Journal of Plant Production

Journal homepage & Available online at: www.jpp.journals.ekb.eg

Impact of Foliar Application of Calcium Nitrate and Chelated Calcium in Combination with Boric Acid on the Vegetative Growth, Yield, Quality Components and Insect Control of Globe Artichoke

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ABSTRACT

This study was conducted to investigate the impact of foliar application calcium nitrate and chelated calcium in three levels (0, 380 and 760 ppm as Ca) in combination with boric acid (85 ppm as B) on the growth, yield, quality, and insect control of globe artichoke cv. Herous in the 2019/2020 and 2020/2021seasons at EL-Qanater Research Station Farm in Qalubia Governorate. The experimental design was a complete randomized block with three replicates. Results showed that foliar spraying of calcium nitrate at 760 ppm or chelated calcium at 380 and 760 ppm + boron (85 ppm) resulted in the highest values of vegetative growth, the physical characteristics of early, total yield and the highest head number of early yield. Moreover, spraying Ca NO_3 at (380 ppm) + B or both Ca-EDTA levels + B produced the maximum head number of total yield. The highest dry matter % and inulin content was achieved by spraying Ca NO_3(760 ppm) + B or both Ca-EDTA levels + B. Spraying Ca-EDTA (380 ppm) + B achieved the highest values of total phenols and phosphorus %. Spraying both Ca NO_3(760 ppm) + B produced the highest N and protein % as well as both Ca-EDTA levels + B produced the highest K, Ca, and B content of heads. It could be suggested that spraying Ca-EDTA at 380 and 760 ppm + boron at 85ppm were effective for enhancing artichoke production, improving its quality, and defending off three types of aphids.

***Keywords**:* Artichoke, Calcium fertilizer, and yield

INTRODUCTION

Globe artichoke (*Cynara scolymus* L.) is an Asteraceae family herbaceous perennial plant. It is recognized as one of the most prominent vegetable crops in bordering countries of the Mediterranean basin. Artichoke is one of the crops with the highest antioxidant property and polyphenols content, as well as a high amount of fructo oligo saccharides like inulin, protein, fiber, and mineral content. Recently, Noriega Rodrguez *et al.*, (2020) found a significant anti-proliferative effect of artichoke extract on colon and breast cancer cells, which enhances its potential benefits for human health. The total area grown with artichoke in Egypt was 16,103 hectares, which produced about 308,884 tons with an average yield of 18.9 ton/ha. (Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, Part "1", Winter Crops, 2020/2021 season). Exportation of fresh or prepared artichoke buds to European or Arab countries were regulated by product safety parameters, that free of pesticide residue is one of the most limited parameters.

Calcium is a mineral that is required for plant growth and development. It participates in physiological functions such as nutrition absorption, optimum plant cell elongation, and cell wall formation. It is found in plant cell walls and forms calcium pectate molecules, which help to strengthen cell walls and join cells. It also participates in enzymatic and hormonal processes, protects the plant from various biotic and abiotic events, and helps in stomatal function. (Mengel and Kirkby 2001; Reyes *et al.*, 2013). Moreover, it is one of the earliest signaling elements associated with plant stress responses, particularly during pest autoimmune Matthus *et al.*, (2019) and promoting the mechanical properties of plant tissues as well as improving plant defense responses (Thor, 2019 and Wang *et al.*, 2021).

Boron allowed the plant to absorb more calcium, so it can be used more efficiently in metabolic activities once it was absorbed (Ganmore-Neumann and Davidov, 1993). It also enhances plasma membrane structure by complexing membrane components (Cakmak *et al.*, 1995)). Boron is essential for hormone production, transport, sugar and protein synthesis, meristematic tissue cell elongation, and cell division. (Camacho-Cristbal *et al.*, 2008).

Different aphids' species were recorded on globe artichoke in Egypt that causing damage to plants and causes serious damage by ingesting phloem sap and distributing viruses (Fadel and Hady, 2006). Aphids are probably having the biggest economic importance because the biological characteristics as polymorphism and alternating kinds of reproduction these sap suckers are causing direct damages on plants and indirectly are vectors of viral infections (Guesmi, *et al.*, 2010). Artichoke plants are attacked by several economic insect pests such as aphid, thrips, leaf miners (Larraín *et al.*, 1994). In Egypt Insect pests of artichoke and their management are one of significant reason for low productivity of cultivated area (Mostafa *et al.*, 2021). Thus, successfully integrated pest management of *C. elaeagni* minimize the use of pesticides and maximize the role of

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DOI: 10.21608/jpp.2022.159772.1165

biological control agents, which include lady beetles (Coleoptera: Coccinellidae) and flower flies (Diptera: Syrphidae) (Capinera, 2001). Thus, they are considered as main predators for artichoke aphid. Therefore, it is necessary to monitoring populations sizes of artichoke aphid and its associated predators by direct field counts especially during the wide artichoke harvest period (throughout winter and spring) to avoid pesticide application during this critical period.

The current study aims to determine the influence of calcium nitrate and calcium chelated as foliar application alone or in combination with boric acid on the growth, early, total yield, chemical components, and pest incidence of globe artichoke cv. Herous.

MATERIALS AND METHODS

A field experiment was carried out at the EL-Qanater Research Station Farm in Qalubia Governorate, over two seasons, 2019/2020 and 2020/2021, to investigate the effect of calcium nitrate Ca $(NO_3)_2$ and Chelated calcium Ca-EDTA in two levels (380 and 760 ppm as Ca) in combination with boric acid H_3BO_3 (85 ppm as B) applied as a foliar application on the growth, early, total yield, chemical components, nutrient contents, and pest incidence of globe artichoke (*Cynara scolymus*) cv. Herous. - The chelating agent utilized in this experiment, chelated calcium, is derived from natural sources. Mid-molecular-weight combinations of amino acids with long organic chains have the chemical characteristics to readily penetrate cell cytoplasm.

The experimental treatments: The treatments contained eight treatments, as well as the following control treatment, were used.

T0: Control (Tap water)
T1: Ca $(NO_3)_2$ (380 ppm as Ca)
T2: Ca $(NO_3)_2$ (760 ppm as Ca)
T3: Ca $(NO_3)_2$ (380 ppm as Ca) + H_3BO_3 (85 ppm as B)
T4: Ca $(NO_3)_2$ (760 ppm as Ca) + H_3BO_3 (85 ppm as B)
T5: Ca-EDTA (380 ppm as Ca)
T6: Ca-EDTA (760 ppm as Ca)
T7: Ca-EDTA (380 ppm as Ca) + H3BO3 (85 ppm as B)
T8: Ca-EDTA (760 ppm as Ca) + H3BO3 (85 ppm as B)

Note: [Calcium nitrate containing 19% Ca and chelated calcium containing 10% Ca, while boric acid containing 17% B].

Stumps (crown parts) were soaked in Topsin fungicide solution(2g/l) for 20 minutes before being planted in raised beds 15-20 cm high and 100 cm wide, 75 cm apart in 18 and 23 August 2019/2020 and 2020/2021 seasons, respectively. All treatments were applied one month and half after planting and were repeated six times every three weeks. The experiment was set up in a randomized complete block design with three replications, each with nine drip-irrigated plants. The physicochemical analyses of the field experiment soil and the chemical analyses of irrigation water are given in Table (1). During both seasons, cultural procedures (irrigation, fertilization, and weeding) were carried out in accordance with Egyptian Ministry of Agriculture instructions.

The physicochemical analyses of the field experiment soil and the chemical analyses of irrigation water are given in Table (1). The available N was determined by Kjeldahl method, and the available K was determined using the Flame Photometer (Page *et al.*, 1982). Available P was extracted according to *Olsen et al*., (1954) and determined by Spectrophotometer.

Table 1. Physicochemical soil properties and chemical analyses for irrigation water.

Physiochemical properties of the soil										
Particle Size Distribution (%)				**Chemical properties**				**Available macronutrients (mg kg^{-1})**		
Sand	**Silt**	**Clay**	**Texture (Class)**	**pH (1:2.5)**	**OM (g kg^{-1})**	**Total $CaCO_3$ (g kg^{-1})**		**N**	**P**	**K**
19.31	25.21	55.48	Clay	7.67	9.60	40.90		53.62	5.72	439.50
Soluble ions (mmolc L^{-1})										
ECe (dSm^{-1})		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	CO_3^{2-}	SO_4^{2-}	SAR
5.10		27.65	13.86	9.23	1.40	21.71	4.29	---	26.14	2.19
Chemical analyses of irrigation water Soluble ions (mmolc L^{-1})										
pH	ECe (dSm^{-1})	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	CO_3^{2-}	SO_4^{2-}	SAR
7.61	0.82	2.94	1.85	3.28	0.17	4.55	0.49	---	3.20	2.12

Data recorded.

Vegetative growth: After 120 days from planting, data were obtained from a random selection of seven plants from each experimental plot to determine: plant height, number of leaves / plants, and number of offshoots/plants also, chlorophyll content was measured using a portable chlorophyll metre as relative values of the youngest fourth entirely expanded leaf (SPAD–502, Konica Minolta Sensing, Inc., Japan.

Yield and its components: The first season's harvest began on November 21st, and the second season's harvest began on December 15th, with harvesting extending until mid-May. From the first harvest until the middle of February, an early yield was recorded as well as from the first harvest until middle of May, total heads / plant and /feddan were recorded. A random sample of seven flower heads was selected from each plot to evaluate; the fresh weight of flower heads, receptacles and their diameter, the number of heads per plant and per feddan for early yield were estimated based on each plot.

Chemical plant analyses.

Dry matter content: one hundred (g) of fresh edible parts were dried in an oven at 70°C until constant weight and the dry matter of receptacle was determined.

Inulin content of heads: Inulin content (mg/100 g dry weight) was determined in edible part of heads using the procedure described by (Winton and Winton 1958).

Total phenolic content: Total polyphenols content (TPC) was quantified using a modified Folin–Ciocalteu method.33 described by Meda, *et al.*, (2005).

Nutrient contents: N, P, K, Ca, and protein were determined according to AOAC (2016). Boron was calorimetrically measured in dry-ash using the method Azomethine–H according to Chapman and Pratt (1962).

Statistical analysis: The statistical analysis was done according to Snedecor and Cochran (1989).

Identification and population fluctuations of Aphids infesting globe artichoke and the associated natural enemies:

The experiments were carried out under field conditions to study the population density and seasonal fluctuations of some piercing sucking insects (Aphids) as well as their natural enemies inhibiting globe artichoke plants in response to foliar spraying calcium nitrate and chelated calcium in two levels (380 and 760 ppm as Ca) in combination with boric acid H_3BO_3 (85 ppm as B). Population study of Aphids and predators started after two months from sowing and continued until the end of the season (May). Weekly counts of Aphids and the predator eleven spotted ladybird beetle were done. All stages of target insects were determined by counting its numbers on sample of 10 leaves chosen randomly, The Aphids were recorded Cotton aphid: *Aphis gossypii*, Green peach aphid: *Mayzus persicae* , Artichoke aphid : *Capitophorous elaegni* . The predator was eleven spotted ladybird beetles *Coccinnella undecimpunctata* all the collected spices were prepared and identified in the Department of Aphids Research, Plant Protection Research institute, Agriculture Research Center, Dokki, Giza. Predators associated with aphid on whole treatments of artichoke plants. The area of experiment was received recommended agriculture practices without any insecticide applications.

RESULTS AND DISSCUION

Vegetative growth characteristics:

Table (2) illustrates that foliar spray with calcium nitrate at 760 ppm and both Ca-EDTA levels (380 and760 ppm) plus boron produced the highest number of leaves/plants and foliar spraying with Ca-EDTA at 760 ppm plus boron provided the maximum plant height with no significant differences with spraying 380 ppm of Ca-EDTA plus boron and $CaNO_3$ 380 ppm in both seasons. Results are in harmony with Salim *et al.*, (2020) and Arab *et al.*, (2022) they found that plants with more leaves and better length were produced when calcium and boron were combined. Also, Boron may be responsible for the beneficial effects of vegetative growth since it affects several plant physiological processes, including cell division, extension, synthesis of cell walls, membrane function, nitrate usage, and photosynthetic activity (O'Neill *et al.* 2004). Spraying two levels of Ca-EDTA plus B produced the maximum offshoots number in the first season, with no significant differences with 760 ppm Ca-EDTA without boron Furthermore, chelated calcium at 760 ppm with B produced the highest number of offshoots in the second season, These findings are in conformity with those of Dordas, (2009) who found that foliar Ca treatment in oregano increased number of stems per plant. Foliar application of Ca-EDTA combined with boron observed the highest values of growth because it was much easily absorbed by the leaves, (Sawan *et al.* 2001).

Results clearly show that spraying two levels of Ca-EDTA had the highest values of total chlorophyll reading in the first season, with no significant differences with both Ca $(NO_3)_2$ levels. Furthermore, in the second season spraying Ca-EDTA at 760 ppm plus B and 760 Ca $(NO_3)_2$ gave the highest chlorophyll reading Table (2). These findings could be attributed to the quick uptake of nitrogen and availability of foliar calcium nitrate, which is a vital component of all proteins, nucleic acids, and chlorophyll. Ca^{2+} may participate in chlorophyll at different levels, for example in regulating the expression of the genes for enzymes involved in chlorophyll synthesis (Im *et al.*, 1996).

Table 2. The effect of foliar application of calcium nitrate and chelated calcium levels in Combination with boric acid on the growth traits of globe artichoke in 2019/2020 and 2020/2021 seasons.

Characters	Leaf No /plant		Plant height (cm)		No. of offshoot/ plant		Chlorophyll reading (SPAD)	
Treatments	Season1	Season2	Season1	Season2	Season1	Season2	Season1	Season2
T0	37.10 g	49.57 f	90.2 g	75.27 f	1.733 e	5.00 b	56.83 e	54.59 g
T1	45.83 bc	79.10 ab	100.8 bc	92.33 d	2.667 d	6.33 ab	6 2.37 ab	57.37 bc
T2	46.00 ab	79.47 a	101.1 ab	95.77 b	2.933 cd	6.73 ab	62.57 ab	57.47 a
T3	44.53 e	70.23 e	100.4 cd	95.40 bc	3.700 b	5.77 ab	62.00 b c	57.24 d
T4	43.67 f	71.33 d	97.43 f	89.23 e	3.133 c	5.33 ab	61.73 c	57.33 c
T5	45.13 d	77.63 c	98.87 e	88.97 e	3.467 b	6.17 ab	60.07 d	56.97 e
T6	45.53 cd	77.17 c	100.1 d	94.87 c	4.167 ab	6.23 ab	60.07 d	56.88 f
T7	46.20 ab	78.47 b	101.1 ab	96.10 ab	4.067 ab	6.63 ab	62.63 a	57.42 ab
T8	46.33 a	78.77 b	101.3 a	96.77 a	4.267 a	6.83 a	62.63 a	57.44 a

Means followed by different letters are significantly different at $P \leq 0.05$ level.

T0: Control (Tap water), T1: Ca $(NO_3)_2$ (380 ppm as Ca), T2: Ca $(NO_3)_2$ (760 ppm as Ca), T3: Ca $(NO_3)_2$ (380 ppm as Ca) + H_3BO_3 (85 ppm as B), T4: Ca $(NO_3)_2$ (760 ppm as Ca) + H_3BO_3 (85 ppm as B), T5: Ca-EDTA (380 ppm as Ca), T6: Ca-EDTA (760 ppm as Ca), T7: Ca-EDTA (380 ppm as Ca) + H3BO3 (85 ppm as B), T8: Ca-EDTA (760 ppm as Ca) + H3BO3 (85 ppm as B).

Early yield characteristics:

Head weight: Table (3) illustrates that spraying 760 ppm Ca $(NO_3)_2$ resulted in the largest head weight, with no significant differences with the two levels of Ca-EDTA+boron in the first season Furthermore, the largest head weight was achieved with 760 ppm Ca $(NO_3)_2$ and 380 ppm Ca-EDTA plus boron in the second season. This increase in head weight may be caused by boron, which may affect the metabolism of auxin, which is crucial for many physiological processes, including cell elongation, maturation, and meristematic tissue growth (Mengel and Kirby, 2001). Boron affects physiological and metabolic functions within plant cells, changing the nutrient concentration and translocation (Tariq and Mott, 2007).

Head diameter: Data in the same table clearly indicates that plants treated with Ca-EDTA at 380 ppm plus boron had the highest head diameter of early production, with no significant differences in the first season between higher levels of Ca +B and Ca-EDTA plus B. However, plants treated with 760 ppm Ca +B and both concentrations of Ca-EDTA plus boron had the maximum head diameter of early in the second season. These findings are consistent with those reported by Weryszko-Chmielewska and Michaoj (2009), they showed that calcium-fertilized plants had more collenchyma layers and leaf parenchyma cells of sweet pepper. Additionally, the findings are consistent with those of Sharaf-Eldin *et al.* (2019), who reported that a bigger root diameter reflects the positive impacts of foliar spraying boron on the quality of the sweet potato root.

Edible part weight: The plants treated by calcium nitrate at 760 ppm plus boron and both levels of Ca-EDTA+ boron had shown the highest edible part weight with no significant differences with Ca $(NO_3)_2$ at 760 ppm in the first season. (Table 3), moreover, spraying high concentration of calcium nitrate alone or combined with B and Ca-EDTA 760 ppm with B produce the greatest weight of edible part. These findings agree with those reported by (Li *et al*., 2020) they show that Ca-EDTA application had a positive impact on tuber weight of potato yield.

Early heads number/plant: The plants treated with 380 ppm Ca $(NO_3)_2$, 760 ppm calcium nitrate + boron, and 760 ppm Ca-EDTA plus boron showed the highest early yield number in the first season (Table 3). Furthermore, spraying 760 ppm calcium nitrate + boron resulted in the highest early yield number in the second season, with no significant differences when compared to 380 ppm Ca $(NO_3)_2$ and both levels of Ca-EDTA+H_3BO_3. The beneficial effect of calcium in improving artichoke yield may be attributable to the increased availability of photosynthesis and boron, which is also associated to hormone metabolism and encourages the synthesis of auxin, a hormone necessary for growth and yield. These findings are consistent with those reported by Xin *et al*., (2008), who revealed that applying calcium nitrate to potato cultivars significantly enhanced tuber yield and Al-Amery (2011) reported that early applications of Ca and B considerably increased the development of sunflower inflorescences.

Table 3. The effect of foliar application of calcium nitrate and chelated calcium levels in combination with boric acid on the early yield characteristics of globe artichoke in 2019/2020 and 2020/2021 seasons

Characters	Head weight(g)		Head diameter(cm)		Edible part weight (g)		Head no. /plant	
Treatments	**Season1**	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
T0	329.8 g	359.6 e	9.277 e	8.033 f	92.73 f	82.69 f	2.583 e	1.953 f
T1	393.0 cd	379.2 c	11.03 bc	9.167 e	116.2 bc	110.3 c	4.180 a	3.670 abc
T2	395.3 a	384.5 a	9.770 d	9.533 cd	117.1 ab	113.0 a	3.667 d	3.613 cd
T3	386.0 f	377.5d	10.97 bc	10.03 b	111.3 e	105.3 e	3.697 d	3.577 de
T4	393.8 bc	381.0 b	11.17 ab	10.43 a	117.5 a	112.8 a	4.197 a	3.713 a
T5	388.6 e	378.7 c	10.70 c	9.233 de	113.8 d	106.6 d	3.880 c	3.540 e
T6	391.9 d	381.4 b	10.03 d	9.667 c	116.0 c	110.3 c	3.690 d	3.647 bc
T7	394.7 ab	384.6 a	11.43 a	10.53 a	117.4 a	113.1 a	4.153 a	3.690 ab
T8	395.2 ab	381.9 b	11.10 ab	10.47 a	118.1 a	112.0 b	4.017 b	3.670 abc

Means followed by different letters are significantly different at $P \leq 0.05$ level.

T0: Control (Tap water), T1: Ca $(NO_3)_2$ (380 ppm as Ca), T2: Ca $(NO_3)_2$ (760 ppm as Ca), T3: Ca $(NO_3)_2$ (380 ppm as Ca) + H_3BO_3 (85 ppm as B), T4: Ca $(NO_3)_2$ (760 ppm as Ca) + H_3BO_3 (85 ppm as B), T5: Ca-EDTA (380 ppm as Ca), T6: Ca-EDTA (760 ppm as Ca), T7: Ca-EDTA (380 ppm as Ca) + H3BO3 (85 ppm as B), T8: Ca-EDTA (760 ppm as Ca) + H3BO3 (85 ppm as B).

Total yield characteristics: These results are in line with

Head weight: Data in Table (4) indicate that plants treated with higher level (760 ppm) Ca-EDTA plus boron achieved the highest total yield head weight with no significant differences with low level (380 ppm) in both tested seasons. Our results are in harmony with those reported by Ding *et al*., (2015) they found that all calcium fertilizers increased productivity, while chelated was the best in quality of cherry tomato. Foliar spraying Ca + B had a positive impact on potato yield production (Ilyasa *et al.,* 2020).

Table 4. The effect of foliar application of calcium nitrate and chelated calcium levels in combination with boric acid on the total yield characteristics of globe artichoke in 2019/2020 and 2020/2021 seasons.

Characters	Head weight (g)		Head diameter (cm)		Edible part weight (g)		Heads no./ Plant	
Treatments	**Season1**	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**	**Season1**	**Season2**
T0	314.7 g	246.1 f	7.483 h	7.070 f	122.8 f	73.17 e	10.00 e	8.933 g
T1	373.5 e	286.2 d	9.010 ef	7.753 e	159.7 c	87.1 d	14.90 d	12.77 e
T2	381.0 b	293.3 ab	9.353 cd	7.960 d	160.7 b	91.77 b	14.77 d	12.53 f
T3	380.0 c	292.3 b	9.180 de	8.120 c	159.9 bc	88.63 c	16.23 a	13.83 a
T4	371.8 f	287.4 d	9.723 a	8.460 a	161.6 a	91.43 b	15.90 b	13.43 c
T5	376.1 d	289.7 c	8.523 g	8.017 cd	157.7 e	89.27 c	15.53 c	13.17 d
T6	374.2 e	280.6 e	8.836 f	8.057 cd	158.6 d	88.89 c	15.33 c	12.63 ef
T7	381.5 ab	293.9 ab	9.477 bc	8.273 b	162.1 a	93.00 a	16.27 a	13.63 b
T8	382.2 a	294.6 a	9.623 ab	8.587 a	162.2 a	93.53 a	16.33 a	13.73 ab

Means followed by different letters are significantly different at $P \leq 0.05$ level.

T0: Control (Tap water), T1: Ca $(NO_3)_2$ (380 ppm as Ca), T2: Ca $(NO_3)_2$ (760 ppm as Ca), T3: Ca $(NO_3)_2$ (380 ppm as Ca) + H_3BO_3 (85 ppm as B), T4: Ca $(NO_3)_2$ (760 ppm as Ca) + H_3BO_3 (85 ppm as B), T5: Ca-EDTA (380 ppm as Ca), T6: Ca-EDTA (760 ppm as Ca), T7: Ca-EDTA (380 ppm as Ca) + H3BO3 (85 ppm as B), T8: Ca-EDTA (760 ppm as Ca) + H3BO3 (85 ppm as B).

Head diameter: Spraying 760 ppm calcium nitrate combining boron resulted in the highest head diameter in the first season with no significant differences with spraying 760 ppm Ca-EDTA+ boron (Table 4). Furthermore, treated plants with both760 ppm calcium nitrate and 760 ppm Ca-EDTA combining H_3BO_3 had the highest diameter in the second season (Table 4). Similarly, increasing Ca and B concentrations reduced the number of smaller tubers in the plant (Ilyasa *et al.*, 2020) and Ca-EDTA- spraying on potatoes resulted in a significantly higher rate of large tubers (Li et al., 2020).

Edible part weight: Plants sprayed with both 380 ppm and 760 ppm Ca-EDTA plus boric acid produced the highest weight of edible part in both tested seasons (Table 4). These results are in harmony with those obtained by *Li et al.,* (2020) they found spraying Ca-EDTA had better effect in potato yield than spraying calcium nitrate. The weight of the edible section can be increased by adding boron, which might lead to early nutrient absorption and later transfer to the heads, in this regard, foliar spraying with Ca + B enhances strawberry fruit quality (Mustafa *et al.*, 2021).

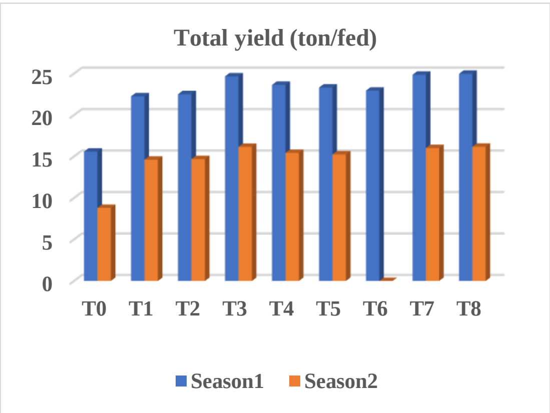
Total heads number/plant: Plants sprayed with low level (380 ppm) of Ca $(NO_3)_2$ combined with boric acid and 760 ppm Ca-EDTA plus boric acid produced the highest number of total yield/plants in first season (Table 4). Also, treatment with low level Ca $(NO_3)_2$ + B had the highest number of total yield/plants with no substantial differences with760 ppm Ca-EDTA plus boric acid in the second season. The growth of inflorescences, flowers, and head quality are all influenced by calcium, which is essential for plant cell growth and division, cell membrane structure and permeability, nitrogen metabolism, and carbohydrate translocation (White, 2000). The findings are consistent with those mentioned by Ahmed *et al.*, (2020) they showed that foliar application of boric acid, nitrogen and calcium have a considerable impact on strawberry yield.

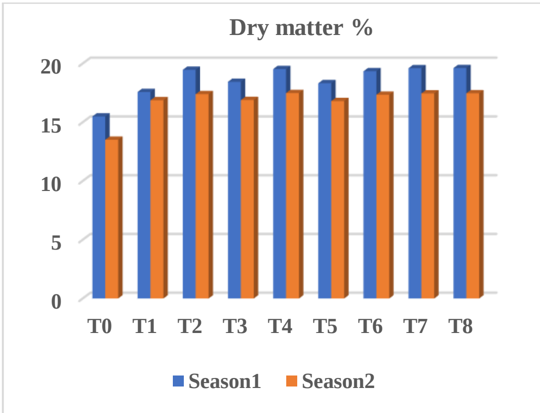
Total yield (ton/fed): Fig (1) shows that spraying plants with low level (380 ppm) of Ca $(NO_3)_2$ combined with boric acid and 760 ppm Ca-EDTA plus boric acid produced the maximum weigh /ton/fed in both tested seasons. Increasing head yield might be attributed to vegetative development and higher shoot number, dry weight, and the early treatments of Ca and B significantly increased total head yield. Additionally, B is essential for nitrogen (N) metabolic as it elevates nitrate levels and plays a critical function in enhancing root growth, which influences the intake of nutrients and thus enhances plant growth (Gupta and Solanki 2013). The present results are in harmony with the previous results of Ilyas *et al.*, (2020) found that application of Ca $(NO_3)_2$ + B resulted in maximum yield and quality of potato compared with applied each of them individually. Also, obtained results are consistent with Li *et al.*, (2020) they found that marketable tuber percentage of potatoes sprayed with Ca-EDTA was better than that treated with Ca $(NO_3)_2$ and (Liu *et al.*, 2021) on peanut

Chemical constituents and nutrient contents.

Dry matter content percentage:

Data in (Fig. 2) indicate that plants treated with both concentrations of Ca-EDTA plus boron and Ca (NO3)2 plus boron at higher rates (760 ppm) in both seasons showed a considerably increased dry matter percentage of edible parts. These increases may be due to the role of boron in photosynthetic efficiency and increasing mineral nutrients uptake and dry matter translocation and accumulation toward the edible parts in plants as reported by (Tariq and Mott, 2007). These results are consistent with those achieved by (Al-Amery *et al*., 2011) on sunflower plants. By regularly supplying exogenous calcium during the growing season, crops can increase their capacity for growth, which has an effect on raising the dry weight of the soybean (Dominguez *et al.*, 2016) and the potato (Ilyas *et al.*, 2020).





Figures 1and 2. The effect of foliar application of calcium nitrate and chelated calcium levels in combination with boric acid on the total yield (ton / fed) and dry matter% in 2019/2020 and 2020/2021 seasons.

T0: Control (Tap water), T1: Ca $(NO_3)_2$ (380 ppm as Ca), T2: Ca $(NO_3)_2$ (760 ppm as Ca), T3: Ca $(NO_3)_2$ (380 ppm as Ca) + H_3BO_3 (85 ppm as B), T4: Ca $(NO_3)_2$ (760 ppm as Ca) + H_3BO_3 (85 ppm as B), T5: Ca-EDTA (380 ppm as Ca), T6: Ca-EDTA (760 ppm as Ca), T7: Ca-EDTA (380 ppm as Ca) + H3BO3 (85 ppm as B), T8: Ca-EDTA (760 ppm as Ca) + H3BO3 (85 ppm as B).

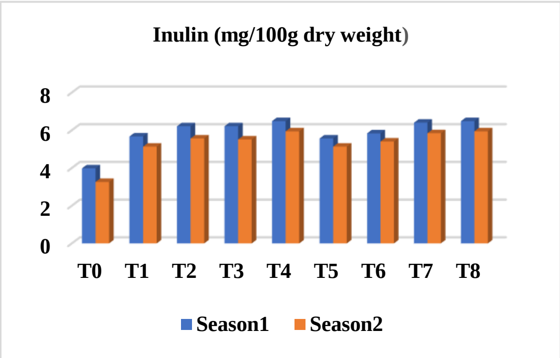
Inulin contents (mg/100g dry weight): Fig (3) shows that spraying 760 ppm non-chelated and chelate calcium (760 ppm) plus boron (85 ppm) resulted in the highest inulin concentration in the edible part over the two tested seasons. These findings could be the result of boron's impacts on several metabolic processes, such as the transport of sugar and carbohydrates, which could lead to an increase in photosynthesis and the movement of carbohydrates from the leaves to the developing flower heads (Nijjar 1985 and Mengel and Kirkby, 2001). Our results are in connection with (Ilyas *et al.*, 2020) and (Abo Ogiela *et al.* 2020) they reported that maximum starch content in potato and pear with boron foliar spraying.

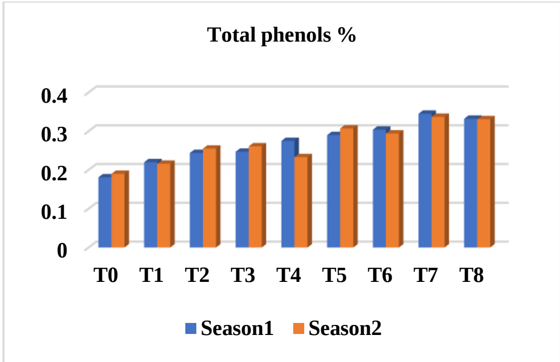
Total phenolic compounds percentage:

Fig (4) clearly shows that spraying with Ca-EDTA at low level (380 ppm) plus B (85 ppm) had the maximum value of total phenolic in both seasons. These findings agree with those of Rouphael (2012), who found that phenolic acids in artichokes decreased as nutritional content increased. Also, calcium has the ability to activate anthocyanin structural genes, which would improve the accumulation of anthocyanins and total phenolics in strawberry fruit, (Xu *et al.*, 2014).

Nitrogen and protein: Table (5) shows that spraying calcium nitrate at an elevated level (760 ppm) plus boric acid resulted in the maximum protein and N content values in both seasons. In addition, no significant differences between spraying Ca $(NO_3)_2$ at a low level (380 ppm) plus H_3BO_3 (85 ppm) and spraying Ca $(NO_3)_2$ at an elevated level alone (760 ppm. Boron may be responsible for the increase in N and protein levels since it is essential for nitrogen (N) metabolism and enhances nitrate levels while decreasing nitrate reductase activity in low-B conditions (Brown *et al.*, 2002)

Phosphorus: Spraying with both levels of Ca-EDTA with B resulted in the maximum P content in the first season, followed by spraying with both concentrations of Ca-EDTA without B. Furthermore, just spraying chelate calcium at a low level + boron had the maximum phosphorus concentration in the second season (Table 5). The highest content of P was appeared with chelated calcium this is due to the direct and indirect role of calcium, especially chelated calcium which keeps the nutrient from loss, thus maximizing its absorption by the plant (Zocchi and Mignani, 1995). The findings are in harmony with those obtained by Mustafa *et al.*, (2021) who found that foliar spraying with Ca +B achieved the highest values of phosphorus in strawberry fruits.





Figures. 3 and 4. The effect of foliar application of calcium nitrate and chelated calcium levels in combination with boric acid on the inulin and total phenols content in 2019/2020 and 2020/2021 seasons.

T0: Control (Tap water), T1: Ca $(NO_3)_2$ (380 ppm as Ca), T2: Ca $(NO_3)_2$ (760 ppm as Ca), T3: Ca $(NO_3)_2$ (380 ppm as Ca) + H_3BO_3 (85 ppm as B), T4: Ca $(NO_3)_2$ (760 ppm as Ca) + H_3BO_3 (85 ppm as B), T5: Ca-EDTA (380 ppm as Ca), T6: Ca-EDTA (760 ppm as Ca), T7: Ca-EDTA (380 ppm as Ca) + H3BO3 (85 ppm as B), T8: Ca-EDTA (760 ppm as Ca) + H3BO3 (85 ppm as B).

Potassium: The data in Table (5) reveal that spraying Ca-EDTA at a low level (380 ppm as Ca) +H_3BO_3 resulted in the highest K content, with no substantial differences between the high level (760 ppm) plus H_3BO_3 and Ca $(NO_3)_2$ plus H_3BO_3 in the first season. Furthermore, spraying the two levels of chelate calcium plus boron in the second season resulted in the highest K percentage. Increasing potassium content may be due to using chelated calcium which can effectively encourage the uptake of the major nutrients and enhance the quality of potatoes when compared to inorganic calcium fertilizer (Arabloo *et al.*, 2017).

Table 5. The effect of foliar application of calcium nitrate and chelated calcium levels in combination with boric acid on the chemical constitutes of globe artichoke heads in 2019/2020 and 2020/2021 seasons.

Characters	N %		Protein%		P%		K%	
Treatments	Season1	Season2	Season1	Season2	Season1	Season2	Season1	Season2
T0	1.270 F	1.193 F	7.937 F	7.460 F	0.169 F	0.173 H	2.270 E	2.240 F
T1	1.957 C	1.893 C	12.23 C	11.84 C	0.193 E	0.199 G	2.553 D	2.513 E
T2	2.117 B	2.160 B	13.23 B	13.58 B	0.208 D	0.217 F	2.520 D	2.603 E
T3	2.150 B	2.187 B	13.44 B	13.67 B	0.226 C	0.228 E	2.827 B	2.863 C
T4	2.270 A	2.307 A	14.19 A	14.36 A	0.213 D	0.240 D	2.847 AB	3.027 B
T5	1.603 E	1.710 D	10.02 E	10.69 D	0.241 B	0. 238 D	2.577 CD	2.563 E
T6	1.677 E	1.633 E	10.48 E	10.21 E	0.244 B	0. 248 C	2.643 C	2.710 D
T7	1.790 D	1.837 C	11.19 D	11.48 C	0.272 A	0.277 A	2.910 A	3.137 A
T8	1.827 D	1.747 D	11.42 D	10.92 D	0.267 A	0.266 B	2.860 AB	3.183 A

Means followed by different letters are significantly different at $P \leq 0.05$ level.

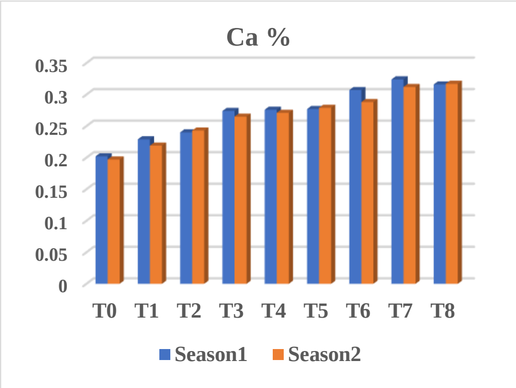
T0: Control (Tap water), T1: Ca $(NO_3)_2$ (380 ppm as Ca), T2: Ca $(NO_3)_2$ (760 ppm as Ca), T3: Ca $(NO_3)_2$ (380 ppm as Ca) + H_3BO_3 (85 ppm as B), T4: Ca $(NO_3)_2$ (760 ppm as Ca) + H_3BO_3 (85 ppm as B), T5: Ca-EDTA (380 ppm as Ca), T6: Ca-EDTA (760 ppm as Ca), T7: Ca-EDTA (380 ppm as Ca) + H3BO3 (85 ppm as B), T8: Ca-EDTA (760 ppm as Ca) + H3BO3 (85 ppm as B).

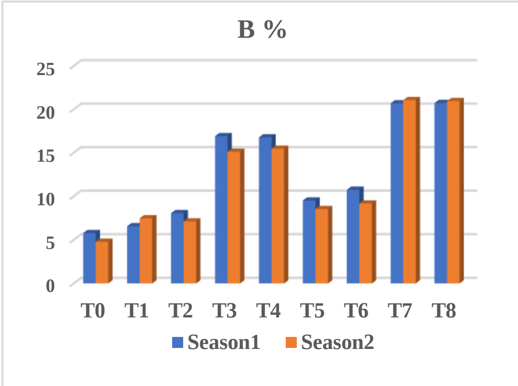
Calcium: Fig (5) demonstrates that spraying with the low concertation of chelate calcium plus boron resulted in the maximum Ca content in the first season, followed by the higher level of same treatment. Furthermore, spraying two concentrations of Ca-EDTA+H_3BO_3 had the maximum Ca content in the second season. This increase in calcium content indicated the improved defense of the plant coupled the influence of boron on the formation of calcium pectate molecules, which support in binding cells together and strengthening cell walls, protecting the plant from numerous biotic and abiotic events (Mengel and Kirkby 2001). The results are consistent with those of (Almeida *et al.*, 2016), who showed that foliar calcium spraying causes an increase in calcium concentration in lettuce leaf tissue, making it a useful method for accelerating plant growth.

Boron: Fig (6) demonstrates that spraying with the two concentrations of Ca-EDTA+H_3BO_3 resulted in the highest B content in edible parts of heads throughout the two seasons examined. Since B improves the integrity of the cell membrane by contributing to its protein and enzymatic activity, an increase in B content in plants is crucial for increasing plant strength by strengthening their cell walls (Wimmer and Eichert 2013)**.**

Effect of treatments on Aphid control:

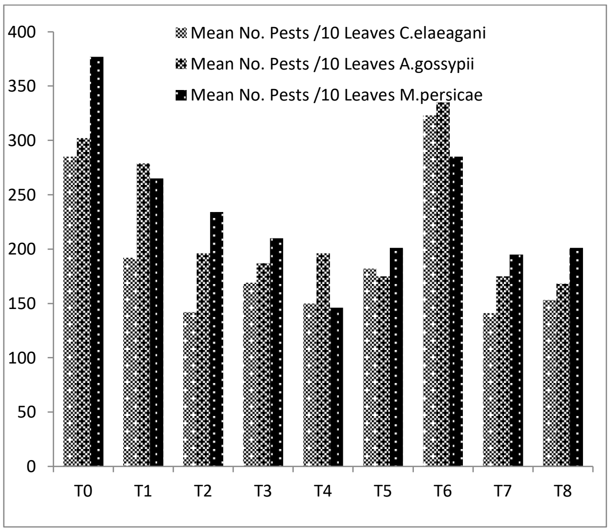
Results showed that three types of aphids infested artichoke the first were *Captiophorus elaeagni*, *Aphis gossypii*, *Mayzus perciscae*. As declared in figures (7) and (8), show that mean numbers of artichoke aphid during 2019-2020, 2021-2022 seasons. The high population density of artichoke aphid was recorded on Ca EDTA at 760 ppm without adding boron (T6 treatment) and the control (T0).





Figures 5 and 6. The effect of foliar application of calcium nitrate and chelated calcium levels in combination with boric acid on the calcium and boron content of globe artichoke heads in 2019/2020 and 2020/2021 seasons.

T0: Control (Tap water), T1: Ca $(NO_3)_2$ (380 ppm as Ca), T2: Ca $(NO_3)_2$ (760 ppm as Ca), T3: Ca $(NO_3)_2$ (380 ppm as Ca) + H_3BO_3 (85 ppm as B), T4: Ca $(NO_3)_2$ (760 ppm as Ca) + H_3BO_3 (85 ppm as B), T5: Ca-EDTA (380 ppm as Ca), T6: Ca-EDTA (760 ppm as Ca), T7: Ca-EDTA (380 ppm as Ca) + H3BO3 (85 ppm as B), T8: Ca-EDTA (760 ppm as Ca) + H3BO3 (85 ppm as B).



Figures 7. Population fluctuations of three types of aphids *C.elaeagani*, *A.gossypii*, *M.persicae* on artichoke leaves and flowers during successive growing season of 2019- 2020.

T0: Control (Tap water), T1: Ca $(NO_3)_2$ (380 ppm as Ca), T2: Ca $(NO_3)_2$ (760 ppm as Ca), T3: Ca $(NO_3)_2$ (380 ppm as Ca) + H_3BO_3 (85 ppm as B), T4: Ca $(NO_3)_2$ (760 ppm as Ca) + H_3BO_3 (85 ppm as B), T5: Ca-EDTA (380 ppm as Ca), T6: Ca-EDTA (760 ppm as Ca), T7: Ca-EDTA (380 ppm as Ca) + H3BO3 (85 ppm as B), T8: Ca-EDTA (760 ppm as Ca) + H3BO3 (85 ppm as B).

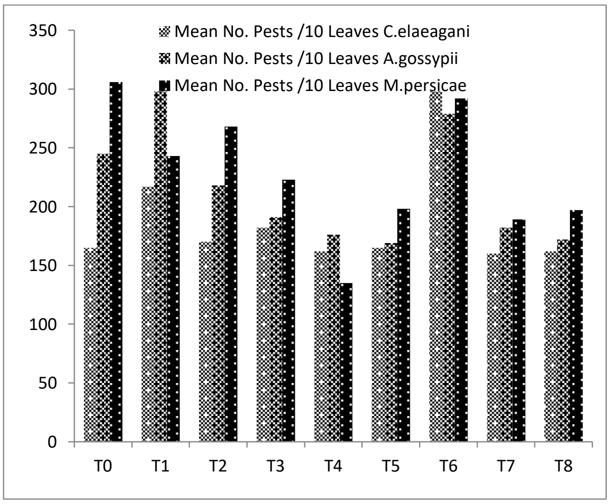


Fig. 8. Population fluctuations of three types of aphids *C.elaeagani*, *A.gossypii*, *M.persicae* on artichoke leaves and flowers during successive growing season of 2020-2021.

T0: Control (Tap water), T1: Ca $(NO_3)_2$ (380 ppm as Ca), T2: Ca $(NO_3)_2$ (760 ppm as Ca), T3: Ca $(NO_3)_2$ (380 ppm as Ca) + H_3BO_3 (85 ppm as B), T4: Ca $(NO_3)_2$ (760 ppm as Ca) + H_3BO_3 (85 ppm as B), T5: Ca-EDTA (380 ppm as Ca), T6: Ca-EDTA (760 ppm as Ca), T7: Ca-EDTA (380 ppm as Ca) + H3BO3 (85 ppm as B), T8: Ca-EDTA (760 ppm as Ca) + H3BO3 (85 ppm as B).

The minimum population density of three type's artichoke aphid was recorded by spraying Ca $(NO_3)_2$ at 760 ppm + boron (T4) in both seasons, on the other hand using calcium in this study as a macro element for plant growth that has important role of reducing of population fluctuation for the three types of aphids according to *Zeng et al.*, (2020) they found that Ca significantly extended the growth period of western flower thrips, and agree with the reduction in the number of spices of thrips of the genera Frankilina and Thrips (Thysanoptera) on tomato plants that received application of acibenzolar-S-methyl (BTH) (Momol *et al.*,2004). Foliar application of calcium alone or associated with anther on cucumber plants increased the nymphal mortality of nymphs and duration of the development period between nymphs and adults of *Bemisia tabaci*, which was attributed to the increase in defense substances of these plants (Correa *et al.*, 2005).

Data in Fig. (9) and fig. (10) Declared that the appearance of predators associated with aphid on whole treatments of artichoke plants. Population fluctuations of predators associated with aphids on artichoke plants along the two seasons mentioned that the higher numbers of predators during 2019-2021, the lowest numbers of predators recorded on 2020-2021. This study recorded two predators on three types of aphids were *Coccinnella undecimpunctata* (Coccinellidae) and *Chrysoperla carnea* (Chrsoperlidae) showed the most common predators of artichoke aphids are lady beetles and their larvae. At least 29 spices of insect predators belonging to 25 genera under 5 families such as Coccinellidae and Chrsoperlidae commonly and feed on aphid species on vegetable crops in Jammu and Kashmir (Bhat *et al.*,2020). The calcium seed priming improves wheat's resistance to the destructive aphid because Ca_2^+ signals are necessary for the activation of plant immune responses. The callose deposition (a naturally occurring permeable barrier and a leak-seal in plant tissues damaged by herbivores), Wang *et al*., (2021) found that the Ca_2^+ increased resistance is strongly related to callose deposition.

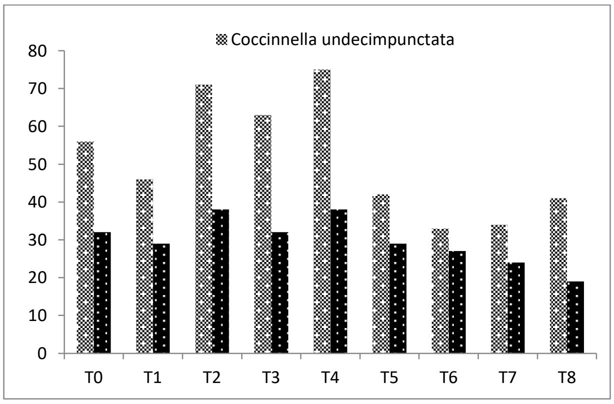


Fig. 9. Population fluctuations of natural enemies (predators) associated with aphids on artichoke plants during successive growing season of 2019-2020.

T0: Control (Tap water), T1: Ca $(NO_3)_2$ (380 ppm as Ca), T2: Ca $(NO_3)_2$ (760 ppm as Ca), T3: Ca $(NO_3)_2$ (380 ppm as Ca) + H_3BO_3 (85 ppm as B), T4: Ca $(NO_3)_2$ (760 ppm as Ca) + H_3BO_3 (85 ppm as B), T5: Ca-EDTA (380 ppm as Ca), T6: Ca-EDTA (760 ppm as Ca), T7: Ca-EDTA (380 ppm as Ca) + H3BO3 (85 ppm as B), T8: Ca-EDTA (760 ppm as Ca) + H3BO3 (85 ppm as B).

Ca given as a foliar spray may cause reduction in incidence in artichoke plants in addition to an increase in vegetative characteristics; transmission of Ca signals stimulates JA, salicylic acid, ethylene, and other signal transduction pathways, which then triggers plant defense mechanisms (Du *et al.,* 2009). As well as boron has also been linked to important roles in the metabolism of IAA, the control of lignin production, and xylem differentiation (Marschner, 1995).

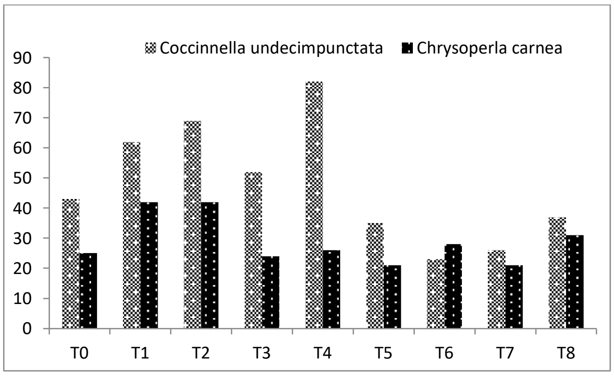


Fig. 10. Population fluctuations of natural enemies (predators) associated with aphids on artichoke plants during successive growing season of 2020-2021.

T0: Control (Tap water), T1: Ca $(NO_3)_2$ (380 ppm as Ca), T2: Ca $(NO_3)_2$ (760 ppm as Ca), T3: Ca $(NO_3)_2$ (380 ppm as Ca) + H_3BO_3 (85ppm as B), T4: Ca $(NO_3)_2$ (760 ppm as Ca) + H_3BO_3 (85 ppm as B), T5: Ca-EDTA (380 ppm as Ca), T6: Ca-EDTA (760 ppm as Ca), T7: Ca-EDTA (380 ppm as Ca) + H3BO3 (85 ppm as B), T8: Ca-EDTA (760 ppm as Ca) + H3BO3 (85 ppm as B).

CONCLUSION

The current study recommended using chelated calcium in two levels (380 and 760 ppm as Ca) in conjunction with boric acid (85 ppm as B) as a foliar fertilizer to enhance vegetative growth, early production, total yield, and head quality in globe artichoke plants as well as decrease three types of aphid incidences.

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أثر الرش الورقي بنترات الكالسيوم والكالسيوم المخلبي مع حمض البوريك علي النمو الخضري والمحصول والجودة ومكافحه الحشرات لنبات الخرشوف

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الملخص

تم اجراء هذه الدراسة لمناقشه تأ ثير الرش بنترات الكالسيوم والكالسيوم المخلبي في ثلاث مستويات هي : الصفر (الكنترول) و380 و 760 ملليجرام/ لتر بالأضافه الي حمض البوريك بتركيز 85 ملليجرام/ لتر علي النمو الخضري والمحصول والجودة ومكافحه الحشرات لنبات الخرشوف في موسمي 2019-2020 و 2020-2021 وقد أجريت التجربه في مزرعه محطه بحوث القناطر بمحافظه القليوبيه في تصميم القطع الكامله العشوائيه في ثلاث مكرارات. وقد أظهرت النتائج: - أن الرش بكلا من نترات الكالسوم بتركيز 760 ملليجرام / لتر أو الكالسيوم المخلبي بتركيزي 380 و760 ملليجرام / لتر بالأضافه لحمض البوريك بتركيز 85 ملليجرام / لتر أدي الي أعلي قيم النمو الخضري و أفضل الصفات الطبيعيه للمحصول المبكر والكلي. - كذالك أدي الرش بكلا من نترات الكالسيوم بتركيز380 ملليجرام / لتر بدون أضافه البورون و الكالسيوم المخلبي بتركيزي 380 و760 ملليجرام / لتر+ البورون الي أعلي عدد لنورات المحصول المبكر. وايضا الرش بكلا من نترات الكالسيوم بتركيز 760 ملليجرام / لتر والكالسيوم المخلبي بتركيز 380 و 760ملليجرام / لتر و أضافه البورون لكليهما الي أعلي عدد نورات المحصول الكلي .- تم الحصول علي أعلي قيم للماده الجافه ومحتوي الأنيولين بالنورات نتيجه الرش بكلا من نترات الكالسيوم بتركيز 760 ملليجرام / لتر+ البورون و الكالسيوم المخلبي بتركيز 380 و760 ملليجرام / لتر + البورون. كما أدي الرش بنترات الكالسيوم عند 760 ملليجرام / لتر+ البورون الي الحصول علي أعلي نسبه من النيتروجين والبروتين بالنورات. - وكذالك الرش بالكالسيوم المخلبي بتركيز 380 ملليجرام / لتر + البورون أدي الي أعلي تركيز لكلا من الفينولات الكليه ونسبه الفسفور بالنورات كما أدي الرش بكلا التركيزين أضافه لحمض البوريك الي أعلي نسبه من البوتاسيوم والفسفور والكالسيوم والبورون بالنورات .- كان أقل عدد لأنواع المن تحت الدراسه مع معامله الرش بترات الكالسوم بالأضافه الي البورون وايضا الرش بالكالسيوم المخلبي بكلا تركيزيه مع أضافه البورون .و توصي الدراسه برش الكالسيوم المخلبي بتركيز380 و760 ملليجرام / لتر بالأضافه الي البورون85 مليجرام/ لتر لتعزيز إنتاج الخرشوف المبكر والكلي وتحسين جودته وزيادة مقاومة ثلاثة أنواع مختلفة من المن .