Effect of iron and calcium chloride on stimulating vegetative growth, flowering and yield of strawberry (*Fragaria* × *ananassa* Duch.) cv. Camarosa

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ABSTRACT

This study examined the effects of foliar iron spraying using chelate Fe-EDDHA (6% Fe) at three concentrations (0, 50, and 100 mg Fe L^{-1}) and two concentrations of calcium chloride (0 and 0.5% $CaCl_2$) on the growth, flowering, and yield of the strawberry plant cv. Camarosa in an unheated plastic greenhouse (35 m long, 5 m wide, and with area of 175 m^2), by using Completely Randomized Block Design with three replicates and six plants per each experimental unit was. The results showed that foliar spraying with iron, particularly at a concentration of 50 mg Fe L^{-1}, and calcium chloride at a concentration of 0.5% each alone led to a significant increase in leaves Fe concentration, single leaf area, plant leaves area, number of flowers and fruits per plant, plant yield, and yield per hectare. The interaction between iron and calcium chloride significantly affected most of the studied traits; the best treatments were 50 mg Fe L^{-1} + 0 % $CaCl_2$, which produced the highest number of flowers (45.53 flower $plant^{-1}$) and fruits (12.78 fruit $plant^{-1}$) , plant yield (180.95 g $plant^{-1}$) and hectare yield (10856.81 kg $ha.^{-1}$), However the treatment of 100 mg Fe L^{-1} + 0.5 % $CaCl_2$ produced the maximum leaves Fe concentration (146.87 mg kg^{-1} dry wt.), number of leaves (18.67 leaf $plant^{-1}$) and fruit weight (15.18 g $fruit^{-1}$). The maximum leaf area (143.64 cm^2) and plant leaves area (2528.06 cm^2) were in the plants treated with 0.5% $CaCl_2$ without Fe.

INTRODUCTION

Strawberry (*Fragaria* x *ananassa* Duch.) is a small fruit of various shapes and colours belonging to the Rosaceae family. Globally, it ranks fourth after apples, oranges, and bananas in terms of consumption and consumer preference. The area cultivated with strawberries worldwide is estimated at approximately 389,665 hectares, with a production of 9,175,384 tons. China is the largest producer, with an output of 3,380,478 tons, followed by the United States with 1,211,090 tons [1]. In Iraq, however, there are no statistics on cultivated areas or production, although there has been an increase in research and studies on this plant and the areas under cultivation.

Strawberries are herbaceous plants that grow no taller than thirty centimeters. According to [2], it is an annual crop in subtropical climates and a perennial in tropical ones. Although it is grown in Europe, Asia, Africa, and the Americas, it is originated in North America[3]. Strawberries are classified according to their flowering and fruiting habits into short-day, long-day, and day-neutral varieties [4].

Strawberry comprise 45 species and are of high economic importance due to their widespread distribution across regions worldwide, the large number of varieties, and their ability to adapt to diverse environmental conditions, their fruits appear in markets early in the spring, they are diverse in shape, including conical, spherical, flattened, and oblong, they are bright red and glossy and are distinguished by their attractive appearance and delicious taste. The fruit is juicy, either sour or sweet, depending on the variety. It is also highly nutritious, easily digestible, and rich in various organic acids, digestive enzymes, and antioxidants, especially vitamin C [5].

Strawberry plants are fast-growing and maturing crops that require special care to ensure healthy growth and good yields. They respond quickly to fertilization, which improves their growth and productivity. The plants need sufficient nutrient absorption to support their rapid growth and maturation, including increased foliage density and nutrient uptake. Appropriate fertilization enhances the plant's fresh and dry weight, increasing overall yield and reducing the risk of diseases and pests, promotes plant health, increases productivity, and enhances resistance to various stresses [6]; [7]. The availability of nutrients within the plant is a method of foliar feeding that involves spraying nutrient solutions onto the foliage of plants, especially when soil conditions are unsuitable for fertilization, and it plays an important role in promoting fruit set and increasing fruit yield and quality, thus improving crop value and producing healthy, high-quality fruit.

Studies have shown that timely foliar feeding of strawberry plants can improve fruit quality and quantity [8]. Among these elements are iron and calcium. Iron is an important element that promotes vegetative and flowering growth and fruit quality in strawberry plants [9]. Plants need iron to produce chlorophyll, and iron deficiency reduces chloroplast size and protein content, leading to yellowing of the leaves. This yellowing occurs between the veins, appearing as lines on young leaves, and, in severe cases, leads to plant death [10] , also examined the structure of Ferredoxin. This protein acts as an electron carrier in photosynthesis and is a component of several enzymes, including Nitrogen Fixation, Nitrate Reduction, Catalase, and Peroxidase. It is involved in the structure of leghemoglobin, which acts as an oxygen carrier in nitrogen fixation. It is involved in the structure of various cytochromes that are important in photosynthesis and respiration. It is also involved in the structure of phytoferritin, which is an iron store in chloroplasts and is the electron donor in the energy-carrying compound NADPH in the first photosynthetic system. Iron deficiency or reduced activity leads to decreased chlorophyll production, causing damage to plants, including pale leaves, and reducing the plant's ability to produce food through photosynthesis, thereby negatively affecting plant yield [11]; [12]

Several researchers have studied the effect of iron on the growth and fruiting of strawberry plants. [8] investigated the effect of foliar iron application at concentrations of 0, 250, 500, and 1000 mg L^{-1} on the vegetative growth and fruiting of the Pajaro strawberry cultivar. He observed a significant increase in plant dry weight, number of flowers, fruits per plant, and fruit weight with foliar iron application at 1000 mg L^{-1} compared to other treatments. [13] investigated the effect of different concentrations of iron oxide (0, 50, 100, and 150 mg L^{-1}) on the Chandler strawberry cultivar. The results showed that foliar application of iron oxide at 150 mg L^{-1} significantly increased plant height, number of leaves per plant, number of flowers and fruits, and total plant yield compared to the control treatment. [14] also noted the effects of foliar application of the strawberry plant cv. Ruby Gem with iron at concentrations of 0, 15, and 30 mg L^{-1}. They showed that a 30 mg L^{-1} concentration caused a significant increase in the number of leaves per plant, leaf area, number of plant crowns, leaf chlorophyll concentration, and some nutrients (Fe, P, K, and N) in the leaves compared to the control treatment. [15] studied the effect of foliar spraying with iron in its regular and nano forms on the flowering characteristics and productivity of the strawberry cv. Festival under greenhouse conditions, at three concentrations: 150 mg L^{-1} of regular iron, 20 and 40 mg L^{-1} of nano iron, in addition to a control treatment. In comparison to the other treatments, the results demonstrated that spraying the plants with nano iron at a concentration of 20 mg L^{-1} considerably enhanced the number of flowers, fruits per plant, fruit weight, length, and diameter, and plant yield. In their investigation on the effects of foliar spraying chelated iron at three concentrations (0, 1, and 2 mg L^{-1}) on the vegetative growth of strawberry plants. [12] Conclusion, that the growth of Festival and Sabrina cvs. was positively impacted by the 2 mg L^{-1} concentration, which led to a notable increase in leaf area, number of leaves per plant, plant height, and root size and density in comparison to the control treatment. [16] discovered that when Camarosa strawberry plants were sprayed with nano-iron at concentrations of 0, 10, and 20 mg L^{-1}, the 20 mg Fe L^{-1} concentration significantly increased leaf area, plant height, number of fruits per plant, fruit weight, size, width, and total plant yield. The growth and production of Albion strawberry plants were examined by[17] in relation to foliar iron sprayed at various concentrations (0, 10, 20, and 30 mg Fe L^{-1}). In comparison to the other treatments, the results showed that foliar iron administration, especially at a concentration of 30 mg L^{-1}, significantly enhanced the total chlorophyll, leaf area, number of leaves, number of fruits per plant, fruit weight and width, and plant yield.

Calcium is one of the macronutrients essential for plants and plays several physiological roles. It is involved in the formation of cell walls, affects the development of meristematic cells, helps in the formation of plant proteins, plays an important role in the formation of root nodules and the fixation of atmospheric nitrogen, reduces the detachment of plant parts before full growth, and activates several enzymes within the plant [18]; [19] It contributes to the formation of pectin compounds that bind cell walls together and plays a vital role in the formation of the middle lamella, thus enhancing the strength and stability of plant tissues. High calcium content in fruits increases firmness and delays ripening, thereby extending storage life and improving post-harvest quality. Calcium also helps strengthen cell walls and lower the respiration rate in fruit cells, thereby reducing the likelihood of biological infection during storage and transportation. It enhances the fruit's resistance to damage during harvesting and handling and reduces fruit drop rates, thus preserving production and storage quality [20]. Calcium plays a vital physiological role in regulating plant life processes. It reduces the respiration rate and improves the integrity and cohesion of cell walls. Calcium also participates in several metabolic pathways related to fruit ripening, delaying the ripening process and increasing tissue firmness. This positively affects the fruit's nutritional content, particularly its vitamins [7].

Foliar spraying of calcium is considered the most effective method for increasing its content in the plant, which improves fruit quality and prolongs shelf life before and after harvest [21]. Calcium plays a vital role in stabilising cell membranes, strengthening cell walls, and increasing their thickness. Calcium supplementation helps delay the onset of fungal rot and maintain fruit firmness. Foliar spraying of calcium before harvest enhances fruit quality and extends shelf life. Conversely, a deficiency of this element can lead to various physiological disorders in fruit crops [22]. Calcium also plays a crucial role in pollen development and germination, as well as in pollen tube growth within the stigma. Furthermore, it contributes to sugar synthesis, accumulation, and energy storage within plant tissues, directly impacting plant growth and productivity. It also contributes to improving the flowering index and increasing flower density [23].

[24] confirmed in the study conducted on the Rubygem strawberry using chelated calcium (Da-EDTA) 14% Ca at two concentrations (0 and 100 mg L^{-1}), the results

showed that the 100 mg L^{-1} concentration led to a significant increase in stem length, number of leaves per plant, leaf area, fruit length, size and weight, as well as an increase plant yield and yield per unit area compared to the control treatment. [25] reported that when foliar spraying Festival strawberry plants with calcium at two concentrations (0 and 300 mg L^{-1}) using $CaCl_2$, the 300 mg L^{-1} concentration significantly increased the number of leaves, leaf area, number of fruits per plant, and their weights and sizes, TSS, and significantly decrease in titrable acidity compared to the control treatment. [26], in their study investigating the effect of spraying different levels of chelated calcium on Rubygem and Sweet Charliem strawberry plants at concentrations of 0, 2.5, and 5 g L^{-1} on some vegetative characteristics, stated that the 2.5 g L^{-1} concentration of calcium was the most effective in improving vegetative characteristics, causing a significant increase in leaf area, chlorophyll content, and calcium concentration in the leaves compared to the control treatment. [27], in their study on strawberry plants using calcium at concentrations of 0, 100, 200, and 400 mg L^{-1}, confirmed that spraying with calcium at a concentration of 400 mg L^{-1} significantly increased the number of leaves per plant, single leaf area, total chlorophyll, and fruit length compared to the control treatment. The results of the study conducted by [23] showed that foliar spraying with calcium significantly improved the growth and productivity characteristics of the Dawn Winter strawberry cultivar at concentrations of 0, 250, 500, 150, 1000, and 1250 mg Ca L^{-1},The results indicated that foliar spraying with 1000 mg Ca L^{-1} was the most effective, causing a significant increase in plant height, number of leaves per plant, shoot diameter, fruit size and weight, plant yield and number of flowers per plant compared to other treatments. [7] studied the effect of foliar spraying with chelated calcium at concentrations of 1.0, 3.0, and 5.0 g L^{-1} on the growth, yield, and fruit quality of the Winter Dawn cultivar. Results showed that 5.0 g L^{-1} treatment significantly increased the number of leaves per plant, plant height, vegetative spread, number of fruits per plant, individual fruit weight, total fruit weight, fruit TSS, and fruit juice percentage, compared to the other concentrations. In a study by [28], Festival cultivars were sprayed with calcium silicate at concentrations of 0, 1, and 2 g L^{-1}. The results showed that the 2 g L^{-1} of calcium silicate significantly increased vegetative growth characteristics, namely plant height, number of leaves, flowers, and fruits per plant. The average fruit weight and size, as well as the total plant yield, were compared with the other two treatments.

Therefore, this study aims to determine the effects of foliar spraying with iron and calcium chloride on the vegetative growth, flowering, and yield of Camarosa strawberry plants, and to identify the most effective treatment for recommendation for Camarosa strawberry plants grown under conditions similar to those of this study.

MATERIAL AND METHODS

This study was conducted inside of unheated greenhouse (35m long, 5m wide, and 175m² in area) belonging to the Department of Horticulture and Landscape Design, College of Agriculture and Forestry, University of Mosul, from November 1, 2023, to September 1, 2024, to investigate the effect of foliar spraying with iron and calcium chloride on stimulating vegetative growth, flowering, and yield of the Camarosa strawberry plants, within the framework of sustainable farming techniques. The greenhouse soil was prepared manually to ensure its fineness and homogeneity. It was levelled and divided into three terraces, each 1.34 m wide, extending the length of the greenhouse. Each terrace was considered a replicate, and three soil samples were randomly collected from different locations on each terrace at a depth of 0–30 cm to estimate soil physical and chemical properties, following the methods described by [29], as detailed in Table 1. Each terrace was completely covered with black polyethene. Openings were made in the top surface at regular intervals of 25 x 25 cm for planting, with a 50 cm gap between each experimental unit (each experimental unit measuring 0.75 m in length, 1.34 m in width, and 1.00 m² in area).

Table (1): Some physical and chemical properties of the polyhouse soil*.

Property	**Unit**	**Value**
Electrical Conductivity	dS m^{-1}	1.80
pH	—	7.04
Organic Matter	g kg^{-1}	12.40
Sand	g kg^{-1}	675.5
Clay	g kg^{-1}	149.50
Silt	g kg^{-1}	175.00
Soil Texture	—	Sandy Loam
Available Nitrogen	%	0.0039
Available Phosphorus	mg kg^{-1}	5.48
Available Potassium	mg kg^{-1}	352.00
Available Iron	mg kg^{-1}	4.81
Available Calcium	mg kg^{-1}	230.00

*The soil analysis was carried out at the Central Laboratory, College of Agriculture and Forestry/ Mosul University.

The Camarosa cv. Plants were selected from a greenhouse belonging to the College of Agriculture and Forestry at the University of Mosul. The plants, which exhibited nearly uniform growth, were uprooted directly from the soil, and any damaged roots and large leaves were removed, leaving only two leaves. Before planting, the roots were dipped in a fungicide (pentanol) at a concentration of 2.22 ml/L for one minute as a preventative treatment against fungi, according to the manufacturer's recommendations. The plants were planted early in the morning on November 1, 2023, with three rows at the top of each terrace in their previously prepared locations. The distance between rows and between plants on each terrace was 25 cm, with 6 plants per experimental unit. A distance of 50 cm was maintained between each experimental unit and another.

The study was conducted using a randomised complete block design (RCBD) with two factors: iron at three levels (0, 50, and 100 mg Fe L^{-1}) using Fe-EDDHA (6% Fe), and calcium chloride at two levels (0% and 0.5%), with three replicates and six plants per experimental unit. The plants were sprayed with iron and calcium chloride three times during the growing season, with a 20-day interval between applications. The first iron application was on February 21, 2024, and the first calcium chloride application was on February 22, 2024.

Traits studied:

Leaves Fe and Ca concentrations

leaves Iron and calcium concentrations: Six fully expanded leaves were collected from each experimental unit, washed thoroughly with distilled water, and dried in an electric oven at 70°C until the weight stabilised (72 hours). They were then ground using an electric grinder. 200 mg of the ground leaves were taken for each experimental unit and digested in a Pyrex flask by soaking them in 5 ml of concentrated sulfuric acid for 24 hours, according to the method proposed by [30]. Afterwards, 1 ml of concentrated perchloric acid was added, and the digestion flask was heated until a clear, transparent solution was obtained. The solution was then cooled and filtered. The filtrate was collected, and the volume was brought up to 50 ml with distilled water. leaves, iron and calcium concentrations in the filtrate were determined. Fe(mg kg^{-1} dry wt.) was determined by using an atomic absorption Spectrophotometer, according to the method described by [31], and Ca (%) was determined according to the method described by [32].

Total chlorophyll (mg g^{-1} fresh weight) in leaves was estimated according to the methods of [33]; [34].

Number of leaves per plant.

Single leaf area, estimated according to the method described by [35].

Plant leaves area(cm^2 $plant^{-1}$), estimated according to the method described by [36], using the following equation: plant leaves area (cm^2) = Single leaf area (cm^2) × Number of leaves per plant.

Number of flowers per plant: The number of flowers in each experimental unit was recorded from the beginning to the end of flowering. The overall average number of flowers per plant was then calculated using the following equation: Total number of flowers per plant = Total number of flowers for all plants in the experimental unit / 6.

Number of fruits (fruit $plant^{-1}$): The number of fruits in each experimental unit was recorded from the first harvest to the last harvest. The overall average number of fruits per plant was then calculated using the following equation: Total number of fruits per plant = Total number of fruits for all plants in the experimental unit / 6**.**

Fruit weight (g).

Plant yield (g $plant^{-1}$).

Yield per hectare, estimated according to [38] method using the following equation:

$$Total\,Yield\ (kg\ ha^{-1}) = \frac{Yield\,plot^{-1}\ (kg)}{Plot\ area(m^2)} \times 10000\ m^2$$

The results were statistically analysed using the SAS program [39], and the means were compared using Duncan's multiple range test at a probability of error of 0.05 [40] .

RESULTS AND DISCUSSION

Leaves Fe and Ca concentrations: Results in Table (2) indicated that foliar application of iron, $CaCl_2$ and their interaction significantly affected leaves Fe concentration, as for spraying with iron, the treatment of 50 mg Fe L^{-1} produced the maximum leaves Fe concentration (145.62 mg Fe kg^{-1} dry wt.). This may be due to increased iron absorption by plants when iron is applied as a foliar spray as a result of increased leaf area and plant leaf area (Table 3). [14];[41]also indicated a positive relationship between plant growth and iron concentration in leaves, they observed that foliar spraying of iron led to an increase in the concentration of several nutrients in the leaves, including iron, nitrogen, phosphorus, and potassium, as a result of increased root growth, which may lead to increased absorption of nutrients from the soil and their accumulation in the plant.

The table also showed that spraying 0.5% $CaCl_2$ led to a significant increase in Fe in the leaves (143.96 mg Fe kg^{-1} dry wt.) compared with the control, which had the lowest Fe in the leaves (138.07 mg Fe kg^{-1} dry wt.). These results may be due to increased root growth, which can lead to greater nutrient absorption from the soil and their accumulation in the plant, as calcium promotes cell division and elongation [37].

The interaction between Fe and $CaCl_2$ significantly affected the leave'sFe concentration; the treatment of 100 mg Fe L^{-1} + 0.5 % $CaCl_2$ produced the maximum means of this parameter (146.87 mg kg^{-1} dry wt.).

Results in the same table showed that foliar application of iron, calcium and their interaction unsignificantly affect leaves Ca concentration, and this may be due to the sufficient amount of Ca in the soil (Table 1).

Table (2): Effect of iron, $CaCl_2$ and their interaction on leaves Fe concentration (mg kg^{-1} dry wt.) and leaves Ca concentration(%) of strawberry plants cv. Camarosa.*

$CaCl_2$ Conc.(%)	Fe Concentration (mg L^{-1})			**Means of $CaCl_2$**
	0	50	100	
	Leaves Fe Concentration (mg kg^{-1} dry wt.)			
0	136.11 b	144.59 a	133.51 b	**138.07 b**
0.5	138.36 b	146.66 a	146.87 a	**143.96 a**
Means of Fe	**137.24 b**	**145.62 a**	**140.19 ab**	
Leaves Ca Concentration(%)				
0	2.11 a	2.04 a	2.18 a	**2.11 a**
0.5	1.87 a	1.80 a	2.09 a	**1.92 a**
Means of Fe	**1.99 a**	**1.92 a**	**2.13 a**	

* The means of iron and $CaCl_2$, each alone or together, for each parameter that shares the same letters are not significantly different according to Duncan's multiple range test at 0.05.

Vegetative parameters: Results in Table, 3 indicated that foliar application of iron significantly effected leaves total chlorophyll, leaf area and plant leaves area, the treatment of 50 mg Fe L^{-1} gave the highest meanes of these traits (5.34 mg g^{-1} fresh wt.,136.64 cm^2 $leaf^{-1}$ and 2403.49 cm^2 $plant^{-1}$) respectively, However number of leaves per plant unsignificantly effected with the application of iron. These results may be due to increased iron concentration in the leaves(Table 2), as iron is a component of ferredoxin, which acts as an electron carrier in photosynthesis, and of various cytochromes important in photosynthesis and respiration. It is also a component of phytoferritin, which serves as an iron storage in chloroplasts [12];[17] [42] stated that iron stimulates vegetative growth in plants, as it is a component of several important plant compounds, including various cytochromes involved in respiration, hormone synthesis, and nucleic acid production. [14] ; [41] also indicated a positive relationship between plant growth and iron concentration in leaves, they observed that foliar spraying of iron led to an increase in the concentration of several nutrients in the leaves, including iron, nitrogen, phosphorus, and potassium, as a result of increased root growth, which may leads to increased absorption of nutrients from the soil and their accumulation in the plant. Also, the increase in the leaf area of the plant when spraying iron may lead to an increase in carbohydrates manufactured in the leaves, which are used in vegetative growth and cell expansion [9]; [43].

Table (3): Effect of iron, $CaCl_2$ and their interaction on leaves total chlorophyll (mg $g.^{-1}$fresh wt.), number of leaves (leaf $plant^{-1}$), leaf area(cm^2 $leaf^{-1}$) and plants leaves area(cm^2 $plant^{-1}$) of strawberry plants cv. Camarosa.*

$CaCl_2$ Conc.(%)	Fe Concentration (mg L^{-1})			**Means of $CaCl_2$**
	0	50	100	
Leaves total chlorophyll(mg g^{-1} fresh wt.)				
0	4.06 b	5.20 a	5.12 a	**4.79 b**
0.5	4.76 b	5.48 a	5.25 a	**5.16 a**
Means of Fe	**4.41 b**	**5.34 a**	**5.18 a**	
Number of leaves (leaf $plant^{-1}$)				
0	16.18 b	18.20 a	16.71 b	**17.03 a**
0.5	17.60 ab	16.98 b	18.67 a	**17.75 a**
Means of Fe	**16.89 a**	**17.59 a**	**17.69 a**	
Leaf area(cm^2 $leaf^{-1}$)				
0	122.09 c	138.56 b	121.34 c	**127.33 b**
0.5	143.64 a	134.71 b	129.97 c	**136.11 a**
Means of Fe	**132.86 ab**	**136.64 a**	**125.66 b**	
Plants leaves area(cm^2 $plant^{-1}$)				
0	1975.41 d	2521.79 a	2027.59 c	**2168.42 b**
0.5	2528.06 a	2287.37 b	2426.53 a	**2415.95 a**
Means of Fe	**2244.00 b**	**2403.49 a**	**2222.92 b**	

* The means of iron and $CaCl_2$, each alone or together, for each parameter that shares the same letters are not significantly different according to Duncan's multiple range test at 0.05.

Iron also contributes to energy production in the form of ATP, which is necessary for cell division and elongation, leading to an increase in leaf size and leaf area [9];[43];[44];[45] also reported that foliar spraying of iron positively affects plant growth under various environmental conditions, such as drought and cold. Iron is also essential for the activity of enzymes responsible for cell division and elongation [46]. Iron also plays a role in plant hormone formation, indirectly participating in auxin synthesis and regulating gibberellins, hormones responsible for cell division [42]. The sufficiency of iron leads to an increase in the plant's tolerance to heat stresses and a reduction in the effect of salinity, as well as maintaining the physiological activity of the plant, which works to ensure the continued growth of the plants[47].

Results in table(3) showed that $CaCl_2$ Foliar application at a concentration of 0.5 % gaves maximum leaves total chlorophyll, leaf area and plant leaves area (5.16 mg g^{-1} fresh wt., 136.11cm^2 $leaf^{-1}$ and 2415.95 cm^2 $plant^{-1}$, respectively) and significantly dominated over control treatment, the number of leaves per plant unsignificantly effected with the application of $CaCl_2$. This may be due to calcium promoting cell division and elongation [37], which may increase leaf area and thus increase the amount of carbohydrates produced in the leaves. These carbohydrates are used in plant growth. Foliar spraying of calcium is beneficial to the plant because absorption is faster through the leaves compared to the soil. This rapidly increases calcium availability in vegetative tissues and enhances physiological functions related to light and energy absorption [21]. Calcium maintains the integrity of cell membranes, including chloroplast membranes, by reducing chlorophyll degradation and increasing photosynthetic efficiency; it also plays an important role in protein synthesis and activates several enzymes in plants [18] ; [19].

The interaction between iron and calcium chloride significantly affected all vegetative growth traits, the treatment of 50 mg Fe L^{-1} + 0.5 % $CaCl_2$ produced maximum leaves total chlorophyll(5.48 mg g^{-1}fresh wt.), While Number of leaves (18.67 leaf $plant^{-1}$) were significantly higer in the treatment of 100 mg Fe L^{-1} + 0.5 % $CaCl_2$, the maximum leaf area (143.64 cm^2) and plant leaves area (2528.06 cm^2) were in the plants treated with 0.5% $CaCl_2$ without Fe.

Flowering and Yield parameters: Table, 4 showed that there were significant iron in

differences for the effect of spraying with the Number of flowers, number of fruits $plant^{-1}$, plant and hectare yield, the treatment of 50 mg Fe L^{-1} produced maximum numbe of flowers (43.66 flower $plant^{-1}$), number of fruits (11.60 fruit $plant^{-1}$), plant yield (159.42 g $plant^{-1}$) and hectare yield(9565.32 kg $ha.^{-1}$), However fruit weight unsignificantly effected with iron spraying. This may be due to increased iron absorption by plants when iron is applied as a foliar spray, resulting from the increased leaf area. Iron is a component of ferredoxin, which acts as an electron carrier in photosynthesis, and of various cytochromes important in photosynthesis and respiration.

Table (4): Effect of iron and $CaCl_2$ and their interaction on the number of flowers (flower $plant^{-1}$), the number of fruits (fruit $plant^{-1}$), fruit weight (g $Fruit^{-1}$), plant yield (g $plant^{-1}$) and hectare yield (kg $ha.^{-1}$) of strawberry plants cv. Camarosa.*

$CaCl_2$ Conc.(%)	Fe Concentration (mg L^{-1})			**Means of $CaCl_2$**
	0	50	100	
Number of flowers (flower $plant^{-1}$)				
0	30.96 b	45.53 a	37.11 ab	**37.87 b**
0.5	39.31 ab	41.78 a	43.89 a	**41.66 a**
Means of Fe	**35.13 b**	**43.66 a**	**40.50 ab**	
Number of fruits (fruit $plant^{-1}$)				
0	6.64 c	12.78 a	9.02 bc	**9.48 b**

0.5	9.82 ab	10.42 ab	11.60 ab	**10.61 a**
Means of Fe	**8.23 b**	**11.60 a**	**10.31 a**	
	Fruit weight (g $Fruit^{-1}$)			
0	13.59 b	13.66 b	13.35 b	**13.53 a**
0.5	14.93 a	13.08 b	15.18 a	**14.40 a**
Means of Fe	**14.26 a**	**13.37 a**	**14.27 a**	
Plant yield (g $plant^{-1}$)				
0	90.62 c	180.95 a	120.7 bc	**130.79 b**
0.5	147.23 abc	137.90 abc	174.19 ab	**153.10 a**
Means of Fe	**118.92 b**	**159.42 a**	**147.49 ab**	
hectar yield (kg $ha.^{-1}$)				
0	5437.12 c	10856.81 a	7247.31 bc	**7847.08 b**
0.5	8833.60 abc	8273.83 abc	10451.19 ab	**9186.20 a**
Means of Fe	**7135.39 b**	**9565.32 a**	**8849.25 ab**	

* The means of iron and $CaCl_2$, each alone or together, for each parameter that shares the same letters are not significantly different according to Duncan's multiple range test at 0.05.

Iron is also a component of phytoferritin, which serves as an iron storage organelle in chloroplasts [42]. Also, the increase in the leaf area of the plant may lead to an increase in carbohydrates manufactured in the leaves, which are used in fruit growth and cell expansion [9] ; [43]. [48] reported that iron availability improves photosynthesis, thereby increasing the translocation of photosynthetic products (carbohydrates) to the fruit and thus increasing fruit weight. Iron also plays a role in plant hormone formation, indirectly participating in the synthesis of auxins and regulating gibberellins, hormones responsible for cell division and its expansion, fruit set, and elongation of fruit cells, and the sufficiency of iron in the plant leads to improved fruit growth and a reduction in the shedding of flowers and new fruits [42].The sufficiency of iron leads to an increase in the plant's tolerance to heat stresses and a reduction in the effect of salinity, as well as maintaining the physiological activity of the plant, which works to ensure the continued growth of fruits well and the stability of quality and productivity even in harsh environmental conditions [47].

The results in the same table showed that Significant differences were recorded for the foliar spraying of $CaCl_2$ in the number of flowers, number of fruits, plant and hectar yield, the treatment of 0.5 % $CaCl_2$ produced maximum numbe of flowers(41.66 flower $plant^{-1}$), number of fruits (10.61 fruit $plant^{-1}$), plant yield (153.10 g $plant^{-1}$) and hectar yield(9186.20 kg $ha.^{-1}$), However fruit weight unsignificantly effected with spraying of $CaCl_2$. This may be due to calcium promoting cell division and elongation [37], which may increase leaf area and thus increase the amount of carbohydrates produced in the leaves. These carbohydrates are used in plant growth and fruiting, potentially leading to increased yield. Foliar spraying of calcium is beneficial to the plant because absorption is faster through the leaves compared to the soil. This rapidly increases calcium availability in vegetative tissues and enhances physiological functions related to light and energy [21] . Calcium maintains the integrity of cell membranes, including chloroplast membranes, by reducing chlorophyll degradation and increasing photosynthetic efficiency. Calcium contributes to increased quantitative crop traits by promoting cell division and elongation. In increasing the plant's leaf area, This leads to increased photosynthetic efficiency and, consequently, more carbohydrates needed for flower and fruit development [46]. also it plays an important role in protein synthesis and activates several enzymes [18; 19] , also Ca reduces the shedding of flowers and newly formed fruits, leading to increase the number of fruits formed per plant. It helps reduce physiological disturbances [49] and improves fruit formation and production by increasing fruit firmness and reducing deformities, especially those resulting from poor fertilisation. [50]; [51] indicated that Ca reduces fruit spoilage after harvest and extends the storage period by preserving cell membranes and reducing juice loss from fruits, thereby reducing fruit rot.

The interaction between iron and $CaCl_2$ spraying significantly affected the flowering and yield parameters of Camarosa strawberry plants (Table 4). The treatment of 50 mg Fe L^{-1} + 0 % $CaCl_2$ produced maximum number of flowers (45.53 flower $plant^{-1}$), number of fruits (12.78 fruit $plant^{-1}$), plant yield (180.95 g $plant^{-1}$) and hectar yield (10856.81 kg $ha.^{-1}$), However the treatment of 100 mg Fe L^{-1} + 0.5 % $CaCl_2$ produced the maximum fruit weight (15.18 g $fruit^{-1}$).

CONCLUSION

It was concluded from this study that foliar spray of strawberry plants cv. Camarosa planting in an unheated polyhouse with 50 mg Fe L^{-1} or 0.5% $CaCl_2$, each alone, significantly enhanced leaf Fe concentration, plant growth parameters such as leaf area and plant leaf area, plant flowering, and yield parameters such as number of flowers per plant, number of fruits per plant, plant yield, and hectare yield. The best treatment was spraying the Camarosa strawberry plants with 50 mg Fe L^{-1} without $CaCl_2$, which produced the highest means for several growth and yield parameters.

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