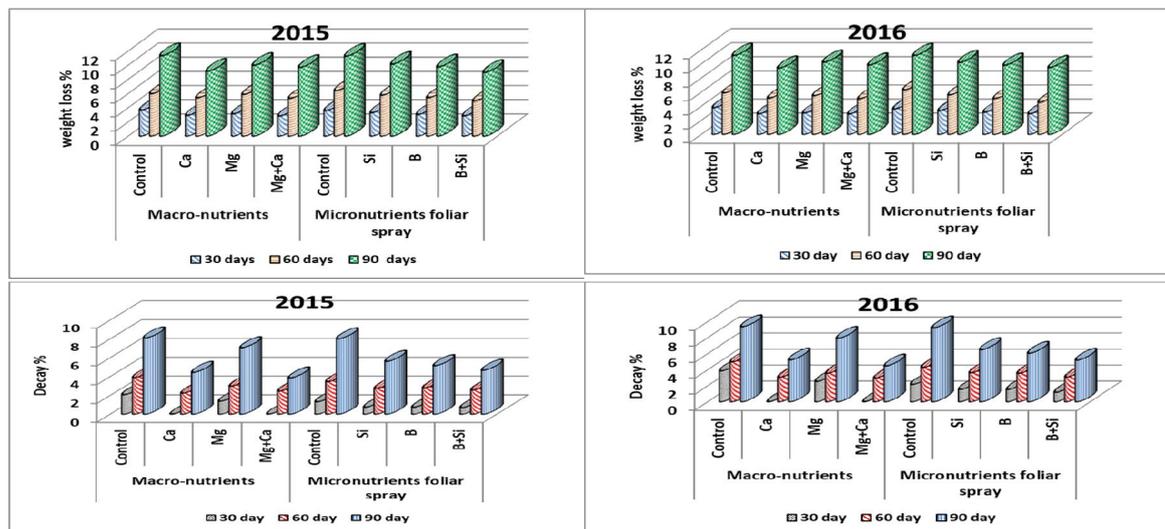
The results presented in the Table 5 and Fig.1 indicate that the percentages of both weight loss and decay in tubers during the storage period were greatly influenced by the treatment with nutrients that contained both calcium and magnesium, whether the addition was a single one element or with a mixture of both elements, as this led to positive effects in reducing the percentages of weight loss and decay in tubers stored in the refrigerator at a temperature of 5°C and humidity of 85% for three consecutive months compared to the control treatment that recorded the highest values in the loss percentage during the storage period during the two studied seasons. However, Fig.1 showing that using a mixture (Mg+Ca) treatment of calcium plus magnesium resulted in the lowest percentage of weight loss in tubers followed by the application of a single Ca element during both 30 and 60 days storage periods and reverse trend in case of 90 days storage period, where a single Ca element exhibited the lowest percentage of weight loss in tubers followed by a mixture (Mg+Ca) treatment.

**Table 5:** Weight loss and decay percentage of Jerusalem artichoke tubers as affected by macro and micro-nutrients as well as their interactions.

Treatments	Weight loss %						Decay %						
	30 day		60 day		90 day		30 day		60 day		90 day		
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	
<b>Macro-nutrients</b>													
Control	3.64	3.78	5.96	5.86	11.33	11.2	2.07	3.84	3.89	4.96	8.09	9.36	
Ca	2.9	2.91	5.37	5.13	9.15	9.4	0	0	2.23	3.04	4.44	5.21	
Mg	3.13	3.01	5.86	5.47	9.98	10.24	1.38	2.53	2.98	3.55	7.06	7.91	
Mg+Ca	2.82	2.88	5.29	5.02	9.68	9.83	0	0.01	2.45	2.93	3.85	4.46	
L.S.D. at	0.22	0.26	0.15	0.05	0.29	0.13	0.06	0.37	0.09	0.38	0.33	0.52	
<b>Micronutrients foliar spray</b>													
Control	3.58	3.6	6.4	6.3	11.26	11.19	1.31	2.15	3.46	4.29	8.01	9.22	
Si	3.29	3.34	5.76	5.58	10.14	10.2	0.73	1.53	2.73	3.6	5.61	6.5	
B	3.03	3.13	5.39	5.05	9.76	9.8	0.73	1.53	2.79	3.54	5.15	6.04	
B+Si	2.84	2.91	4.93	4.55	8.98	9.48	0.69	1.17	2.57	3.06	4.67	5.18	
L.S.D. 0.05	0.11	0.14	0.16	0.16	0.3	0.27	0.03	0.47	0.07	0.43	0.38	0.64	
<b>Interactions:</b>													
<b>Macro* Micro**</b>													
Control	0	4.11	4.24	7	6.95	13.38	12.74	3.15	5.22	6.01	7.01	13.04	15.59
	Si	3.82	3.91	6.04	6.03	12.01	11.35	1.84	3.81	3.35	4.81	6.95	8.13
	B	3.41	3.58	5.61	5.33	10.82	10.35	1.74	3.41	3.52	4.19	7.02	7.48
	B+Si	3.25	3.4	5.2	5.11	9.13	10.37	1.53	2.92	2.7	3.83	5.34	6.23
Ca	0	3.46	3.14	6.16	6.26	10.53	10.35	0	0	2.51	3.51	5.17	6.04
	Si	2.79	2.94	5.72	5.23	9.02	9.45	0	0	2.15	3	4.37	5.11
	B	2.75	2.83	5.09	4.93	8.84	9.03	0	0	2.19	3.2	4.12	4.96
	B+Si	2.62	2.75	4.5	4.11	8.22	8.78	0	0	2.08	2.45	4.1	4.73
Mg	0	3.74	3.42	6.34	6.12	10.72	10.96	2.08	3.35	3.33	4.12	9.32	10.3
	Si	3.10	3.04	6	5.96	10.01	10.33	1.23	2.32	3.01	3.51	7.13	8.05
	B	3.01	3.07	5.82	5.04	9.96	10.1	1.15	2.7	3.08	3.88	5.73	6.99
	B+Si	2.68	2.51	5.27	4.76	9.22	9.571	1.03	1.74	2.52	2.72	5.09	6.3
Mg+Ca	0	3.04	3.2	6.10	5.88	10.42	10.73	0	0	3.01	3.07	4.5	4.94
	Si	2.98	2.87	5.30	5.1	9.537	9.671	0	0	2.41	2.88	4.01	4.71
	B	2.73	2.76	5.03	4.92	9.42	9.721	0	0	2.37	2.54	3.76	4.73
	B+Si	2.56	2.68	4.76	4.21	9.36	9.23	0	0	2	2.24	3.15	3.48
L.S.D.0.05	0.225	0.298	0.324	0.335	0.600	0.546	0.06	0.64	0.13	0.78	0.64	1.21	

\*: Macro-nutrients as ground application (Ca: Calcium nitrate at 60kg/fed., Mg: magnesium sulfate at 50kg/fed.)

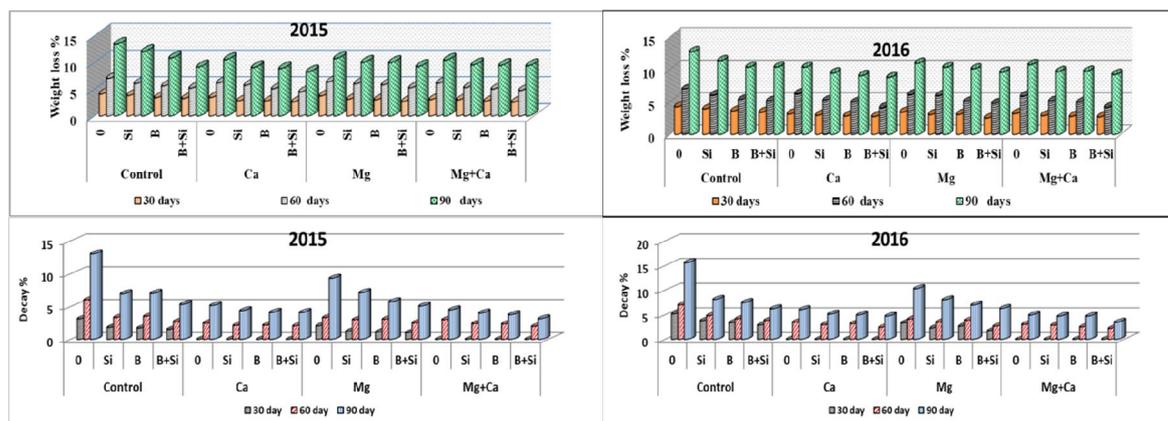
\*\*: Micro-nutrients as foliar spray (Si: Silicon at 100 ppm., B: Boron at 100 ppm)



**Fig.1:** Weight loss (upper) and decay (down) percentage of Jerusalem artichoke tubers as affected by macro and micro-nutrients

Regarding decay percentage (Table 5 and Fig.1), using a mixture (Mg+Ca) treatment of calcium plus magnesium resulted in the lowest percentage of decay in tubers followed by the application of a single Ca element during both 60 (2<sup>nd</sup> season) and 90 days (both seasons) storage periods and reverse trend in case of 30 days (both seasons) and the 1<sup>st</sup> season of 60 days storage periods, where a single Ca element exhibited the lowest decay percentage in tubers followed by a mixture (Mg+Ca) treatment.

This positive role may be due to the reinforcement of plants by ground fertilizer with both calcium and magnesium, which are the most important nutrients needed to build cellular walls and maintain tubers from external influences, where both calcium and magnesium play integral role in the quality of stored tubers and calcium is a key component of cell walls, helping to build a strong structure and ensuring cell stability (Reddy and Reddi, 2002; Awad *et al.*, 2010 and El- Zohiri and Youssef, 2015). The same Table 5 and Fig. 1 show that adding the micro-elements (boron, silicon) spraying on the leaves, whether the treatment with only one element or the treatment with a mixture of both elements, led to the existence of significant differences. However, the control treatment showed the highest rate of both weight loss and decay percentage during the whole period, while using a mixture (B+Si) treatment of the elements of boron and silicon together in one treatment resulted in the lowest percentage of both weight loss and decay percentage in tubers during the three periods (30 - 60 - 90 days), and this may be due to the spraying of each boron and silicon. The superiority of spraying mixture over the control treatments may be due to the severe competition between spray elements and each other and their entry into different physiological processes, including maintaining cell stability against external changes (El-Sayed *et al.*, 2007). Regarding the effect of the interaction between macro nutrients soil application and micro foliar spray, Table 5 and Fig. 2 show that there was significant effect on both weight loss and decay percentage.



**Fig. 2:** Weight loss (upper) and decay (down) percentage of Jerusalem artichoke tubers as affected by the interactions between macro and micronutrients

Concerning the weight loss (Fig.2), soil application of 10 kg Ca/fed treatment interacted with foliar spray with mixture (B+Si) at 100ppm each, significantly decreased weight loss percentage followed by soil application of the mixture (5 kg Mg + 10 kg Ca) treatment interacted with foliar spray with mixture (B+Si) at 100ppm each in both 60 and 90 days storage periods of both seasons and reverse trend in case of 30 days storage period of 1<sup>st</sup> season. However, the combination of a single Mg with mixture B+Si exhibited significantly the lowest weight loss followed by the combination of Mg+Ca treatment with mixture B+Si and then the combination of a single Ca with mixture B+Si in descending order without any significant differences between them in case of 30 days storage period of 2<sup>nd</sup> season comparing to all other tested treatments. Respecting to decay percentage (Fig. 2), soil application of Mg+Ca or a single Ca treatment interacted with foliar spray with B, Si, mixture (B+Si) and corresponding control, significantly decreased decay percentage to zero in the 30 days storage period of both seasons followed by soil application of 5 kg Mg treatment interacted with foliar spray with all a single B and Si treatments. However, the combination of mixture Mg+Ca with mixture B+Si exhibited the significant lowest decay in case of both 60 and 90 days storage periods of both

seasons comparing to all other tested treatments. On the contrary, the greatest weight loss and decay percentage of tubers were obtained in untreated control. The positive effect of Ca, Mg and B and its combinations treatments on Jerusalem artichoke tubers yield components could be interpreted by multiple physiological functions to each element (El-Zohiri and Youssef, 2015).

### Conclusion

This study recommends soil fertilizing with 5kg/fed magnesium and 10 kg/fed calcium, spraying with boron and silicon at a concentration of 100 ppm each for obtaining strong plant growth that positively affects the crop and its components and also works to increase the quality and chemical content inside the tubers as well as reduce the weight loss and increase the capacity of the tubers on the storage process for more than three months in cold storage at 5°C and relative humidity 85-95%

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