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Effect of Iron and Sulfur on Leaves Nutrient Concentrations of Dixired Peach Trees

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Abstract A present study was conducted during 2010 and 2011 growing seasons on Dixired peach trees (*Prunus persica* Batsch), five years old at the beginning of the experiment which were grown in Gr-Rash orchard / Duhuk governorate / Iraq, to investigate the effect of iron and sulfur on leaves N, P, K, S, Fe, Mn and Zn concentrations at 2010 and 2011 growing seasons. The experiment was carried out in a Randomized Complete Block Design (R.C.B.D.), Including two factors, first was foliar spray with three concentrations of iron (0, 50 and 100 mg Fe. L^{-1}) using Fe-EDDHA (6% Fe) which was sprayed at two equal sprays, first was done after 15 days of full bloom, the second spray was applied after one month of the first spray, second factor was soil application of Sulfur which was applied in the first week of January at four levels (0, 250, 500 and 750 gm S.$tree^{-1}$). Results indicated that foliar spray of Fe at a concentration of 100 mg Fe. L^{-1} and sulfur application a level of 750 gm S.$tree^{-1}$ each alone or with each other significantly increased leaves N, P, K, S, Fe, Mn and Zn, especially at the second season.

Keywords Leaves nutrient, Peach, Iron, Sulfur

1. Introduction

The peach *(Prunus persica* L. Batsch) is revered as a delicious and healthy summer fruit in most temperate regions of the world, it belongs to "Rosaceae" family, and it one of the most important stone fruits, due to heavy loading and dietetic value, the fruit is a good source of carbohydrate, protein and vitamins especially A, B and C and mineral nutrient such as phosphorus, potassium and iron, so that besides the different uses of the fruit, it often used as fresh fruit, juice and jams [10]. The trees crop grew heavily year after year, this tends to decrease nutrients availability in the soil due to the continuous removal of nutrients from the soil subsequently, the application of fertilizers to improve leaves nutrients and yield of the plant is required [11].

Most soils contain adequate total iron which is ranged from 100 to 100000 $mg.kg^{-1}$ soil, but amounts that are available to plants might be inadequate especially in calcareous soils dependent on various soil factors, such as high pH, $CaCO_3$ content, ion imbalance and poor physical properties such as very high or low soil temperature, high humidity, poor soil aeration, compaction can induce iron deficiency, low organic matter content and excess phosphorus fertilization also exacerbates the chlorosis problem [22] [12] [23] [20].

Foliar application of iron leads to improving leaves of some mineral concentrations of fruit trees, [30] sprayed chelates and sulfates of iron and zinc on "Sharbati "peach trees and recorded that leaf chlorosis was reduced and leaf Zn and Fe increased significantly with the application of iron. [35] showed that the foliar treatment of peach trees cvs. "Katerina" and "Fire Blight" with $FeSO_4.7H_2O$ (0 and 500mg. L^{-1}) caused a significant increase in Fe concentration in leaves. [16] found that "Florida Prince and Desert Red" peach trees were sprayed once, twice and thrice a year with combinations of chelate material at the rate of 0.7gm Fe. L^{-1}, 0.3gm Zn. L^{-1} and 0.3gm Mn. L^{-1} or combinations of Zn, Mn and Fe sulphate at 0.5gm. L^{-1} of each nutrient. The results indicated that spraying the trees twice or thrice yearly was more effective than spraying once a year and the control, that lead in improving leaf mineral Zn, Mn and Fe content of both peach trees. An experiment conducted by [31] showed that foliar application of 0.5% of ferrous sulphate to peach trees cv. Florida Prince significantly increased leaves active iron, total iron and ferric iron.

Calcareous soils typically those of pH $\geq$ 7.2, so that acidification may be the need for trees with a low optimum pH range grown on calcareous soils. To decrease soil pH, elemental S is an effective soil acidulated. Adding the elemental sulfur to the soil, it will be oxidized by the action of Thiobacillus bacteria to form sulfuric acid [33] and [18].

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The produced sulfuric acid leads to reduce soil pH and increase its acidity at rhizosphere. This reaction is very important especially for the Iraqi soils which are basic (pH of most Iraqi soils is over 7). It leads to raising the availability of many nutrient elements in the soli like Fe [88], and the plants required sulfur for the synthesis of S-containing amino acids such as cystine, cysteine, and methionine, which are an essential component of protein that comprise about 90% of S in plants. Sulfur also is needed for the synthesis of coenzyme A, which is involved in oxidation and synthesis of fatty acids, synthesis of amino acids, and oxidation of intermediates of the citric acid cycle, although S required for the synthesis of chlorophyll, and S is a vital part of the ferredoxin and Fe-S protein in the chloroplasts (Havlin *et. al.*, 2005).

Sulfur can be supplied to fruit trees from many sources including fertilizers, soil amendments, pesticides, irrigation water, acidic rains and even atmospheric pollutants. Therefore, S deficiency has seldom been encountered in peach-growing areas and often is not included in nutrient deficiency threshold tables [14]. [28] mentioned that fertilizing local orange trees (11 years old) with 500gm S. tree^{-1} significantly increased N and K in leaves, Whereas the concentration of phosphorous was not significantly affected by the sulfur application, this while fertilizing with sulfur at three levels (0, 250 and 500gm S. tree^{-1}). [9] found that fertilizing Kamali and Halwani grapevines with different levels of sulfur (0, 250, 500 and 750gm S. vine $^{-1}$) led to a significant increase in the concentrations of N, P and K in the leaves of both cultivars especially at a level of 500gm S.vine^{-1} as compared with control and 250gm S. vine^{-1}. [8] mentioned that fertilizing the young apple trees cvs. Anna and Vistabella with sulfur at 100 and 200gm S. tree^{-1} led to a significant increase in the concentrations of N, P, K and S in the leaves of both cultivars except nitrogen in the leaves of Anna trees. [6] studied the effect of sulfur application (0, 250 and 500mg S. kg^{-1} soil) on some mineral concentration in leaves of "Dixired" peach transplants. They found that there were a significant increase in N, P, K and S concentrations in the leaves when the transplants were treated with 500mg S.kg^{-1} soil. [7] investigated the effect of sulfur application (0, 250 and 500mg S. Kg $^{-1}$ soil) on some mineral concentration in leaves of "Coronet" peach transplants. The results illustrated that there was a significant increase in N, P, K and S concentrations in the leaves when the transplants were treated with 500 mg S. Kg^{-1} soil. [4] studied the effect of three levels of sulfur (0, 100 and 200gm S. tree^{-1}) on the young apple tree cvs. "Anna and Vistabella" during 2006 growing season. The results demonstrated that sulfur application significantly increases leaves the content of S, N, P and K concentration at both cultivars. [25] studied the effect of slow-release nitrogen fertilization such as sulfur coated urea at a concentration of 200, 300 and 400gm. tree^{-1} and ammonium sulfate (200gm. tree^{-1}) as the control on growth and fruiting of Guava trees. Conclusively, that sulfur coated urea fertilizer at all concentrations enhanced leaves mineral content, such as N, P, and K as compared with control. [3] studied the effect of organic fertilizer, urea and sulfur on concentrations of some nutrient of young peach trees cv. Dixie. The results demonstrated that the application of organic fertilizer and urea each alone or with each other with sulfur significantly increased the amount of N, P, K and S concentrations in the leaves. [21] investigated the effect of some slow-release nitrogen fertilizers such as sulfur coated-urea at several levels (500, 750, and 1000gm. tree^{-1} year $^{-1}$) and fast release nitrogen (Urea) at the same concentrations, on nutrient status of "Mit Ghamr" peach trees. The results showed that the increased supplying of sulfur coated-urea from 500-1000gm. tree^{-1} year $^{-1}$ was superior over the application of the fast release nitrogen (Urea) in improving the percentage of leaf N, P and K. [27] showed that the application of 1000mgS kg^{-1} soil to olive transplants significantly increased leaves N and P. Therefore this study aimed to test the effect of iron and sulfur each alone or with each other on some nutrient concentrations in the leaves of Dixired peach trees.

2. Materials and Methods

A present study was conducted during 2010 and 2011 growing seasons on peach trees (*Prunus persica* Batsch), five years old at the beginning of the experiment which were grown in Gr-Rash orchard / Duhuk governorate / Iraq, which were budded on seedling peach rootstock and grown in clay loam soil (table,1), the trees were similar as it is possible in growth vigour, and trained on open central method, to investigate the effect of iron and sulfur on leaf N, P, K, S, Fe, Mn and Zn concentrations. Trees were spaced at 3.5 x 3.5 meter and irrigated by a single cistern method. The experiment was carried out in a Randomized Complete Block Design (R.C.B.D.), Including two factors, first was foliar spray with three concentrations of iron (0, 50 and 100 mg Fe . L^{-1}) using Fe-EDDHA (6% Fe) which was sprayed at two equal sprays, first was done after 15 days of full bloom, the second spray was applied after one month of the first spray. A surfactant agent (Tween 80) was added to all spray treatment solutions at ten drops per holder (0.025%) to reduce surface tension of solution, and the second factor was soil application of sulfur which was applied in the first week of January at four levels (0, 250, 500 and 750 gm S .tree^{-1}).

On the 15th of July of each season, 20 leaves were randomly collected from the periphery of each tree under treatment. The leaves were picked up from the third leaf to six leaves of shoots (from all side of the trees). The leaves were put in polythene bags to be quickly transferred to the laboratory. These leaves were cleaned and washed several times with tap water, then washed again by HCl 0.01 *N* and rinsed by distilled water to remove any spray residues. The leaf samples were air-dried, then transferred to an oven at 70 ℃ until a constant weight [20].

Dry matters of leaves were used to determine the leaves mineral concentration. The leaves have grinned and 0.5gm of dry-ashed samples were taken for digestion using a mixture

of concentrated H_2SO_4 with $HClO_4$ (4:1), to determine N, P, K, Fe, Mn and Zn [32]. Also, 0.5gm of dry samples were taken for digestion using a mixture of concentrated HNO_3 with $HClO_4$ (3:1) to determine leaves sulfur concentration [26]. The leaves concentration of the following minerals was determined according to the methods described with [13].

Table (1). Some physical and chemical properties of orchard soil (75 cm depth)

Characteristics	Measurement units	Value
Electrical conductivity	(disysimns.m.$^{-1}$)	0.12
pH		7.34
Organic matter	g. kg^{-1}	16.7
Sand	g. kg^{-1}	397.4
Silt	g. kg^{-1}	307.7
Clay	g. kg^{-1}	294.9
Texture		Clay Loam
Total nitrogen	%	0.235
Available Phosphorus	mg. kg^{-1}	8.40
Available Potassium	mg. kg^{-1}	72.33
Available Sulfur	mg. kg^{-1}	18.99
Available Iron	mg. kg^{-1}	1.788
Available zinc	mg. kg^{-1}	0.387
Available manganese	mg. kg^{-1}	0.760
Calcium carbonate	%	15.89
Bicarbonate HCO_3^-	m mole. L^{-1}	3.02
Cat-ions exchangeable capacity (CEC)	Centi mole. Kg^{-1}	20.35

The analysis was carried out at Directorate of Research in Erbil Laboratory Division, Agricultural ministry.

Nitrogen (%): it was determined by the Microkjelhdahls.

Phosphorus (%): it was determined with the colourimetric method at 882nm using Spectrophotometer Pharmacia LKB (Novaspec, U.K.).

Potassium (%): it was determined by the Flame Photometer (JANEWAY PFP7, U.K.).

Sulfur (%): it was determined with the colourimetric method, after turbidity formation, Amusing Spectrophotometer (Pharmacia LKB) method at 420 nm [34].

3.5.5 Iron, Manganese and Zinc (mg.kg^{-1}): it was determined using Atomic Absorption Spectrophotometer (GBC 932 AA, AUSTRALIA).

All the data were tabulated and statistically analyzed with a computer using the SAS program [29]. The differences between various treatment means were tested with the Duncan Multiple Range Test at 5% level [15].

3. Results and Discussion

The obtained results from tables (2 and 3) showed that iron application especially100mg Fe.L^{-1} significantly improved some of leaf nutrient concentrations, such as Fe at both study seasons, N and K in the second season and S in the first season. Similar results were recorded by [30] [35] [16] and [31]. The increase in some nutrients in leaves with increasing iron levels may be attributable to the improving of leaf area and leaves total chlorophyll content which may because in an enhancing of photosynthesis and its protects. Trees may be using a part of this protects in an improvement of root growth, consequently, it is important to improve absorption of some nutrients from the soil and increasing its concentration in leaves. In addition to the spraying of iron LEDs to more absorption of this element by leaves and this maybe lead to increase its concentration in leaves [2].

Table (2). Effect of Iron on leaves N, P, K and SO_4(%) of Dixired peach trees in 2010 and 2011 seasons

Fe conc. (mg Fe. L^{-1})	N		P		K		SO_4	
	2010	2011	2010	2011	2010	2011	2010	2011
0	2.05a	2.16b	0.124a	0.131a	1.89a	2.42b	0.137b	0.154a
50	2.05a	2.19b	0.126a	0.132a	1.91a	2.46b	0.139ab	0.157a
100	2.12a	2.39a	0.125a	0.132a	1.91a	2.60a	0.141a	0.156a

Means of each column followed by the same letters are not significantly different from each other according to Duncan's multiple ranges test at 5% level.

Table (3). Effect of Iron on leaves Fe, Mn and Zn(mg.kg^{-1}) of Dixired peach trees in 2010 and 2011 seasons

Fe conc. (mg Fe . L^{-1})	Fe		Mn		Zn	
	2010	2011	2010	2011	2010	2011
0	177.7 b	272.66 c	114.3 a	146.71 a	68.5 a	73.67 a
50	191.7 a	316.05 b	114.9 a	145.78 a	66.9 a	72.41 a
100	203.2 a	330.87 a	113.4 a	144.71 a	70.8 a	71.83 a

Means of each collom followed by the same letters are not significantly different from each other according to Duncan's multiple ranges test at 5% level.

For the effect of sulfur application on leaf nutrient concentrations, it was noticed from the obtained results that the application of 500 and 750 gm S.tree^{-1} most leaf nutrients significantly increased S, Fe, Mn, and Zn at both seasons, N, P, and K at the second season only (Tables 4 and 5). These results are in agreement with those reported by [9] [8] [6] [7] [4] [5] [25] [3] and [21]. The reason of this might be interpreted to decreasing soil pH at rhizosphere with the increase the levels of sulfur, and then increasing the availability of some nutrients in the soil, consequently increasing in its absorption by roots and its concentrations in leaves, and/or of increasing the number and growth of roots and its distribution in the soil of trees as a result of increasing the synthesized nutrients in the leaves and using portion of them in roots growth, consequently increasing the absorption of nutrients from soil and its concentration in leaves [8], in addition to that, the increasing of sulfur application may lead to increasing the amount of oxidative sulfur, whereof increasing of sulfur availability in soil and its concentration in the leaves.

Table (4). Effect of sulfur on leaves N, P, K and SO_4(%)of Dixired peach trees in 2010 and 2011 seasons

S levels (gm.tree^{-1})	N		P		K		SO_4	
	2010	2011	2010	2011	2010	2011	2010	2011
0	2.11 a	2.14 b	0.127 a	0.130 c	1.92 a	2.38 c	0.133b	0.147b
250	2.16 a	2.14 b	0.126 a	0.131 bc	1.89 a	2.37 c	0.133b	0.151b
500	1.94 a	2.34 a	0.123 a	0.132 b	1.89 a	2.53 b	0.143a	0.160a
750	2.08 a	2.37 a	0.124 a	0.133 a	1.91 a	2.69 a	0.147a	0.164a

Means of each collom followed by the same letters are not significantly different from each other according to Duncan's multiple ranges test at 5% level.

Table (5). Effect of Sulfur on leaves Fe, Mn and Zn (mg.kg^{-1}) of Dixired peach trees in 2010 and 2011 seasons

S levels (gm.tree^{-1})	Fe		Mn		Zn	
	2010	2011	2010	2011	2010	2011
0	183.1 b	285.62 b	101.1 c	129.91 b	65.1 b	68.27 c
250	185.6 ab	287.93 b	114.2 b	135.29 b	66.1 ab	70.84 c
500	200.3 a	324.13 a	114.9 b	154.52 a	73.1 a	73.58 b
750	194.3 ab	328.42 a	126.6 a	163.22 a	70.7 ab	77.84 a

Means of each collom followed by the same letters are not significantly different from each other according to Duncan's multiple ranges test at 5% level.

Table (6). Effect of Iron and sulfur interaction on leaves N, P, K and SO_4 (%) of Dixired peach trees in 2010 and 2011 seasons

Fe conc. (mg Fe. L^{-1})	S levels gm.tree^{-1}	N		P		K		SO_4	
		2010	2011	2010	2011	2010	2011	2010	2011
0	0	2.04a	2.12def	0.126a	0.130b	1.91ab	2.43bcd	0.130d	0.147f
	250	2.14a	2.09ef	0.125a	0.131b	1.86b	2.30cd	0.131d	0.153def
	500	1.88a	2.24cde	0.122a	0.131b	1.89ab	2.48bcd	0.141abc	0.156cde
	750	2.11a	2.19cde	0.122a	0.133a	1.91ab	2.49bcd	0.147abc	0.162bc
50	0	2.06a	1.95f	0.128a	0.130b	1.94a	2.49bcd	0.134cd	0.149ef
	250	2.10a	2.17c-f	0.126a	0.131b	1.90ab	2.34cd	0.133cd	0.151def
	500	2.03a	2.28b-e	0.124a	0.132b	1.89ab	2.42bcd	0.140bc	0.165ab
	750	2.02a	2.37abc	0.126a	0.133a	1.90ab	2.58bc	0.147ab	0.161bc
100	0	2.23a	2.36a-d	0.128a	0.130b	1.91ab	2.22d	0.135cd	0.146f
	250	2.25a	2.18c-f	0.126a	0.131b	1.91ab	2.48bcd	0.136cd	0.149ef
	500	1.90a	2.49ab	0.123a	0.133a	1.89ab	2.69b	0.149a	0.159bcd
	750	2.11a	2.55a	0.123a	0.134a	1.91ab	3.01a	0.146ab	0.170a
Mean of seasons		2.07b	2.25a	0.125b	0.132a	1.90b	2.49a	0.139b	0.156a

Means of each collom followed by the same letters are not significantly different from each other according to Duncan's multiple ranges test at 5% level.

Table (7). Effect of Iron and sulfur interaction on leaves Fe, Mn and Zn (mg.kg^{-1}) of Dixired peach trees in 2010 and 2011 seasons

Fe conc. (mg Fe. L^{-1})	S levels gm.tree^{-1}	Fe		Mn		Zn	
		2010	2011	2010	2011	2010	2011
0	0	165.0d	237.50f	103.8de	138.09cde	67.1a-d	66.44c
	250	176.0cd	242.61f	113.2b-e	144.76bcd	73.66abc	70.37bc
	500	185.6bcd	307.29de	114.0a-d	158.97ab	69.2a-d	73.86b
	750	184.0bcd	303.22e	126.0ab	145.03bcd	64.1bcd	84.00a
50	0	178.5cd	308.78de	104.3de	120.21e	63.1cd	68.16c
	250	182.4cd	304.00e	110.1b-e	137.34cde	65.9bcd	71.65bc
	500	220.2a	328.42bc	123.9abc	156.23abc	69.4a-d	75.23b
	750	185.6bcd	323.00bcd	121.3a-d	169.34a	69.3a-d	74.58b
100	0	205.7abc	310.58de	95.1e	131.42de	65.1bcd	70.22bc
	250	198.3abc	317.17cde	119.2a-d	123.78e	58.7d	70.51bc
	500	195.2a-d	336.68b	106.7c-e	148.36cd	80.7a	71.64bc
	750	213.4ab	359.04a	132.6a	175.28a	78.6ab	74.95b
Means of season		190.83b	306.52a	114.18b	145.73a	68.74b	72.63a

Means of each collom followed by the same letters are not significantly different from each other according to Duncan's multiple ranges test at 5% level.

The effect of the interaction between Fe and S significantly effected on leaves K, S, Fe, Mn and Zn at both seasons, N and P concentrations at the second season, It was noticed from the obtained results that the combination between 100mg Fe. L^{-1} and 750gm S. tree^{-1} appeared to be the most operative treatment, as it gave the highest concentrations of most nutrients in the leaves (Tables, 6 and 7). Results in tables (6 and 7) displays that there was the significant effect of the season on all leaf nutrient concentrations, where the second season was surpassed significantly on the first season in increasing all studied parameters. This may be due to an accumulation effect of iron and sulfur that used in both seasons, which led to increasing the leaf chlorophyll content and their effect on the probable increase of photosynthesis and its protects, trees may be using a part of this protects in improving roots growth and distribution which led to more absorption of several nutrients [24] [19] and [17].

4. Conclusions

Based on the obtained results from this study, foliar spray of Fe at a concentration of 100 mg Fe. L^{-1} and sulfur application at a level of 750 gm S .tree^{-1} were most effective on leaves nutrients of Dixired trees as compared with other treatments, also the interactions of the factors in the second season were more effective on the studied parameters than the first season.

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