The Future of Horticulture

FSA

Article

Effect of Wood Ash on Growth and Productivity of Valencia Orange Trees Under New Reclaimed Land Conditions

Sahar A. Farid

Plant Production Department, Desert Research Center, Cairo, **Egypt**.

*Corresponding author: dr_s.faried@yahoo.com

Abstract: This investigation was carried out during two successive seasons (2020 and 2021) on the 8 -year- old of Valencia orange trees budded on a Volcameriana rootstock planted on a 5x5 m^2 and irrigated with Nile River under drip irrigation system grown in a private orchard located at Cairo- Alex. Road to study the effects of wood ash levels, (W1= 0, W2= 625, W3=1250 and W4=2500 g/tree/year), two levels of elemental sulfur without or with sulfur (S_1 = 0 and $S_2$500g/ tree/year S) and their interactions, on growth fruit quality of Valencia orange trees were studied under desert stress conditions. The best results were recorded with wood ash treatment at 2500 g/tree/year level with elemental sulfur at 500g/ tree/year (S)which improved shoot length, shoot diameter, number of leaves/ shoot, leave area, total chlorophyll in leaves, leaf dry matter %, nutrients, fruit set%, fruit retention%, number of fruits per tree, fruit weight, yield kg/ tree, yield ton/ feddan, yield increment %, fruit volume, fruit length, fruit diameter, fruit shape index, fruit TSS, fruit T.S.S./acid ratio, vitamin C and total sugar, Juice %.While, reduced rind thickness, fruit total acidity content. So this treatment was proved to be the most efficient in enhancing, the yield and fruit quality of Valencia orange trees.

Key words: Citrus, Valencia orange, Wood ash, Elemental sulfur, Leaf mineral content.

Future Science Association

Available online free at www.futurejournals.org

Print ISSN: 2692-5826

Online ISSN: 2692-5834

DOI: 10.37229/fsa.fjh.2024.01.7

Received: 30 November 2023
Accepted: 30 December 2023
Published: 7 January 2024

Publisher's Note: FA stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

INTRODUCTION

Citrus is a genus of flowering trees and shrubs in the family, Rutaceae. Plants in the genus produce citrus fruits, including important crops such as oranges, lemons, grapefruits, pomelos, and limes. The genus Citrus is native to South Asia, East Asia, Southeast Asia, and Australia. **Wu *et al.* (2018)** has shown that the center of origin of the genus Citrus is likely the southeast foothills of the Himalayas, in a region stretching from eastern Assam, northern Myanmar, to western Yunnan. Citrus considered the most popular fruit in Egypt according to M.A.L.R. (2021). Valencia orange considered the major citrus species in Egypt whereas, the total cultivated area in 2023 was about 1,673,612faddan (one faddan=0.42ha) and produced about 11,627,546 ton.

Wood ash is a very heterogeneous material with characteristics depending on the species and the type of vegetable, burning parts (bark,

timber and fruits). **Campbell (1990)**. **Someshwar (1996)** reported that some people believe that ashes from a wood fire make an excellent fertilizer. Wood ashes are rich in potassium and other minerals that can be beneficial for fruit trees. They can help the tree to produce more fruit, and the potassium can also help to prevent disease. Wood ash is high in calcium, iron, potassium, magnesium, phosphorus, and manganese, all of which are required for fruit trees growth and vigor.

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 **(Demeyer *et. al.*, 2001).** Wood ash contains many important plant nutrients such as potassium (K) and phosphorus (P) and can be used as a fertilizer **(Jonna, 2017).** Wood ashes have the ability to benefit almost any fruit tree. Wood ash will be beneficial in slightly changing the pH of the soil. Therefore, it is hypothesized that the combined use of potassic fertilizers, charcoal, and wood ash in tropical acid soils could improve the K availability because of their acid, Al3+, and Fe2+ neutralizing effects, **Puvan *et. al.* (2021).** Wood ashes have been shown to help plants grow successfully, also wood ash can be used to mulch around fruit trees. Wood ash is a useful addition to fruit trees because of its properties. Wood ash has 3% potassium in it, which is an essential nutrient for plant growth and development (**Sabin, 2022**).

An important plant nutrient, sulfur (S) is needed for the creation of proteins and enzymes in addition to the amino acids cysteine and methionine. Both of those amino acids are sulfur's precursors. Containing compounds such as coenzymes and secondary plant products. It has been shown to play an important role in yield and quality of crops. **Marschner (1995). Pavlista (2005). Heeb (2006).** 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 **Erdal and Tarakç olu (2000)**.

Generally, plants require about a tenth as much sulfur (S) as nitrogen (N), but sulfur deficiencies restrict plant growth as surely and severely as nitrogen deficiencies. Canola and alfalfa are examples of high sulfur-using crops. Sulfur is not mobile in the plant, so a continuous supply from sulfur be needed from emergence to crop maturity. A deficiency of sulfur at any stage of growth can result in reduced yields.

This investigation aimed to study the effect of wood ash treatments, elemental sulfur (S) and their combination on vegetative growth and productivity of Valencia orange trees under new reclaimed land conditions.

MATERIAL AND METHODS

This study was carried out in two successive seasons of 2020 and 2021 in a private orange orchard in Alexandria Desert Road Egypt. Eight years old Valencia orange trees budded on Volkameriana rootstock was used. Planting distance was 5 × 5 meters apart and the irrigation system was drip irrigation using Nile river water. The soil texture class was sandy soil. The study was involved three levels of wood ash (W1= 0, W2= 625, W3=1250 and W4=2500 g/tree/year) and two levels of elemental sulfur without or with sulfur (S_1 = 0 and $S_2$500g/ tree/year S). 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. Physical and chemical analyses of the experimental soil were shown in Table (1) and the chemical analyses of the used irrigation water is recorded in table (2). The main proprieties of wood ash were summarized in Table (3). The following data were recorded:

Table (1). Analysis of experimental soil

Soil Depth (cm)	Texture Class	pH at 1:2.5	E.Ce (dSm^{-1})	Soluble cations (meq/l)				soluble anions (meq/l)			%
				Ca^{++}	K^{+}	Na^{+}	Mg^{++}	Cl^{-}	$CO_3^{=}$	HCO_3^{-}	$CaCO_3$
0-30	Sand	8.20	0.88	4.15	0.68	2.20	1.05	2.20	-	4.50	5.00
30-60	Sand	8.22	1.13	5.65	0.65	2.56	0.55	2.75	-	7.95	5.375

Table (2). Chemical analysis of water used for irrigation

pH	E.C. dSm^{-1}	mill equivalent / liter Soluble cations (meq/l)				mill equivalent / liter soluble anions (meq/l)		
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	$CO_3^{=}$	HCO_3^{-}	Cl^{-}
7.88	1.20	3.00	2.00	7.00	0.63	0.00	8.24	1.64

Table (3). Chemical analysis of wood ash

Humidity	pH	EC dsm	OM %	N %	P %	K %	Na %	Ca %	Mg %	CaCo3 %	C:N	Fe %	Zn mg/kg	Cu mg/kg	Mn mg/kg	Co mg/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	6.6	92	55	670	22

Forty healthy trees, nearly uniform in shape, size and productivity, received the same horticultural practices were used in this experiment.

Foliage measurements included the following characters: shoot length, shoot diameter, number of leaves/shoot were recorded 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 was recorded using a Cl203Area Meter (CID, Inc., USA). Paper have been collected at 5-7 months age from spring flushes leaves 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 (1973).** Leaf total chlorophyll content was determined by Minolta chlorophyll meter SPAD-502.Leaf dry matter percentage was calculated at the end of each season in spring flushes leaves. Leaf mineral content of N, P, K, Ca and Mg were determined on dry weight basis according to **Cottenie *et al*. (1982**), while, Fe, Zn and Mn were determined by Atomic Absorption Spectrophotometer (Jaril-Ash 850). Leaf total chlorophyll content was determined by Minolta chlorophyll meter SPAD-502.

Fruit set Percent and fruit retention Percent were calculated by the following formula **according to Jayalakshmi (2020).** Total number of fruits per tree for each replication was recorded when the fruit attained maximum size and maturity.

Fruit set (%)

Number of tagged four shoots had flowers were labeled at full bloom, thereafter number of set fruitlets was recorded. Fruit set percentages were calculated at May, in the first and second seasons, as follows:

$$\text{Fruit set \%} = \frac{\text{No. of set fruitlets}}{\text{Total No. of flowers at full bloom}} \times 100$$

Fruit retention %

$$\text{Fruit retention \%} = \frac{\text{Number of fruitlets per panicle harvest}}{\text{Number of initial set}} \times 100$$

Number of fruits / tree, yield Kg / tree, yield ton / feddan and yield increment % over the control

The average number of fruits/tree was recorded at harvesting time. Yield as kg /tree was recorded at the harvesting time in both seasons at the third week of January.

Fruit physical and chemical properties

Five orange fruits of each replicate at maturity stage were taken at harvest time at May during two seasons from each replicate for determination of the following physical and chemical properties. Fruit weight (g), fruit volume (cm^3), fruit length (cm) fruit diameter (cm), fruit shape index (F.L. /F.D.), rind thickness (mm) were measured. There are separating pulp from the peel and the fruit juice %, fruit total soluble solids (TSS) % was determined by Hand refract meter, total acidity percentage was determined in fruit juice according to **(A.O.A.C., 1995),** T.S.S./Acid ratio according to **A.O.A.C. (2000).** Total sugars (%) were determined in fruit juice (100 nm juice) photo-metrically at 490 nm to the phenol method and using ethyl alcohol for 1 hour at 70^0C as described by **Dubois *et al*. (1956).** Pulp content of vitamin C (mg/100g f. w.) according to **A.O.A.C. (1990)** were determined.

Statistical Analysis

Data obtained of this study were statistically analyzed using the analysis of variance method as reported by **Snedecor and Cochran (1980)**, and the differences between means were differentiated by using **Duncan's multiple range tests (1955).**

RESULTS AND DISCUSSION

Data in table (4): showed the effect of wood ash, sulfur and their interaction on Shoot length, Shoot diameter and number of leaves/shoot of Valencia orange trees during 2020 and 2021 seasons.

Shoot length, Shoot diameter and number of leaves/shoot

Regarding to wood ash treatments, the treatment 2500 g/tree/year had highest significant values of shoot length, shoot diameter and number of leaves/shoot in both seasons. Concerning sulfur (S) treatments, the addition of sulfur (S) had higher significant values than without sulfur (S) on shoot length, shoot diameter and number of leaves/shoot in both seasons. The interaction between two studies factors, the treatment of wood ash at 2500 g/tree/year with addition of sulfur (S) recorded highest significant values on shoot length, shoot diameter and number of leaves/shoot in both seasons.

Table (4). Effect of wood ash, sulfur and their interaction on Shoot length, Shoot diameter and number of leaves/shoot of Valencia orange trees during 2020 and 2021 seasons

Treatments	Shoot length			Shoot diameter			No of leaves/shoot		
	Without S	With S	Mean	Without S	With S	Mean	Without S	With S	Mean
First season									
Control	11.18h	14.19d	**12.69D**	0.320f	0.321f	**0.321D**	4.58d	4.92d	**4.75D**
625Wood ash	12.88g	14.07e	**13.47C**	0.353e	0.372d	**0.363C**	6.33c	7.33b	**6.83C**
1250 Wood ash	13.84f	15.81b	**14.82B**	0.385cd	0.408b	**0.396B**	7.17bc	8.00b	**7.58B**
Wood ash 2500	14.69c	18.89a	**16.79A**	0.397bc	0.454a	**0.425A**	7.67b	7.50a	**8.58A**
Mean	**13.15B**	**15.74A**		**0.364B**	**0.349A**		**6.44B**	**7.44A**	
Second season									
Control	11.37h	14.38d	**12.88D**	0.328f	0.329f	**0.329D**	5.00e	5.25e	**5.13D**
625Wood ash	12.93g	14.16e	**13.55C**	0.361e	0.380de	**0.371C**	6.67d	7.83bc	**7.25C**
1250 Wood ash	13.90f	15.90b	**14.90B**	0.393cd	0.416b	**0.404B**	7.42cd	8.42b	**7.92B**
Wood ash 2500	14.81c	19.02a	**16.92A**	0.405bc	0.462a	**0.433A**	8.08bc	10.00a	**9.04A**
Mean	**13.25B**	**15.86A**		**0.372B**	**0.397A**		**6.79B**	**7.88A**	

Means having the same letter (s) in each row, column or interaction are insignificantly different at 5% level.

Data in table (5): showed the effect of wood ash, sulfur and their interaction on leaf area (cm^2) total Chlorophyll (mg/100 g f.w.) and dry weight (%)of Valencia orange trees during 2020 and 2021 seasons.

Leaf area percentage, total Chlorophyll (mg/100 g f.w.) and dry weight percentage

Regarding to wood ash treatments, the treatment 2500 g/tree/year had highest significant values of leaf area percentage, total Chlorophyll mg/100g.f.wand leaf dry matter percentage in both seasons. Concerning sulfur (S) treatments, the addition of sulfur (S) had higher significant values than without sulfur (S) on leaf area percentage, total Chlorophyll mg/100 g f.w. and leaf dry matter percentage in both seasons. The interaction between two studies factors, the treatment of wood ash at 2500 g/tree/year with addition of sulfur (S) recorded highest significant values on leaf area percentage, total Chlorophyll mg/100 g f.w. and leaf dry matter percentage in both seasons.

Table (5). Effect of wood ash, sulfur and their interaction on leaf area (cm^2), total Chlorophyll (mg/100 g f.w.) and dry weight (%)of Valencia orange trees during 2020 and 2021 seasons

Treatments	Leaf area (cm^2)			Total Chlorophyll (mg/100g.f.w)			Leaf dry matter (%)		
	Without S	With S	Mean	Without S	With S	Mean	Without S	With S	Mean
First season									
Control	19.79g	19.85g	19.82D	6.07e	6.09e	6.08**D**	54.17g	55.83f	55.00**D**
Wood ash 625 (g/tree/year)	21.71f	23.09e	22.40**C**	7.23d	7.97c	7.60**C**	67.02e	71.19d	69.10**C**
(g/tree/year)1250 Wood ash	24.75d	27.64b	26.20**B**	7.49d	8.81b	8.15**B**	66.75e	74.66b	70.70**B**
Wood ash) 2500 (g/tree/year	25.58c	32.11a	28.85**A**	8.17c	9.23a	8.70**A**	73.21c	77.61a	75.41**A**
Mean	22.96**B**	25.67 **A**		7.24**B**	8.02**A**		65.29**B**	69.82**A**	
Second season									
Control	19.86g	19.89g	19.88**D**	6.13d	6.17d	6.15**D**	55.04g	56.65f	55.85**D**
Wood ash625 (g/tree/year)	21.91f	23.26e	22.58**C**	7.29c	8.00b	7.64**C**	67.60e	71.56d	69.58**C**
Wood ash1250 (g/tree/year)	24.96d	27.69b	26.33**B**	7.53c	8.19b	7.86**B**	67.47e	74.93b	71.20**B**
Wood ash2500 (g/tree/year)	25.71c	32.60a	29.16**A**	8.26b	9.28a	8.77**A**	73.88c	78.08a	75.98**A**
Mean	23.11**B**	25.86 **A**		7.30**B**	7.91**A**		66.00**A**	70.31**A**	

Means having the same letter (s) in each row, column or interaction are insignificantly different at 5% level.

Data in table (6): showed the effect of wood ash, sulfur and their interaction on fruit set (%) and fruit retention (%) of Valencia orange trees during 2020 and 2021 seasons.

Initial fruit set percentage and fruit retention percentage

Regarding to wood ash treatments, the treatment 2500 g/tree/year had highest significant values on fruit set percentage and fruit retention percentage in both seasons. Concerning sulfur (S) treatments, the addition of sulfur (S) had higher significant values than without sulfur (S) on fruit set percentage and fruit retention percentage in both seasons. The interaction between two studies factors, the treatment of wood ash at 2500 g/tree/year with addition of sulfur (S) recorded highest significant values on fruit set percentage and fruit retention percentage in both seasons.

Table (6). Effect of wood ash, sulfur and their interaction on fruit set (%) and fruit retention (%) of Valencia orange trees during 2020 and 2021 seasons

Treatments	Initial fruit set (%)			Fruit retention (%)		
	Without S	With S	Mean	Without S	With S	Mean
First season						
Control	13.36g	13.39g	13.38**D**	13.30f	13.32f	13.31**D**
Wood ash625 (g/tree/year)	18.30f	22.13d	20.22**C**	18.70e	18.78e	18.74**C**
Wood ash1250 (g/tree/year)	20.41e	25.99b	23.20**B**	20.73d	21.41c	21.07**B**
Wood ash2500 (g/tree/year)	23.22c	30.01a	26.61**A**	22.68b	23.34a	23.01**A**
Mean	18.82**B**	22.88**A**		18.85**B**	19.21**A**	
Second season						
Control	14.63g	14.66g	14.64**D**	13.52g	13.54g	13.53**D**
Wood ash625 (g/tree/year)	19.57f	23.40d	21.49**C**	16.06f	16.85e	16.46**C**
Wood ash1250 (g/tree/year)	21.68e	27.26b	24.47**B**	18.75d	19.43c	19.09**B**
Wood ash2500 (g/tree/year)	24.49c	31.28a	27.88**A**	20.81b	22.15a	21.48**A**
Mean	20.09**B**	24.15**A**		17.29**B**	17.99**A**	

Means having the same letter (s) in each row, column or interaction are insignificantly different at 5% level.

Number of fruits/tree and fruit weight (g)

Data in table (7): showed the effect of wood ash, sulfur and their interaction on number of fruits/tree and fruit weight (g) of Valencia orange trees during 2020 and 2021 seasons.

Regarding to wood ash treatments, the treatment 2500 g/tree/year had highest significant values on number of fruits/tree and fruit weight (g)in both seasons. Concerning sulfur (S) treatments, the addition of sulfur (S) had higher significant values than without sulfur (S) on number of fruits/tree and fruit weight (g) in both seasons. The interaction between two studies factors, the treatment of wood ash at 2500 g/tree/year with addition of sulfur (S) revealed to highest significant values on number of fruits/tree and fruit weight (g)in both seasons.

Yield (kg)/tree, yield (ton/fed) and yield increment (%) over the control

Data in table (8): showed the effect of wood ash, sulfur and their interaction on yield (kg)/tree, yield (ton/fed) and yield increment (%) of Valencia orange trees during 2020 and 2021 seasons.

Regarding to wood ash treatments, the treatment 2500 g/tree/year had highest significant values on yield (kg)/tree, yield (ton/fed) and yield increment percentage over the control in both seasons. Concerning sulfur (S) treatments, the addition of sulfur (S) had higher significant values than without sulfur (S) on yield (kg)/tree, yield (ton/fed) and yield increment percentage over the control in both seasons. The interaction between two studies factors, the treatment of wood ash at 2500 g/tree/year with addition of sulfur (S) revealed to highest significant values on yield (kg)/tree, yield (ton/fed) and yield increment percentage over the control in both seasons.

Table (7). Effect of wood ash, sulfur and their interaction on number of fruits/tree and fruit weight (g) of Valencia orange trees during 2020 and 2021 seasons

Treatments	No. fruits/tree			Fruit weight (g)		
	Without S	With S	Mean	Without S	With S	Mean
First season						
Control	204.0g	205.3g	204.7**D**	182.1g	182.8g	182.5**D**
Wood ash625 (g/tree/year)	210.3f	227.7d	219.0**C**	190.0f	209.7d	199.8**C**
Wood ash1250 (g/tree/year)	214.7e	244.0b	229.3**B**	201.3e	228.4b	214.9**B**
Wood ash2500 (g/tree/year)	233.3c	271.7a	252.5**A**	220.0c	238.5a	229.3**A**
Mean	215.6**B**	237.2**A**		198.3**B**	214.9**A**	
Second season						
Control	212.0f	213.7f	212.8**D**	187.2g	187.5g	187.3**D**
Wood ash625 (g/tree/year)	228.0e	240.7d	234.3**C**	193.0f	208.7d	200.9**C**
Wood ash1250 (g/tree/year)	228.3e	257.3b	242.8**B**	203.8e	229.2b	216.5**B**
Wood ash2500 (g/tree/year)	250.7c	281.3a	266.0**A**	220.9c	246.4a	233.6**A**
Mean	229.8**B**	248.3**A**		201.2**B**	217.9**A**	

Means having the same letter (s) in each row, column or interaction are insignificantly different at 5% level.

Table (8). Effect of wood ash, sulfur and their interaction on yield (kg)/tree, yield (ton/fed) and yield increment (%)of Valencia orange trees during 2020 and 2021 seasons

Treatments	Yield (kg)/tree			Yield (ton/fed)			Yield increment (%) over the control		
	Without S	With S	Mean	Without S	With S	Mean	Without S	With S	Mean
First season									
Control	37.14g	37.54g	37.34**D**	6.24g	6.31g	6.27**D**	0.00g	0.00g	0.00**D**
Wood ash625 (g/tree/year)	39.96f	47.73d	43.85**C**	6.71f	8.02d	7.37**C**	7.58f	27.15d	17.36**C**
Wood ash1250 (g/tree/year)	43.21e	55.74b	49.48**B**	7.26e	9.36b	8.31**B**	16.35e	48.47b	32.41**B**
Wood ash2500 (g/tree/year)	51.34c	64.80a	58.07**A**	8.63c	10.89a	9.76**A**	38.23c	72.61a	55.42**A**
Mean	42.91**B**	51.45**A**		7.21**B**	8.64**A**		15.54**B**	37.06**A**	
Second season									
Control	39.68g	40.06g	39.87**D**	6.67g	6.73g	6.70D	0.00g	0.00g	0.00**D**
Wood ash625 (g/tree/year)	44.00f	50.24d	47.12**C**	7.39f	8.44d	7.92C	10.88f	25.41d	18.15**C**
Wood ash1250 (g/tree/year)	46.53e	58.98b	52.76**B**	7.82e	9.91b	8.86B	17.28e	47.25b	32.26**B**
Wood ash2500 (g/tree/year)	55.36c	69.32a	62.34**A**	9.30c	11.65a	10.47A	39.53c	73.06a	56.30**A**
Mean	46.39**B**	54.65**A**		7.79**B**	9.18**A**		16.92**B**	34.43**A**	

Means having the same letter (s) in each row, column or interaction are insignificantly different at 5% level.

Data in table (9): showed the effect of wood ash, sulfur and their interaction on fruit volume, fruit length (cm) and fruit diameter (cm) of Valencia orange trees during 2020 and 2021 seasons.

Fruit volume, fruit length (cm) and fruit diameter (cm)

Regarding to wood ash treatments, the treatment 2500 g/tree/year had highest significant values on fruit volume, fruit length and fruit diameter in both seasons. Concerning sulfur (S) treatments, the addition of sulfur (S) had higher significant values than without sulfur (S) on fruit volume, fruit length and fruit diameter in both seasons. The interaction between two studies factors, the treatment of wood ash at 2500 g/tree/year with addition of sulfur (S) had highest significant values on fruit volume, fruit length and fruit diameter in both seasons.

Table (9). Effect of wood ash, sulfur and their interaction on fruit volume(cm^3), fruit length (cm) and fruit diameter (cm) of Valencia orange trees during 2020 and 2021 seasons

Treatments	Fruit volume (cm^3)			Fruit length (cm)			Fruit diameter cm)		
	Without S	With S	Mean	Without S	With S	Mean	Without S	With S	Mean
First season									
Control	187.7g	188.5g	188.1**D**	6.53d	6.55d	6.54**C**	6.48d	6.52d	6.50**C**
Wood ash625 (g/tree/year)	190.7f	212.0d	201.3**C**	7.25c	7.59d	7.42**B**	7.11c	7.47b	7.29**B**
Wood ash1250 (g/tree/year)	204.7e	231.0b	217.8**B**	7.17c	7.66b	7.42**B**	7.04c	7.55b	7.29**B**
Wood ash2500 (g/tree/year)	222.0c	240.7a	231.3**A**	7.53b	7.86a	7.70**A**	7.45b	7.76a	7.61**A**
Mean	201.3**B**	218.0**A**		7.12**B**	7.42**A**		7.02**B**	7.33**A**	
Second season									
Control	189.7h	191.1g	190.4**D**	6.72d	6.74d	6.73**C**	6.67e	6.65e	6.66**C**
Wood ash625 (g/tree/year)	195.0f	211.3d	203.2**C**	7.23c	7.62b	7.43**B**	7.12d	7.51bc	7.32**B**
Wood ash1250 (g/tree/year)	206.3e	231.7b	219.0**B**	7.26c	7.69b	7.48**B**	7.13d	7.62b	7.38**B**
Wood ash2500 (g/tree/year)	224.0c	249.0a	236.5**A**	7.57b	7.86a	7.72**A**	7.46c	7.75a	7.60**A**
Mean	203.8**B**	220.8**A**		7.20**B**	7.48**A**		7.09**B**	7.38**A**	

Means having the same letter (s) in each row, column or interaction are insignificantly different at 5% level.

Data in table (10): revealed to the effect of wood ash, sulfur and their interaction on fruit shape index and rind thickness (mm) of Valencia orange trees during 2020 and 2021 seasons.

Fruit shape index

All treatments of wood ash, sulfur (S) and interaction between two studies factors, showed insignificant differences among treatments in both seasons.

Rind thickness (mm)

Concerning to wood ash treatments, control treatment had lowest significant values. Regarding to sulfur treatment without sulfur (S) treatment had lower values than that with sulfur (S) in both seasons. The interaction between two studies factors, control treatment of wood ash with the treatment of without and with sulfur had lowest significant values in both seasons.

Table (10). Effect of wood ash, sulfur and their interaction on fruit shape index and rind thickness (mm) of Valencia orange trees during 2020 and 2021 seasons

Treatments	Fruit shape index			Rind thickness (mm)		
	Without S	With S	Mean	Without S	With S	Mean
First season						
Control	1.008a	1.006a	1.007**A**	0.367f	0.369f	0.368**D**
Wood ash625 (g/tree/year)	1.019a	1.016a	1.017**A**	0.403e	0.445cd	0.424**C**
Wood ash1250 (g/tree/year)	1.019a	1.015a	1.017**A**	0.427de	0.484ab	0.456**B**
Wood ash2500 (g/tree/year)	1.011a	1.012a	1.011**A**	0.464bc	0.510a	0.487**A**
Mean	1.014**A**	1.012**A**		0.415**B**	0.452**A**	
Second season						
Control	1.008a	1.013a	1.011**A**	0.379f	0.380f	0.380**D**
Wood ash625 (g/tree/year)	1.016a	1.014a	1.015**A**	0.411e	0.452cd	0.431**C**
Wood ash1250 (g/tree/year)	1.018a	1.009a	1.014**A**	0.433de	0.487ab	0.460**B**
Wood ash2500 (g/tree/year)	1.015a	1.015a	1.015**A**	0.469bc	0.513a	0.491**A**
Mean	1.014**A**	1.013**A**		0.423**B**	0.458**A**	

Means having the same letter (s) in each row, column or interaction are insignificantly different at 5% level.

TSS (%) and TSS/acid ratio

Data in table (11): revealed to the effect of wood ash, sulfur and their interaction on TSS (%), acidity (%) and TSS/acid ratio of Valencia orange trees during 2020 and 2021 seasons.

Regarding to wood ash treatments, the treatment 2500 g/tree/year had highest significant values on TSS and TSS/acid ratio in both seasons. Concerning sulfur (S) treatments, the addition of sulfur (S) had higher significant values than without sulfur (S) on TSS and TSS/acid ratio in both seasons. The interaction between two studies factors, the treatment of wood ash at 2500 g/tree/year with addition of sulfur (S) revealed to highest significant values on TSS and TSS/acid ratio in both seasons.

Acidity (%)

Regarding wood ash treatments, all wood ash treatments had lower acidity than control in both seasons. Concerning sulfur (S) treatments, the addition of sulfur recorded lower values than without values. The interaction between two studies factors, the treatment of wood ash at 2500 g with sulfur addition showed higher values than most of other treatments.

Total sugars (%), vitamin C (mg/100g f. w.) and Juice percentage

Data in table (12): showed the effect of wood ash, sulfur and their interaction on total sugars (%), vitamin C and Juice % of Valencia orange trees during 2020 and 2021 seasons.

Regarding to wood ash treatments, the treatment 2500 g/tree/year had highest significant values on total sugars (%), vitamin C and Juice percentage in both seasons. Concerning sulfur (S) treatments, the addition of sulfur (S) had higher significant values than without sulfur (S) on total sugars (%), vitamin C and Juice percentage in both seasons. The interaction between two studies factors, the treatment of wood ash at 2500 g/tree/year with addition of sulfur (S) revealed to highest significant values of total sugars (%), vitamin C and Juice percentage in both seasons.

Table (11). Effect of wood ash, sulfur and their interaction on TSS (%), acidity (%) and TSS/acid ratio of Valencia orange trees during 2020 and 2021 seasons

Treatments	TSS (%)			Acidity (%)			TSS/acid ratio		
	Without S	With S	Mean	Without S	With S	Mean	Without S	With S	Mean
First season									
Control	8.40f	8.43f	8.42**D**	0.970a	0.972a	0.971**A**	8.66g	8.60g	8.63**D**
Wood ash625 (g/tree/year)	9.69e	10.56c	10.13**C**	0.870ab	0.800bc	0.835**B**	11.14f	12.04c	11.59**C**
Wood ash1250 (g/tree/year)	10.14d	11.10b	10.62**B**	0.850bc	0.757c	0.803**B**	11.93e	13.03b	12.48**B**
Wood ash2500 (g/tree/year)	10.49c	11.80a	11.14**A**	0.852bc	0.740c	0.786**B**	12.61d	14.12a	13.37**A**
Mean	9.68**B**	10.47**A**		0.880**A**	0.817**B**		11.08**B**	11.95**A**	
Second season									
Control	8.51f	8.52f	8.51**D**	0.980a	0.982a	0.981**A**	8.75g	8.67g	8.71**D**
Wood ash625 (g/tree/year)	9.76e	10.62c	10.19**C**	0.877b	0.803b-d	0.840**B**	12.20f	13.23e	12.71**C**
Wood ash1250 (g/tree/year)	10.20d	11.17b	10.69**B**	0.852bc	0.763cd	0.808**B**	13.48c	14.64b	14.06**B**
Wood ash2500 (g/tree/year)	10.58c	11.89a	11.24**A**	0.835b-d	0.744d	0.790**B**	14.30d	15.98a	15.14**A**
Mean	9.76**B**	10.55**A**		0.886**A**	0.823**B**		12.18**B**	13.13**A**	

Means having the same letter (s) in each row, column or interaction are insignificantly different at 5% level.

Table (12). Effect of wood ash, sulfur and their interaction on total sugars (%), vitamin C and Juice percentage of Valencia orange trees during 2020 and 2021 seasons

Treatments	Total sugars (%)			Vitamin C(mg/100g f. w.)			Juice (%)		
	Without S	Without S	Without S	Without S	Without S	With S	Without S	With S	Mean
First season									
Control	6.73f	6.78f	6.75**D**	40.32g	40.34g	40.33**D**	55.97g	56.00g	55.99**D**
Wood ash 625 (g/tree/year)	8.02e	8.89c	8.46**C**	44.24f	48.20d	46.22**C**	61.43f	65.41c	63.42**C**
(g/tree/year)1250 Wood ash	8.47d	9.43b	8.95**B**	46.34e	51.55b	48.94**B**	63.45e	67.63b	65.54**B**
Wood ash) 2500 (g/tree/year	8.82c	10.13a	9.47**A**	49.39c	54.82a	52.11**A**	64.23d	69.67a	66.95**A**
Mean	8.01**B**	8.81**A**		45.07**B**	48.73**A**		61.27**B**	64.68**A**	
Second season									
Control	6.84f	6.86f	6.85**D**	40.53h	50.55c	45.54**D**	56.12g	56.14g	56.13**D**
Wood ash625 (g/tree/year)	8.09e	8.95c	8.52**C**	44.29g	48.35e	46.32**C**	61.62f	65.63c	63.63**C**
Wood ash1250 (g/tree/year)	8.53d	9.50b	9.02**B**	46.40f	51.65b	49.02**B**	63.65e	67.90b	65.78**B**
Wood ash2500 (g/tree/year)	8.91c	10.22a	9.57**A**	49.44c	54.87a	52.16**A**	64.40d	69.90a	67.15**A**
Mean	8.09**B**	8.88**A**		45.16**B**	51.35**A**		61.45**B**	64.89**A**	

Means having the same letter (s) in each row, column or interaction are insignificantly different at 5% level.

Data in table (13): showed the effect of wood ash, sulfur and their interaction on nitrogen %, phosphor % and potassium of Valencia orange trees during 2020 and 2021 seasons.

Nitrogen, phosphor and potassium (percentage)

Regarding to wood ash treatments, the treatment 2500 g/tree/year had highest significant values on nitrogen, phosphor and potassium (percentage) in both seasons. Concerning sulfur (S) treatments, the addition of sulfur (S) had higher significant values than without sulfur (S) on nitrogen, phosphor and potassium (percentage) in both seasons. The interaction between two studies factors, the treatment of wood ash at 2500 g/tree/year with addition of sulfur (S) revealed to highest significant values of nitrogen, phosphor and potassium (percentage) in both seasons.

Table (14). Effect of wood ash, sulfur and their interaction on nitrogen %, phosphor % and potassium of Valencia orange trees during 2020 and 2021 seasons

Treatments	N (%)			P (%)			K (%)		
	Without S	With S	Mean	Without S	With S	Mean	Without S	With S	Mean
First season									
Control	1.91d	1.93d	1.92**D**	0.197d	0.198d	0.198**C**	1.15e	1.17e	1.16**D**
Wood ash625 (g/tree/year)	2.18c	2.35bc	2.27**C**	0.222cd	0.244bc	0.233**B**	1.24e	1.36d	1.30**C**
Wood ash1250 (g/tree/year)	2.23c	2.65a	2.44**B**	0.234bc	0.255ab	0.244**AB**	1.49bc	1.40cd	1.45**B**
Wood ash2500 (g/tree/year)	2.42b	2.69a	2.56**A**	0.239bc	0.277a	0.258**A**	1.58b	1.84a	1.71**A**
Mean	2.19**B**	2.40**A**		0.223**B**	0.244**A**		1.37**B**	1.44**A**	
Second season									
Control	1.93e	1.95e	1.94**D**	0.199d	0.202d	0.201**C**	1.17e	1.19e	1.18**D**
Wood ash625 (g/tree/year)	2.20d	2.37bc	2.29**C**	0.224cd	0.246bc	0.235**B**	1.27e	1.38d	1.32**C**
Wood ash1250 (g/tree/year)	2.27cd	2.66a	2.46**B**	0.237bc	0.258ab	0.247**AB**	1.51c	1.42cd	1.46**B**
Wood ash2500 (g/tree/year)	2.45b	2.73a	2.59**A**	0.242bc	0.280a	0.261**A**	1.61b	1.85a	1.73**A**
Mean	2.21**B**	2.43**A**		0.226**B**	0.247**A**		1.39**B**	1.46**A**	

Means having the same letter (s) in each row, column or interaction are insignificantly different at 5% level.

The optimum level of nitrogen, phosphor and potassium in orange trees leaves = 2.5 – 2.7 % Nitrogen, 0.12 – 0.16 % phosphor and 1.2 – 1.7 % potassium **(Koo *et al.* 1984**).

Data in table (14): showed the effect of wood ash, sulfur and their interaction on calcium %and magnesium (%) of Valencia orange trees during 2020 and 2021 seasons.

Calcium and magnesium percentage

Regarding to wood ash treatments, the treatment 2500 g/tree/year had highest significant values on calcium and magnesium percentage in both seasons. Concerning sulfur (S) treatments, the addition of sulfur (S) had higher significant values than without sulfur (S) on calcium and magnesium percentage in both seasons. The interaction between two studies factors, the treatment of wood ash at 2500 g/tree/year with addition of sulfur (S) revealed to highest significant values of calcium and magnesium percentage in both seasons.

Table (14). Effect of wood ash, sulfur and their interaction on calcium %and magnesium (%) of Valencia orange trees during 2020 and 2021 seasons

Treatments	Ca (%)			Mg (%)		
	Without S	With S	Mean	Without S	With S	Mean
First season						
Control	3.00g	3.02g	3.01**D**	0.419f	0.421f	0.420**D**
Wood ash625 (g/tree/year)	3.35f	3.79d	3.57**C**	0.538e	0.653c	0.596**C**
Wood ash1250 (g/tree/year)	3.58e	3.91c	3.75**B**	0.594d	0.755ab	0.675**B**
Wood ash2500 (g/tree/year)	4.11b	4.46a	4.28**A**	0.715b	0.796a	0.756**A**
Mean	3.51**B**	3.79**A**		0.567**B**	0.656**A**	
Second season						
Control	3.07f	3.09f	3.08**D**	0.428g	0.430g	0.429**D**
Wood ash625 (g/tree/year)	3.42e	3.83c	3.63**C**	0.547f	0.662d	0.605**C**
Wood ash1250 (g/tree/year)	3.63d	3.94c	3.79**B**	0.603e	0.764b	0.684**B**
Wood ash2500 (g/tree/year)	4.14b	4.47a	4.31**A**	0.724c	0.805a	0.765**A**
Mean	3.57**B**	3.83**A**		0.576**B**	0.665**A**	

Means having the same letter (s) in each row, column or interaction are insignificantly different at 5% level.

The optimum level of calcium and magnesium in orange trees leaves = 3.0 – 4.9 % calcium and 0.30 – 0.49 % magnesium **(Koo *et al*. 1984).**

Data in table (15): showed the effect of wood ash, sulfur and their interaction on iron ppm, zinc ppm and manganese ppm of Valencia orange trees during 2020 and 2021 seasons.

Iron, zinc and manganese (ppm)

Regarding to wood ash treatments, the treatment 2500 g/tree/year had highest significant values on iron, zinc and manganese (ppm) in both seasons. Concerning sulfur (S) treatments, the addition of sulfur (S) had higher significant values than without sulfur (S) on iron, zinc and manganese (ppm) in both seasons. The interaction between two studies factors, the treatment of wood ash at 2500 g/tree/year with addition of sulfur (S) revealed to highest significant values of iron, zinc and manganese (ppm) in both seasons.

These results were in a harmony with those found by **(Jonna, 2017)** who found that wood ash contains many important plant nutrients such as potassium (K) and phosphorus (P) and can be used as a fertilizer. Furthermore, (**Sabin, 2022**) wood ash has 3% potassium in it, which is an essential nutrient for plant growth and development. **Demeyer *et. al.* (2001)** reported high levels of Ca and K and occasionally Mg, in form of oxides, hydroxides and carbonates. **Marschner (1995). Pavlista (2005). Heeb (2006)** found that sulfur plays an important role in yield and quality of crops. Briefly, Valencia orange trees grown under desert stress soil condition gave with wood ash the best results of growth, yield and fruit quality.

Table (15). Effect of wood ash, sulfur and their interaction on iron ppm, zinc ppm and manganese ppm of Valencia orange trees during 2020 and 2021 seasons

Treatments	Fe (ppm)			Zn (ppm)			Mn (ppm)		
	Without S	With S	Mean	Without S	With S	Mean	Without S	With S	Mean
First season									
Control	74.35f	74.38f	74.37**D**	49.76g	49.80g	49.78**D**	63.27g	63.31g	63.29**D**
Wood ash625 (g/tree/year)	76.33e	79.61d	77.97**C**	51.19f	54.52d	52.6**C**	66.51f	71.26d	68.88**C**
Wood ash1250 (g/tree/year)	79.15d	83.66b	81.41**B**	52.70e	56.99c	54.85**B**	68.51e	77.66b	73.09**B**
Wood ash2500 (g/tree/year)	80.63c	86.23a	83.43**A**	59.90b	62.61a	61.25**A**	72.48c	83.67a	78.08**A**
Mean	77.61**B**	80.97**A**		53.39**B**	55.98**A**		67.69**B**	73.97**A**	
Second season									
Control	74.50f	74.57f	74.54**D**	50.51g	50.55g	50.53**D**	64.22g	64.26g	64.24**D**
Wood ash625 (g/tree/year)	76.48e	79.76d	78.12**C**	51.94f	55.27d	53.61**C**	67.46f	72.21d	69.83**C**
Wood ash1250 (g/tree/year)	79.30d	83.81b	81.56**B**	53.45e	57.74c	55.60**B**	69.46e	78.61b	74.04**B**
Wood ash2500 (g/tree/year)	80.78c	86.38a	83.58**A**	60.65b	63.36a	62.00**A**	73.43c	84.62a	79.03**A**
Mean	77.76**B**	81.13**A**		54.14**B**	56.73**A**		68.64**B**	74.92**A**	

Means having the same letter (s) in each row, column or interaction are insignificantly different at 5% level.

The optimum level of iron, zinc and manganese in orange trees leaves = 60- 120 ppm iron, 25 – 100 ppm zinc and 25-100 ppm manganese **(Koo *et al*. 1984)**.

Conclusion

Finally, it could be concluded that adding wood ash at 2500g/tree/year with 500gm sulfur (S)/ tree as soil application as the most appropriate treatment enhanced fruit quality of Valencia orange under desert stress conditions, where improved natural and chemical properties of fruits. On the other side, reduced rind thickness, fruit total acidity content. This treatment was proved to be the most efficient in enhancing, the yield and fruit quality of the cultivar had been studied.

REFERENCES

A.O.A.C. (1995). Association of Official Agricultural Chemists, Official Methods of Analysis, 15th ed. A.O.A.C., Washington, DC.

Association of Official Agricultural Chemists (2000). Official Methods of Analysis (A.O.A.C.) 12th Ed. Benjamin Franklin Station, Washington D.C.U.S.A. pp: 490-510.

A.O.A.C, (1990). Official methods of analysis. The association of official analytical chemists. Artlingt on, West Virginia, USA 15th Ed. Washington D.C.

Campbell, A.G. (1990). Recycling and disposing of wood ash. Tappi. Journal, 73: 141-146.

Cottenie, A.; Verloo, M.; Kiekens, L.; Velgh, G. and Camerlynk, R. (1982). Chemical Analysis of Plants and Soils. State Univ. Ghent, Belgium, 63: 44-45.

Demeyer, A.; Voundi, J.C. and Verloo, M.G. (2001). Characteristics of wood ash and influence on soil properties and nutrient uptake: an overview. Bioresource Technology, 77(3): 287-295.

Dubois, M.; Gilles, K.; Hamilton, J.K.; Rebers, P.A. and Smith, F. (1956): A colorimetric method for the determination of sugars and related substances. Anal. Chem. 28: p.350

Duncan, D.B. (1955). Multiple Range and Multiple F Tests. Biometrics, 11: 1-42.

Erdal, I. and Tarakç olu, C. (2000). Effect of different organic materials on growth and mineral composition of corn plant (*Zea mays* L.). J. Agric. Sci., 15(2): 80-85.

Heeb, A.; Lundegardh, B.; Savage G. and Ericsson, T. (2006). Impact of organic and inorganic fertilizers on yield, taste and nutritional quality of tomatoes. J. Plant Nutr. Soil Sci., 69: 535-541.

Wu, G. A.; Javier, T.; Victoria, I.; López-García, A. and Pérez-Román, E. (2018). Genomics of the origin and evolution of Citrus.

Jackson, M.L. (1973). Soil chemical Analysis. Prentice- Hall of India Private Limited, New Delhi.

Jayalakshmi, C. (2020). Yield performance of mango (*Mangifera indica* L.) Genotypes under the condition of theni. Agricultural science paripex. Volume-9.

Jonna, W. (2017). Effects of wood ash on soil fertility and plant Performance in southwestern Kenya Master's Thesis in Soil Science Agriculture Program me – Soil and Plant Sciences 16.

Koo *et al*. (1984). Guideline for interpreting orange tree leaf analysis based on four- to six –month – old spring flush leaves from non- fruiting twigs.

M.A.L.R. (2012). Ministry of Agriculture and Land Reclamation, Central Administration of Agricultural Economics, Egypt. Economic Affairs Sector (EAS), Agricultural Statistics, 2: 328.

Marschner, H. (1995). Mineral Nutrition in Higher Plants. Acad. Press, London.

Pavlista, A.D. (2005). Early-season application of sulfur fertilizers increase potato yield and reduce tuber defects. Agron. J., 97: 599-603.

Puvan, P.; Osumanu, H.; Ahmed, L. O.; Huck Y. C.; Prisca, D. J. (2021) han and Nur Hidayah Hamidi Co-Application of Charcoal and Wood Ash to Improve Potassium Availability in Tropical Mineral Acid Soils.

Sanin, A (2022). The benefits of fertilizing fruit trees with wood ashes. All rights reserved to SabinoCanyon.com.

Snedecor, G.W. and Cochran W.G. (1980). Statistical Methods. 7th Ed. Iowa State, Univ. Press. Ames, Iowa, U.S.A. pp: 507.

Someshwar, A.V. (1996). Wood and combination wood-fired boiler ash characterization. Journal of Environmental Quality, 25: 962-972.