

## Fertilizing Young Navel Orange Trees with Sulfur and Wood Ash as a Source of Sustainable Agriculture

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**Abstract:** This study was carried out during two successive seasons 2012 and 2013 to investigate the effect of sulfur & wood ash and their combination on soil pH & EC, vegetative growth and leaf mineral content of the four years old Navel orange trees budded on sour orange rootstock grown in a private orange orchard in Qalubia Governorate Egypt on clay loam soil. In order to define the suitable wood ash and sulfur combination addition at the first few years of tree planting in the orchard which induce great tree growth and optimum leaf mineral content. The study was involved two levels of sulfur ( $S_1=0$  and  $S_2=500$  g tree/year) and five levels of wood ash ( $W_1=0$ ,  $W_2=250$ ,  $W_3=500$ ,  $W_4=1000$  and  $W_5=2000$  g/tree/year). It could be concluded that soil pH and Ec values were increased by increasing wood ash level. So, it must be mixed with other compound decreased soil pH especially under our soil condition in Egypt. May be sulfur is good source for this purpose. Vegetative growth of Navel orange trees was increased slightly by applying 500g sulfur/tree in combination with all wood ash levels, except ( $S_2 \times W_1$ ) treatment. Regarding leaf mineral content, combining sulfur with wood ash increased the macro- and micronutrients content of Navel orange trees compared to applied wood ash alone. Generally, different combinations gave high increase in mineral content and in most cases treatment ( $S_2 \times W_3$ ) gave the highest values of N, P, K, Mg and Mn in leaves.

**Key words:** Leaf mineral content • Navel orange • Soil EC • Soil pH • Sulfur • Wood ash

### INTRODUCTION

Citrus is considered the most popular fruit in Egypt and according to the census of MALR [1], Navel orange is considered the major citrus species in Egypt whereas, the total cultivated area in 2012 was about 177.814 faddan (one faddan=0.42ha) and produced about 1.398.426 ton. It is known that more than 40% of citrus production costs are devoted to nutrition practices. The growers don't be care with their young orange trees get their demands of fertilizers with enter crops fertilizing. The objective in young tree fertilization program is to produce fruit as soon as possible by growing the tree as rapidly as possible. Sustainable agriculture is mainly related to environment, agronomic, ethical and socioeconomics. Tree harvesting operations contribute to the impoverishment of the soil at the time that wood is removed. Wood ash is a very heterogeneous material with characteristics depending on the species and the

type of vegetable, burning parts (bark, timber and fruits), combination with other flammable materials, burning and storage conditions. However, wood ashes always show high alkalinity with pH values above 10 in most of the cases and high levels of Ca and K and occasionally Mg, in form of oxides, hydroxides and carbonates [2, 3, 4]. Elements such as C and N can be present if combustion was not complete. Microelement concentrations are very variable, Fe being the most abundant [3, 5, 6]. Sulfur (S) is an essential plant nutrient required for the synthesis of the amino acids cysteine and methionine, hence of proteins and enzymes. Both of these amino acids are precursors of the sulfur. Containing compounds such as coenzymes and secondary plant products. It has been shown to play an important role in yield and quality of crops [7-9]. Erdal and Tarakçıolu [10] indicated that, while soil pH decreased by 0.11-0.37 unit, plant dry weight and phosphorus concentration and uptake were increased with the application of sulfur.

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Table 1: Chemical analysis of wood ash.

Humidity %	pH	ECdS/m	OM%	N%	P%	K%	Na%	Ca%	Mg%	CaCO <sub>3</sub> %	C:N	Fe%	Znmg/kg	Cumg/kg	Mnmg/kg	Comg/kg
2.4	8.15	2.43	37.7	0.22	0.90	0.17	0.18	4.1	2.3	5.5	171.3	6.66	92	55	670	22

In Egypt all the agricultural areas are under irrigation. Agriculture is a prime importance for the livelihood of Egyptian population. However, degradation of soils through salinity and alkalinity has been a major agricultural problem. Egypt soils are generally characterized by slightly alkaline to alkaline pH due to the high evapotranspiration rate in combination with high ground water level causes salinity development especially in the northern part of the Nile Delta. Thus, the main goal of this research is to study the effect of (sulfur & wood ash and their combination) on soil (pH & EC), vegetative growth and leaf mineral content of the four year old Navel orange trees budded on sour orange rootstock grown on clay loam soil (Typic Torriorthents). In order to define the suitable wood ash and sulfur combination addition at the first few years of tree planting in the orchard which induce great tree growth and optimum leaf mineral content.

## MATERIALS AND METHODS

This study was carried out in two successive seasons of 2012 and 2013 in a private orange orchard in Qalubia Governorate Egypt. Four years old Navel orange trees budded on sour orange rootstock was used. Planting distance was  $2.5 \times 5$  meters apart and the irrigation system was surface irrigation. The soil was characterized by: pH = 7.55, ECe = 1.2 dS/m, organic matter = 2.18%, CaCO<sub>3</sub> = 1.7%, sand = 31%, silt = 36% and clay = 33%. The soil texture class was clay loam (Typic Torriorthents). The study was involved two levels of elemental sulfur (95% S) (S<sub>1</sub> = 0 and S<sub>2</sub> = 500 g/ tree/year) and five levels of wood ash (W<sub>1</sub> = 0, W<sub>2</sub> = 250, W<sub>3</sub> = 500, W<sub>4</sub> = 1000 and W<sub>5</sub> = 2000 g/tree/year). The experiment was laid out in factorial experiment in a randomized complete block design with five replicates and each replicate was represented by one tree. All treatments were added once in March around the trees in the two seasons. The main properties of wood ash were summarized in Table 1. The following data were recorded:

**Soil Samples:** Soil samples were taken from root system zone (20 cm from soil surface) at the end of the two successive seasons; air dried and kept in plastic bags for electrical conductivity was determined in the extract of saturated soil paste according to the method mentioned by Jackson [11]. The pH values were measured in (1:2.5) soil suspension using pH meter according to the method mentioned by Black *et al.* [12].

## Growth Measurements:

- Twenty fully expanded leaves from spring flushes leaves were collected at different four sides of each tree and average leaf area at the end of spring growth cycle (September) was calculated using the equation of Leaf area (cm<sup>2</sup>) =  $\frac{2}{3}$  length  $\times$  width [13].
- The same leaf samples were used to measure total chlorophyll content by using a SPAD - 502 MINOLTA chlorophyll meter.
- Leaves dry matter percentage was calculated at the end of each season in spring flushes leaves.

**Leaf Mineral Content:** Leaf mineral content was determined as follow: Twenty leaves 5-7 months age from spring flushes leaves were collected at random from each replicate. The leaf samples were washed several times with tap water then rinsed with distilled water, dried at 70°C in an electric oven till a constant weight, grounded in electric mill and digested according to the method of Jackson [11]. Leaf mineral content of N, P, K, Ca and Mg were determined on dry weight basis according to Cottenie *et al.* [14], while, Zn, Fe and Mn were determined by Atomic Absorption Spectrophotometer (Jaril-Ash 850).

**Statistical Analysis:** Data obtained of this study were statistically analyzed using the analysis of variance method as reported by Snedecor and Cochran [15] and the differences between means were differentiated by using Duncan's multiple range tests [16].

## RESULTS AND DISCUSSION

**Effect of Different Sulfur and Wood Ash Levels on Soil pH and EC:** Results in Table 2 show the effect of different levels of sulfur, wood ash and their interaction on soil pH and EC during 2012 and 2013 seasons. Results concerning soil pH were affected significantly by sulfur, wood ash additions and their interaction in the 1<sup>st</sup> and 2<sup>nd</sup> seasons. Adding sulfur in soil decreased soil pH. On the other hand, soil pH was gradually increased significantly by increasing wood ash up to (1000 and 2000g/plant). Regarding interaction the obtained data showed that, soil pH was increased by increasing the level of wood ash under both sulfur level. On the other hand, adding wood ash alone gave higher values than adding in combination with wood ash and sulfur under the same wood ash level. Soil EC was affected

Table 2: Effect of sulfur and wood ash levels on soil pH and EC (dS/m) during 2012 and 2013 seasons.

	Sulfur (g/tree/year)					
	0(S1)	500(S2)	Mean	0(S1)	500(S2)	Mean
Wood ash (g/tree/year)	Soil pH			Soil (EC dS/m)		
	2012 season					
0 (W <sub>1</sub> )	7.63d	7.30e	7.46C	0.95g	1.15f	1.05E
250 (W <sub>2</sub> )	7.75cd	7.70cd	7.73B	1.35e	1.34e	1.34D
500 (W <sub>3</sub> )	7.83bc	7.75cd	7.79B	1.72d	1.68d	1.69C
1000 (W <sub>4</sub> )	7.99b	7.84bc	7.92A	2.05b	1.93c	1.99B
2000 (W <sub>5</sub> )	8.20a	7.83bc	8.01A	2.45a	2.42a	2.44A
Mean	7.88A	7.68B	--	1.70A	1.70A	--
	2013 season					
0 (W <sub>1</sub> )	7.53c	7.15d	7.34D	1.15e	1.10e	1.13E
250 (W <sub>2</sub> )	7.60c	7.60c	7.60C	1.45d	1.35d	1.40D
500 (W <sub>3</sub> )	7.95ab	7.60c	7.78BC	1.75c	1.68c	1.72C
1000 (W <sub>4</sub> )	8.07a	7.76bc	7.91AB	2.21a	1.95b	2.08B
2000 (W <sub>5</sub> )	8.04ab	8.01ab	8.02A	2.33a	2.35a	2.34A
Mean	7.84A	7.62B	--	1.78A	1.69B	--

In each season, means of each of sulfur and wood ash levels or their interactions having the same letters are not significantly different at 5% level.

significantly by sulfur addition in the second season only. Consequently, adding sulfur in soil decreased slightly soil EC. In the 1<sup>st</sup> and 2<sup>nd</sup> seasons, soil EC was affected significantly by applying wood ash levels. Soil EC was gradually increased significantly by increasing wood ash up to (2000g/plant). Values of interaction pointed out that, soil EC was affected significantly by different sulfur and wood ash combinations in the two seasons. Generally, untreated plants (S<sub>1</sub> x W<sub>1</sub>) gave the lowest EC values. In both seasons, EC values were increased by increasing ash level irrespective the level of sulfur. Nevertheless, when combined the second level of sulfur (S<sub>2</sub>) with any level of wood ash gave lower significant values than other combinations under the same wood ash level. This result is in agreement with those obtained by Kaya *et al.* [17], who reported that sulfur applications resulted in decreased in soil pH. While the initial soil pH was 8.12, it was reduced to 7.49 and 7.55 with application of elemental S and 7.77 and 7.61 with S containing waste applications at the highest S level (120kg Sda<sup>-1</sup>). Mutowal *et al.* [18] reported that increasing the dose of sulfur decreased the soil EC and the highest soil EC occurred on the control and the lowest soil EC happened on the 6 ton/ha sulfur dose.

On the other hand, Orman [19] indicated that the application of elemental sulfur decreased soil pH and increased the soil EC. The generated salinity was high by sulfur applications, which means that plants might be faced high salinity problems. High rates of elemental sulphur (> 50 mg kg<sup>-1</sup>) should be avoided, especially in soils with high EC level. The generated SO<sub>4</sub><sup>-2</sup> due to microbial oxidation of S in soils increases soil salinity and

salt load of drainage water. Wood ash application resulted in a significantly elevated pH in the humus layer on all the sites. An ash-induced pH increase of 0.6-1.0 pH units and exchangeable acidity (EA) decrease of 58 -83% were detected in the humus layer 16 years after wood ash application [20]. Consequently, it could be concluded that wood ash increased soil pH and EC. The increase in soil pH after wood ash application is due to its alkaline nature. Wood ash is rich in oxides, hydroxides and carbonates of Ca and K then when used as a soil additive may contribute to raise pH. So, it must be mixed with other compound decreased soil pH especially under our soil condition in Egypt. May be sulfur is good source for this purpose.

**Effect of Different Sulfur and Wood Ash Levels on Some Growth Characteristics:** Results in Table 3 show the effect of different levels of sulfur, wood ash and their interaction on some growth characteristics of Navel orange trees during 2012 and 2013 seasons. Leaf area in both seasons was insignificantly affected by adding sulfur. Generally, in the two seasons, leaf area was affected significantly by wood ash levels. Leaf area was gradually increased by increasing wood ash level up to (500 g/tree/year) which gave the highest value. High increase in wood ash level gave more or less similar values with the same statically stand point. Different sulfur and wood ash combinations affected leaf area significantly in the 1<sup>st</sup> and 2<sup>nd</sup> seasons. Generally, [treatments (S<sub>1</sub> x W<sub>1</sub>) and (S<sub>2</sub> x W<sub>1</sub>) decreased leaf area, while high increase in wood ash level up to (S<sub>1</sub> x W<sub>5</sub>) tended to increase leaf area. Almost the highest values

Table 3: Effect of sulfur and wood ash levels on some growth characteristics of young Navel orange trees during 2012 and 2013 seasons.

	Sulfur (g/tree/year)								
Wood ash (g/tree/year)	0(S1)	500(S2)	Mean	0(S1)	500(S2)	Mean	0(S1)	500(S2)	Mean
	-----Leaf area (cm <sup>2</sup> )-----			-----Leaf chlorophyll (SPAD)-----			-----Leaf dry matter %-----		
2012 season									
0 (W <sub>1</sub> )	12.59bc	12.39c	12.49B	80.27cd	84.60a-c	82.43BC	50.50a	47.41a	48.95A
250 (W <sub>2</sub> )	12.33c	13.21bc	12.77B	84.63a-c	88.00a	86.32A	45.42a	48.01a	46.72A
500 (W <sub>3</sub> )	15.49a-c	16.16ab	15.83A	82.53b-d	85.17a-c	83.85AB	48.50a	48.85a	48.68A
1000 (W <sub>4</sub> )	13.12bc	17.48a	15.30A	79.37d	87.27ab	83.32A-C	46.07a	47.78a	46.93A
2000 (W <sub>5</sub> )	14.46a-c	14.89a-c	14.67AB	77.97d	82.47b-d	80.22C	42.24a	44.17a	43.21A
Mean	13.60A	14.83A	--	80.95B	85.50A	--	46.55A	47.25A	--
2013 season									
0 (W <sub>1</sub> )	11.88b	13.13b	12.51B	81.30c	81.37c	81.33B	40.18b	48.37a	44.28A
250 (W <sub>2</sub> )	12.68b	16.44ab	14.56AB	85.20a-c	89.07a	87.13A	48.38a	47.68a	48.03A
500 (W <sub>3</sub> )	15.91ab	20.48a	18.20A	86.07a-c	83.86a-c	84.97AB	47.58a	47.14a	47.36A
1000 (W <sub>4</sub> )	16.91ab	20.40a	18.66A	84.37a-c	87.77ab	86.07A	46.49a	49.46a	47.97A
2000 (W <sub>5</sub> )	17.79ab	16.71ab	17.25A	82.20bc	82.30bc	82.25B	40.03b	46.86a	43.44A
Mean	15.04A	17.43A	--	83.83A	84.87A	--	44.53B	47.90A	--

In each season, means of each of sulfur and wood ash levels or their interactions having the same letters are not significantly different at 5% level.

were obtained by treatments [(S<sub>2</sub> x W<sub>3</sub>), (S<sub>2</sub> x W<sub>4</sub>) and (S<sub>2</sub> x W<sub>5</sub>)] with insignificant differences among them. Total chlorophyll content was affected significantly by levels of sulfur in the first season only, adding sulfur S<sub>2</sub> (500 g/plant/year) gave the highest significant value. On the other hand, in both seasons, total chlorophyll content was affected significantly by levels of wood ash. The least values of chlorophyll content were obtained by W<sub>1</sub> and W<sub>5</sub> levels. Other wood ash levels gave more or less similar values which were similar from the statistical stand point. Different sulfur and wood ash combinations affected chlorophyll content significantly. The highest values were obtained by some different treatments during the two growing seasons, but treatment (S<sub>2</sub>x W<sub>2</sub>) gave the highest values of chlorophyll content in the 1<sup>st</sup> and 2<sup>nd</sup> seasons. Leaves dry matter was affected significantly by sulfur levels in the second season only, adding sulfur S<sub>2</sub> (500 g/tree/year) gave the highest dry matter significant value. In the two seasons, leaves dry matter was insignificantly affected by levels of wood ash. Different sulfur and wood ash combinations affected leaves dry matter significantly in the second season only. The least significant values were obtained by treatments (S<sub>1</sub>x W<sub>1</sub>) and (S<sub>1</sub>x W<sub>5</sub>). Other treatments gave more or less similar values which were similar from the statistical stand point. In this respect, application of elemental S had positive effect on dry matter production of bean [17]. Significantly higher maize plant and dry matter were observed in ash amended plot compared to the control in both seasons [21].

**Effect of Different Sulfur and Wood Ash Levels on Macronutrients Content:** Results in Table 4 show the effect of different levels of sulfur, wood ash and their interaction on macronutrients content in leaves of Navel orange during 2012 and 2013 seasons. Values of nitrogen content in the two seasons were insignificantly affected by adding sulfur. Generally, in the 1<sup>st</sup> and 2<sup>nd</sup> seasons, nitrogen content was significantly affected by wood ash levels. However, the trend was clearer in the second season than the first one; nitrogen content was gradually increased by increasing wood ash level up to (500 g/plant/year) which gave the highest significant value. Different sulfur and wood ash combinations affected nitrogen content significantly in both seasons. Generally, in the second season, [treatments (S<sub>1</sub> x W<sub>1</sub>) and (S<sub>2</sub> x W<sub>1</sub>) decreased nitrogen content, while high increase in wood ash level up to (S<sub>2</sub> x W<sub>3</sub>) tended to increase nitrogen content. However, when combining sulfur with different levels of wood ash created more stimulative effect on nitrogen content. Almost the highest values were obtained by treatment (S<sub>2</sub> x W<sub>3</sub>) in the two seasons. Consequently, it could be concluded that during the two seasons when combining sulfur and wood ash levels gave the higher values of nitrogen content than adding each one alone up to treatment (S<sub>2</sub> x W<sub>3</sub>).

Concerning, phosphorus content was affected significantly by sulfur application in the 1<sup>st</sup> and 2<sup>nd</sup> seasons. The second level of sulfur (500g/tree/year) gave the highest significant values in both seasons. Consequently, it could be concluded that adding sulfur

Table 4: Effect of sulfur and wood ash levels on some macronutrients content in leaves of young Navel orange trees during 2012 and 2013 seasons.

	Sulfur (g/tree/year)								
Wood ash (g/tree/year)	0(S1)	500(S2)	Mean	0(S1)	500(S2)	Mean	0(S1)	500(S2)	Mean
	-----N%-----			-----P%-----			-----K%-----		
	2012 season								
0 (W <sub>1</sub> )	2.72ab	2.84ab	2.78A	0.139bc	0.168ab	0.153AB	1.18d	1.34cd	1.26B
250 (W <sub>2</sub> )	2.72ab	2.22c	2.47B	0.121bc	0.122bc	0.121B	1.30cd	1.41cd	1.36B
500 (W <sub>3</sub> )	2.73ab	2.88a	2.80A	0.117bc	0.215a	0.166A	1.37cd	1.65ab	1.51A
1000 (W <sub>4</sub> )	2.67b	2.82ab	2.75A	0.123bc	0.168ab	0.146AB	1.76a	1.46bc	1.61A
2000 (W <sub>5</sub> )	2.78ab	2.68b	2.73A	0.104c	0.124bc	0.114B	1.35cd	1.31cd	1.33B
Mean	2.72A	2.69A	--	0.121B	0.159A	--	1.39A	1.43A	--
	2013 season								
0 (W <sub>1</sub> )	2.24e	2.32c-e	2.28C	0.145bc	0.180bc	0.163B	1.20d	1.58ab	1.39C
250 (W <sub>2</sub> )	2.44b-d	2.50a-c	2.47B	0.140c	0.185bc	0.163B	1.48bc	1.52b	1.50B
500 (W <sub>3</sub> )	2.52ab	2.66a	2.59A	0.170bc	0.280a	0.225A	1.40c	1.58ab	1.49B
1000 (W <sub>4</sub> )	2.35b-e	2.23e	2.29C	0.215a-c	0.180bc	0.198AB	1.66a	1.54b	1.60A
2000 (W <sub>5</sub> )	2.38b-e	2.28de	2.33C	0.195bc	0.230ab	0.213AB	1.50bc	1.40c	1.45BC
Mean	2.28A	2.39A	--	0.173B	0.211A	--	1.45B	1.52A	--

In each season, means of each of sulfur and wood ash levels or their interactions having the same letters are not significantly different at 5% level.

Table 4: continued

	Sulfur (g/tree/year)					
	0(S1)	500(S2)	Mean	0(S1)	500(S2)	Mean
Wood ash (g/tree/year)	Ca %			Mg %		
	2012 season					
0 (W <sub>1</sub> )	3.76ab	3.68a-c	3.72A	1.22a	1.14a	1.18A
250 (W <sub>2</sub> )	3.58a-c	3.85ab	3.71A	1.24a	1.29a	1.26A
500 (W <sub>3</sub> )	3.94a	3.74ab	3.84A	1.25a	1.43a	1.34A
1000 (W <sub>4</sub> )	3.84ab	3.62a-c	3.73A	1.36a	1.24a	1.30A
2000 (W <sub>5</sub> )	3.38bc	3.24c	3.31B	1.29a	1.44a	1.36A
Mean	3.70A	3.62A	--	1.27A	1.31A	--
	2013 season					
0 (W <sub>1</sub> )	3.70ab	3.94a	3.82A	0.867c	1.38a-c	1.12A
250 (W <sub>2</sub> )	3.68ab	3.94a	3.81A	1.39a-c	1.45ab	1.42A
500 (W <sub>3</sub> )	3.86a	3.81a	3.83A	1.26a-c	1.47ab	1.37A
1000 (W <sub>4</sub> )	3.78ab	3.64ab	3.71AB	1.59a	0.970bc	1.28A
2000 (W <sub>5</sub> )	3.41b	3.73a	3.57B	1.42ab	1.00bc	1.21A
Mean	3.68B	3.81A	--	1.31A	1.25A	--

In each season, means of each of sulfur and wood ash levels or their interactions having the same letters are not significantly different at 5% level.

in soil decreased soil pH and released more phosphorus for trees. Erdal *et al.* [10] reported that application of elemental S to the soil resulted in 0.11 - 0.37 unit decrease in soil pH and the phosphorus uptake of plant and residual P in the soil after the harvest. On the other hand, in both seasons phosphorus content was affected significantly by wood ash level. Phosphorus content was gradually increased by increasing wood ash up to 500g (W<sub>3</sub>) which gave the highest values. Phosphorus content was affected significantly by the interaction between sulfur and wood ash levels in both seasons. Consequently, it is quite evident that in the two seasons, under sulfur addition, phosphorus content was increased

by increasing the level of wood ash up to 500g (W<sub>3</sub>). So, the highest values of phosphorus content were obtained by (S<sub>2</sub> x W<sub>3</sub>) treatment in both seasons.

Concerning, potassium content was affected significantly by sulfur addition in the second season only. Potassium content was affected significantly by wood ash level in both seasons. It was gradually increased by increasing wood ash up to 1000g (W<sub>4</sub>) which gave the highest potassium content value. Potassium content was affected significantly by the interaction between sulfur and wood ash levels and (S<sub>1</sub> x W<sub>1</sub>) treatment gave the least value in the 1<sup>st</sup> and 2<sup>nd</sup> seasons. Other combination created more stimulative effect on potassium content

whereas, the highest values were obtained by treatment ( $S_1 \times W_4$ ) followed closely with the same statistically stand point by ( $S_2 \times W_3$ ) treatment.

Calcium content was affected significantly by sulfur addition in the second season only. On the other hand, in both seasons, calcium content was affected significantly by the levels of wood ash. Generally,  $W_1$ :  $W_4$  levels gave more or less similar values with the same statistical standpoint. However, more increase in wood ash level up to  $W_5$  gave the least significant values of calcium content. Calcium content was affected significantly by the interaction between sulfur and wood ash levels in the two seasons. Treatments ( $S_2 \times W_5$ ) and ( $S_1 \times W_5$ ) gave the least values in the first and second season, respectively. Other combination gave more or less similar values with the same statistical stand point.

The values of magnesium content in the both seasons were insignificantly affected by adding sulfur and wood ash. Magnesium content was affected significantly by the interaction between sulfur and wood ash levels in the second season only. The least significant value was obtained by untreated trees ( $S_1 \times W_1$ ). Other combinations gave more or less similar values however, treatments ( $S_2 \times W_3$ ) and ( $S_1 \times W_4$ ) gave the highest magnesium content in the first and second seasons, respectively.

In this respect, application of elemental S and S containing waste positively affected nitrogen concentration of bean. On the other hand, P concentration of bean decreased with S application from both sources compared with the control. Otherwise, application of increasing levels of S from both sources did not show any significant effect on plant potassium content. Even though the average of Ca content of plants gradually increased with application of increasing S levels. Finally, Mg content was decreased at higher levels of elemental S applications [17]. Otherwise, application of sulfur and cattle manure together, had significant effect in reducing soil pH, thereby increasing macronutrient availability in soil and ultimately leads to increased concentrations of these nutrients in canola leaves and seeds [22]. Naylor and Schmidt [23] have equated wood ash fertilization effects to commercial fertilizers on the basis of the N, P ( $P_2O_5$ ) and K ( $K_2O$ ) concentrations. For a commercial wood boiler this would be similar to a 0-1-3 fertilizer, but for a domestic wood stove (lower temperature burn) the ash has a higher proportion of K and would be equivalent to a 0-3-14 fertilizer. They showed that the availability of K was a linear function of the amount added to the soil. Only approximately 18-35%

of that added in boiler ash, but 51% from the wood stove would be available to plant uptake. This was probably due to K compounds forming with Si at higher temperatures. Other study revealed that under salinity level  $S_1$  (4.2 dS  $m^{-1}$ ), application of wood ash [150 mg (WA)  $kg^{-1}$  soil] increased maize shoot concentrations of K, Mg and Ca [24].

#### **Effect of Different Sulfur and Wood Ash Levels on Leaf**

**Micronutrients Content:** Results in Table 5 show the effect of different levels of sulfur, wood ash and their interaction on micronutrients content in leaves of Navel orange trees during 2012 and 2013 seasons. The values of iron content in the 1<sup>st</sup> and 2<sup>nd</sup> seasons were insignificantly affected by adding sulfur. Generally, in both seasons, iron content was affected significantly by wood ash levels. The lowest significant values of iron content were obtained by level ( $W_5=2000g$  wood ash / plant) followed by level ( $W_1=$  untreated plants). Others levels gave more or less similar values, however level ( $W_3=500g$  wood ash/plant) gave the highest values of iron content in the two seasons. Different sulfur and wood ash combinations affected iron content significantly in the two seasons. Generally, in both seasons, the lowest significant values were obtained by [treatments ( $S_1 \times W_5$ ) and ( $S_2 \times W_5$ )], which decreased iron content. However, other treatments gave more or less similar values with the same statically stand point especially in the first season. Consequently, it could be concluded that during the 1<sup>st</sup> and 2<sup>nd</sup> seasons when combining sulfur and wood ash levels up to treatment ( $S_2 \times W_3$ ) gave the higher values of iron content than untreated plant or adding each one alone high increase in wood ash level [treatments ( $S_1 \times W_4$ ) and ( $S_2 \times W_4$ )] decreased iron content significantly.

The values of zinc content in the 1<sup>st</sup> and 2<sup>nd</sup> seasons were insignificantly affected by adding sulfur. On the other hand, in both seasons, zinc content was affected significantly by wood ash levels. Zinc content was gradually increased by increasing wood ash up to 1000g ( $W_4$ ), which gave the highest values, however, high increase in wood ash level decreased zinc content insignificantly. Different sulfur and wood ash combinations affected zinc content significantly in the both seasons. Generally, the lowest significant values were obtained by treatments ( $S_1 \times W_2$ ) and ( $S_1 \times W_1$ ) in the first and second season, respectively. Other combination gave more or less similar values. Consequently, it could be concluded that treatment ( $S_2 \times W_2$ ) is it sufficient treatment for gave the optimum level of zinc in Navel orange leaves.

Table 5: Effect of sulfur and wood ash levels on some micronutrients content in leaves of young Navel orange trees during 2012 and 2013 seasons.

	Sulfur (g/tree/year)								
Wood ash (g/tree/year)	0(S1)	500(S2)	Mean	0(S1)	500(S2)	Mean	0(S1)	500(S2)	Mean
	-----Fe (ppm)-----			-----Zn (ppm)-----			-----Mn (ppm)-----		
	2012 season								
0 (W <sub>1</sub> )	454 bc	544 ab	499 B	21.0bc	20.3c	20.6B	26.0e	27.0e	26.5D
250 (W <sub>2</sub> )	569 a	604 a	587 A	24.8a-c	27.0a-c	25.9A	27.0e	33.0d	30.0C
500 (W <sub>3</sub> )	645 a	579 a	612 A	20.3c	27.8ab	24.0AB	32.0d	31.0d	31.5C
1000 (W <sub>4</sub> )	569 a	572 a	571 A	27.0a-c	27.0a-c	27.0A	37.0c	41.0b	39.0B
2000 (W <sub>5</sub> )	307 d	419 c	363 C	29.3a	24.8a-c	27.0A	41.0b	46.0a	43.5A
Mean	509 A	544 A	--	24.5A	25.4A	--	32.6B	35.6A	--
	2013 season								
0 (W <sub>1</sub> )	512b	525 b	518 B	22.2d	26.6b-d	24.4C	26.0c	25.5c	25.8C
250 (W <sub>2</sub> )	509 b	539ab	524 B	25.2b-d	27.7a-d	26.4BC	26.8c	24.0c	25.4C
500 (W <sub>3</sub> )	570ab	639a	604 A	30.1ab	23.5cd	26.8A-C	25.5c	37.0ab	31.3B
1000 (W <sub>4</sub> )	524 b	597ab	561 AB	32.7a	28.2a-c	30.5A	33.0b	39.0ab	36.0A
2000 (W <sub>5</sub> )	312c	338 c	325 C	32.6a	26.8b-d	29.7AB	36.5ab	42.5a	39.5A
Mean	485 A	528 A	--	28.6A	26.5A	--	29.6B	33.6A	--

In each season, means of each of sulfur and wood ash levels or their interactions having the same letters are not significantly different at 5% level.

Manganese content was affected significantly by sulfur addition in both seasons. Consequently, it could be concluded that adding sulfur in soil decreased soil pH and released more manganese for trees. Generally, in both seasons, manganese content was affected significantly by wood ash levels. Manganese content was gradually increased significantly by increasing wood ash up to 2000g (W<sub>4</sub>) and 1000g (W<sub>3</sub>) in the first and second season, respectively. Different sulfur and wood ash combinations affected manganese content significantly in the 1<sup>st</sup> and 2<sup>nd</sup> seasons. The obtained data showed that, more increase in wood ash level under the second level of sulfur (S<sub>2</sub>= 500g/plant) gave the highest values of manganese content up to (S<sub>2</sub> x W<sub>5</sub>) treatment especially in the first season. However in the second season treatments [(S<sub>2</sub> x W<sub>3</sub>), (S<sub>2</sub>x W<sub>4</sub>), (S<sub>1</sub> x W<sub>5</sub>) and (S<sub>2</sub> x W<sub>5</sub>)] gave more or less similar values with the same statically stand point. Consequently, it could be concluded that wood ash is good source of micronutrients for Navel orange trees and sulfur enhance the solubility of this nutrient by decreased soil pH.

In this respect Weatman *et al.* [25] mentioned the following optimum levels of leaf macro and micronutrients content in Navel orange leaf sample (N= 2.4-2.8%, P= 0.20 - 0.26%, K=1.3-1.6%, Fe= >500 ppm, Zn= 18-80 ppm and Mn= 50-160ppm). Elemental sulfur decreased pH from 8.2 to 7.7 and concentration of Fe in leaf increased with applications of elemental sulfur depending on decrease in pH [26]. Thus it could be explain by the oxidation of H<sub>2</sub>SO<sub>4</sub> is particularly beneficial in alkaline soils to reduce pH, supply SO<sub>4</sub> to plants, make P and micronutrients more available [17]. Short-term effects of different doses

(0.25 and 0.5 kg m<sup>2</sup>) of wood ash fertilization in a field experiment in a 20-year-old Scots pine stand on a nutrient-poor sandy soil (Arenosol) was studied in North Estonia. Changes in soil properties brought about changes in nutrient accumulation into trees and the needle diagnosis showed an essential increase in the K, Mg, Fe, Mn and Zn concentrations in needles [27]. On the other hand, Evans *et al.* [28] found that increasing amounts of ash decreased tomato shoot nitrogen (N), potassium (K), iron (Fe), manganese (Mn), zinc (Zn) and copper (Cu) concentration and increased concentrations of phosphorus (P), calcium (Ca), sulfur (S) and boron (B).

## CONCLUSION

From the foregoing results, it could be concluded that soil pH and EC values were increased by increasing wood ash level. So, it must be mixed with other compound decreased soil pH especially under our soil condition in Egypt. May be sulfur is good source for this purpose. Regarding vegetative growth characters in most cases were insignificantly affected by adding sulfur. On the other hand, all wood ash levels increased leaf area and chlorophyll content when compared with that of level W<sub>1</sub>. It was gradually increased in leaf area and chlorophyll content characters by increasing wood ash up to 250: 1000 g wood ash / plant more increase in wood ash level decreased vegetative growth characters. Regarding the combination between sulfur and wood ash levels in most cases, it is clear that vegetative growth of Navel orange trees was increased slightly by the second level of sulfur

under any given of wood ash except ( $S_2 \times W_1$ ) treatment. Regarding the effect of sulfur and wood ash levels on leaf nutrient content, generally, sulfur decreased soil pH so the nutrient became more available for trees especially phosphorus, potassium, calcium and manganese. With respect to wood ash levels, in most cases levels  $W_2$ ,  $W_3$  and  $W_4$  gave the highest values than those of other levels especially for (N), (P, Fe) and (K, Zn, Mn), respectively. Depending upon the values of interaction between sulfur and wood ash levels, it could be concluded that, combining sulfur with wood ash creates slightly more increasing effect on macro- and micronutrients content of Navel orange trees than adding wood ash alone. Generally, different combinations gave more increase in mineral content and in most cases treatment ( $S_2 \times W_3$ ) gave the highest values of N, P, K, Mg and Mn in leaves. Therefore, it seems that use wood ash as a fertilizer under our soil condition in Egypt is a virgin field moreover; wood ash could be useful for contributing increase soil fertility. Otherwise, more research works should be carried out to evaluate wood ash as a source for plant nutrition and to answer other questions about, how many does of wood ash should add each year or year intervals.

## REFERENCES

1. MALR, 2012. Ministry of Agriculture and Land Reclamation, Central Administration of Agricultural Economics, Egypt. Economic Affairs Sector (EAS), Agricultural Statistics, 2: 328.
2. Campbell, A.G., 1990. Recycling and disposing of wood ash. *Tappi. Journal*, 73: 141-146.
3. Someshwar, A.V., 1996. Wood and combination wood-fired boiler ash characterization. *Journal of Environmental Quality*, 25: 962-972.
4. Demeyer, A., J.C. Voundi and M.G. Verloo, 2001. Characteristics of wood ash and influence on soil properties and nutrient uptake: an overview. *Bioresource Technology*, 77(3): 287-295.
5. Ohno, T. and M.S. Erich, 1990. Effect of wood ash application on soil pH and soil test nutrient levels. *Agriculture, Ecosystems and Environment*, 32: 223-239.
6. Ohno, T., 1992. Neutralization of soil acidity and release of phosphorus and potassium by wood ash. *Journal of Environmental Quality*, 21: 433-438.
7. Marschner, H., 1995. Mineral Nutrition in Higher Plants. Acad. Press, London
8. Pavlista, A.D., 2005. Early-season application of sulfur fertilizers increase potato yield and reduce tuber defects. *Agron. J.*, 97: 599-603.
9. Heeb, A., B. Lundegardh, G. Savage and T. Ericsson, 2006. Impact of organic and inorganic fertilizers on yield, taste and nutritional quality of tomatoes. *J. Plant Nutr. Soil Sci.*, 69: 535-541.
10. Erdal, I. and C. Tarakçiolu, 2000. Effect of different organic materials on growth and mineral composition of corn plant (*Zea mays* L.). *J. Agric. Sci.*, 15(2): 80-85.
11. Jackson, M.L., 1973. Soil chemical Analysis. Prentice-Hall of India Private Limited, New Delhi.
12. Black, C.A., D.D. Evans, L.E. Ensminge, J.L. White, F. E. Clark and R.C. Dinauer, 1965. Methods of Soil Analysis. II: Chemical and Microbiological Properties. Amer. Soc. Agron. Inc. Bull., Madison, Wisconsin, USA.
13. Chou, G.J., 1966. A new method of measuring the leaf area of citrus trees. *Acta Hort. Sci.*, 5: 17-20.
14. Cottenie, A., M. Verloo, L. Kiekens, G. Velgh and R. Camerlynk, 1982. Chemical Analysis of Plants and Soils. State Univ. Ghent, Belgium, 63: 44-45.
15. Snedecor, G.W. and W.G. Cochran, 1980. Statistical Methods. 7<sup>th</sup> Ed. Iowa State, Univ. Press. Ames, Iowa, U.S.A. pp: 507.
16. Duncan, D.B., 1955. Multiple Range and Multiple F Tests. *Biometrics*, 11: 1-42.
17. Kaya, K., K. Kucukyumuk and I. Erdal, 2009. Effects of elemental Sulfur and Sulfur containing waste on nutrient concentrations and growth of bean and corn plants grown on a calcareous soil. *African Journal of Biotechnology*, 8(18): 4481-4489.
18. Mutowal, W., S. Al-Solaimani and S. Ismail, 2013. Effect of sulfur amendment levels on calcareous saline sodic soil and squash yield in Saudi Arabia. *Asian Journal of Science and Technology*, 4(12): 48-051.
19. Orman, S., 2012. Effects of elemental sulphur and farmyard manure applications to calcareous saline clay loam soil on growth and some nutrient concentrations of tomato plants. *Journal of Food, Agriculture & Environment*, 10(2): 720-725.
20. Saarsalmi, A., E. Mälkönen and S. Piirainen, 2001. Effects of wood ash fertilization on forest soil chemical properties. *Silva Fennica*, 35(3): 355-368.



21. Mbah, C.N., N. Jokuc, P. Ngene and C.G. Oludare, 2013 Use of ash to improve the nutrient content of an ultisol and its effect on maize (*Zea mays* L.) growth and dry matter yield. *Int. J. Forest, Soil and Erosion*, 3(4): 118-121.
22. Karimi, F., M.A. Bahmanyar and M. Shahabi, 2012. Investigation the effects of sulfur and cattle manure application on macronutrient availability in calcareous soil and accumulation in leaf and seed of canola. *European Journal of Experimental Biology*, 2(3): 836-842.
23. Naylor, L.M. and L. Schmidt, 1986. Agricultural use of wood ash as a fertilizer and liming material. *Tappi Journal*, 69: 114-119.
24. Boh, M.Y., T. Müller and J. Sauerborn, 2013. Maize (*Zea mays* L.) response to urine and wood ash fertilization under saline (NaCl) soil conditions. *International Journal of Agric. Science*, 3(4): 333-345.
25. Weatrman, R.H., T.V. Barid, N.W. Cxhristensen, P.E. Fixen and D.A. Whiteney, 1990. *Soil Testing and Plant Analysis*. Soil Sci. Soc. Am. In., Madison, Wisconsin, U.S.A.
26. Erdal, I., K. Kepenek and I. Kızılgöz, 2006. Effect of elemental sulphur and sulphur containing waste on the iron nutrition of strawberry plants grown in a calcareous soil. *Biol. Agric. Hort.*, 23: 263-272.
27. Mandre Malle 2006. Influence of wood ash on soil chemical composition and biochemical parameters of young Scots pine. *Proc. Estonian Acad. Sci. Biol. Ecol.*, 55(2): 91-107.
28. Evans, B. William, B. Guihong and Glenn B. Fain, 2011. Addition of pulp mill ash raises pH, modifies physical properties and alters young tomato plant growth and mineral nutrition in a peat-based substrate. *Journal of Plant Nutrition*, 34(12): 1894-1903.