Scientific Journal of Agricultural Sciences

Print (ISSN 2535-1796) / Online (ISSN 2535-180X)

A Comparative Study Between The Use Of Mineral and Organic Nitrogen and Foliar Feeding With Boron and Calcium on The Growth, Productivity and Tubers Quality of Jerusalem Artichoke

Fawzy Y.O. Mansour[1], Heba Allah, M. M. Khalil[1] and Samar, A. Bardisi[2]

[1]Hort. Res. Inst., Agric. Res. Cent., Giza, Egypt
[2]Hort. Dept. Fac. Agric. Zagazig University, Egypt.

Citation: Fawzy Y.O. Mansour, Heba Allah, M. M. Khalil and Samar, A. Bardisi (2025). A Comparative Study Between The Use Of Mineral and Organic Nitrogen and Foliar Feeding With Boron and Calcium on The Growth, Productivity and Tubers Quality of Jerusalem Artichoke. Scientific Journal of Agricultural Sciences, 7 (1): 1-20. https://doi.org/10.21608/sjas.2025.352530.1492.

Publisher :
Beni-Suef University, Faculty of Agriculture

Received: 12 / 1 / 2025
Accepted: 15 / 2 / 2025

Corresponding author:
Samar, A. Bardisi

Email:
samarbardisi30@gmail.com

ABSTRACT

This study was conducted during the summer seasons of 2022 and 2023 at the Research Farm of the Agricultural Research Station in Gemmeiza, affiliated with the Agricultural Research Center located in Gharbia Governorate ,Egypt. This is to study the effect of the interaction between fertilizing Jerusalem artichoke plants with three forms of nitrogen fertilization (100% of the recommended rate (RR) in mineral nitrogen (MN), which is equivalent to 90 nitrogen units/fed.), 100% RR in organic nitrogen (ON), which is equivalent to 10 tons per fed. of farmyard manure (FYM) fertilizer, MN at 50% RR, which is equivalent to 45 nitrogen units/fed. + ON at 50% RR, which is equivalent to 5 tons per fed. FYM and spraying with all of boron (B) at a concentration of 50 ppm and calcium ($CaCl_2$) at a concentration of 150 ppm), beside spraying with water (control treatment) on the growth, yield and quality of Jerusalem artichoke tubers of the Fuseau variety grown under clay soil conditions.

The interaction between MN at 50 %RR (45 kg N/fed.) +ON at 50 %RR (5 ton FYM/fed.) and spraying with $CaCl_2$ at 150 ppm increased plant height , number of branches /plant , both fresh and dry weight of shoots/plant , the concentrations of chlorophyll a , chlorophyll b, total chlorophyll (a+b) in leaf tissues, N, P and K contents and its uptake by shoots at of Jerusalem at 135 days after planting , number of tubers/ plant , average tuber weight , yield / plant , total yield /fed. as well as nitrogen use efficiency (NUE) in both seasons. Furthermore , the interaction between MN at 50 %RR +ON at 50 %RR and spraying with B at 50 ppm or $CaCl_2$ at 150 ppm increased total carbohydrates ,inulin and B concentration in tuber in both season. In this regard, the yield its components, and NUE of the fertilization treatment were MN at 100% RR, and spraying with $CaCl_2$ at 150 ppm gave a yield and its components, and the nitrogen use efficiency equal to the interaction treatment between MN at 50% RR. +ON at 50% RR and foliar spraying with $CaCl_2$ 150 ppm.

KEYWORDS: Jerusalem artichoke, N, Ca, B, yield and quality.

1.INTRODUCTION

Native to North America, the Jerusalem artichoke (*Helianthus tuberosus* L.) has been introduced to a number of countries for immediate use and development, particularly because to its drought tolerance and reduced production costs (Denoroy *et al*., 1996). Applications for the Jerusalem artichoke

include ethanol production, animal feed, and human nourishment.

Mineral nitrogen fertilizer is of great importance for the growth and development of most vegetable plants. However, the excessive use of large amounts of nitrogen as mineral fertilizers in agricultural production during the past decades may lead to some harmful effects, such as the accumulation of both nitrates and nitrites in the food chain, causing serious effects on human health. Some of these chemical fertilizers also seep into the water through leaching into the soil, causing disturbances in the biological balance and polluting groundwater (Waksman, 1952). To achieve higher yields and a good quality product, soil condition is a crucial factor. Therefore, chemical fertilizers must be combined with organic fertilizers such as renewable and environmentally friendly FYM to achieve sustainable productivity with minimal harmful effects of chemical fertilizers on soil health and the environment. The yield per unit area can be increased while improving its quality through the balanced use of organic and mineral fertilizers in the appropriate combination.

Fertilizing Jerusalem artichoke plants with mineral, organic nitrogen or the combination with mineral and organic produced the best values of plant growth, productivity and tuber quality (El-Sharkawy , 2003, Feleafel, 2004, Ragab, *et al.*, 2008 , Sawicka, and Kalembasa, 2008, Anwar, *et al*., 2011 , Gao *et al.*, 2011, Sawicka and Kalembasa, 2013 , Matías *et al*., 2013, Tony , 2013, Li *et al*., 2016, , Epie *et al*., 2018, Mohamed, 2020, Wierzbowska *et al*., 2021, Skiba *et al.*, 2023, Wierzbowska *et al*., 2023 and Jankowski and Dubis (2024).

The production of cell walls, cell division, cell growth, auxin metabolism, sugar transport, control of carbohydrate metabolism, and the movement of photosynthates from source to sink all depend on boron (Jafari-Jood *et al*., 2013).

Foliar spray with boron had significant effect on plant growth, productivity and quality as compared to unsprayed plants (El-Dissoky, and Abdel-Kadar,2013 on potato El-Zohiri, and Youssef, 2015 and Samy *et al*., 2015 on Jerusalem artichoke, Tantawy, 2017 on sweet potato, Alkharpotly *et al*.,2018 , Lenka and Das 2019 on potato, Singh *et al.*, 2018, Sharaf-Eldin *et al*., 2019 on sweet potato and Sarker *et al*., 2019 on potato).

Calcium is necessary for the two processes of cell division and elongation, which are critical to plant growth. Additionally, calcium enters the cell as calcium bactate in the intermediate lamella structure. Additionally, it aids in the production of phosphatidic acid, which enters cell membrane composition and enhances the membrane's efficacy and range of functions (Hassan, 2016). One of the key macronutrients in Jerusalem artichoke tubers is calcium; a lack of it can cause young leaves to distort and flower buds to die (Sawicka and Kalembasa, 2013).

Plant growth, yield and quality were affected by spraying with calcium than unsprayed plants (El-Seifi *et al*., 2014 , Saif El-Deen *et al*., 2015 on sweet potato, Hamdi *et al*.,2015 on potato, Chowdhury, 2017, El-Hadidi *et al*. 2017, Saaseea and Al-a'amry 2018, Mansour and Abo El-Fotoh 2019 , EL-Morsy *et al*., 2020 and Duwadi *et al*., 2022 on potato , Hasan 2023 on sweet potato and Agha *et al*., (2024) on potato.

The aim of conducting this research is the possibility of reducing dependence on the use of mineral nitrogen fertilizer by using organic nitrogen fertilizer, as well as foliar spraying with some microelements such as calcium and boron, with the aim of improving the growth, yield and tuber quality of Jerusalem artichoke plants growing in clay soil.

2.MATERIALS AND METHODS

This experiment was conducted during the summer seasons of 2022 and 2023 at the Research Farm of the Agricultural Research Station affiliated with the Agricultural Research Center in Gemmeiza - Gharbia Governorate - Egypt, in order to study the response of Jerusalem artichoke plants to three forms of nitrogen fertilization as a soil additive and foliar spraying with both boron and calcium and the interaction between them and the effect of this treatments on plant growth , yield and the tuber quality of Jerusalem artichoke is the Fuseau variety grown in clay soils.

Table 1. Physical and chemical parameters of the experimental soil in 2022 and 2023 seasons.

Season	OM (%)	Clay (%)	Silt (%)	Sand (%)	Texture class	E.C ds/m	pH	Available (mg/kg)		
								N	P	K
2022 season	1.55	48.56	39.80	11.64	Clay	1.72	7.80	35.64	6.22	304.7
2023 season	1.56	50.15	37.67	12.18	loam	1.73	7.82	37.18	7.19	312.2

Nine treatments were used in this experiment, which combined three different types of nitrogen fertilization: 100% RR in the form of MN (90 nitrogen units/fed.), 100% RR in the form of ON (10 tons per fed. of FYM), and 50% RR in the form of MN+50% RR in the form of ON (45 nitrogen units/fed. + 5 tons FYM per fed.). In addition to, spraying with water (control treatment), and foliar spray with B at 50 ppm and $CaCl_2$ at 150 ppm.

These treatments were set up in a split plot design with three replicates. The main plots had nitrogen sources assigned at random, and the sub-plots had foliar feeding with Band $CaCl_2$ dispersed at random.

The Jerusalem artichoke tuber seeds were acquired from the Hort. Res. Instit. and planted 50 cm apart on April 23 and April 28 of the first and second seasons, respectively. There were 16.8 m^2 in the experiment plot. It has three 8-meter-long ridge with a 70-cm divide between each two ridges.

The following types of nitrogen were added: Mineral nitrogen treatments (ammonium sulphate 20.6%N) were applied in the following manner: one third was applied during soil preparation, and the remaining two thirds were applied 45 and 70 days after planting. All organic nitrogen (FYM) treatments were added during soil preparation.

Four times (75, 90, 105, and 120 days after planting) foliar applications of B and $CaCl_2$ and boron were sprayed.

The vegetative development characteristics were measured on one ridge, while yield and tuber quality were assessed on the remaining two ridges. To prevent overlapping soil infiltration or spraying application, a guard row was also left between each pair of experimental plots.

150 kg of calcium super phosphate (15.5 % P_2O_5) and 192 kg of potassium sulphate (48–52 % K_2O) were given to each experimental unit. While potassium was added 60, 90, and 120 days after planting, P_2O_5 was added during the soil preparation phase.

The agricultural procedures followed the Ministry of Agriculture's recommendations for the commercial production of Jerusalem artichokes.

2.1. Data recorded

1. Plant growth: To measure plant height (cm), number of branches per plant, and shoot fresh weight (g), three plants were randomly selected from each experimental unit 135 days after planting. Additionally, the dry weight of the shoots (g)/plant was determined using dried fresh shoots/plant at 70ºC until the weight remained constant.

Leaf Pigments: To determine the concentrations levels of chlorophyll a ,b and carotenoides after 135 days after planting, a random sample was taken from the fourth upper leaf for the two seasons under study using the method described by **Wettestein (1957**).

2. Nitrogen, phosphorus and potassium contents: After 135 days from planting shoots in both seasons had their N, P, and K contents measured using the procedures outlined by the A.O.A.C. (2016). The uptake of potassium, phosphorus, and nitrogen (mg/shoot) was computed.

3. Yield and its components: Number of tuber per plant, average tuber weight (g), tuber yield per plant (kg), and total yield (ton/fad.) at harvest time, 180 days after planting was recorded.

4. Nitrogen use efficiency

$$NUE = \frac{Y_N}{N_R} = \text{kg tuber /one unit nitrogen (Janssen, 1998)}$$

Where: Y_N is yield as the particular N level, and N_R is the particular N rate.

5. Tuber quality:

Carbohydrate percentage*:* In dry tuber, it was measured colorimetrically using the procedures outlined by A.O.A.C. (2016).

Inulin contents: According to Winton and Winton (1985), the inulin concentration in tubers was measured.

Dry matter (%):DM (%) was computed after 100 g of grated tuber tissues were dried at 105 ^{o}C until their weight remained constant.

Cottenie *et al*. (1982) calculated the calcium content of tubers as a percentage, while Allen *et al.* (1997) used the Atomic Absorption/Flame Spectrophotometer AA-646 to determine the B content of tubers.

2.2. Statistical Analysis:

Snedecor and Cochran's (1980) statistical analysis of variance was applied to the recorded data, and Duncan's (1958) means separation was performed.

3.RESULTS AND DISCUSSION

3.1.Plant Growth

3.1.1.Effect of mineral and organic nitrogen fertilization

Data in Table 2 show that fertilizing Jerusalem artichoke plants growing in clay soil with mineral nitrogen (MN) at 100 % of recommended rate (RR) (90 kg N/fed.) and MN at 50% RR (45 kg N/fed.) + organic nitrogen (ON) at 50%RR (5 ton /fed. farmyard manure) (FYM) significantly increased plant height , number of branches /plant, fresh weight of shoots an dry weight of shoots/ plant at 135 days after planting (DAP) in both seasons. On the other hand, fertilized plants with 100 %RR ON produced the lowest values of abovementioned parameters of Jerusalem artichoke in both seasons.

This means that MN at 50%RR +ON at 50%RR was the best treatment for enhancing plant height , number of branches /plant , fresh weight of shoots an dry weight of shoots/ plant at 135 days after planting (DAP) in both seasons.

The increases in dry weight of shoot/ plant were about 86.03 and 67.96% for 100%RR MN and 87.40 and 70.97% for treatment MN at 50%RR + ON at 50%RR over 100 %RR ON in the 1st and 2nd seasons, respectively.

Applying organic manure to soil can increase the growth of Jerusalem artichoke plants by improving the physical characteristics of the soil, such as its texture and water-holding capacity. It also improves soil aeration and lowers pH, which makes nutrients in the soil more available for plant growth (Khandaker *et al.,* 2017). However, the presence of N mineral fertilization allowed for the balance among the combined items that resulted in the highest average values of vegetative growth traits; this improved the given vegetative growth characteristics and increased nitrogen uptake and its associated role in chlorophyll synthesis, which was followed by the process of photosynthesis and carbon dioxide assimilation (Jasso-Chaverria et al., 2005). This, in turn, enhanced the growth of Jerusalem artichokes.

Table 2. Effect of mineral, organic nitrogen on plant growth of Jerusalem artichoke at 135 days after planting under clay soil in 2022 and 2023 seasons

Treatments	Plant height (cm)	Number of branches / plant	Fresh weight of shoots (g)	Dry weight of shoots (g)
		2022 season		
100 % RR MN	174.41 a	11.11 a	422.73 a	145.16 a
100 %RRON	103.26 b	6.41 b	256.85 b	79.07 b
50%RRMN+50%RR ON	173.39 a	11.24 a	416.64 a	150.11 a
LSD at 5% level	2.66	0.52	12.65	7.72
		2023 season		
100 % RR MN	173.37 a	11.58 a	422.13 a	142.76 a
100 %RRON	107.68 b	6.01 b	258.28 b	84.99 b
50%RRMN+50%RR ON	171.31 a	10.95 a	419.60 a	145.31 a
LSD at 5% level	5.58	0.64	10.52	5.86

100 % RRMN=90 kg mineral nitrogen /fed., 100 %RROM= 10 ton/fed. farmyard manure (0.9 %N) and 50%RRMN+50%RR ON= 45 kg N/fed.+ 5 ton/fed. farmyard manure (0.9 %N).

These results are agree with those reported with El-Sharkawy , 2003, Sawicka, and Kalembasa, 2008, Anwar, et al., 2011 Tony, 2013, Epie et al., 2018 and Mohamed, 2020. They showed that fertilizing Jerusalem artichoke with mineral and organic nitrogen recorded the best plant growth parameters.

3.1.2.Effect of foliar spray with boron and calcium

Foliar spray with boron (B) at 50 ppm and calcium chloride (CaCl2) at 150 ppm increased plant height, number of branches /plant , both fresh and dry weight of shoots/plant of Jerusalem artichoke than control treatment (sprayed with water) at 135 days after planting in both seasons as shown in Table 3. However, spraying with CaCl2 at 150 ppm gave the highest values (158.23 and 162.06 cm), 10.66 and 10.83 branch/plant), (388.09 and 385.51 g) and (132.01 and 129.63 g) for plant height , number of branches /plant , both fresh and dry weight of shoots/plant in the 1st and 2nd seasons, respectively , followed by spraying plants with B at 50 ppm .

The increases in shoot dry weight were about 4.02 and 2.74%, for B at 50 ppm and 11.14 and 7.96 % for CaCl2 at 150 ppm over unsprayed plants in the 1st and 2nd seasons, respectively.

There are numerous ways to highlight the critical role that calcium plays in plant growth. In severely deficient plants, it is most readily identified by a loss of cell segmentation, a general breakdown of membrane structures, and an increase in the leakage of low molecular-weight solutes from cells of Ca-deficient tissues (Van Goer, 1996).

In plants, boron's main function is to increase calcium's mobility, solubility, and metabolism. It also aids in nitrogen absorption (Pandav et al., 2016). Additionally, it plays a role in the transport and metabolism of carbohydrates, the synthesis of nucleic acids, the elongation of roots, photosynthetic processes, and the absorption of water by plant parts, all of which contribute to increased fresh and dry weight (Islam et al., 2016).

These results were in coinciding with that obtained by El-Seifi et al., 2014 , Saif El-Deen et al., 2015 on sweet potato, Hamdi et al.,2015, Chowdhury, 2017, El-Hadidi et al. 2017 and Agha et al., 2024 on potato as for calcium effect. Also, El-Zohiri, and Youssef, 2015 and Samy et al., 2015 on Jerusalem artichoke and Tantawy, 2017 on sweet potato cams the similar results for boron effect.

Table 3. Effect foliar application with boron and calcium on plant growth of Jerusalem artichoke at 135 days after planting under clay soil in 2022 and 2023 seasons

Treatments	Plant height (cm)	Number of branches / plant	Fresh weight of shoots (g)	Dry weight of shoots (g)
		2022 season		
0 (water)	137.65 c	8.42 c	334.59 c	118.78 b
B	155.18 b	9.68 b	373.55 b	123.55 b
Ca Cal_2	158.23 a	10.66 a	388.09 a	132.01 a
LSD at 5% level	2.09	0.41	9.92	6.05
		2023 season		
0 (water)	136.19 c	8.10 c	342.13 c	120.07 b
B	154.11 b	9.61 b	372.37 b	123.36 b
Ca Cal_2	162.06 a	10.83 a	385.51 a	129.63 a
LSD at 5% level	4.38	0.50	8.25	4.60

B=Boron at 50 ppm and Ca= calcium chloride at 150 ppm

3.1.3.Effect of the interaction treatment

The interaction between MN at 100% RR and foliar spay with CaCl2 at 150 ppm significantly increased plant height , number of branches /plant , both fresh and dry weight of shoots/plant at 135 DAP in both seasons with no significant differences with the interaction between MN at 50 %RR +ON at 50 %RR and CaCl2 at 150 ppm , except plant height in the 1st seasons (Table 4). This means that the

Table 4. Effect of interaction between mineral, organic nitrogen and foliar application with boron and calcium on plant growth of Jerusalem artichoke at 135 days after planting under clay soil in 2022 and 2023 seasons

Treatments		Plant height (cm)	Number of branches / plant	Fresh weight of shoots (g)	Dry weight of shoots (g)
Nitrogen treatments	Foliar spray				
			2022 season		
100 % RR MN	0(water)	156.11 c	9.88 d	404.69 b	139.69 c
	B	181.49 b	10.84 c	429.00 a	142.92 bc
	Ca Cal_2	185.63 a	12.62 a	434.49 a	152.87 ab
100 %RRON	0(water)	98.27 f	5.67 f	207.73 e	72.70 e
	B	103.68 e	6.37 f	265.90 d	80.04 de
	Ca Cal_2	107.82 d	7.21 e	296.93 c	84.47 d
50%RRMN+50%RRON	0(water)	158.58 c	9.73 d	391.34 b	143.95 bc
	B	180.36 b	11.83 b	425.74 a	147.70 abc
	Ca Cal_2	181.24 b	12.17 ab	432.85 a	158.68 a
LSD at 5% level		3.62	0.71	17.19	10.49
			2023 season		
100 % RR MN	0(water)	152.80 c	9.86 c	406.03 c	138.60 c
	B	180.69 ab	11.68 b	424.12 ab	141.89 bc
	Ca Cal_2	186.63 a	13.21 a	436.23 a	147.78 ab
100 %RRON	0(water)	100.08 e	5.52 e	214.66 e	80.84 e
	B	106.12 e	6.05 de	274.09 d	84.76 de
	Ca Cal_2	116.84 d	6.48 d	286.09 d	89.38 d
50%RRMN+50%RRON	0(water)	155.68 c	8.93 c	405.70 c	140.76 bc
	B	175.53 b	11.12 b	418.90 bc	143.44 bc
	Ca Cal_2	182.72 ab	12.81 a	434.20 a	151.73 a
LSD at 5% level		7.59	0.87	14.30	7.96

100 % RRMN=90 kg mineral nitrogen /fed., 100 %RROM= 10 ton/fed. farmyard manure (0.9 %N) and 50%RRMN+50%RR ON= 45 kg N/fed.+ 5 ton/fed. farmyard manure (0.9 %N). B=Boron at 50 ppm and Ca Cal_2= calcium chloride at 150 ppm

interaction between MN at 50 %RR +ON at 50 %RR and CaCl2 at 150 ppm increased plant height , number of branches /plant , both fresh and dry weight of shoots/plant at 135 DAP in both seasons of Jerusalem artichoke. On the contrary, fertilizing with ON at 100 % RR gave the lowest values of all above-mentioned parameters for plant growth under foliar spray treatments with water (control), B at 50 ppm and CaCl2 at 150 ppm at 135 DAP in both seasons.

These increases in shoot dry weight were about 9.43 and 9.47% for the interaction between MN at 50% RR +ON at 50 %RR and spraying with CaCl2 at 150 ppm over fertilizing with MN at 100 % RR only in the 1st and 2nd seasons, respectively.

The results are harmony with Akter (2020) they indicated that plant height, number of leaves / plant and shoot dry weight were the highest with the interaction between fertilizing with mineral nitrogen at 150 kg N/fed. and spraying with boron.

3.2.Leaf pigments

3.2.1. Effect of mineral and organic nitrogen fertilization

Mineral nitrogen at 100 % RR and MN at 50 % RR +ON at 50 %RR significantly improved the concentrations of chlorophyll a , chlorophyll b, total chlorophyll (a+b) in leaf tissues of Jerusalem artichoke, whereas ON at 100% RR increased the concentration of carotenoides in leaf tissues at 135 DAP in both seasons (Table 5).

Nitrogen is one of the main element which has direct part in vital roles in

Table 5. Effect of mineral, organic nitrogen on leaf pigments of Jerusalem artichoke at 135 days after planting under clay soil in 2022 and 2023 seasons

Treatments	Chlorophyll a (mg/gDW)	Chlorophyll b (mg/gDW)	Chlorophyll a+b (mg/gDW)	Carotenoides (mg/gDW)
		2022 season		
100 % RR MN	4.04 a	2.06 a	6.04 a	1.82 b
100 %RRON	2.15 b	1.15 b	4.68 b	2.20 a
50%RRMN+50%RR ON	4.03 a	2.08 a	6.01 a	1.20 c
LSD at 5% level	0.084	0.07	0.26	0.25
		2023 season		
100 % RR MN	3.92 a	2.06 a	5.98 a	1.83 b
100 %RRON	2.23 b	1.20 b	4.86 b	2.17 a
50%RRMN+50%RR ON	4.10 a	2.12 a	6.10 a	1.26 c
LSD at 5% level	0.21	0.11	0.31	0.21

100 % RRMN=90 kg mineral nitrogen /fed. , 100 %RROM= 10 ton/fed. farmyard manure (0.9 %N) and 50%RRMN+50%RR ON= 45 kg N/fed.+ 5 ton/fed. farmyard manure (0.9 %N).

chlorophyll synthesis and growth processes especially the vegetative growth parameters of plants (Jafari-Jood et al.,2013). Results agree with Majeed and Ahmed (2023). They showed that the combination between organic, mineral and bio-fertilizer had significant effect on leaf pigments of potato plant.

3.2.2.Effect of B and $CaCl_2$

Sparing with CaCl2 at 150 ppm significantly increased the concentrations of chlorophyll a, chlorophyll b, total chlorophyll (a+b) and carotenoides in leaf tissues of Jerusalem artichoke with no significant differences with spraying with B at 50 ppm with respect to chlorophyll a, and chlorophyll b in the 2nd seasons and carotenoides in both seasons (Table 6).

The increases in total chlorophyll (a+b) in leaf tissues were about 7.42 and 9.37 %, for B at 50 ppm and 19.53 and 14.34 % for CaCl2 at 150 ppm over unsprayed plants in the 1st and 2nd seasons, respectively. These outcomes may be explained by boron's efficient regulation of different enzyme activities and the production of photosynthetic pigments (Bari et al., 2001).

Mansour and Abu El-Fotoh (2018) found a similar pattern with potatoes. They showed that, in comparison to plants that were not sprayed with calcium and boron, plants that were sprayed with these nutrients produced more chlorophyll overall in their leaf tissues.

Table 6. Effect of foliar application with boron and calcium leaf pigments of Jerusalem artichoke at 135 days after planting under clay soil in 2022 and 2023 seasons

Treatments	Chlorophyll a (mg/gDW)	Chlorophyll b (mg/gDW)	Chlorophyll a+b (mg/gDW)	Carotenoides (mg/gDW)
		2022 season		
0 (water)	3.12 c	1.62 b	5.12 c	1.55 b
B	3.35 b	1.71 b	5.50 b	1.79 a
Ca Cl_2	3.75 a	1.96 a	6.12 a	1.88 a
LSD at 5% level	0.177	0.11	0.20	0.19
		2023 season		
0(water)	3.20 b	1.63 b	5.23 c	1.53 b
B	3.47 a	1.82 a	5.72 b	1.83 a
Ca Cl_2	3.59 a	1.93 a	5.98 a	1.90 a
LSD at 5% level	0.17	0.12	0.24	0.16

B=Boron at 50 ppm and $CaCl_2$= calcium chloride at 150 ppm

3.2.3. Effect of the interaction treatment

The interaction between MN at 100 % RR (90 kg N/fed.) and foliar spray with $CaCl_2$ at 150 ppm and the interaction between MN at 50 % RR +ON at 50 %RR (5 ton FYM/fed.) and spraying with $CaCl_2$ significantly enhanced the concentrations of chlorophyll a , chlorophyll b, total chlorophyll (a+b) in leaf tissues of Jerusalem artichoke at 135 DAP in both seasons (Table7). Whereas, the interaction between ON at 100% RR and spraying with B at 50 ppm or $CaCl_2$ at 150 ppm increased the concentration of carotenoides in leaf tissues.

Table 7. Effect of interaction between mineral, organic nitrogen and foliar application with boron and calcium leaf pigments of Jerusalem artichoke at 135 days after planting under clay soil in 2022 and 2023 seasons

Treatments		Chlorophyll a (mg/gDW)	Chlorophyll b (mg/gDW)	Chlorophyll a+b (mg/gDW)	Carotenoides (mg/gDW)
Nitrogen treatments	**Foliar spray**		**2022 season**		
100 % RR MN	**0(water)**	3.68 b	1.93 b	5.61 bc	1.58 cd
	B	3.94 b	2.03 b	5.97 b	1.91 bc
	Ca Cal_2	4.50 a	2.22 a	6.55 a	1.98 b
100 %RRON	**0(water)**	1.93 d	1.02 d	4.25 f	2.01 b
	B	2.21 cd	1.19 cd	4.70 e	2.22 ab
	Ca Cal_2	2.33 c	1.26 c	5.09 d	2.37 a
50%RRMN+50%RR ON	**0(water)**	3.77 b	1.92 b	5.50 c	1.06 e
	B	3.90 b	1.93 b	5.83 bc	1.24 de
	Ca Cal_2	4.42 a	2.40 a	6.72 a	1.31 de
LSD at 5% level		0.31	0.19	0.36	0.34
			2023 season		
100 % RR MN	**0(water)**	3.78 c	1.95 b	5.73 bc	1.49 b
	B	3.92 bc	2.12 b	6.04 ab	1.98 a
	Ca Cal_2	4.08 ab	2.13 b	6.18 a	2.04 a
100 %RRON	**0(water)**	1.96 e	1.03 d	4.39 e	2.03 a
	B	2.34 d	1.26 c	4.90 d	2.20 a
	Ca Cal_2	2.40 d	1.33 c	5.30 cd	2.29 a
50%RRMN+50%RR ON	**0(water)**	3.86 bc	1.93 b	5.58 bc	1.07 c
	B	4.15 ab	2.09 b	6.24 a	1.32 bc
	Ca Cal_2	4.29 a	2.34 a	6.48 a	1.39 b
LSD at 5% level		0.29	0.21	0.43	0.29

100 % RRMN=90 kg mineral nitrogen /fed., 100 %RROM= 10 ton/fed. farmyard manure (0.9 %N) and 50%RRMN+50%RR ON= 45 kg N/fed.+ 5 ton/fed. farmyard manure (0.9 %N). B=Boron at 50 ppm and Ca Cal_2= calcium chloride at 150 ppm

3.3. Contents and uptake of N, P and K in shoots

3.3.1. Effect of mineral and organic nitrogen fertilization

Data in Table 8 show that all amounts of MN (90 kg N/fed.) and half amount of MN (45 kg N/fed)+ half amount of ON (5 ton FYM/fed.) increased the contents of N, P and K in shoots as well as N,P and K uptake by shoots at 135 (DAP) in both seasons (Table 8). In this concern, fertilizing with MN at 50 %RR+ON at 50 %RR recorded the highest values of N uptake (3490 and 3352 mg), P (501 and 489 mg) and K (2807 and 2775 mg/shoot) in the each of the two seasons. On the other hand, fertilizing with organic manure at 100 %RR (10 ton /fed. FYM) produced the lowest N,P and K uptake by shoots in both seasons.

Increased availability of N, P, and K in the soil solution makes them available to the

Table 8. Effect of mineral, organic nitrogen on N,P and K contents and its uptake by shoots of Jerusalem artichoke shoots at 135 days after planting under clay soil in 2019 and 2020 seasons

Treatments	Mineral Contents (%)					
	N		P		K	
	2022 season	2023 season	2022 season	2023 season	2022 season	2023 season
100 % RR MN	2.30 a	2.32 a	0.331 a	0.335 a	1.84 a	1.86 a
100 %RRON	2.02 b	2.12 b	0.303 b	0.307 b	1.61 b	1.61 b
50%RRMN+50%RR ON	2.32 a	2.30 a	0.333 a	0.336 a	1.86 a	1.90 a
LSD at 5% level	0.12	0.13	0.011	0.015	0.17	0.18
	Minerals uptake (mg /shoots)					
100 % RR MN	3352a	3316 a	481a	478 a	2671 a	2669a
100 %RRON	1604b	1801 b	240b	262 b	1284 b	1376b
50%RRMN+50%RR ON	3490a	3352 a	501a	489 a	2807 a	2775a
LSD at 5% level	113.0	122.16	19.19	33.32	676.0	650.0

100 % RRMN=90 kg mineral nitrogen /fed. , 100 %RROM= 10 ton/fed. farmyard manure (0.9 %N) and 50%RRMN+50%RR ON= 45 kg N/fed.+ 5 ton/fed. farmyard manure (0.9 %N).

plant and enhances root growth, which in turn increases the root absorption area. This may be the reason for the superior N, P, and K content of Jerusalem artichoke shoot tissues. As a result, there would be more absorption and nutrient accumulation in the tissue of the shoots. These results are harmony with Gao et al., 2011, Tony, 2013 and Li et al., 2016 on Jerusalem artichoke. They showed that, the highest N, P and K uptake were observed with the plants which fertilized with the combination with mineral and organic nitrogen.

3.3.2.Effect of B and $CaCl_2$

Foliar application with B at 50 ppm or CaCl2 at 150 ppm significantly increased N, P and K contents and their uptake by shoots at 135 DAP as compared to spraying with water (control) treatment in both seasons (Table 9). However, spraying with CaCl2 at 150 ppm , followed by spraying with B at 50 ppm increased N, P and K contents and their uptake by shoots.

The increases in N, P and K uptake by shoot were about 10.15 and 10.80%, 7.80 and 16.24%, and 13.67 and 9.00% for spraying with B at 50 ppm and were about 31.51 and 17.94%, 20.70 and 27.64 % and 27.45 and 24.45 % for spraying with CaCl2 at 150 ppm over unsprayed plants in the 1st and 2nd seasons, respectively.

Table 9. Effect of foliar application with boron and calcium on N,P and K contents and its uptake by shoots of Jerusalem artichoke at 135 days DAP under clay soil in 2019 and 2020 seasons

Treatments	Mineral contents (%)					
	N		P		K	
	2022 season	2023 season	2022 season	2023 season	2022 season	2023 season
0 (water)	2.05 c	2.14 b	0.309 c	0.307 c	1.62 b	1.66 b
B	2.18 b	2.27 a	0.321 b	0.329 b	1.80 a	1.79 ab
Ca Cl_2	2.41 a	2.32 a	0.337 a	0.342 a	1.89 a	1.93 a
LSD at 5% level	0.09	0.10	0.008	0.012	0.13	0.14
	Mineral Uptake (mg / shoots)					
0 (water)	2472 c	2592 c	372 c	351 c	1982 b	2045 b
B	2723 b	2820 b	401 b	408 b	2253ab	2229 ab
Ca Cl_2	3251 a	3057 a	449 a	448 a	2527a	2545 a
LSD at 5% level	88.67	95.86	15.06	26.149	523.47	490.0

B=Boron at 50 ppm and $CaCl_2$= calcium chloride at 150 ppm

These results are agreement with those reported by Saaseea and Al-a'amry 2018, Mansour and Abo El-Fotoh 2019 and EL-Morsy et al., 2020 on potato for calcium effect and Sharaf-Eldin et al., 2019 on sweet potato for boron effect . They indicated that spraying with calcium or boron produced the highest N, P and K uptake by plants than unparsed plants.

3.3.3.Effect of the interaction treatments

Fertilizing of Jerusalem artichoke plants with MN at 100 %RR and foliar spray with $CaCl_2$ at 150 ppm and MN at 50 %RR+ON at 50 %RR significantly increased N, P and K contents and its uptake by shoots at 135 DAP in both seasons Tables 10 and 11). However, the highest values of N uptake (4110 and 3717 mg), P (552 and 536 mg)and K (3110 and 3110) were observed with the interaction between MN at 50 %RR+ON at 50 %RR and spraying with $CaCl_2$ in the first and second seasons, respectively. Fertilizing with organic manure at 100 %RR produced the lowest values of N, P and K contents and their uptake by shoots in both seasons.

Table 10. Effect of interaction between mineral, organic nitrogen and foliar application with boron and calcium on N,P and K contents of Jerusalem artichoke shoots at 135 days after planting under clay soil in 2022 and 2023 seasons

Treatments		Mineral Contents (%)					
		N		P		K	
Nitrogen treatments	Foliar spray	2022 season	2023 season	2022 season	2023 season	2022 season	2023 season
100 % RR MN	0 (water)	2.11 c	2.21 bc	0.322 bc	0.319 b	1.73 ab	1.70 c
	B	2.28 b	2.31 ab	0.326 bc	0.335 ab	1.84 ab	1.89 abc
	$CaCl_2$	2.52 a	2.44 a	0.346 a	0.351 a	1.94 a	2.01 ab
100 %RRON	0 (water)	1.91 d	2.07 c	0.287 e	0.284 c	1.39 c	1.42 d
	B	2.04 cd	2.22 bc	0.305 d	0.315 b	1.67 b	1.68 c
	$CaCl_2$	2.12 bc	2.07 c	0.317 cd	0.324 b	1.78 ab	1.74 bc
50%RRMN+50%RRON	0 (water)	2.14 bc	2.16 bc	0.318 cd	0.320 b	1.75 ab	1.87 abc
	B	2.22 bc	2.30 ab	0.334 ab	0.337 ab	1.89 ab	1.80 bc
	$CaCl_2$	2.59 a	2.45 a	0.348 a	0.353 a	1.96 a	2.05 a
LSD at 5% level		0.16	0.18	0.015	0.020	0.23	0.24

100 % RRMN=90 kg mineral nitrogen /fed. , 100 %RROM= 10 ton/fed. farmyard manure (0.9 %N) and 50%RRMN+50%RR ON= 45 kg N/fed.+ 5 ton/fed. farmyard manure (0.9 %N). B=Boron at 50 ppm and $CaCl_2$= calcium chloride at 150 ppm

3.4. Yield and its components

3.4.1. Effect of mineral and organic nitrogen fertilization

Fertilizing Jerusalem artichoke plants with MN at 50 %RR (45 kg N/fed.)+ON at 50 %RR (5 ton /fed. FYM) significantly increased number of tubers/ plant (39.47 and 39.75) , average tuber weight (50.73 and 50.58 g), yield / plant (2.003 and 2.034 g), total yield /fed.(23.740 and 24.042 ton/fed.) as well as nitrogen use efficiency (NUE) (395.67 and 400.67 kg tuber / kg N) in both seasons, followed by MN at 100% RR (90 kg N/fed.) as shown in Table 12. On the other hand, the lowest values of all yield and its components were observed with 100 %RR organic nitrogen (10 ton /fed. FYM).

Plant height, leaf number per plant, branch number per plant, and dry weight of the plant are all indicators of quantitative vegetative growth, which is enhanced by the use of organic fertilizer as a source of slow-releasing nutrients and rapid dissolved N element as a mineral (inorganic) fertilizer. This results in the production of more flowers, more fruits per plant, and the highest average fruit

Table 11. Effect of interaction between mineral, organic nitrogen and foliar application with boron and calcium on N,P and K uptake of Jerusalem artichoke shoots at 135 days after planting under clay soil in 2022 and 2023 seasons

Treatments		Mineral Uptake (mg / shoots)					
		N		P		K	
Nitrogen treatments	Foliar spray	2022 season	2023 season	2022 season	2023 season	2022 season	2023 season
100 % RR MN	0(water)	2947 d	3063 c	450 c	442 c	2417 bc	2358 bc
	B	3259 c	3279 b	466 bc	475 bc	2630 ab	2682 a
	$CaCl_2$	3852 b	3606 a	529 a	519 ab	2996 a	2970 a
100 %RRON	0(water)	1389 g	1673 e	209 e	230 f	1011 c	1148 c
	B	1633 f	1882 d	244 d	267 ef	1337 c	1424 c
	$CaCl_2$	1791 e	1850 d	268 d	290 e	1504 c	1555 c
50%RRMN+50%RR ON	0(water)	3081 d	3040 c	458 c	450 d	2519 ab	2632 ab
	B	3279 c	3299 b	493 b	483 bc	2792 a	2582 ab
	$CaCl_2$	4110 a	3717 a	552 a	536 a	3110 a	3110 a
LSD at 5% level		153.59	166.0	26.09	45.29	906.6	835.0

100 % RRMN=90 kg mineral nitrogen /fed., 100 %RROM= 10 ton/fed. farmyard manure (0.9 %N) and 50%RRMN+50%RR ON= 45 kg N/fed.+ 5 ton/fed. farmyard manure (0.9 %N). B=Boron at 50 ppm and $CaCl_2$= calcium chloride at 150 ppm

Table 12. Effect of mineral, organic nitrogen on yield and its components and nitrogen use efficiency (NUE) of Jerusalem artichoke under clay soil in 2022 and 2023 seasons

Treatments	Number of tuber/ plant	Average tuber weight (g)	Yield / plant (kg)	Total yield (ton /fad.)	NUE (kg tuber / kg N)
			2022 season		
100 % RR MN	39.08 a	47.76 b	1.869 b	22.141 b	369.00 b
100 %RRON	37.20 b	46.00 c	1.710 c	20.291 c	338.20 c
50%RRMN+50%RR ON	39.47 a	50.73 a	2.003 a	23.740 a	395.67 a
LSD at 5% level	1.00	1.43	0.107	0.642	19.63
			2023 season		
100 % RR MN	39.40 a	47.46 b	1.874 b	22.175 b	369.60 b
100 %RRON	38.04 b	45.01 c	1.709 c	20.316 c	338.60 c
50%RRMN+50%RR ON	40.20 a	50.58 a	2.034 a	24.042 a	400.67 a
LSD at 5% level	1.08	0.87	0.117	0.596	21.81

100 % RRMN=90 kg mineral nitrogen /fed. , 100 %RROM= 10 ton/fed. farmyard manure (0.9 %N) and 50%RRMN+50%RR ON= 45 kg N/fed.+ 5 ton/fed. farmyard manure (0.9 %N).

weight, all of which positively contribute to fruit yield.

Obtained results are in a good line with those reported by Matías et al., 2013, Li et al., 2016, Epie et al., 2018, Mohamed, 2020, Wierzbowska et al., 2021, Skiba et al., 2023, and Jankowski and Dubis (2024). They showed that fertilizing plants with the mixture with mineral and organic nitrogen superior the productivity Jerusalem artichoke as compared to fertilizing with mineral nitrogen only. In the same time, Ramadan, and Bardisi (2020) came the similar results for nitrogen use efficiency in pepper.

3.4.2.Effect of B and $CaCl_2$

Foliar spray with B at 50 ppm or $CaCl_2$ at 150 ppm significantly enhanced increased number of tubers/ plant , average tuber weight , yield / plant , total yield /fed. as well as NUE as compared to spraying with water (control treatment) in both seasons as shown in Table 13. Spraying plants with $CaCl_2$ at 150 ppm recorded the maximum values of number of tubers/ plant (39.65 and 39.93) , average tuber

Table 13. Effect of foliar application with boron and calcium on yield and its components and nitrogen use efficiency (NUE) of Jerusalem artichoke under clay soil in 2022 and 2023 seasons

Treatments	Number of tuber/ plant	Average tuber weight (g)	Yield / plant (kg)	Total yield (ton /fad.)	NUE (kg tuber / kg N)
			2022 season		
0(water)	37.75 c	45.33 c	1.725 c	20.475 c	341.27 c
B	38.34 b	48.66 b	1.854 b	21.985 b	366.43 b
$CaCl_2$	39.65 a	50.50 a	2.004 a	23.711 a	395.17 a
LSD at 5% level	0.55	1.12	0.084	0.504	15.40
			2023 season		
0(water)	38.08 b	45.33 c	1.728 c	20.479 c	341.30 c
B	39.64 a	47.53 b	1.883 b	22.310 b	371.83 b
$CaCl_2$	39.93 a	50.20 a	2.006 a	23.743 a	395.73 a
LSD at 5% level	0.84	0.68	0.092	0.468	17.11

B=Boron at 50 ppm and $CaCl_2$= calcium chloride at 150 ppm

weight (50.50 and 50.20 g), yield / plant (2.004 and 2.006 g) , total yield /fed. (23.711 and 23.743 ton/fed.) as well as NUE (395.17 and 395.73 kg / kg N) in the each of the two seasons.

The involvement of boron in photosynthetic efficiency, enhancing mineral nutrient uptake, and dry matter translocation and accumulation toward the roots may be the cause of the improvements in total yield when compared to the control treatment (Tariq and Mott, 2006).

These results are harmony with those obtained with EL-Morsy *et al*., 2020 and Duwadi *et al*., 2022 on potato, Hasan 2023 and Agha *et al*., (2024) on sweet potato respecting calcium effect , Lenka and Das 2019 on potato, Singh *et al.,* 2018 , Sharaf-Eldin *et al*., 2019 on sweet potato and Sarker *et al*., 2019 on potato regarding boron effect . All showed that spraying plants with calcium or boron recorded the best results for yield and its components as compared to unsprayed plants.

3.4.3.Effect of the interaction treatments

The interaction between MN at 100%RR (90 kg N/fed.) and spraying with $CaCl_2$ at 150 ppm and the interaction between MN at 50 %RR (45 kg N/fed.) +ON at 50 %RR (5 ton FYM/fed.) and spraying with $CaCl_2$ significantly increased number of tubers/ plant , average tuber weight , yield / plant , total yield /fed. as well as NUE with no significant differences with the interaction between MN at 50 %RR (45 kg N/fed.) +ON at 50 %RR (5 ton FYM/fed.) and spraying with B at 50 ppm in both seasons (Table 14). Yield and its components and NUE for MN at 100%RR and $CaCl_2$ at 150 ppm equal yield and its components and NUE for MN at 50 %RR (45 kg N/fed.) +ON at 50 %RR (5 ton FYM/fed.) and spraying with $CaCl_2$ at 150 ppm and MN at 50 %RR (45 kg N/fed.) +ON at 50 %RR (5 ton FYM/fed.) and spraying with B at 50 ppm. This means that fertilizing Jerusalem artichoke plants growing in clay soil with MN at 50 %RR (45 kg N/fed.) +ON at 50 %RR (5 ton FYM/fed.) and spraying with $CaCl_2$ at 150 ppm or with B at 50 ppm were the best treatments for enhancing number of tubers/ plant , average tuber weight , yield / plant , total yield /fed. as well as NUE .

In this concern, El-Hadidi, *et al*. (2017) indicated that fertilization with nitrogen at 150 kg N/fed. and spraying with boron at 100 ppm was the best for increasing the productivity of potato plants.

3.5. Tuber Quality

3.5.1. Effect of mineral and organic nitrogen fertilization

Data in Table 15 indicate that fertilizing Jerusalem artichoke with MN at 50 %RR+ON at 50 %RR or 100 %RR as ON significantly increased all values of tuber quality as compared to fertilizing with MN at 100 %RR in both seasons. Total carbohydrates (50.96 and 50.47 %),

Table 14. Effect of interaction between nitrogen sources and foliar application with calcium and boron on yield and its components and nitrogen use efficiency (NUE) of Jerusalem artichoke under clay in 2022 and 2023 seasons

Treatments		Number of tuber/ plant	Average tuber weight (g)	Yield / plant (kg)	Total yield (ton /fad.)	NUE (kg tuber / kg N)
Nitrogen treatments	Foliar spray					
				2022 season		
100 % RR MN	**0(water)**	37.98 bc	44.50 e	1.690 ef	20.006 e	333.40 ef
	B	38.02 bc	48.30 cd	1.836 bcd	21.732 c	362.20bcd
	$CaCl_2$	41.24 a	50.50 ab	2.083 a	24.684 a	411.40 a
100 %RRON	**0(water)**	36.49 d	42.00 f	1.564 f	18.568 f	309.50 f
	B	38.17 b	46.70 d	1.746 de	20.752de	345.90 de
	$CaCl_2$	36.94 cd	49.30 bc	1.821 cde	21.552 cd	359.20cde
50%RRMN+50%RR ON	**0(water)**	38.80 b	49.51 bc	1.921 bc	22.852 b	380.90 bc
	B	38.84 b	51.00 ab	1.981 ab	23.472 b	391.20 ab
	$CaCl_2$	40.78 a	51.70 a	2.108 a	24.896 a	414.90 a
LSD at 5% level		0.96	1.95	0.145	0.872	26.68
				2023 season		
100 % RR MN	**0(water)**	37.78 efg	45.00 e	1.700 de	20.148 d	335.80 de
	B	38.58 def	47.00 d	1.813 cd	21.556 c	359.30 cd
	$CaCl_2$	41.86 a	50.40 ab	2.110 a	24.821 a	413.70 a
100 %RRON	**0(water)**	37.38 fg	41.53 f	1.552 e	18.494 e	308.20 e
	B	39.86bcd	44.60 e	1.772 cd	21.006 cd	350.10 cd
	$CaCl_2$	36.90 g	48.90 c	1.804 cd	21.448 c	357.50 cd
50%RRMN+50%RR ON	**0(water)**	39.08 cde	49.46 bc	1.933 bc	22.796 b	379.90 bc
	B	40.48 abc	51.00 a	2.064 ab	24.368 a	406.10 ab
	$CaCl_2$	41.04 ab	51.30 a	2.105 a	24.961 a	416.00 a
LSD at 5% level		1.47	1.18	0.160	0.811	29.65

100 % RRMN=90 kg mineral nitrogen /fed. , 100 %RROM= 10 ton/fed. farmyard manure (0.9 %N) and 50%RRMN+50%RR ON= 45 kg N/fed.+ 5 ton/fed. farmyard manure (0.9 %N). B=Boron at 50 ppm and $CaCl_2$= calcium chloride at 150 ppm

Table 15. Effect of mineral, organic nitrogen on tuber quality at harvesting time of Jerusalem artichoke in under clay soil in 2022 and 2023 seasons

Treatments	Total carbohydrates (%)	Inulin (mg/g dry matter)	Dry matter (%)	Ca (%)	B (ppm)
			2022 season		
100 % RR MN	46.07 c	11.21 c	21.11 c	0.441 c	5.63 c
100 %RRON	47.81 b	12.02 b	26.65 a	0.476 b	6.70 b
50%RRMN+50%RR ON	50.96 a	12.68 a	24.95 b	0.518 a	7.91 a
LSD at 5% level	1.09	0.27	1.00	0.020	0.19
			2023 season		
100 % RR MN	46.36 c	11.52 b	21.61 c	0.460 b	5.45 c
100 %RRON	47.41 b	12.58 a	26.71 a	0.486 a	6.33 b
50%RRMN+50%RR ON	50.47 a	12.90 a	24.83 b	0.502 a	7.80 a
LSD at 5% level	0.44	0.34	1.05	0.021	0.16

100 % RRMN=90 kg mineral nitrogen /fed. , 100 %RROM= 10 ton/fed. farmyard manure (0.9 %N) and 50%RRMN+50%RR ON= 45 kg N/fed.+ 5 ton/fed. farmyard manure (0.9 %N).

inulin (12.68 and 12.90%), dry matter percentage (24.95 and 24.83%), concentrations of Ca (0.518 and 0.502 %) and B (7.91 and 7.80 ppm) in tuber were the maximum when fertilized plants with MN at 50 %RR+ON at 50 %RR, followed by 100 %RR as ON in both seasons.

The increases in inulin contents in tuber were about 7.23 and 9.20 % for fertilizing with ON at 100 % RR (10 ton /fed. FYM), 13.11 and 11.98 % for fertilizing MN at 50 %RR (45 kg N/fed.)+ON at 50 %RR (5 ton /fed. FYM) over fertilizing with 100 %RR MN (90 kg N/fed.) in the both seasons, respectively.

These results are harmony with those reported by Mohamed (2020) , Wierzbowska *et al*., 2021, Skiba *et al.*, 2023, Wierzbowska *et al*., 2023 and Jankowski and Dubis, 2024. All on Jerusalem artichoke.

3.5.2.Effect of B and $CaCl_2$

Foliar spray with $CaCl_2$ at 150 ppm or B at 50 ppm significantly enhanced all tuber quality of Jerusalem artichoke as compared to unsprayed plants in both seasons. spraying plants with $CaCl_2$ at 150 ppm gave the maximum values of total carbohydrates (49.31 and 49.17 %), dry matter (25.39 and 24.81 %) and calcium percentage (0.510 and 0.508 %) in the first and second seasons, respectively, while spraying with B at 50 ppm predicted the maximum inulin(12.24 and 12.68 %) and B concentration (7.08 and 7.03 ppm) in tubers in the both seasons (Table 16).

The increases in inulin contents in tuber were about 5.61 and 5.84 % for spraying with B at 50 ppm , 4.31 and 2.92 % for spraying with $CaCl_2$ at 150 ppm over control treatment in both seasons.

Calcium facilitates the movement of photosynthetic products from the manufacturing sites in the leaves to storage locations in tubers (sinks) and other plant parts, which improves production, quantity, and quality (Marschner, 2012). The stimulative effect of calcium on DM%, may be due to that spraying plants with $CaCl_2$ increased Ca content in tuber (Table 15). There were positive correlation among DM percentage and calcium content in tuber.

These results are harmony with those obtained with Mansour and Abo El-Fotoh 2019, EL-Morsy *et al*., 2020 and Duwadi *et al*., 2022 on potato and Hasan 2023 on sweet potato regarding calcium effect , El-Zohiri, and Youssef, 2015 and Samy *et al*., 2015 on Jerusalem artichoke respecting boron effect. They showed that tuber quality of Jerusalem artichoke were the best with spraying by calcium or boron as compared to unsprayed plants.

Table 16. Effect of foliar application with boron and calcium on tuber quality at harvesting time of Jerusalem artichoke in under clay soil in 2022 and 2023 seasons

Treatments	Total carbohydrates (%)	Inulin (mg/g dry matter)	Dry matter (%)	Ca (%)	B (ppm)
			2022 season		
0 (water)	46.83 b	11.59 b	22.93 c	0.439 c	6.37 c
B	48.71 a	12.24 a	24.38 b	0.486 b	7.08 a
$CaCl_2$	49.31 a	12.09 a	25.39 a	0.510 a	6.80 b
LSD at 5% level	0.85	0.21	0.79	0.015	0.15
			2023 season		
0(water)	46.71 c	11.98 c	23.80 b	0.466 b	6.11 c
B	48.35 b	12.68 a	24.54 ab	0.474 b	7.03 a
$CaCl_2$	49.17 a	12.33 b	24.81 a	0.508 a	6.44 b
LSD at 5% level	0.35	0.26	0.82	0.017	0.12

B=Boron at 50 ppm and $CaCl_2$= calcium chloride at 150 ppm

3.5.3.Effect of the interaction treatment

The interaction between MN at 50 %RR (45 kg N/fed.) +ON at 50 %RR (5 ton FYM/fed.) and foliar spray with B at 50 ppm or $CaCl_2$ at 150 ppm increased total carbohydrates ,inulin and B concentration in

tuber in both season (Table17). The interaction between MN at 50 %RR +ON at 50 %RR and spraying with $CaCl_2$ at 150 ppm increased Ca content in tuber. The interaction between ON at 100 %RR (10 ton FYM/fed.) and spraying with B at 50 ppm or $CaCl_2$ at 150 ppm increased dry matter percentage in tuber. On the other hand, the interaction between fertilizing Jerusalem artichoke with 100 %RR as MN (90 kg N/fed.) and spraying with water recorded the lowest values of all tuber quality in both seasons. This results are harmony with those obtained with Shaker and Abdul Rasool (2023) showed that the highest concentration of B in tuber was obtained by the interaction between 24 ton/.ha organic manure and spraying with boron at 100 mg /l.

Generally, the best way to increase productivity and tuber quality when growing Jerusalem artichokes in clay soil was to fertilize them with MN at 50%RR (45 kg N/fed.) + ON at 50%RR (5 ton FYM/fed.) and to spray them with 150 ppm $CaCl_2$ four times (75, 90, 105, and 120 days after planting).

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Table 17. Effect of interaction between mineral, organic nitrogen and foliar application with boron and calcium on tuber quality at harvesting time of Jerusalem artichoke under clay soil in 2022 and 2023 seasons

Treatments		Total carbohydrates (%)	Inulin (mg/g dry matter)	Dry matter (%)	Ca (%)	B (ppm)
Nitrogen treatments	Foliar spray					
				2022 season		
100 % RR MN	**0 (water)**	44.85 e	10.93 e	19.31 g	0.414 d	5.27 g
	B	46.35 d	11.64 d	21.03 f	0.460 c	5.98 e
	$CaCl_2$	47.03 cd	11.07 e	22.99 e	0.444 c	5.66 f
100 %RRON	**0 (water)**	46.95 cd	11.60 d	25.41 cd	0.446 c	6.45 d
	B	48.10 bc	12.08 c	26.81 ab	0.467 c	6.99 c
	$CaCl_2$	48.40 bc	12.40 bc	27.73 a	0.546 a	6.68 d
50%RRMN+50%RR ON	**0 (water)**	48.70 b	12.24 c	24.09 de	0.463 c	7.41 b
	B	51.70 a	13.00 a	25.31 cd	0.503 b	8.27 a
	$CaCl_2$	52.50 a	12.80 ab	25.47 bc	0.564 a	8.06 a
LSD at 5% level		1.48	0.37	1.36	0.027	0.26
				2023 season		
100 % RR MN	**0 (water)**	44.80 f	10.94 f	20.60 e	0.444 e	5.20 h
	B	46.18 e	12.04 de	21.82 de	0.450 de	6.04 f
	$CaCl_2$	48.10 c	11.58 e	22.42 d	0.486 bc	5.11
100 %RRON	**0 (water)**	46.60 e	12.56 bc	26.30 ab	0.475 cde	5.78 g
	B	47.23 d	12.78 abc	26.82 a	0.474 cde	6.85 d
	$CaCl_2$	48.40 c	12.40 cd	27.03 a	0.510 ab	6.38 e
50%RRMN+50%RR ON	**0 (water)**	48.73 c	12.45 cd	24.52 c	0.480 bcd	7.37 c
	B	51.65 a	13.24 a	24.98 bc	0.498 bc	8.20 a
	$CaCl_2$	51.03 b	13.02 ab	24.99 bc	0.528 a	7.85 b
LSD at 5% level		0.61	0.46	1.43	0.029	0.21

100 % RRMN=90 kg mineral nitrogen /fed. , 100 %RROM= 10 ton/fed. farmyard manure (0.9 %N) and 50%RRMN+50%RR ON= 45 kg N/fed.+ 5 ton/fed. farmyard manure (0.9 %N). B=Boron at 50 ppm and $CaCl_2$= calcium chloride at 150 ppm

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الملخص العربي

دراسه مقارنه بين إستخدام النيتروجين المعدنى والعضوى والتغذيه الورقيه بالبورون والكالسيوم على نمو وانتاجية وجودة درنات الطرطوفه

فوزى يحيى عمر منصور[١]، هبه الله محمد محمد خليل[١] و سمر عبد الله برديسى[٢]

[١]معهد بحوث البساتين، مركز البحوث الزراعية، مصر

[٢]قسم البساتين، كلية الزراعة، جامعه الزقازيق

أجريت هذه الدراسه خلال موسمى صيف ٢٠٢٢، ٢٠٢٣ وذلك بالمزرعه البحثيه لمحطه البحوث الزراعيه بالجميزه والتابعه لمركز البحوث الزاعيه والكائنه بمحافظه الغربيه– مصر وذلك لدراسه تاثير التفاعل بين تسميد نباتات الطرطوفه بثلاث صور من التسميد النيتروجينى (١٠٠ % من النيتروجين الموصى به فى صوره معدنيه والذى يعادل ٩٠ وحده نيتروجين / فدان ، ١٠٠ % من النيتروجين فى صوره عضويه والذى يعادل ١٠ طن للفدان من السماد البلدى ، ٥٠ % من النيتروجين الموصى به فى صوره معدنيه والذى يعادل ٤٥ وحده نيتروجين + ٥٠ % من النيتروجين فى صوره عضويه والذى يعادل ٥ طن للفدان من السماد البلدى) والرش بكل من البورون بتركيز ٥٠ جزء فى المليون والكالسيوم بتركيز ١٥٠ جزء فى المليون) بجانب معامله المقارنه الرش بالماء على النمو والمحصول وجوده الدرنات للصنف فيوزا النامى تحت ظروف الارض الطينيه .

سجلت معامله التفاعل بين ٥٠ % من النيتروجين الموصى به فى صوره معدنية والتى تساوى (٤٥ كجم نيتروجين/فدان) +٥٠ % من النتيروجين الموصى به فى صوره عضويه والتى تساوى (٥ طن سماد بلدى / فدان) والرش بكلوريد الكالسيوم بتركيز ١٥٠ جزء في المليون إلى زيادة فى ارتفاع النبات وعدد الأفرع/النبات ، الوزن الطازج والجاف لعرش /النبات، تركيزات كل من كلوروفيل أ، كلوروفيل ب، الكلوروفيل الكلي (أ+ب) في أنسجة الأوراق، محتوى العرش من النيتروجين والفوسفور والبوتاسيوم والممتص منهم بواسطه العرش فى الطرطوفه بعد ١٣٥ يوم من الزراعه، عدد الدرنات/نبات، متوسط وزن الدرنه ، محصول النبات، المحصول الكلي/فدان، وكذلك كفاءة إستخدام النيتروجين في كلا الموسمين. علاوة على ذلك ، فقد أدى التفاعل بين ٥٠ % من النيتروجين الموصى به فى صوره معدنية +٥٠ % من النتيروجين الموصى به فى صوره عضويه والرش الورقي بالبورون بتركيز ٥٠ جزء في المليون أو كلوريد الكالسيوم بتركيز ١٥٠ جزء في المليون إلى زيادة تركيز الكربوهيدرات الكلية والإينولين والبورون في الدرنات في كلا الموسمين. في هذا الصدد، كان المحصول ومكوناته وكفاءة إستخدام النيتروجين لمعامله التسميد عند ١٠٠٪ من النيتروجين الموصى به فى صوره معدنيه والرش بكلوريد الكالسيوم عند ١٥٠ جزء في المليون فقد أعطى محصولًا ومكوناته وكفاءه استخدام النيتروجين مساويًا لمعامله التفاعل بين ٥٠ % من النيتروجين الموصى به فى صوره معدنية +٥٠ % من النتيروجين الموصى به فى صوره عضويه والرش الورقي بكلوريد الكالسيوم بتركيز ١٥٠ جزء في المليون.