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Effect of Foliar Application of Calcium on the Growth, Yield, and Fruit Quality of fresh and Frozen Strawberry (*Fragaria* × *ananassa* Duch.) within Sustainable Agriculture

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Abstract: The effect of foliar application of calcium at three concentrations (0%, 4%, and 8%), and two types of cultivated strawberry ((fresh) and (frigo)), on the growth, yield, and fruit quality of strawberry (*Fragaria* × *ananassa Duch.)* grown in an unheated plastic house belonging to the Department of Horticulture and Landscape Engineering, College of Agriculture and Forestry, University of Mosul, was studied during the 2024–2025 growing season. Foliar spraying with calcium was carried out three times during the study period. The first spray was applied on 15/11/2024 in the early morning until complete wetting, with an interval of 20 days between each spray. The results obtained showed that foliar application of calcium at a concentration of 8% led to a significant increase in all studied traits (total chlorophyll content in leaves, leaf area, number of runners per plant, number of days from planting to the appearance of the first runner, fruit weight, number of fruits per plant, total yield per plant, total soluble solids percentage in fruits, fruit firmness, calcium concentration in fruits, and total phenols in fruits). Furthermore, the cultivated strawberry type (fresh) also showed a significant superiority in (total chlorophyll content in leaves, leaf area, number of runners per plant, number of days from planting to the appearance of the first runner, fruit weight, number of fruits per plant, total yield per plant, total soluble solids percentage in fruits, fruit firmness, calcium concentration in fruits, and total phenols in fruits). The best treatment obtained was the interaction between foliar application of calcium at a concentration of 8% with the cultivated strawberry type (fresh), which surpassed most of the other treatments, including the control treatment, in all studied traits.

Key words: Strawberry, calcium, (fresh), (frigo).

1. Introduction

The increasing population, together with the decline and scarcity of agricultural land, represents a major challenge for food security. It is expected that the world population will exceed 9 billion by 2050, with an estimated 70% increase in food demand **(Daszkiewicz, 2022)**. To meet this demand, both

chemical and organic fertilizers are used as nutrient sources for crops, including strawberry plants, to enhance plant growth and increase yield in order to meet growing food requirements **(Balali-Mood *et al.*, 2021)**.

Strawberry (*Fragaria* × *ananassa* Duch.) is an important fruit crop belonging to the family Rosaceae. The commercially cultivated strawberry is a relatively recent hybrid that originated in Europe during the eighteenth century **(Faris *et al.*, 2025)**, resulting from hybridization between Fragaria species from North and South America. It was subsequently developed through plant breeding programs to become the dominant commercial form. This hybrid origin and subsequent development explain the genetic diversity and global distribution of strawberry. The number of cultivated strawberry cultivars worldwide is estimated at approximately 600 **(Yamamoto *et al.*, 2021)**. Strawberry cultivars are generally classified into three types based on ripening time and photoperiod response: June-bearing (spring-bearing), everbearing, and day-neutral types **(Ren *et al.*, 2024)**.

Strawberry is considered a crop with high adaptability to diverse environmental conditions and desirable growth and productivity characteristics **(Yamamoto *et al.*, 2021)**. It is cultivated in various regions around the world, ranging from Mediterranean climates to cooler valley regions. Strawberry prefers a moderate climate with suitable moisture distribution. Recent studies indicate that the optimal temperature range for strawberry growth is between 10–26 °C, with variation between day and night temperatures. In addition, adequate light, suitable humidity, well-drained soil, and soil pH ranging from 5.5 to 6.5 contribute to high growth and productivity of strawberry. These conditions are consistent with protected cultivation systems such as greenhouse production **(Yamamoto *et al.*, 2021)**.

The content of strawberry in vitamin C, flavonoids, and dietary fiber provides important health benefits, including improvement of oxidative status indicators, support for cardiovascular health (by reducing certain cardiac risk factors related to inflammation and oxidative stress), and contribution to the supply of essential micronutrients such as folate and calcium **(Pincot, 2021)**. Global strawberry production has exceeded approximately 9.57 million tons, with a cultivated area estimated at about 1.3 million hectares. China ranks first among strawberry producers, followed by the United States of America and Egypt **(FAO, 2023)**.

Calcium (Ca) is one of the most abundant mineral nutrients in most plants after nitrogen and potassium and is classified as a secondary macronutrient. It is absorbed from the soil solution through the roots and transported mainly through the apoplastic pathway to the xylem via a transpiration-dependent mechanism. Calcium concentration in plants ranges from 300 µmol to 16.5 mmol and is influenced by calcium availability in the soil, the intensity of transpiration, and the presence of calcium-chelating compounds in the xylem sap **(Wdowiak *et al.*, 2024)**. Calcium is an essential element for plant growth and metabolism through various physiological, chemical, and biological processes; however, its exact role is still not fully understood **(Pathak *et al.*, 2020)**. Although the total concentration of calcium in plants reaches millimolar levels, plants still require a continuous supply of this element. Within the cell, calcium is found mainly in two compartments where it has direct effects. The first is the cell wall, where calcium primarily binds with pectin, forming calcium pectate. The second compartment is the cellular membranes and cytoplasm, where a decrease in extracellular calcium concentration increases plasma membrane permeability **(Hepler, 2025)**. Among the important functions of calcium in plants is its role in cell wall formation and the development of calcium pectate in the middle lamella, which regulates the entry of non-toxic nutrients into plant tissues. Calcium is also essential for meristematic activity and plays a key role in cell division (mitosis), as well as maintaining chromosome structure. It acts as an essential cofactor or activator for several enzymes, including hydrolytic enzymes, phospholipases, arginine kinase, amylase, and adenosine triphosphatase (ATPase). Moreover, calcium participates in intracellular signaling pathways under biotic and abiotic stress conditions **(Wdowiak *et al.*, 2024)** and assists in nitrogen assimilation into organic compounds, particularly proteins **(Tongali *et al.*, 2024)**. Calcium deficiency symptoms in plants include poor root growth, leaf necrosis and curling, blossom-end rot, bitter pit, fruit cracking, poor storability, and tissue water-soaking **(Tongali *et al.*, 2024**). Therefore, calcium clearly contributes to the growth and productivity of strawberry plants. Several researchers have emphasized this role. **Bakshi *et al.* (2013)** reported that foliar application of calcium resulted in a significant increase in leaf area, fruit weight, number of fruits per plant, total yield per plant, and total soluble solids percentage in strawberry cultivar (Chandler), particularly at a

concentration of 0.6% calcium applied as calcium chloride ($CaCl_2$), compared with other treatments, using three calcium concentrations (0.2%, 0.4%, and 0.6%). **Mehraj *et al.* (2015)** studied the effect of foliar spraying with three concentrations of calcium in the form of calcium oxide (CaO) (0, 50, and 100 mg Ca L^{-1}) on strawberry cultivar (RABI-3), applied twice: 15 and 45 days after planting. The results showed that foliar application at 100 mg Ca L^{-1} produced the highest increase in the number of runners per plant, fruit weight, number of fruits per plant, total yield per plant, and total soluble solids percentage compared with the control and 50 mg Ca L^{-1} treatment. **Hamail *et al.* (2018)** reported that foliar application of calcium in the form of calcium chloride ($CaCl_2$), calcium nitrate ($Ca(NO_3)_2$), and calcium citrate ($Ca_3(C_6H_5O_7)_2$) at concentrations of 1%, 0.5 mL Ca L^{-1}, and 2.5 mL Ca L^{-1}, respectively, over two growing seasons, showed that 0.5 mL Ca L^{-1} of calcium nitrate ($Ca(NO_3)_2$) resulted in a significant increase in total chlorophyll content in leaves. Meanwhile, 2.5 mL Ca L^{-1} of calcium citrate ($Ca_3(C_6H_5O_7)_2$) increased the number of runners per plant, whereas 1% calcium chloride ($CaCl_2$) improved leaf area per plant, fruit weight, total yield per plant, and total soluble solids percentage. **Chandrakar *et al.* (2018)** studied foliar application of calcium chloride ($CaCl_2$) at three concentrations (0.4%, 0.6%, and 0.8%) and found that 0.6% produced the highest fruit weight, number of fruits per plant, and total yield per plant compared with other treatments. **Ahmed *et al.* (2020)** investigated the effect of foliar calcium application on strawberry cultivar (Liberation D'Orleans) using calcium chloride ($CaCl_2$) at concentrations of 0.25% and 0.5%. They observed that total chlorophyll content, number of runners per plant, fruit weight, and total yield per plant increased significantly with higher calcium concentrations. **Rozbiany and Taha (2020)** studied foliar application of calcium pectate ($Ca(C_6H_{10}O_7)_2$) at concentrations of 0, 250, and 500 mg Ca L^{-1} on vegetative growth, nutrient content, yield, and fruit quality of strawberry cultivars (Albion and Festival). The results showed a significant increase in total chlorophyll content at 500 mg Ca L^{-1} for both cultivars. In addition, the number of runners per plant increased significantly at the same concentration in cultivar Albion, while fruit number per plant, total yield per plant, and total soluble solids percentage increased at 500 mg Ca L^{-1} in cultivar Festival compared with other treatments. **Khalil and Hammoodi (2021)** reported that foliar application of calcium chloride ($CaCl_2$) improved vegetative growth, yield, and fruit quality of strawberry cultivar (Festival). Application of 300 mg Ca L^{-1} resulted in significant improvements in leaf area, fruit weight, number of fruits per plant, total soluble solids percentage, fruit firmness, and calcium content in fruits compared with the control. **Cvelbar Weber *et al.* (2021)** studied foliar application of calcium at two concentrations (0% and 10%) in the form of nano-calcium on three strawberry cultivars (116 Fortuna, Elyana, and 029 Red merlln). The 10% treatment produced the highest total phenolic content in fruits compared with the control. **El-Hefnawi *et al.* (2021)** reported that foliar spraying of calcium at concentrations of 1000, 1500, and 2000 mg Ca L^{-1} on three strawberry cultivars (116 Fortuna, Elyana, and 029 Red merlln) over two growing seasons (2016–2017 and 2017–2018) showed that 1500 mg Ca L^{-1} resulted in significant increases in leaf area, fruit weight, and total yield per plant compared with other treatments**. Mohammed and Majeed (2024)** found that foliar application of granulated calcium at 1000 mg Ca L^{-1} significantly increased total yield per plant, while the highest total soluble solids percentage was obtained at 2000 mg Ca L^{-1}. **Harika *et al.* (2024)** reported that foliar spraying of chelated calcium at concentrations of 1000, 3000, and 5000 mg Ca L^{-1} on strawberry cultivar (Winter Dawn) increased fruit weight, number of fruits per plant, and total yield per plant, with the highest values obtained at 5000 mg Ca L^{-1}. **Aguilar-Delgado *et al.* (2024)** reported that foliar application of nano-calcium at concentrations of 2.5, 5, and 7 meq Ca L^{-1} on strawberry cultivar (Albion) showed that 5 meq Ca L^{-1} significantly improved total soluble solids percentage, fruit firmness, and total phenolic content compared with other treatments.

Strawberry plants are cultivated using two main types of planting materials: (fresh) plants (fresh), which are planted immediately after separation from the mother plant, and cold-stored plants (frigo), which are stored under refrigeration before planting. (fresh) strawberry plants are newly produced from runners and represent one of the most commonly used methods of vegetative propagation in strawberry. These plants are rooted in a specific growing medium and then planted directly in the field or in a new production system. The runners are taken from strong, healthy mother plants free from diseases, usually grown in a greenhouse or a specific cultivation system. After the runners grow and come into contact with the soil, and with adequate moisture, they form a root system. Once small rooted plantlets develop, they can be transferred to plastic bags or directly to the field to acclimatize, after which horticultural

practices are applied. (fresh) strawberry plants are characterized by their ability to quickly renew the field through runners. They can also be planted shortly after land or greenhouse preparation without the need for a long waiting period or prolonged storage, and they are less costly than cold-stored (frigo) plants. The cultivation of (fresh) plants directly from newly produced seedlings is widely practiced **(Türemiş *et al.*, 1998)**. In contrast, (frigo) plants are grown from plants that have been previously stored. It is preferable to harvest (frigo) plants when they are in the dormant stage, typically at the end of autumn or early winter **(Lee *et al.*, 2020)**, after growth activity declines. Before lifting (frigo) plants, moisture is reduced or stopped to decrease water content and prepare the plants for dormancy. The plants are then cleaned by removing excess leaves (usually all leaves are removed) and soil from the roots, if present, and graded according to quality criteria such as crown diameter, number of roots, and freedom from diseases. (frigo) plants are stored in refrigerated rooms under low temperature and relatively high humidity to prevent root desiccation, with careful attention to ventilation. The plants are stored in plastic bags inside boxes, and the storage period may extend from several weeks up to nine months **(Bosc, 2008)**. Some studies indicate that (frigo) strawberry plants can be stored for up to 11 months at temperatures ranging from −1 to −2 °C **(Lieten *et al.*, 2005)**. At the end of the storage period and before planting, acclimatization of the stored plants is essential by gradually increasing the temperature before planting. It is also recommended to check root moisture or soak the roots in water for a few minutes before planting. (frigo) strawberry plants are usually planted in spring or early summer after removal from cold storage **(Duralija *et al.*, 2006)**. Improper storage conditions, such as inappropriate temperature or lifting plants before they reach full dormancy, may result in premature growth, root desiccation, or increased susceptibility to root rot diseases. In addition, prolonged storage may reduce the plant's future productivity due to depletion of carbohydrate reserves. Several studies indicate that the use of (fresh) and (frigo) strawberry plants significantly affects plant growth and productivity **(Capocasa, 2019)**. The importance of (fresh) and (frigo) strawberry plants is further supported by numerous studies examining their effects on strawberry growth and productivity. Many studies have reported clear improvements in growth and yield parameters as part of ongoing efforts to enhance strawberry productivity. The use of (fresh) and (frigo) plants has been shown to significantly improve plant growth and increase productivity. **Economides and Gregoriou (1988)** reported that planting two types of strawberry plants ((fresh) and (frigo)) over two growing seasons in cultivars (Aliso, Tufts, Taro, Aiko, and Cruz) resulted in a significant increase in fruit weight and total yield per plant in (frigo) plants compared with (fresh) plants across all cultivars. **Maroto *et al.* (1996)** found that planting (frigo) strawberry plants under greenhouse conditions in three cultivars (Chandler, Pajaro, and Vilanova) significantly improved fruit weight and total yield per plant compared with (fresh) plants under greenhouse conditions for all cultivars**. Türemiş *et al.* (1996)**, in their study on ten strawberry cultivars grown in plastic bags inside a greenhouse using both (fresh) and (frigo) plants over two growing seasons, observed that (frigo) plants produced significantly higher values in the number of runners, fruit weight, total yield per plant, and total soluble solids percentage compared with (fresh) plants of the same cultivars. **Duralija *et al.* (2006)** reported that (frigo) strawberry plants produced significantly higher values in the number of fruits per plant and total yield per plant compared with (fresh) plants. **Capocasa *et al.* (2008)** reported that cultivating (frigo) strawberry plants over two growing seasons for ten cultivars resulted in significant increases in fruit weight, total yield per plant, and total soluble solids percentage compared with (fresh) plants. **Usanmaz (2019)**, in a study on two strawberry cultivars (Florida and Fortuna) using both (fresh) and (frigo) plants under greenhouse conditions, found that (frigo) plants produced significantly higher fruit weight, number of fruits per plant, and total yield per plant. However, no significant difference was observed in the total soluble solids percentage compared with (fresh) plants for both cultivars. **Salkić *et al.* (2024)** reported that (fresh) strawberry plants produced greater leaf area per plant, higher number of runners per plant, earlier runner emergence, higher fruit weight, and greater number of fruits compared with (frigo) plants.

2. Materials and Methods

The experiment was conducted during the 2024–2025 growing season in an unheated greenhouse belonging to the Department of Horticulture and Landscape Engineering, College of Agriculture and Forestry, University of Mosul. The total area of the greenhouse was 486 m² (54 m in length and 9 m in

width). Strawberry plants were obtained from a reliable private nursery in Sulaymaniyah Governorate. The plants were transported to the experimental site in plastic boxes, carefully wrapped with large transparent polyethylene bags to protect them during transportation. Prior to planting, a preventive treatment was applied to the strawberry root systems to avoid fungal infections by immersing the roots in pentanol fungicide at a concentration of 1 mL L^{-1} for 60 seconds, according to recommended practices. Thereafter, the soil was thoroughly ploughed and leveled, and then divided into three ridges representing the experimental replicates, each with a width of 70 cm. To evaluate the physical and chemical properties of the soil, random soil samples were collected from the field at a depth of 30 cm from three different locations within the greenhouse. The samples were then analyzed in the laboratory according to **Page *et al.* (1982) and Black (1965)**, as shown in Table (1).

Table (1) Physical and Chemical Properties of the Field Soil (Greenhouse)

Parameters	Valu	Unit
Mechanical analysis		
Sand	62.55	%
Silt	21.45	%
Clay	16	%
Ph	8.0	__
EC	1.30	Ms/cm
CaCO3	23.5	%
O.M	1.37	%
Nitrogen (N)	49	PPM
Phosphorus (P)	4.84	PPM
Potassium (K)	168	PPM
$CaCO_3$	170,8	$mg.Kg^{-1}$

After soil preparation, a drip irrigation system was installed (two drip lines on each bed in an alternating arrangement). NPK fertilizer was applied to the beds before planting according to the fertilizer recommendation **(Al-Khayyat, 2022)**, and the soil was irrigated immediately prior to planting. The beds were covered with black polyethylene mulch, and planting holes were made at a spacing of 25 cm between holes, resulting in a plant-to-plant spacing of 25 × 25 cm. A 50 cm space was maintained between experimental units; thus, the length of each experimental unit was 1.50 m, the width was 1.10 m, and the area was 1.65 m^2. The experiment was conducted using a split-plot arrangement within a Randomized Complete Block Design (RCBD) for factorial experiments. Foliar application treatments of calcium were applied in the form of calcium chloride ($CaCl_2$). Strawberry plants were sprayed with calcium at three concentrations (0%, 4%, and 8%). The plants were sprayed three times during the study period, with the first application carried out on 15/11/2024 in the early morning until complete wetting, and subsequent sprays applied at 20-day intervals. A total of 180 plants were used in the experiment. The type of cultivated strawberry plant occupied the main plots, while calcium concentrations were assigned to the subplots. The experiment included three levels of calcium, two types of strawberry plants ((fresh) and (frigo)), and three replicates.

Studied Trait

1. Total Chlorophyll Content in Leaves (mg g^{-1} fresh weight)

Samples of (fresh) green leaves were collected from the treated plants, with 2–4 leaves taken from each randomly selected plant. The leaves were thoroughly washed with distilled water to remove dust and debris. A 0.2 g (fresh) sample was then placed in a test tube containing 10 mL of 80% acetone, and the tissue was homogenized thoroughly. The samples were centrifuged for 5 minutes at 3000 rpm, after which the supernatant (extract) was carefully separated from the residue. The absorbance of the extract was measured at wavelengths of 645 nm and 663 nm using a spectrophotometer (Spectronic 20 – Bausch & Lomb). The total chlorophyll content was determined according to the method of **Mackinney (1941)**, as modified by **Arnon (1949)**, and as described by **Saieed (1990)**. The following equation was used to calculate total chlorophyll content (mg g^{-1} fresh weight):

Total Chlorophyll = $8.02 \times A_{663} + 20.2 \times A_{645}$

Where:
A_{663} and A_{645} represent the absorbance readings at wavelengths of 663 nm and 645 nm, respectively.

2. Single Leaf Area (cm^2)

Single leaf area was estimated according to the method described by **Dvornic (1965)**. Ten fully expanded leaves were taken from each experimental unit, and the petioles were removed. Ten discs were cut from each leaf, each with an area of 1 cm^2. The leaves and discs were dried by placing them in perforated paper bags and drying in an electric oven at 70°C for 48 hours. The dry weight of the whole leaves and the dry weight of the discs were recorded separately. The average leaf area was calculated using the following equation:

Total area of ten leaves (cm^2) = (Dry weight of the ten whole leaves (g) × Total area of the ten discs (cm^2)) / Dry weight of the ten discs (g)

The obtained value was divided by 10 to calculate the area of a single leaf.

Fig. (1). Shows the size of the strawberry leaf

3. Number of Runners (runner $plant^{-1}$)

The number of runners was recorded at the end of the experiment on the selected plants (eight plants). The average number of runners per plant was calculated by dividing the total number of runners by eight.

Fig. (2). Shows the runners in strawberry

4. Number of Days from Planting to First Runner Emergence

The number of days from planting (15/10/2024) until the appearance of the first runner was recorded at the end of the study.

Fig. (3). Shows the beginning of runner emergence.

5. Fruit Weight (g)

The average fruit weight was calculated by dividing the total yield per plant by the number of fruits produced per plant across all harvests.

Fig. (4). Shows strawberry fruits

6. Number of Fruits per Plant (fruit plant^{-1})

The number of fruits was recorded for the eight plants in each experimental unit, starting from the first harvest until the final harvest. After completing all harvests, the total number of fruits produced within the experimental unit was calculated and then divided by eight to determine the number of fruits per plant.

Fig. (5). Shows the fruits on strawberry plants

7. Total Yield per Plant (g plant^{-1})

For the quantitative assessment of fruit yield, the cumulative weight of fruits produced from all successive harvests was recorded for the eight plants in each experimental unit, beginning from the first harvest until the end of the harvesting season. After recording the total yield, the average fruit yield per plant was calculated by dividing the total weight of fruits produced in the experimental unit by the number of plants (8).

Fig. (6). Shows the yield of strawberry plants

8. Total Soluble Solids Percentage in Fruits (TSS %)

This trait was determined according to the method described in **A.O.A.C. (2000)** using a hand refractometer. Ten fruits from each experimental unit were cut into slices in each harvest, then homogenized using a blender for 2–3 minutes. The juice was filtered through cotton cloth, and two readings were taken from the filtrate. The average of the two readings was calculated to represent the total soluble solids percentage in fruit juice for each harvest. The TSS values obtained from all harvests were then summed and divided by the number of harvests to obtain the final TSS value for each treatment.

9. Fruit Firmness (lb)

Fruit firmness was measured using a penetrometer equipped with a plunger (7.8 mm diameter). A thin layer of the strawberry skin was removed from two opposite sides of each fruit using a suitable peeler. The fruit was held perpendicular to the laboratory bench surface, and the plunger was pressed into the fruit until the constricted region was reached on both sides. The firmness was calculated as the average of all measured fruits.

10. Calcium (Ca) Concentration in Fruits

Calcium content in fruits was determined using the EDTA titration method.

11. Total Phenols in Fruits (mg 100 mL^{-1} juice)

Total phenolic content was determined according to the method described by **Ranganna (1986)**. Five milliliters of clear juice, previously used for anthocyanin determination, were placed in a test tube, and 5 mL of a pre-prepared extraction solution consisting of 85% ethanol and 15% hydrochloric acid (v/v) at concentrations of 95% and 1.5%, respectively, was added. The mixture was thoroughly homogenized to ensure complete mixing and then centrifuged at 3000 rpm for 3 minutes to separate solid particles. The supernatant was carefully collected, and its volume was adjusted to 10 mL using the same extraction solution to maintain a uniform concentration. Absorbance was measured at 280 nm using a spectrophotometer (Apel PD-303). Total phenols were calculated using the appropriate equation while accounting for sample dilution, and expressed as mg per 100 mL of juice:

Total phenols (mg 100 mL^{-1} juice) = (Total solution volume × instrument reading) / (98.2 × sample volume) × dilution × 100

Where 98.2 represents the molar extinction coefficient of phenolic compounds under the analytical conditions.

3. Results

1- Total Chlorophyll Content in Leaves (mg g^{-1} fresh weight) and Single Leaf Area (cm^2)

The data presented in (Table 2) showed that foliar application of calcium at a concentration of 8%, when applied individually, as well as the strawberry plant type (fresh), and the interaction between foliar application of calcium at 8% with the strawberry plant type (fresh), resulted in a significant increase in total chlorophyll content in leaves (12.77, 11.35, and 13.41 mg g^{-1} fresh weight, respectively), and single leaf area (134.38, 140.60, and 143.85 cm^2, respectively), compared with the control treatment and other treatments.

2- Number of Runners (runner plant^{-1}) and Number of Days from Planting to First Runner Emergence

The results presented in (Table 3) showed that the number of runners per plant increased significantly due to foliar application of calcium at a concentration of 8% and the strawberry plant type (fresh) (13.90 and 12.46 runner plant^{-1}), respectively, each factor individually. The best treatment was the interaction between (8% calcium + (fresh) strawberry plant type), which recorded the highest mean number of runners per plant (15.53 runner plant^{-1}). Regarding the number of days from planting to the appearance of the first runner, the lowest number of days required for first runner emergence was

recorded under foliar application of calcium at 8%, which was (209.27 days), while the strawberry plant type (fresh) also recorded the lowest number of days required for first runner emergence (204 days), each factor individually. The best significant difference was observed in the interaction treatment between foliar application of calcium at 8% and the strawberry plant type (frigo), which resulted in the lowest number of days required for first runner emergence in strawberry plants (199.11 days).

Table (2). Effect of Foliar Application of Calcium on the Growth, Yield, and Fruit Quality of Strawberry (*Fragaria* × *ananassa* Duch.) ((fresh) and (frigo)) under Sustainable Agriculture in Total Leaf Chlorophyll Content and Single Leaf Area (cm^2)

Treatments	Calcium concentration (%)			Means of Strawberry Varieties
	0	4	8	
Strawberry Varieties	Leaves chlorophyll (mg g^{-1} (fresh) weight)			
(fresh)	d 9.92	c 10.72	a 13.41	a 11.35
(frigo)	f 6.35	e 9.72	b 12.13	b 9.40
Means of Ca	c 8.14	b 10.22	a 12.77	
Strawberry Varieties	Leaf area (cm^{-2})			
(fresh)	d 137.46	c 140.49	a 143.85	a 140.60
(frigo)	e 131.31	d 137.49	b 142.37	b 137.06
Means of Ca	c 134.36	b 138.99	a134.38	

*Means of each factor individually and their interactions are presented separately. Different letters indicate significant differences among treatments at the 0.05 probability level according to Duncan's Multiple Range Test.

Table (3). Effect of Foliar Application of Calcium on the Growth, Yield, and Fruit Quality of Strawberry (*Fragaria* × *ananassa* Duch.) ((fresh) and (frigo)) under Sustainable Agriculture in Number of Runners per Plant (runner $plant^{-1}$) and Single Leaf Area (cm^2)

Treatments	Calcium concentration (%)			Means of Strawberry Varieties
	0	4	8	
Strawberry Varieties	Number of runner (runner $plant^{-1}$)			
(fresh)	e 9.40	b 12.45	a 15.53	a 12.46
(frigo)	f 6.63	d 9.58	c 12.27	b 9.50
Means of Ca	c 8.01	b 11.02	a 13.90	
Strawberry Varieties	Days to first runner emergence			
(fresh)	a 230.22	b 224.44	c 219.44	b 204.11
(frigo)	d 209.33	e 203.88	f 199.11	a 224.70
Means of Ca	a 219.77	b 214.16	c 209.27	

*Means of each factor individually and their interactions are presented separately. Different letters indicate significant differences among treatments at the 0.05 probability level according to Duncan's Multiple Range Test.

3- Fruit Weight (g) and Number of Fruits per Plant (fruit plant^{-1})

The results presented in (Table 4) indicated that both studied factors and their interaction significantly affected fruit weight and number of fruits per plant. Regarding foliar application of calcium, it was observed that the 8% treatment produced the highest fruit weight and number of fruits per plant, which significantly outperformed the 4% treatment and the control treatment. In turn, the 4% treatment also showed superiority over the control treatment, which recorded the lowest values for both fruit weight and number of fruits per plant.

On the other hand, the strawberry plant type (fresh) showed a significant superiority over the strawberry plant type (frigo) in both fruit weight and number of fruits per plant. Regarding the interaction between calcium concentration and strawberry plant type, the treatment (8% calcium + (fresh) strawberry plant type) recorded the highest values for fruit weight and number of fruits per plant, and it significantly outperformed all other treatments.

Table (4). Effect of Foliar Application of Calcium on the Growth, Yield, and Fruit Quality of Strawberry (*Fragaria* × *ananassa* Duch.) ((fresh) and (frigo)) under Sustainable Agriculture in Fruit Weight (g) and Number of Fruits (fruit plant^{-1})

Treatments	Calcium concentration (%)			Means of Strawberry Varieties
	0	4	8	
Strawberry Varieties	Fruit weight (g)			
(fresh)	c 13.37	b 16.41	a 19.25	a 16.34
(frigo)	d 10.43	c 13.37	b 16.41	b 13.40
Means of Ca	c 11.90	b 14.89	a 17.83	
Strawberry Varieties	Number of fruits (fruit plant^{-1})			
(fresh)	e 25.38	c 28.61	a 31.60	a 28.53
(frigo)	f 22.59	d 25.59	b 29.36	b 25.84
Means of Ca	c 23.98	b 27.10	a 30.48	

*Means of each factor individually and their interactions are presented separately. Different letters indicate significant differences among treatments at the 0.05 probability level according to Duncan's Multiple Range Test.

4- Total Yield per Plant (g plant^{-1}) and Total Soluble Solids Percentage in Fruits (TSS%)

The results presented in (Table 5) indicated that the studied factors and their two-way interactions significantly affected total yield per plant and total soluble solids percentage in fruits. Regarding foliar application of calcium, it was observed that the 8% treatment produced the highest total yield per plant and the highest TSS%, and it significantly outperformed both the control and the 4% calcium treatment. The 4% treatment, in turn, showed a significant superiority over the control treatment, which recorded the lowest total yield per plant and the lowest total soluble solids percentage in fruits. On the other hand, the strawberry plant type (fresh) showed a significant superiority over the strawberry plant type (frigo) in both total yield per plant and total soluble solids percentage in fruits. As for the effect of the interaction between the studied factors, the results confirmed that it had a significant effect on total yield per plant and TSS%. The interaction between the highest calcium concentration and the strawberry plant type (fresh) recorded the highest total yield per plant and TSS%, where the treatment (8% + strawberry plant type (fresh)) achieved values of (609.28 g plant^{-1} and 13.91%), respectively.

Table (5). Effect of Foliar Application of Calcium on the Growth, Yield, and Fruit Quality of Strawberry (*Fragaria* × *ananassa* Duch.) ((fresh) and (frigo)) under Sustainable Agriculture in Total Yield per Plant (g plant^{-1}) and Total Soluble Solids Percentage (TSS%)

Treatments	Calcium concentration (%)			Means of Strawberry Varieties
	0	4	8	
Strawberry Varieties	Total yield (g plant^{-1})			
(fresh)	d 340.51	c 470.71	a 609.28	a 473.50
(frigo)	e 236.36	d 344.18	b 482.37	b 354.30
Means of Ca	c 288.43	b 407.44	a 545.82	
Strawberry Varieties	TSS (%)			
(fresh)	e 10.63	b 12.61	a 13.91	a 12.38
(frigo)	f 10.43	d 11.44	c 11.98	b 11.28
Means of Ca	c 10.53	b 12.02	a 12.94	

*Means of each factor individually and their interactions are presented separately. Different letters indicate significant differences among treatments at the 0.05 probability level according to Duncan's Multiple Range Test.

5- Fruit Firmness (lb), Calcium Concentration in Fruits (%), and Total Phenols in Fruits (mg 100 g^{-1} fresh weight)

The results presented in (Table 8) indicated that foliar application of calcium led to a significant increase in fruit firmness, calcium concentration in fruits, and total phenolic content in fruits. The application of calcium at 8% recorded the highest values for these traits, significantly outperforming the 4% calcium treatment and the control treatment. In addition, the 4% treatment showed significant superiority over the control treatment, which recorded the lowest fruit firmness, calcium concentration in fruits, and total phenolic content. It was also observed that the strawberry plant type (fresh) resulted in a significant increase in these traits compared with the strawberry plant type (frigo).

Furthermore, the interaction between calcium application and strawberry plant type had a significant effect on fruit firmness, calcium concentration in fruits, and total phenolic content. The treatment (8% + (fresh) strawberry plant type) recorded the highest values for these traits and was significantly superior to all other interaction treatments.

Table (6). Effect of Foliar Application of Calcium on the Growth, Yield, and Fruit Quality of Strawberry (*Fragaria* × *ananassa* Duch.) ((fresh) and (frigo)) under Sustainable Agriculture in Fruit Firmness (lb), Calcium Concentration in Fruits (%), and Total Phenols in Fruits (mg 100 mL^{-1} juice)

Treatments	Calcium concentration (%)			Means of Strawberry Varieties
	0	4	8	
Strawberry Varieties	Fruit firmness (lb)			
(fresh)	d 0.491	b 0.494	a 0.497	a 0.494
(frigo)	f 0.485	e 0.488	c 0.492	b 0.488
Means of Ca	c 0.488	b 0.491	a 0.495	

Strawberry Varieties	Calcium content in fruits (%)			
(fresh)	a 0.59	a 0.52	a 0.56	a 0.55
(frigo)	a 0.38	a 0.44	a 0.50	a 0.44
Means of Ca	a 0.48	a 0.48	a 0.53	
Strawberry Varieties	Total phenolic content (mg 100 mL^{-1})			
(fresh)	d 28.49	b 31.59	a 34.68	a 31.59
(frigo)	f 24.64	e 27.49	c 30.65	b 27.59
Means of Ca	c 26.57	b 29.54	a 32.67	

*Means of each factor individually and their interactions are presented separately. Different letters indicate significant differences among treatments at the 0.05 probability level according to Duncan's Multiple Range Test.

4. Discussion

From the results presented in (Tables 2–6), it can be observed that foliar application of calcium and the type of cultivated strawberry plant, whether individually or in combination at a concentration of 8% calcium with the strawberry plant type (fresh) , produced the highest values for the studied traits, including (total chlorophyll content in leaves, single leaf area, number of runners per plant, fruit weight, number of fruits per plant, total yield per plant, total soluble solids percentage in fruits, calcium concentration in fruits, and total phenolic content in fruits). These treatments significantly outperformed all other treatments. These results are consistent with the findings reported by **Mehraj *et al.* (2015)**, **Hamail *et al.* (2018)**, **Chandrakar *et al.* (2018)**, **Ahmed *et al.* (2020)**, **Rozbiany and Taha (2020)**, **Khalil and Hammoodi (2021)**, **Cvelbar Weber *et al.* (2021)**, **El-Hefnawi *et al.* (2021)**, **Mohammed and Majeed (2024)**, **Harika *et al.* (2024)**, **and Aguilar-Delgado *et al.* (2024)**. Foliar application of calcium in strawberry plants increased the concentration of salicylic acid within plant tissues, which in turn enhanced the levels of key phytohormones such as auxins, gibberellins, and cytokinins. These hormones are responsible for stimulating cell division and elongation, thereby contributing to increased leaf area and a greater number of runners per plant. In addition, calcium plays a positive role in several important physiological processes within the plant, such as regulating the activity of photosynthetic enzymes and enhancing carbon fixation in the Calvin cycle. It also stimulates the activity of the enzyme RuBP carboxylase, which is responsible for carbon dioxide fixation, leading to increased carbohydrate production in the plant. Moreover, calcium contributes to regulating cellular responses and improving plant tolerance to environmental stresses, which in turn enhances vegetative growth, including leaf area and the number of runners per plant. Calcium also plays a role in improving root system development by increasing root elongation and the number of root hairs, thereby enhancing nutrient uptake. The increased production of carbohydrates synthesized in leaves further supports vegetative growth, resulting in higher total chlorophyll content, increased leaf area, and a greater number of runners per plant **(Rasheed Al-Karawi and Habeeb, 2024)**.

Calcium has the ability to activate calcium-signal sensing proteins such as (calmodulin, calmodulin-like proteins, and calcineurin-like proteins), which are involved in regulating many vital cellular processes. This, in turn, stimulates cell division and differentiation in meristematic tissues. In addition, calcium plays a role in increasing the levels of plant hormones within plant tissues, including auxin, by enhancing auxin synthesis and reducing its degradation. This leads to cell wall loosening and increased extensibility as a result of decreased cell wall pH and enhanced water influx into the cell, contributing to cell elongation and increased cell size, ultimately resulting in larger fruit size. Furthermore, the availability of carbohydrates in strawberry plants, as a result of increased vegetative growth manifested in higher leaf chlorophyll content and increased leaf area, contributed to greater food production. This led to increases in fruit weight, number of fruits, total yield per plant, and improvements in fruit quality, including higher total soluble solids (TSS) and increased phenolic content in fruits **(Rasheed Al-Karawi and Habeeb, 2024)**.

Moreover, foliar application of calcium to strawberry plants contributed to reduced fruit softening and increased fruit firmness by strengthening the structure of the cell wall. This occurs through

maintaining the fibrillar arrangement within the cell wall, thereby enhancing cell-to-cell adhesion and promoting the formation of calcium pectate through its binding with pectin in plant cells. This mechanism counteracts the activity of pectin methylesterase and increases resistance to cellulase activity, delaying cell wall degradation, fruit ripening, and tissue softening, thereby reducing deterioration processes. Consequently, this leads to improved fruit quality and firmness **(Gad El-Rab *et al.*, 2025 and Abdelaleem *et al.*, 2025)**.

The results also indicate that (fresh) transplants exhibit slow growth during the early stages after planting because they require the formation of their nutrient reserves during the same growing season. In addition, the ability of these transplants to adapt to certain environmental and soil conditions may be limited due to their relatively low stored reserves. Nevertheless, (fresh) strawberry plants may, in some cases, produce fruits with high quality attributes, such as improved color, higher total soluble solids content, and increased total phenolic content. This is attributed to the greater exposure of these plants to environmental stresses during the growth phase, which stimulates the production of secondary metabolites, including soluble solids and phenolic compounds in the fruits **(Lee *et al.*, 2020)**.

5. Conclusions

Strawberry plants (*Fragaria* × *ananassa* Duch.) were grown in loamy soil inside an unheated greenhouse at a planting spacing of 25 × 25 cm between plants. The plants were sprayed with three concentrations of calcium (0%, 4%, and 8%) using two types of strawberry planting material ((fresh) and (frigo)). The results showed that different calcium concentrations and the (fresh) strawberry plant type, each individually, improved the growth, yield, and fruit quality of strawberry compared with the control treatment. Furthermore, the combined treatment of 8% calcium + (fresh) strawberry plants produced the highest mean values for all studied traits, resulting in a significant increase in vegetative growth and yield, as well as an improvement in fruit quality of strawberry plants.

References

A.O.A.C, Official methods of analysis of the association of official analytical chemists (1970). William hortwitz, George banta company. Ins. Menashay, Wisconsin, USA.

Abdelaleem, H. M., EL-Dkeshy, M. H. and Abdalla, R. M. (2025). Preharvest Spraying of Calcium Chloride, Chitosan, and their Combination Effects on Tomato Growth, Yield, Fruit Characteristics, and Quality. Assiut Journal of Agricultural Sciences, 56(1), 296-313.

Aguilar-Delgado, M. J., Parra-Quezada, R. A., Olivas-Orozco, G. I., Jacobo-Cuéllar, J. L., Cuz-Álvarez, O. and Frías-Moreno, M. N. (2024). Yield, quality, and phytochemicals of two strawberry cultivars in response to foliar calcium nanofertilization. Agro Productividad, 17(5), 191-201.

Ahmed, A. A. M., Zuhair, A. D. and Wisam, K. K. (2020). Role of Boron and Calcium on growth, flowering and yield of strawberry (*Fragaria x ananassa* Duch) var. Liberation D'Orleans. Middle East J. Agric. Res, 9(1), 130-133.

Al-Khayyat, A. T. K. (2022). The role of foliar spraying with selenium, salicylic acid, and urea on growth, productivity, and some physiological traits of a strawberry cultivar (*Fragaria* × *ananassa* Duch.). (Doctoral dissertation). College of Agriculture and Forestry, University of Mosul, Iraq.

Arnon, D. I. (1949). Copper enzymes in isolated chloroplasts. Polyphenoloxidase in Beta vulgaris. Plant physiology, 24(1), 1.

Bakshi, P., Jasrotia, A., Wali, V. K., Sharma, A. and Bakshi, M. (2013). Influence of pre-harvest application of calcium and micro-nutrients on growth, yield, quality and shelf-life of strawberry cv. Chandler. Indian Journal of Agricultural Sciences, 83(8), 831-835.

Balali-Mood, M., Naseri, K., Tahergorabi, Z., Khazdair, M. R. and Sadeghi, M. (2021). Toxic Mechanisms of Five Heavy Metals: Mercury, Lead, Chromium, Cadmium, and Arsenic. – Frontiers in Pharmacology 12.

Black, C. A. (1965). Method of Soil Analysis. Part (2). Amer. Soc. Agron. Inc. USA.

Bosc, J. P. (2008). Strawberry production systems in France. Pomologia Croatica: Glasilo Hrvatskog agronomskog društva, 14(4), 259-268.

Capocasa, F., Balducci, F., Marcellini, M., Bernardini, D., Navacchi, O. and Mezzetti, B. (2019). Comparing nursery behavior, field plant yield and fruit quality of in vitro and in vivo propagated strawberry mother plants. Plant Cell, Tissue and Organ Culture (PCTOC), 136(1), 65-74.

Capocasa, F., Bordi, M. and Mezzetti, B. (2008). Comparing (frigo) and (fresh) plants in non-fumigated and heavy soil: The response of 10 strawberry genotypes. In VI International Strawberry Symposium 842 (pp. 129-134).

Chandrakar, S., Singh, P., Panigrahi, H. K. and Paikra, S. (2018). Effect of foliar feeding of calcium and micro-nutrients on quality parameters of strawberry (Fragaria× ananassa Duch.) cv. Nabila under net tunnel. Int. J. Chem. Studies, 6, 658-661.

Cvelbar Weber, N., Koron, D., Jakopič, J., Veberič, R., Hudina, M. and Baša Česnik, H. (2021). Influence of nitrogen, calcium and nano-fertilizer on strawberry (*Fragaria× ananassa* Duch.) fruit inner and outer quality. Agronomy, 11(5), 997.

Daszkiewicz, T. (2022). Food Production in the Context of Global Developmental Challenges. – Agriculture 12: 832.

Duralija, B., Miličević, T., Vokurka, A., Mešić, A., Jemrić, T. and Čmelik, Z. (2006). Cold stored tray plants in open field cultivation of strawberries. Agriculturae Conspectus Scientificus, 71(4), 167-170.

Dvorinic, V. (1965). Lacarali pactic de amelo graphic, Ed. Dielactict Spedagogica. Bucureseti. RS Romania.

Economides, C. V. and Gregoriou, C. (1988). Strawberry variety trials under cover and in the open field using (fresh) and (frigo) plants.

El-Hefnawi, N. N., Arafa, M. and Shahin, S. I. (2021). Effect of foliar application with calcium, boron and zinc on the yield and quality of strawberry fruits and post-harvest diseases. Journal of Environmental Studies and Researches, 11(2), 300-314.

FAO STAT (2023). Food and Agriculture Organization of the United Nation (FAO). http://fao.Org.

Faris, F. A., Al-A'Areji, J. M. and Al-Abbasi, A. T. (2025). Effect of foliar spray with iron and zinc on the growth and yield of strawberry plants. International Journal of Environmental Sciences, 11(1s), 673-683.

Gad El-Rab, N. A., Saad, M. E. and Atala, S. A. (2025). Effect of Preharvest Spray of Different Calcium Sources on Quality Attributes and Storability of Strawberry Fruits. Horticulture Research Journal, 3(2), 63-82.

Hamail, A., Hamada, M., El-Awady, A. and Salim, M. (2018). Effect of foliar spray with some plants extracts and different calcium sources on productivity and quilty of strawberry fruits. I. Vegetative growth, productivity and fruit quality. Journal of Productivity and Development, 23(3), 653-667.

Harika, N., Topno, S. E. and Joseph, A. V. (2024). Effect of Calcium Chelate and Carbonic Powder on Growth, Yield and Quality of Strawberry (Fragaria x ananassa Duch.) cv. Winter Dawn. Journal of Advances in Biology & Biotechnology, 27(6), 275-284.

Hepler, P. K. (2005). Calcium: a central regulator of plant growth and development. The Plant Cell, 17(8), 2142-2155.

Khalil, N. H. abd Hammoodi, J. K. (2021). Effect of nitrogen, potassium and calcium in strawberry fruit quality. Int. J. Agricult. Stat, 3899, 16-1967.

Lee, G. B., Lee, J. E., Je, B. I., Lee, Y. J., Park, Y. H., Choi, Y. W. and Kang, J. S. (2020). Effect of low-light intensity on growth, yield and quality of strawberries. Journal of Environmental Science International, 29(2), 167-175.

Lieten, P., Evenhuis, B. and Baruzzi, G. (2005). Cold storage of strawberry plants. International Journal of Fruit Science, 5(1), 75-82.

Mackinney, G. (1941). Absorption of light by chlorophyll solutions. *Journal of biological chemistry*, *140*(2), 315-322.

Maroto, J. V., López-Galarza, S., San Bautista, A. and Pascual, B. (1996, April). Cold stored and (fresh) multicrown strawberry plants for autumn-winter production in eastern Spain. In III International Strawberry Symposium 439 (pp. 545-548).

Mehraj, H., Hussain, M. S., Parvin, S., Shiam, I. H. and Jamal Udddin, A. F. M. (2015). Foliar application of calcium for quality production of strawberry. J. Expt. Biosci, 6, 73-76.

Mohammed, R. R. and Majeed, B. H. (2024). Response of strawberry growth, yield and marketable fruit quality to spraying with moringa leaf extract, calcium and potassium silicate. Iraqi Journal of Agricultural Sciences, 55(1), 440-452.

Page, A. L., Miller, R. H. and Keeny, D. R. (1982). Methods of Soil analysis part (2) 2nd (ed). Agronomy 9. Amer. Soc. Agron. Madison Wisconsin. Papanicolaou, EP (1976). Determination of cation. Exchange capacity of calcareous soils and their percent base saturation. soil Sci, 121, 67-71.

Pathak, J., Ahmed, H., Kumari, N., Pandey, A., Rajneesh, R. and Sinha, R.P. (2020). Role of calcium and potassium in amelioration of environmental stress in plants. Protective Chemical Agents in the Amelioration of Plant Abiotic Stress 535-562. https://doi.org/10.1002/9781119552154.ch27.

Pincot, D. D. A., Ledda, M., Feldmann, M. J., Hardigan, M. A., Poorten, T. J., Runcie, D. E. and Knapp, S. J. (2021). Social network analysis of the genealogy of strawberry: retracing the wild roots of heirloom and modern cultivars. G3, 11(3), jkab015.

Ranganna, S. (1986). Handbook of analysis and quality control for fruit and vegetable products. Tata McGraw-Hill Education.

Rasheed Al-Karawi, H. N. and Habeeb, H. (2024, July). Application of Calcium and Zinc Improves Vegetative Growth Characteristics and Plant Hormones in Strawberry. In IOP Conference Series: Earth and Environmental Science (Vol. 1371, No. 4, p. 042013). IOP Publishing.

Rasheed Al-Karawi, H. N. and Habeeb, H. (2024, July). Application of Calcium and Zinc Improves Vegetative Growth Characteristics and Plant Hormones in Strawberry. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1371, No. 4, p. 042013). IOP Publishing.

Ren, C., Jiang, L., Chen, W. and Wang, Z. (2024). Effect of different post-flowering photoperiods on main agronomic traits of strawberry (*Fragaria× ananassa* Duch. cv. Akihime). Agronomy, 14(9), 2039.

Rozbiany, P. M. K. and Taha, S. M. (2020). Influence of Calcium Foliar Application to Increase Growth and Yield of Two Strawberry Cultivars (*Fragaria x ananassa* Duch.). Zanco Journal of Pure and Applied Sciences, 32(2), 145-150.

Saieed, N. T. (1990). Studies of variation in primary productivity morphology in relation to elective improvement of broad-leaved tree species (Doctoral dissertation, PhD Dissertation. Naational University of Ireland).

Salkić, B., Salihović, E. and Omerčević, M. (2024). The Influence of Container and (frigo) Planting Material on the Vegetative Growth and Fertility of the Variety Clery. Journal of Agriculture and Ecology Research International, 25(3), 139-145.

Tongali, N. C., Ashoka, K. R., Ananthakumar, M. A. and Kumar, N. K. (2024). Effect of Different Sources and Levels of Calcium on Growth and Yield of Tomato (*Solanum lycopersicum* L.) In Alfisols. Plant Archives (09725210), 24(2).

Türemis, N., Kaska, N., Kafkas, S. A. L. İ. H. and Cömlekçioglu, N. (1996, April). Comparison of yield and quality of strawberry cultivars using (frigo) plants and (fresh) runners rooted in pots (1993–94 growing season). In III International Strawberry Symposium 439 (pp. 537-542).

Türemiş, N., Kaşka, N., Kafkas, S. and Çömlekçioğlu, N. (1998). Comparison of yield and quality of strawberry cultivars using (frigo) plants and (fresh) runners rooted in pots (1993–94 growing season). Acta Horticulturae, 439, 537-542. https://doi.org/10.17660/ActaHortic.1998.439.74

Usanmaz, S. (2019). Effects of different propagation methods on the strawberry cv.'Florida Fortuna'yield gown under low tunnel. International Journal of Agriculture Environment and Food Sciences, 3(4), 257-264.

Wdowiak, A., Podgórska, A. and Szal, B. (2024). Calcium in plants: An important element of cell physiology and structure, signaling, and stress responses. Acta Physiologiae Plantarum, 46(12), 108.

Yamamoto, E., Kataoka, S., Shirasawa, K., Noguchi, Y. and Isobe, S. (2021). Genomic selection for F1 hybrid breeding in strawberry (*Fragaria*× *ananassa*). Frontiers in Plant Science, 12, 645111

تأثير الرش الورقي بعنصر الكالسيوم في نمو وإنتاج وجودة ثمار الشليك (*Fragaria* × *ananassa* Duch.) الفريش والمجمدة ضمن الزراعة المستدامة

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الملخص

تم دراسة تأثير الرش الورقي بعنصر الكالسيوم وبثلاث تراكيز (0 %و 4 %و 8 %)، ونوعين من الشليك المزروعة (فريش و فريكو) ، في نمو وإنتاج وجودة ثمار الشليك (*Fragaria* x *ananassa* Duch.) المزروعة في البيت البلاستيكي الغير مدفأة التابع لقسم البستنة وهندسة الحدائق في كلية الزراعة والغابات جامعة الموصل خلال موسم النمو 2024-2025 . تم الرش الورقي لنباتات الشليك بعنصر الكالسيوم خلال فترة الدراسة ثلاث مرات ، حيث كانت الرشة الاولى بتاريخ 2024/11/15 في الصباح الباكر حتى البلل التام ، وبين رشة واخرى 20 يوم ، أظهرت النتائج التي تم الحصول عليها ان الرش الورقي بعنصر الكالسيوم وبتركيز 8 % أدى الى حصول زيادة معنوية في جميع الصفات المدروسة (نسبة الكلوروفيل الكلي في الاوراق ومساحة الورقة الواحدة وعدد المدادات لكل نبات وعدد الأيام من بداية زراعة النباتات وحتى ظهور اول مداد ووزن الثمرة وعدد الثمار لكل نبات والحاصل الكلي لكل نبات والنسبة المئوية للمواد الصلبة الذائبة الكلية في الثمار وصلابة الثمار وتركيز الكالسيوم في الثمار والفينولات الكلية في الثمار) ، بينما كان لنوع نبات الشليك المزروعة الـ (fresh)قد اعطانا كذلك اعلى فرق معنوي في (نسبة الكلوروفيل الكلي في الاوراق ومساحة الورقة الواحدة وعدد المدادات لكل نبات وعدد الأيام من بداية زراعة النباتات وحتى ظهور اول مداد ووزن الثمرة وعدد الثمار للنبات الواحد والحاصل الكلي للنبات الواحد والنسبة المئوية للمواد الصلبة الذائبة الكلية في الثمار وصلابة الثمار وتركيز الكالسيوم في الثمار والفينولات الكلية في الثمار) ، وكانت أفضل المعاملات التي تم الحصول عليها هي معاملة التداخل بين الرش الورقي بعنصر الكالسيوم بتركيز 8 % مع نوع نبات الشليك المزروعة الـ (fresh) في جميع الصفات المدروسة التي تفوقت على معظم المعاملات بما فيها معاملة المقارنة.