



## **Effect of chelated iron, iron filings and sulfur on vegetative, yield and fruit characteristics of strawberry (*Fragaria x ananassa* Duch) Cv. Cadonca**

Shukri H. Salih Bani

*Faculty of Agriculture, University of Duhok, Department of Horticulture, Zakho Street, Duhok, Kurdistan Region - Iraq.*

*E-mail: shukri.haji@uod.ac*

### **Article info**

Original: 19 Apr. 2015  
Revised: 20 May 2015  
Accepted: 31 May 2015  
Published online:  
20 Dec. 2015

### **Key Words:**

Strawberry, chelated iron, iron filings, sulfur.

### **Abstract**

The present study was conducted during growing season 2013-2014, to investigate the effects of chelated iron (0, 50 and 100mg Fe l<sup>-1</sup>), iron filings (0 and 10g plant<sup>-1</sup>) and agricultural sulfur (0 and 10g S plant<sup>-1</sup>) on vegetative, yield and fruit characteristics of strawberry Cadonca cultivar. The results showed that the foliar spray with chelated iron (50 and 100mg Fe l<sup>-1</sup>) and soil treatment with iron filings (10g plant<sup>-1</sup>) caused significant increases in each of leaf iron content, leaf total chlorophyll content, leaf dry matter percentage, plant yield, and fruit total soluble solids. Soil treatment with agriculture sulfur (10g S plant<sup>-1</sup>) also caused increases in each of leaf iron content, leaf total chlorophyll content, leaf dry matter percentage, plant yield, and fruit total acidity but did not reach to significant levels.

The effect of interactions between each of iron filings + sulfur, iron filings + chelated iron and sulfur + chelated iron were significant with the most of parameters. The interaction between 10g iron filings plant<sup>-1</sup> + 10g S plant<sup>-1</sup>, 10g iron filings plant<sup>-1</sup>+100mg chelated iron l<sup>-1</sup> and 10g S plant<sup>-1</sup> + 100mg chelated iron l<sup>-1</sup> significantly increased the most studied parameters. In respect of interaction of the three studied factors, the interaction of 10g iron filings plant<sup>-1</sup> + 10g S plant<sup>-1</sup> +100mg chelated iron l<sup>-1</sup> was the best thrice interaction in promoting the most studied characteristics.

## **I- Introduction**

Strawberry is one of the most important and demanded small fruits in Iraqi Kurdistan Region; its planting is still very limited and some large plastic tunnels are present in some areas; this is because of some culture practices causes low yield, limited knowledge about its planting and production processes, selecting wrong cultivars (Short-day cultivars), which are quick destroyed during handling, infection by some fungus diseases [1]. Cadonca is a Spanish cultivar, produced by hybridization in 1992, early-yielding cultivar, its fruits are medium in size and entered introduced into Iraqi Kurdistan Region in 2008 [2].

Iron is a constituent of the enzymes catalase and peroxidase, which involve molecular oxygen directly in oxidation-reduction reactions. [3 and 4] stated that iron is involved as an active factor in the structure of catalase, peroxidase, oxidase and cytochrome enzyme which facilitates the activation performance of many physiological processes in plant cells [5] noted that iron is essential for the synthesis of chlorophyll, but its mechanism and action on chlorophyll synthesis is uncertain.

Iron deficiency chlorosis is a common nutritional disorder affecting plants, and limiting factor for fruit production in many areas of the world especially in Kurdistan region of Iraq (Which characterized with calcareous soils, high pH, high  $\text{CaCO}_3$ ). Iron deficiency decrease fruit quality and yield, and can finally lead to tree death [6 and 7]. Fruit production under soil conditions usually leading to Fe deficiency requires continuous (every year) adding with Fe-containing compounds. The most efficient method to control Fe deficiency in fruit crops is currently the supply of synthetic iron-chelates to the rhizosphere, although these treatments are very costly [8]. The possibility to provide small amounts of Fe to fruit crops *via* foliar sprays could be a target method, cheaper strategy to overcome Fe deficiency in fruit crops, although variable responses to Fe sprays have been often reported [9 and 10]. Development of suitable iron spray formulations is currently prevented by the limited understanding of the mechanisms involved in the penetration, translocation and bioavailability of the Fe-containing solutions applied to the foliage [11]. [12] found a significant increase in growth parameters and nutrient leaves content of strawberry after sprayed with Fe-EDTA ( $83.4 \text{ mg l}^{-1}$ ). [13] indicated that strawberry foliar sprayed with Fe-EDTA at ( $60 \text{ mg l}^{-1}$ ) caused significant increasing in dry matter of vegetative growth and total chlorophyll and yield of plants, but without any effects on qualitative characteristics.

Sulfur is one of the essential nutrient elements for plant growth. It was known by man since thousands of years and it is natural present as a yellowish powder (solid) or in a liquid state [14]. Sulfur is the most abundant element in the earth's crust, averaging 0.06 to 0.10 %. It presents as organic and inorganic forms. In most of soils, the restricted sulfur is organic and is the main stored sulfur in the soil especially under wet environmental conditions. Whereas the inorganic sulfur (mineral) in the soil is present in the form of sulfate which is precipitated in the form of soluble or non soluble salts like calcium, potassium, magnesium and sodium sulfate under arid and semi-arid regions conditions, which are existed in soil solution or are exchanged on the colloidal soil surfaces in the wet areas conditions [4]. The sulfur-containing amino acids cysteine, cystine and methionine are essential protein constituents comprising a large proportion of the total sulfur content in plants, a fact that is reflected by the relatively uniform N/S ratio in tissues [15]. Additional organic Sulfur compounds present in abundance in most plants are the nonprotein tripeptide glutathione ( $\gamma$ -glutamyl-cysteinyl-glycine, GSH) and its precursor of  $\gamma$ -glutamyl-cysteine, sulfolipids, thionins, thioazoles, and others, as well as a large number of secondary compounds specific to certain species and/or induced only under particular conditions. Inorganic sulfur is mainly present as sulfate, because sulfite ( $\text{SO}_3^-$ ) and sulfide ( $\text{SO}_2^-$ ) are metabolized at high rates and their tissue concentrations are usually kept very low. Total Sulfur contents and the ratio of inorganic to organic S in tree tissues may vary according to the species, the tissue type, environmental conditions, developmental stage, seasonal fluctuations, and supply with S and other nutrients [16]. [17] Studied the effects of pre-plant sulfur (S) sources on "Festival" strawberry growth and yield. Plots treated with elemental sulfur (90% S), polymer-coated ammonium sulfate (20% N and 23% S), ammonium sulfate nitrate (26% N and 14% S) and ammonium sulfate (21% N and 24% S), had the highest total marketable fruit weights as compared with control plots. The data indicated that the strawberry total yield increases can be attributed to the use of pre-plant fertilizer sources containing sulfur.

This study aimed to determine the effect of foliar spray with chelated iron (Fe-EDDHA), soil application with iron filings and agricultural sulfur on growth and yield characteristics of strawberry cv. Cadonca in Duhok Governorate.

## II- Materials and Methods

This study was carried out in 2013-2014 season on strawberry plants (Cadonca cultivar) planted in horticulture orchard at the Faculty of Agriculture / University of Duhok. The plants of Cadonca strawberry were obtained from Malta Agricultural Research Center on October 4, 2013. The plants were planted in white pots (20\*30cm size) in clay loam soil mixed with equaled amount of sheep manure on October 5-10, 2013.

A factorial experiment in Randomized Complete Block Design (RCBD) was including three factors with their interactions. The first factor was foliar spray with three concentrations of iron (0, 50 and 100 mg Fe l<sup>-1</sup>) using a chelated iron Fe-EDDHA (6% iron) under the commercial name Sequestrene as a source of iron on March 19, 2014 (10 days before blooming). The second factor was soil application of iron filings at two levels (0 and 10g filings plant<sup>-1</sup>), filings was applied in the first week of January, 2014 by work bands around the plants, then covered by the soil. The third factor was soil application of agricultural sulfur (96% sulfur) at two levels (0 and 10g S plant<sup>-1</sup>), sulfur was applied in the first week of December 2013, by work bands around the plants, then covered by the soil. The experiment was consisted of 12 treatment combinations (3 x 2 x 2) with three replications and four plants per each experimental unit [18]. The data were statistically analyzed using SAS program [19]. The differences between various treatment means were tested with Duncan's test at 5% level. During the harvest period (April 17, 2014 to June 5, 2014), the yield per plant was recorded. The determination of fruit characteristics including total soluble solid (TSS %) measured by using table refractometer and total acidity (%), measured by titration of sodium hydroxide solution (0.1 N) as percentage of citric acid [20 and 21]. Leaves dry matter percentage was determined for the four mature leaves of fourth plants of each experimental unit after the last harvest. Total chlorophyll was determined by chlorophyll meter SPAD-502. Samples of 0.5g of grinded leaves were taken for digestion by using the mixture of sulfuric acid and perchloric acid [22]. The samples were diluted and then the chemical analysis was conducted. The element of Fe was determined by Atomic Absorption Spectrophotometer [23].

## III- Results and Discussion

### Leaf Iron Content (mg l<sup>-1</sup>)

Table (1) displays that spraying strawberry plants with 50 and 100 mg chelated iron l<sup>-1</sup> and iron filings applications (10 g plant<sup>-1</sup>) significantly increased leaf iron content in comparison with the control. Whereas, there was no significant differences between the means of leaf iron content as a result of sulfur application.

Concerning the interactions of iron filings + sulfur, iron filings + chelated iron and sulfur + chelated iron, results in (Table 1) show that the interaction between 10g iron filings plant<sup>-1</sup> + 10g S plant<sup>-1</sup>, 10g iron filings plant<sup>-1</sup> + 100mg chelated iron l<sup>-1</sup> and 10g S plant<sup>-1</sup> + 100mg chelated iron l<sup>-1</sup> gave the highest significant values 160.86, 171.28 and 181.1 mg. Fe. Kg<sup>-1</sup>, respectively. In respect of the interaction of the three studied factors, the interaction effect of 0g iron filings plant<sup>-1</sup> + 10g S plant<sup>-1</sup> + 100mg chelated iron l<sup>-1</sup> gave the highest leaf content of iron (188.93 mg. kg<sup>-1</sup>).

**Table (1): Effect of chelated iron, iron filings, sulfur and their interactions on leaf iron content (mg. Fe. Kg<sup>-1</sup> dry wt.) of Cadonca strawberry plants.**

Iron Filings (g plant <sup>-1</sup> )	Sulfur (g plant <sup>-1</sup> )	Chelated Iron (mg l <sup>-1</sup> )			Iron filings + Sulfur	Mean of iron filings
		0	50	100		
0	0	118.87 d	140.27bcd	149.53 bcd	136.22 b	145.22 b
	10	127.73 cd	146 abc	188.93 a	154.22 a	
10	0	143.2 bcd	165.47 ab	169.3 ab	159.32 a	160.09 a
	10	151.77bcd	157.53abc	173.27 ab	160.86 a	
<b>Iron Filings +</b>	0	123.3 d	143.13 cd	169.23 ab	<b>Mean of Sulfur</b>	

<b>Chelated Iron</b>	10	147.48 bc	161.5 abc	171.28 a	
<b>Sulfur + Chelated Iron</b>	0	131.03 c	152.87 bc	159.42 b	147.77 a
	10	139.75 bc	151.77 bc	181.1 a	157.54 a
<b>Mean of Chelated Iron</b>		135.39 c	152.32 b	170.26 a	

\* Means of each factor and their interactions followed by the same letters are not significantly different from each other according to Duncan's test at 5% level.

### Leaf Total Chlorophyll Content (%)

It is obvious from Table (2) that spraying strawberry plants with 50 and 100 mg chelated iron l<sup>-1</sup> and iron filings applications (10 g filings plant<sup>-1</sup>) significantly enhanced leaf total chlorophyll content as compared with the control. While, there were no significant differences in leaf total chlorophyll content for sulfur application.

Regarding the interaction of iron filings + sulfur, filings + iron and sulfur + iron, results in Table (2) displayed that the interaction between 10g filings plant<sup>-1</sup> + 10g S plant<sup>-1</sup>, 10g filings plant<sup>-1</sup> + 100mg Fe l<sup>-1</sup> and 10g S plant<sup>-1</sup> + 100mg Fe l<sup>-1</sup> gave the highest significant values of leaf total chlorophyll content 37.48, 39.13 and 38.27 % , respectively. The tri interaction of 10 g iron filings plant<sup>-1</sup> + 10 g S plant<sup>-1</sup> +100 mg chelated iron l<sup>-1</sup> gave the highest value (39.26 %).

**Table (2): Effect of chelated iron, iron filings, sulfur and their interactions on leaf total chlorophyll content (%) of Cadonca strawberry.**

Iron Filings (g. plant <sup>-1</sup> )	Sulfur (g. plant <sup>-1</sup> )	Chelated Iron (mg. l <sup>-1</sup> )			Iron Filings + Sulfur	Mean of Iron Filings
		0	50	100		
<b>0</b>	0	31.19 d	35.68 abc	35.72 abc	34.19 b	34.29 b
	10	31.91 cd	33.97 bcd	37.29 ab	34.39 b	
<b>10</b>	0	33.88 bcd	36.71 ab	38.99 a	36.53 ab	37.00.a
	10	36.11 abc	37.06 ab	39.26 a	37.48 a	
<b>Iron Filings + Chelated Iron</b>	0	31.55 c	34.83 b	36.50 ab	<b>Mean of Sulfur</b>	
	10	35.00 b	36.89 ab	39.13 a		
<b>Sulfur + Chelated Iron</b>	0	32.54 c	36.20 ab	37.35 a	35.36 a	
	10	34.01 bc	35.52 ab	38.27 a	35.93 a	
<b>Mean of Chelated Iron</b>		33.27 c	35.86 b	37.81 a		

\* Means of each factor and their interactions followed by the same letters are not significantly different from each other according to Duncan's test at 5% level.

### Leaf Dry Matter Percentage (%)

Table (3) reveals that there were significant differences in leaf dry matter percentage as a result of foliar spraying with chelated iron (50 and 100 mg chelated iron l<sup>-1</sup>) and soil application of iron filings (10 g iron filings plant<sup>-1</sup>). While, sulfur application did not show any significant effect on leaf dry matter.

The significant effect on leaf dry matter was found in interaction of 10 g iron filings plant<sup>-1</sup> + 10 g S plant<sup>-1</sup>, 10 g iron filings plant<sup>-1</sup> + 100 mg chelated iron l<sup>-1</sup> and 10 g S plant<sup>-1</sup> + 100 mg chelated iron l<sup>-1</sup> by giving the highest significant values of leaf dry matter percentage 40.53, 41.63 and 41.09 % , respectively. The highest value of leaf dry matter (42.54 %) was obtained when strawberry plants were treated with 10g filings plant<sup>-1</sup> + 10g S plant<sup>-1</sup> +100mg Fe l<sup>-1</sup>.

**Table (3): Effect of chelated iron, iron filings, sulfur and their interactions on leaf dry matter percentage (%) of Cadonca strawberry.**

Iron Filings (g plant <sup>-1</sup> )	Sulfur (g. plant <sup>-1</sup> )	Chelated Iron (mg. l <sup>-1</sup> )			Iron Filings + Sulfur	Mean of Iron Filings
		0	50	100		
0	0	34.07 d	40.09 abc	38.89 bc	37.68 c	37.95 b
	10	37.34 c	37.64 c	39.65 bc	38.21 bc	
10	0	38.69 bc	38.65 bc	40.73 ab	39.36 ab	39.95 a
	10	39.15 bc	39.91 abc	42.54 a	40.53 a	
Iron Filings + Chelated Iron	0	35.70 c	38.86 b	39.27 b	Mean of Sulfur	
	10	38.92 b	39.28 b	41.63 a		
Sulfur + Chelated Iron	0	36.38 c	39.37 ab	39.81 ab	38.52 a	
	10	38.25 b	38.78 b	41.09 a	39.37 a	
Mean of Chelated Iron		37.31 c	39.07 b	40.45 a		

\* Means of each factor and their interactions followed by the same letters are not significantly different from each other according to Duncan's test at 5% level.

### Plant Yield (g. plant<sup>-1</sup>)

Spraying strawberry plants with chelated iron (50 and 100 mg chelated iron l<sup>-1</sup>) and iron filings application (10 g iron filings plant<sup>-1</sup>) was significantly effective in increasing plant yield of strawberry (Table 4). No significant difference was found as a result of sulfur application to the strawberries plants.

Concerning the interaction of iron filings + sulfur, iron filings + chelated iron and sulfur + chelated iron, from (Table 4), the results displayed that the interactions between 10 g iron filings plant<sup>-1</sup> + 0 g S plant<sup>-1</sup>, 10 g iron filings plant<sup>-1</sup> + 100 mg chelated iron l<sup>-1</sup> and 10 g S plant<sup>-1</sup> + 100 mg chelated iron l<sup>-1</sup> significantly increased plant yield 114.12, 119.92 and 123.09 g plant<sup>-1</sup>, respectively. The interaction of 10 g iron filings plant<sup>-1</sup> + 10 g S plant<sup>-1</sup> + 100 mg chelated iron l<sup>-1</sup> gave the highest yield reaching to 126.33g. plant<sup>-1</sup>.

**Table (4): Effect of chelated iron, iron filings, sulfur and their interactions on plant yield (g. plant<sup>-1</sup>) of Cadonca strawberry.**

Iron Filings (g. plant <sup>-1</sup> )	Sulfur (g. plant <sup>-1</sup> )	Chelated Iron (mg. l <sup>-1</sup> )			Iron Filings + Sulfur	Mean of Iron Filings
		0	50	100		
0	0	49.56 e	92.85 bcd	114.61 ab	85.67 c	99.21 b
	10	108 a-d	110.41abc	119.85 a	112.75 ab	
10	0	116.71 a	112.14 abc	113.51 abc	114.12 a	108.06 a
	10	87.76 d	91.9 cd	126.33 a	102.00 b	
Iron Filings + Chelated Iron	0	78.78 c	101.63 b	117.23 a	Mean of Sulfur	
	10	102.24 b	102.02 b	119.92 a		
Sulfur + Chelated Iron	0	83.14 d	102.50 bc	114.06 ab	99.90 a	
	10	97.88 c	101.16 bc	123.09 a	107.38 a	
Mean of Chelated Iron		90.51 c	101.83 b	118.58 a		

\* Means of each factor and their interactions followed by the same letters are not significantly different from each other according to Duncan's test at 5% level.

**Fruit Total Soluble Solids (TSS %)**

Table (5) displays significant increase in fruit TSS percentage as a result of foliar spraying with chelated iron (50 and 100mg Fe l<sup>-1</sup>) and soil application of iron filings (10g iron filings plant<sup>-1</sup>). Whereas, no significant difference was found as a result of sulfur application to the strawberries plants.

Regarding the interaction of iron filings + sulfur, iron filings + chelated iron and sulfur + chelated iron, from Table (5) shows that the interactions between 10 g iron filings plant<sup>-1</sup> + 10 g S plant<sup>-1</sup>, 10 g iron filings plant<sup>-1</sup> + 100 mg chelated iron l<sup>-1</sup> and 10 g S plant<sup>-1</sup> + 100 mg chelated iron l<sup>-1</sup> were the best binary interaction which significantly increased fruit TSS % (10.69, 11.02 and 10.68 % respectively). The interaction of 10 g iron filings plant<sup>-1</sup> + 10 g S plant<sup>-1</sup> +100 mg chelated iron l<sup>-1</sup> was the best interaction treatment in increased fruit TSS percent, which gave the highest value (11.22 %).

**Table (5): Effect of chelated iron, iron filings, sulfur and their interactions on fruit TSS (%) of Cadonca strawberry.**

Iron Filings (g. plant <sup>-1</sup> )	Sulfur (g. plant <sup>-1</sup> )	Chelated Iron (mg. l <sup>-1</sup> )			Iron Filings + Sulfur	Mean of Iron Filings
		0	50	100		
0	0	9.17 d	10.37 abc	10.52 abc	10.02 b	9.92 b
	10	9.45 cd	9.87 bcd	10.15 a-d	9.82 b	
10	0	10.4 abc	10.77 ab	10.82 ab	10.66 a	10.67 a
	10	10.29 abc	10.56 abc	11.22 a	10.69 a	
Iron Filings + Chelated Iron	0	9.31 c	10.12 b	10.34 ab	Mean of Sulfur	
	10	10.34 ab	10.66 ab	11.02 a		
Sulfur + Chelated Iron	0	9.78 c	10.57 ab	10.67 a	10.34 a	
	10	9.87 bc	10.22 abc	10.68 a	10.26 a	
Mean of Chelated Iron		9.83 b	10.39 a	10.68 a		

\* Means of each factor and their interactions followed by the same letters are not significantly different from each other according to Duncan's test at 5% level.

**Fruit Total Acidity (%)**

Table (6) shows that the three studied factors caused non significant increases in fruit total acidity. In respect of all interactions of the studied factors, the effects were non significant on fruit total acidity percentage.

**Table (6): Effect of chelated iron, iron filings, sulfur and their interactions on fruit total acidity (%) of Cadonca strawberry.**

Iron Filings (g. plant <sup>-1</sup> )	Sulfur (g. plant <sup>-1</sup> )	Chelated Iron (mg. l <sup>-1</sup> )			Iron Filings + Sulfur	Mean of Iron Filings
		0	50	100		
0	0	0.327 a	0.303 a	0.373 a	0.334 a	0.344 a
	10	0.350 a	0.350 a	0.362 a	0.354 a	
10	0	0.354 a	0.303 a	0.373 a	0.344 a	0.350 a
	10	0.383 a	0.358 a	0.327 a	0.356 a	
Iron Filings + Chelated Iron	0	0.338 a	0.327 a	0.368 a	Mean of Sulfur	
	10	0.369 a	0.331 a	0.350 a		

<b>Sulfur +</b>	0	0.341 a	0.303 a	0.373 a	0.339 a
<b>Chelated Iron</b>	10	0.367 a	0.354 a	0.344 a	0.355 a
<b>Mean of Chelated Iron</b>			0.329 a	0.359 a	
		0.354 a			

\* Means of each factor and their interactions followed by the same letters are not significantly different from each other according to Duncan's test at 5% level.

Spraying strawberry plants with iron chelated at 50 and 100mg. Fe. l<sup>-1</sup> and iron filings alone or with sulfur was significantly effective in increasing each of leaf iron content, leaf total chlorophyll content, leaf dry matter percentage, plant yield, and fruit total soluble solids (Tables, 1, 2, 3, 4, and 5). These results are in accordance with those obtained by [24 and 13] on strawberry; [25] on peach trees and [26] on apple trees. Thus, the increases in each of above characteristics might be attributed to the role of iron in increasing leaf iron content (Table 1) and chlorophyll content in leaves (Table 2). These results might be interpreted that iron was implicated as a co-enzyme in the synthesis of the chlorophyll [27], and participated as a co-enzyme in the chlorophyll synthesis and as active components of cytochromes [28], finely that iron possessed a role in the condensation of glutamate to  $\delta$ - aminolevulinic acid and facilitated the conversion of Mg-protophyrin IX methyl ester to protochlorophyllide which were the two main steps in chlorophyll synthesis [29]. In addition, iron is involved as an active factor in the structure of some enzymes such as catalase, peroxidase and cytochrome oxidase that act to activation of many physiological processes in plants [3], All these will be leading to increase quickness and products of photosynthesis that used in different growth processes [30, 24 and 13], which cause increasing leaf dry matter (Table 3), this might lead to increase the roots growth and distribution in the soil, more absorption of elements (Table 1) and more use of these elements in the metabolic process [31], which lead to improve tree yield and its characteristics [32], this was clear in (Tables 4 and5).

Sulfur application did not affect significantly on studied parameters, while its effect in interaction with chelated iron and iron filings come from the synergism effect of iron.

#### IV- Conclusion

According to the above results, it can be concluded that strawberry spraying with chelated iron (Fe-EDDHA) or in form of filings caused significant increase in growth vegetative and yield characteristics of strawberry cv. Cadonca. Whereas, the effect of sulfur was no significant with all studied parameters. On the other hand, iron in the form of filings can be recommended instead of chelated iron.

#### Reverences

- [1] Kader, J. SH. Effect of Plant distances and mode protected cultivation on growth , yield and quality of two varieties strawberry ( Regina and Kaiser ). MSc. Thesis, Hort. / Fruit / college. Agric./ Sulaimani University. 2008.
- [2] Muhamed Salih, L. M. SH. The effect of spraying seaweed extract (Matrix-5) on some vegetative and root growth of two strawberry varieties. High Diploma Thesis. College of Agric. Salahaddin Univ. Iraq. 2010. (In Arabic).
- [3] Singh, A. Fruit Physiology and Production. Kalyani Publishers-new Delhi-India. 2003.
- [4] Havlin, L. L.; Beaton J. D.; Tisdale S. L. and Nelson W. L. Soil Fertility and Fertilizers. 7<sup>th</sup> ed. Upper Saddle River, New Jersey 07458. 2005.
- [5] Marschner, H. Functions of Mineral Nutrients: micronutrients. Iron. In Mineral Nutrition of Higher Plants; Academic Press: Cambridge, UK. p. 313-324. 1995.
- [6] Álvarez-Fernández, A.; Paniagua P.; Abadía, J. and Abadía A. Effects of Fe deficiency chlorosis on yield and fruit quality in peach (*Prunus persica* L. Batsch). J. Agric. Food Chem. 51: 5738-5744. 2003.

- [7] Álvarez-Fernández, A.; Abadía J. and Abadía A. Iron deficiency, fruit yield and quality. In Iron Nutrition in Plants and Rhizospheric microorganisms. Eds. L. L. Barton and J. Abadía. pp. 85-101, Springer, Dordrecht, the Netherlands. ISBN-101-4020-4742-8. 2006.
- [8] Álvarez-Fernández, A.; García-Laviña P.; Fidalgo J.; Abadía J. and Abadía A. Foliar fertilization to control iron chlorosis in pear (*Pyrus communis* L.) trees. Plant and Soil, 263: 5-15. 2004.
- [9] Abadía, J. A., Álvarez-Fernández, A., Morales, F., Sanz M., and Abadía, A." Correction of iron chlorosis by foliar sprays " Acta Hort. 594, ISHS .2002.
- [10] Fernández V and Ebert G. Foliar iron fertilization- a critical review. J. Plant Nutr. 28, 2113–2124. 2005.
- [11] Fernández, V.; Ebert G. and Winkelmann G. The use of microbial siderophores for foliar iron application studies. Plant Soil, 27(2): 245-252. 2005.
- [12] Erdal, I. K., Kahraman, and Lthan K. Effect of Foliar Iron Applications at Different Growth Stage on Iron and Some Nutrient Concentrations in Strawberry Cultivars. Turk. Agric. For. 28: 421-427. 2004.
- [13] Dawood, Z. A. Effect of concentrations and application dates of Fe-EDTA on growth and yield of strawberry. Cv. Hapil. Meso. J. Agric. 36(2):4-10. 2008. (In Arabic).
- [14] Berglen, T. F. B. Sulfur in the atmosphere-studies of processes, distribution and changes. Ph.D. Dissertation, Dep. of Geosciences, Univ. of Oslo, Oslo, Norway. 2006.
- [15] Hogan, G. D. and Rennenberg H. Role and Effect of Sulfur in Tree Biology. In: Maynard DG (ed.), Sulfur in the Environment. Marcel Dekker, New York, pp.173–217. (C. F. Hawkesford, and De Kok (2007). 1998.
- [16] Tausz, M.; Weidner W.; Wonisch A.; De Kok L. J. and Grill D. Uptake and distribution of <sup>35</sup>S-sulfate in needles and roots of spruce seedlings as affected by exposure to SO<sub>2</sub> and H<sub>2</sub>S. Environ. Exp. Bot. 50: 211–220. 2003.
- [17] Santos, B. M. Effects of Pre-Plant Nitrogen and Sulfur Fertilizer Sources on Strawberry. J. Hort. Technology. 20(1): 193-196. 2010.
- [18] Roger Mead, R. N. C. and Hasted A. M. Statistical methods in agriculture and experimental biology. Champan Hall, CRC, ACRC Press Co., Washington, DC. 2003.
- [19] SAS Institute, Inc. Statistical Analysis System Ver. 9.0. SAS institute Inc., Cary, NC. USA. 2002.
- [20] Ranganna, S. Manual of Analysis of Fruit and Vegetable Products. Tata McGraw Hill Publishing Company Limited, New Delhi. 1977.
- [21] Sourour, M. M. Response of "Anna" apple trees to different methods and forms of iron applications. Alex. J. Agric. Res. 37 (2): 191-204. 1992.
- [22] Joslyn, M. A. Methods in Food Analysis (2). Acad. Press, N. Y. London. 1970.
- [23] Bhargava, B. S. and Raghupathi H. B. Analysis of Plant Materrals for Macro and Micronutrients. P: 49-82. In Tandon, H. L. S. (edt.) Methods of Analysis of Soils, Plants, Waters, and Fertilizers. Binng Printers L-14, Lajpat. Nagar New Delhi, 110024. 1999.
- [24] Kessel, C. Strawberry Diagnostic Workshops: Nutrition. Ministry of Agriculture, Food and Rural Affaies. Pages 1-7. 2006.
- [25] Bani, Sh. A.S. Effect of iron, sulfur, ascorbic acid and their interactions on the vegetative growth, yield and fruit quality of peach trees cv. Dixired. Ph.D. Dissertation. Duhok Univ. Kurdistan Region. Iraq. 2012.
- [26] Al-Aa'reji, J. M.; Duhoky M.S. and Mayi A. A. T. Effect of foliar spray with iron and GA<sub>3</sub> on yield and quality of apple fruits cv. Starking Delicious. Meso. J. Agric. 38(3): 4-11. 2010. (In Arabic).
- [27] Al-Taai, A. A. H.; Al-Khafaji M. A. and Selman M. A. The effect of nitrogen, iron and zinc application on the productivity of some citrus species. B- Clemanatina mandarin (*Citrus reticulata*). Iraqi. J. Agri. Sci. 25(2): 122-133. 1994. (In Arabic).
- [28] AL-Kwami, S. M. J.; Salman A. M. and Salman M. A. Effect of spraying GA<sub>3</sub>, N, Zn, and Fe on physical and chemical properties of Fig fruits *Ficus carica* L. cvs. Aswad Diala. Iraqi. J. Agri. Sci. 33(4): 71-76. 2002. (In Arabic).
- [29] Mukherji, S. and Ghosh A. K. Plant Physiology. New Central Book Agency (p) Ltd. 8/1 Chintamoni Das Land, Kolkata/India. 2005.
- [30] Hurley, A. K.; Walser R. H.; Dais T. D. and Barney D.L. Net photosynthesis, chlorophyll, and foliar iron in apple trees after injection with ferrous sulfate. Hort. Sci. 21(4): 1029-1031. 1986.
- [31] Al-Aa'reji, J. M. A. Effect of bicarbonate and iron on vegetative growth of sour orange seedling. J. Tikret. Univ. Agri. Sci. 3(5): 93-104. 2003. (In Arabic).
- [32] Gobara, A. A. Response of 'Le-Conte' pear trees to foliar applications of some nutrients. Egypt. J. Hort. 25(1): 55-70. 1998.