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EFFECT OF SULFUR SOURCES, RATES AND METHODS OF APPLICATION ON GROWTH, YIELD, FRUIT QUALITY, LEAF MINERAL CONTENT AND SOME SOIL PROPERTIES OF "VALENCIA" ORANGE ORCHARDS

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Abstract

Field experiment was conducted to assess the impact of added two sulfur sources [elemental sulfur (S) and sulfur mixture (SM)] with different rates [S or SM equivalent gypsum requirements SR, SMR and SR or SMR +/- 25%] and 2 methods of application [broadcast under the tree canopy (M1) and banded at the edge of the tree skirt (M2)] at two selected alkali "Valencia" orange orchards in kafr El-sheikh Governorate in two successive seasons, 1998 and 1999 on some soil properties, growth, yield, fruit quality and leaf mineral content .

Most soil chemical (pH, SAR, Na/Cl, and EC) and physical (A.I, I.R, and Cr) properties were markedly improved by SMR or SR with M1 application. Moreover, total N and P, K, Fe, Zn, Mn and Cu solubility and availability were increased particularly in the surface layer with slightly Ec increasing in the deepest layer.

Consequently, the greatest fibrous root density with a more typical distribution, highest vegetative growth (as indexed by shoot length and number and leaf area and D.W) and less preharvest fruit drop were noticed, thus, the highest yield with enhanced fruit quality was obtained. SM treatments gave the highest vegetative growth and yield followed by S treatments.

Meanwhile, soil physical and chemical properties improvement were decreased, EC and Ca^{++} percentage were increased and the availability of many macro and micronutrient were negatively affected by more S or SM addition than SR or SMR treatments. Therefore, the vegetative growth and yield were decreased compared to S or SM treatments.

SMR or SR application with M1 slightly increased leaf N, P, Fe, Zn, Mn and Cu while K was slightly decreased, however, they were progressively decreased with increasing S or SM particularly micronutrients without significant differences among all S or SM treatments.

It could be concluded that SMR or SR application with M1 was the best treatment to improve or to conserve, increase fertilizers use efficiency and may overcome salt effects for increasing the productivity of "Valencia" orange trees with best fruit quality.

INTRODUCTION

Salinity and alkalinity are the main problems in many arid and semi - arid regions of the world which limit citrus growth and productivity. Alkalinity affects most soil chemical, physical, biological properties and some nutrient elements solubility and availability (Hilal *et al.*, 1990; Shata *et al.*, 1990; Spiers and Braswell, 1992 and Koriem, 1994).

Low yielding and development of citrus orchards area were associated with soil having; highly alkaline, lower infiltration velocity and permeability, heavy texture which had few non-capillary pores and bad structure, strongly saline due to capillary action, highly compacted and highly ESP (Koudounas, 1994; Nunez-Moreno and Valdez-Gascon, 1994 and Sagee *et al.*, 1994), and excessively accumulation of Ca, P, Mg and K and some micro-nutrient unavailability in the rhizosphere (Pavan and Wutscher, 1993 and Nunez-Moreno and Valdez-Gascon,1994).

It is well known that citrus do best at neutral or close to neutral pH (Anderson and Martin, 1970). In Egypt, the majority of citrus bearing areas are located on soils that are inherently basic (MAFS, 1987) which decreased productivity. Without an adequate chemical amendment program, these soils might become more basic. Therefore, the need of soil chemical amendment program is evident.

Recently, there has been an increasing concern about the role of sulfur application as a soil amendment and as a factor increasing fertilizer use efficiency in alkali soil (Hilal *et al.*, 1990). Sulfur application plays several important roles in soils, such as, reducing soil pH, improving water relations, increasing solubility and availability of some nutrient elements, i.e. S, P, Fe, Mn and Zn (Hilal *et al.*, 1990 and Mostafa *et al.*, 1990), improving soil aggregation, structure, permeability, infiltration, EC and SAR values (Khafagi and Abdelhadi, 1990; Shata *et al.*, 1990; Spiers and Braswell, 1992 and Koriem, 1994) and may overcome the harmful effect of saline water application (Mostafa *et al.*, 1990) .

The acidulation effect of sulfur exceeds that of all other amendments and the rate of sulfur oxidation is dependent on several factors such as microbial type, population and temperature (Shata *et al.*, 1990). Moreover, methods of application are simple and do not require special tools or equipments. Sulfur is frequently considered the most important amendment for alkali soil reclamation. In general sulfur seems to promote rhizosphere activity. Therefore, attention has been paid to the application of sulfur as soil amendment to correct alkaly soil (Shata *et al.*, 1990).

This study was carried out to assess the adequate sulfur or sulfur mixture rate with some application methods required to correct alkaly orchard soil at two sites in Kafr El-sheikh governorate, for increasing yield and improving fruit quality of "Valencia" orange trees.

MATERIALS AND METHODS

Field soil and trees: The present study was carried out during 1998 and 1999 seasons. Two sites varying in its soil chemical, physical properties and sulfur requirements (Table 1) in Kafr El-Sheikh governorate, were selected. The two soils were classified as clay loam (38.2% and 36.9% clay) with 1.4 and 1.25 m water table, respectively. For site 1 (slightly alkaline soil) and site 2 (slightly saline alkaline soil) seventy eight uniform 18 and 22 years old "Valencia" orange trees on sour orange rootstock, planted at 5x5 meters were selected. Each treatment was replicated by two trees plot three times in a randomized complete block design. The replicates were surrounded on all sides by guard rows. All trees received the regular fertilization and cultivation practices as recommended by the Ministry of Agriculture.

Table 1. Some initial soil chemical and physical properties of the selected sites, and its sulfur requirements in November 1997.

Location	Some chemical properties				Some physical properties					GR (Ton/ fed)	S or SM (Ton / fed)
	EC (ds/m)	pH	SAR	Na/Ca	W.S.A (%)	A.I	M.W.D	I.R	Cr		
Site 1	3.28	8.63	7.05	2.29	8.54	0.16	0.92	251	1.76	2.13	0.396
Site 2	4.19	8.41	9.64	3.26	6.32	0.13	0.85	272	1.63	4.86	0.908

W.S.A = Water stable aggregates. M .W.D = Mean Weight Diameter. A.I = Aggregation index.
Cr = Structure coefficient. I.R = Infiltration rate (time in minutes). GR = Gypsum requirements.

Sulfur treatments: (a) Source: Two sulfur sources were used, 99.5% elemental sulfur and sulfur mixture (39% elemental sulfur with sulfur oxidation bacteria, 49% some fertilizer elements and 12% Nile fraction extract) produced by the National Research Center.

(b) Rates: three sulfur and sulfur mixture rates were used as tabulated in table (2). Gypsum requirements were determined, then sulfur requirements was calculated (one ton of sulfur is equivalent to 5.38 tons of Gypsum) according to Chapman and Pratt (1978) and the amount of sulfur mixture = the amount of sulfur requirements.

Table 2. The used treatments.

Sulfur levels	Site 1				Site 2			
	GR (ton/fed)	SR or SMR (ton/fed)	Kg/ tree	Kg/ plot	GR (ton/fed)	SR or SMR (ton/fed)	Kg/ tree	Kg/ plot
Control	...	...	...	...	...	...	...	...
SR or SMR -25%	1.598	0.297	1.768	3.536	3.645	0.681	4.054	8.108
SR or SMR	2.13	0.396	2.357	4.714	4.86	0.908	5.405	10.81
SR or SMR +25%	2.66	0.459	2.946	5.892	6.08	1.131	6.756	13.513

GR = Gypsum Requirements. SMR = the amount of SR.S = elemental sulfur. SM = Sulfur mixture.
SR = Sulfur requirements. Values indicated are the amount added per application.

(c) Methods of application: Sulfur or sulfur mixture were applied by two methods (Koriem, 1994): (M1) broadcasting on the surface soil under the tree canopy, 50 cm away from the tree trunk. (M2): banded in a hole under the edge of the tree skirt.

The soil was hoed after sulfur or sulfur mixture addition to mix it with soil and drains were deepened. The orchards were directly irrigated afterwords. Care was taken to irrigate each plot alone to prevent the migration from one plot to another.

Tree growth and leaf analysis: (a) Vegetative growth: Four main branches on each tree in different directions were labeled. All shoots on these branches in the growing cycles were numbered and measured, then the average length / shoot was calculated. Also, sixty mature leaves per replicate were taken in August and November 1998 and 1999, respectively (Embleton *et al.*, 1978). Leaf area was measured as cm^2 according to Singh and Snyder (1984). Leaf sample were cleaned with damp cloth, and then washed three times with redistilled water. Dry weight was estimated after being oven–dried at 65 – 70°C to a constant weight.

(b) Leaf analysis: A sub sample of 0.5 g was digested in H2SO4 and H2D2 made up to volume, filtered and then analyzed, (Cottenie, 1980). For P, K, Fe, Zn, Mn and Cu using atomic absorption (Carter, 1993). Total nitrogen was determined by modified Kjeldahl procedure according to Chapman and Pratt (1978)

(c) Fibrous root: density were determined in each soil sample taken with a hand operated well–drilling type soil auger with a cup of 10 cm in diameter to make a core of 10 cm in diameter and 30 cm depth, in December, 1997 and 1998, (Cahoon *et al.*, 1959). All samples were taken at 150 – 180 cm away from the trunk of each tree, in four directions. Fibrous roots were cleaned and their fresh weight was determined at different depth (0–30, 30–60, 60–90 and 90–120 cm), then the average root weight per core was calculated and was expressed as g/core.

Yield and fruit quality: (a) Yield was recorded at harvest time in both seasons (April, 1999 and 2000) on an individual tree basis and was expressed as total fruit number and kgs per tree.

(b) Preharvest fruit drop: The number of preharvest fruit drop was weekly recorded from August to April, and the percentage of pre harvest fruit drop was calculated per season.

(c) Fruit quality: A sample of 16 fruits were collected from each tree at harvest time for determination of fruit weight, peel thickness, total soluble solids, acidity, TSS/ acid ratio and vitamin C, (A.O.A.C., 1960).

Soil analysis: Soil samples as described aformentioned were taken from the major root zone before the commencement of the treatments and at the end of the two growing seasons. Soil samples were air dried and passed through 2 mm sieves to be ready for chemical analysis; electrical conductivity (EC), soluble ions and soil pH. Soil chemical, physical properties, nutrient availability and gypsum requirements were determined according to Chapman and Pratt (1978). Then, sulfur and sulfur mixture were calculated (one ton sulfur equivalents 5.38 ton gypsum).

Statistical analysis: The experiment was arranged in a randomized complete block design. All data were subjected to statistical analysis according to Steel and Torrie (1982).

RESULTS AND DISCUSSION

1. Soil chemo-physical properties and some soil nutrient elements:

With respect to the effect of adding SR or SMR with different rates and methods, the obtained data (Table 3) revealed that SR or SMR application caused a pronounced decrease in soil pH values within different soil layers. EC values in the upper (0–30 cm) layer decreased, meanwhile it was increased gradually with increasing soil depths. Moreover SAR values and Na/Ca ratio were greatly reduced in all soil depths. This may be due to the improvement of soil structure, consequently salt leaching through irrigation water moved downword. Also, improved aggregations index (A.I), structure coefficient (Cr) and infiltration rate (I.R) and consequently, improved soil structure and permeability. Soil structure improvement was accompanied with decreasing Ec and SAR values. As for soil nutrient elements, SR or SMR increased available soil P and micronutrients (Fe, Mn, Zn and Cu). This may be due to the reduction in soil pH values, which rather directly or indirectly lead to increasing the availability of these soil nutrients.

It could be concluded that no clear differences were noticed between S and SM effects on most soil chemical and physical properties, although, SM has lower amount of sulfur. This may be attributed to the presence of sulfur oxidation bacteria, which regulate the sulfur oxidation, also, the other sulfur mixture components. Adding S or SM was more effective in the site 2 where the soil is saline alkaline. This might be due to the presence of $CaCO_3$. Broadcast application (M1) was the most efficient for soil chemo physical properties improvement and some soil macro and micronutrients availability.

Table 3. Some chemical, physical properties and nutrient elements of the two sites soil as affected by sulfur or sulfur mixture application. (Average of 1998 and 1999).

Treatments		Chemical properties				Physical properties			Available nutrients (ppm)				
		Ec ds/m	pH	SAR	Na/Ca	A.I	I.R	Cr	P	Fe	Zn	Mn	Cu
Site 1													
Control		3.22	8.58	7.96	2.24	0.17	246	1.72	12.60	8.80	2.20	1.60	0.29
SR-25%	M1	2.73	8.17	2.33	0.66	0.34	143	2.21	18.50	15.20	3.30	5.60	0.46
	M2	2.83	8.26	2.38	0.69	0.30	148	1.93	17.30	12.40	2.90	4.80	0.38
SR	M1	2.64	7.86	2.28	0.63	0.38	141	2.49	26.40	18.60	3.90	7.40	0.56
	M2	2.68	8.08	2.32	0.66	0.32	142	2.36	25.60	17.80	3.50	6.90	0.50
SR+25%	M1	2.79	7.78	2.18	0.58	0.38	138	2.11	28.90	13.60	3.10	5.10	0.41
	M2	2.86	7.98	2.26	0.61	0.33	139	1.86	27.20	11.70	2.70	4.00	0.36
SMR-25%	M1	2.70	8.02	2.16	0.62	0.37	139	2.26	30.90	16.10	3.40	6.20	0.48
	M2	2.82	8.19	2.21	0.66	0.31	141	1.98	29.30	13.30	3.00	5.10	0.39
SMR	M1	2.63	7.76	2.11	0.57	0.40	134	2.54	30.80	19.90	4.10	7.80	0.58
	M2	2.67	8.02	2.18	0.58	0.34	135	2.42	29.60	18.40	3.80	7.30	0.52
SMR+25%	M1	2.76	7.64	2.08	0.54	0.41	132	2.18	34.60	14.40	3.20	5.40	0.43
	M2	2.85	7.83	2.13	0.56	0.36	134	1.92	33.80	12.50	2.80	4.10	0.38
Site 2													
Control		4.19	8.41	9.64	3.26	0.13	272	1.63	9.40	6.40	1.80	1.20	0.22
SR-25%	M1	3.37	8.16	2.92	0.76	0.29	156	2.09	16.90	13.80	2.60	4.90	0.36
	M2	3.47	8.24	2.96	0.80	0.22	151	1.83	15.30	12.20	2.20	4.30	0.30
SR	M1	3.27	7.91	2.89	0.71	0.33	148	2.41	22.20	16.00	3.20	5.60	0.40
	M2	3.33	8.06	2.93	0.78	0.26	152	2.32	21.60	15.50	2.90	5.10	0.38
SR+25%	M1	3.43	7.83	2.83	0.69	0.36	146	1.98	24.60	13.20	2.30	4.60	0.32
	M2	3.51	7.94	2.89	0.74	0.27	148	1.74	23.60	11.30	2.10	4.00	0.27
SMR-25%	M1	3.34	8.03	2.68	0.68	0.32	152	2.14	19.30	14.50	2.80	5.00	0.37
	M2	3.46	8.13	2.74	0.73	0.28	155	1.86	18.60	11.80	2.30	4.30	0.31
SMR	M1	3.23	7.76	2.56	0.64	0.37	145	2.46	23.80	16.30	3.40	5.90	0.41
	M2	3.31	7.91	2.61	0.70	0.29	147	2.38	22.90	15.70	3.10	5.20	0.39
SMR+25%	M1	3.40	7.68	2.54	0.62	0.38	143	2.02	24.30	13.60	2.50	4.70	0.34
	M2	3.49	7.82	2.60	0.69	0.31	146	1.80	23.70	11.40	2.10	4.20	0.28

A.I = Aggregate index. I.R = Infiltration rate (time in minutes). Cr = Structure coefficient.

Increasing S or SM application over SR or SMR did not do more developing and improving in soil chemo physical properties, but on the other hand, decreased soil structure coefficient and permeability improvement. This might be due to the decrease in aggregation parameters. Moreover EC and Ca^{++} percentage increased to the extent it might decrease the availability of many of macro and micronutrients in the soil extract.

Most chemical and physical properties improvement were largely confined to the soil surface where SR or SMR were mixed with the soil. The same trend was observed in the two selected sites in the two studed seasons.

The beneficial effects of SR or SMR were mainly attributed to the reduction of soil pH, EC, SAR, Na/Ca ratio and soil physical properties improvement which lead to better soil conditions. Consequently, increased the availability of some macro and micronutrients. These results coincide with those obtained by Singh and Sharma (1983); Modiahsh *et al.* (1989); Khafagi and Abdelhadi (1990); Hilal *et al.* (1990); Mostafa *et al.* (1990) Shata *et al.* (1990); Spiers and Braswell (1992) and Koriem (1994).

2. Growth parameters:

(a) Fibrous root density: As a result of lowering soil PH, EC, SAR, Na/Ca values and increasing soil permeability and structure improvement (Table 3) by adding SMR or SR with broadcast method (M1) which allowed better conditions for air and water movement into the soil profile, "Valencia" orange fibrous root density were significantly increased (Table 4 and 5) compared to the control trees. The highest fibrous root density increase (g/core/tree) was shown when SMR or SR was added with broadcast method (M1). With respect to the two sulfur sources, SMR had the greatest fibrous root density followed by SR, thus SMR-M1 followed by SR-M1 were the most efficient treatments. This was true for the two selected sites in the two seasons. On the contrary, more S or SM addition (SR+25%or SMR+25%) with the two methods of application decreased significantly fibrous root density (g/core/tree) compared with S or SM treatments. This may be due to the decrease in aggregation parameters. Increased ca^{++} percentage and EC occurred by adding S or SM over SR or SMR rate. Koudounas (1994) and Dawood (1996) are in accordance with the obtaining results. They mentioned that, fibrous root density, weight and distribution of citrus trees were influenced by soil characteristics. Also, Banuls *et al.* (1991) and Zikri (1993) stated that NaCl reduced root density and dry weight by approximately 30% and supplemental Ca was found to mitigate the adverse effect on plant growth.

(b) Vegetative growth: Vegetative growth parameters of "Valencia" orange trees as indexed by shoot length and number, leaf area and dry weight were significantly increased (Tables 4 and 5) by all treatments. The highest increase was obtained by SMR followed by SR when added with broadcast method (M1). This may be due to better soil characteristics attained by adding the adequate amount of SR or SMR which lead to the greatest fibrous root density (Tables 4 and 5) and the increase in some nutrient elements availability. On the other hand, adding S or SM over SR or SMR decreased significantly the vegetative growth parameters compared to S or SM treatments particularly SR or SMR treatment. This may be due to the adverse effects of adding more S or SM on soil characteristics, which affected some soil chemical, physical properties and some nutrient availability (Table 3). Obreza *et al.*, (1993); Pavan and Wutsher (1993) and Nunez-Moreno and Valdez-Gascon (1994) are in line with those reports these results.

3. Leaf mineral content:

Data of table (4 and 5) showed a slight increase in macronutrients (N, P) and micronutrients (Fe, Zn, Mn and Cu) and a slight decrease in K in leaves of "Valencia" orange trees treated with S or SM compared to the control. SR or SMR caused the highest increase with broadcast method (M1). Koriem (1994) reported the effect of S application on increasing N concentration in orange leaves. The increase of P concentration may be due to both the solubility and availability of P in soil as a result of reducing soil pH or release of P ions from soil colloids by sulfur ions. Koriem (1994) obtained similar results. The decrease in K concentration in "Valencia" orange leaves can be explained on the basis of the dilution effect (Koriem, 1994). The increase in micronutrients (Fe, Zn, Mn and Cu) in "Valencia" orange leaves may be due to either increasing its solubility and availability in soil as a result of reducing soil pH or S soil applications under the basic condition prevailing in soils, have the ability to keep nutrients soluble, stable and consequently facilitate the absorption by trees (Spiers and Braswell, 1992).

On the other hand, adding more S or SM over SR or SMR with any application method decreased the studied nutrient elements in "Valencia" orange leaves compared to SR or SMR level. This may be due to unfavorable conditions (Table 3) attained by increasing S or SM rate (SR+25% or SMR+25%), which caused high soil Ca concentration and salinity (El-Galla *et al.*, 1990 and Koriem, 1994). Also these results agree with those of Pavan and Wutscher (1993).

Table 4. Vegetative growth, root density and some leaf mineral content of Valencia orange trees as affected by sulfur or sulfur mixture at the selected sites in 1998 season.

Treatments			Shoot		Leaf		Root/ Core	Macronutrients (%)			Micronutrients (ppm)			
			Length (Cm)	No/br-anch	Area (Cm^2)	DW (mg)	(g)	N	P	K	Fe	Zn	Mn	Cu
Site 1														
Control			8.52	11.17	23.26	216	1.968	2.55	0.126	1.086	83.90	18.80	23.40	24.10
SR-	25%	M1	10.85	14.31	24.93	238	2.479	2.67	0.151	0.869	92.50	33.10	46.60	25.60
		M2	10.18	12.70	23.76	223	2.322	2.59	0.136	0.791	86.60	22.70	31.30	24.80
SR		M1	12.84	16.24	26.77	252	2.716	2.73	0.167	0.948	105.10	45.70	57.80	32.00
		M2	12.19	15.21	25.73	246	2.621	2.69	0.158	0.906	96.90	39.80	52.70	26.20
SR+	25%	M1	10.39	13.52	24.32	230	2.401	2.63	0.143	0.824	90.30	28.40	37.10	25.10
		M2	9.72	11.86	23.34	220	2.163	2.57	0.131	0.784	84.50	19.50	24.10	24.30
SMR-	25%	M1	11.33	15.08	25.68	224	2.519	2.69	0.157	0.904	96.70	37.20	51.30	26.10
		M2	10.38	13.48	24.29	229	2.366	2.62	0.142	0.832	89.30	27.60	35.40	25.60
SMR		M1	13.32	16.97	27.35	257	2.775	2.80	0.147	0.986	112.60	49.30	62.60	35.90
		M2	12.66	16.01	26.51	251	2.652	2.71	0.164	0.940	104.20	43.20	56.90	28.30
SMR+	25%	M1	10.79	14.28	24.91	236	2.440	2.65	0.149	0.858	92.40	32.30	41.60	25.20
		M2	9.91	12.62	23.72	222	2..204	2.58	0.135	0.788	85.40	21.40	30.60	24.70
L.S.D.	at	5%	0.46	0.71	0.52	4.12	0.018	0.14	0.006	0.320	7.46	2.69	3.56	4.12
		1%	0.63	0.96	0.71	5.61	0.025	0.19	0.008	0.044	10.15	3.68	4.87	5.57
Site 2														
Control			8.16	10.68	22.63	210	1.873	2.47	0.114	1.022	76.80	16.30	20.90	22.70
SR-	25%	M1	10.78	13.17	24.41	236	2.367	2.64	0.139	0.851	89.10	31.80	36.20	26.30
		M2	9.60	11.92	22.99	221	2.257	2.53	0.126	0.798	83.40	22.50	24.70	24.70
SR		M1	12.03	14.68	26.01	248	2.578	2.71	0.158	0.907	103.20	40.30	47.10	29.40
		M2	11.57	14.00	25.34	241	2.462	2.68	0.156	0.878	95.20	35.50	40.90	26.90
SR-	25%	M1	10.33	12.58	23.74	231	2.313	2.58	0.131	0.824	81.60	26.60	29.80	25.70
		M2	9.11	11.06	22.66	214	2.212	2.49	0.121	0.768	78.60	17.60	21.90	23.60
SMR-	25%	M1	11.46	13.98	25.26	240	2.435	2.67	0.148	0.871	95.00	35.20	40.60	26.50
		M2	10.02	12.58	23.68	225	2.302	2.56	0.129	0.816	86.10	26.10	29.30	25.20
SMR		M1	12.66	15.27	26.93	253	2.616	2.76	0.168	0.926	108.80	43.50	51.40	31.30
		M2	12.22	14.61	25.99	247	2.547	2.70	0.159	0.899	100.90	38.80	45.40	27.60
SMR+	25%	M1	10.32	13.34	24.40	234	2.352	2.61	0.137	0.840	87.30	30.70	34.50	26.10
		M2	9.86	11.75	23.05	220	2.264	2.51	0.123	0.783	79.30	21.80	24.20	23.90
L.S.D.	at	5%	0.43	0.59	0.63	4.29	0.024	0.12	0.008	0.016	5.52	3.12	4.32	5.13
		1%	0.58	0.81	0.86	5.87	0.033	0.16	0.011	0.022	7.54	4.26	5.90	7.01

Table 5. Vegetative growth, root density and some leaf mineral content of Valencia orange trees as affected by sulfur or sulfur mixture at the selected sites in 1999 season.

Treatments			Shoot		Leaf		Root/ core	Macronutrients (%)			Micronutrients (ppm)			
			Length (cm)	No/br-anch	Area (Cm^2)	DW (mg)	(g)	N	P	K	Fe	Zn	Mn	Cu
Site 1														
Control			8.86	11.62	23.41	219	1.984	2.63	0.128	1.092	90.10	21.20	24.80	25.40
SR-	25%	M1	11.58	13.99	25.86	241	2.498	2.68	0.149	0.859	102.50	34.80	37.90	29.90
		M2	10.00	13.17	24.60	225	2.374	2.65	0.134	0.809	94.30	25.20	28.70	26.80
SR		M1	12.95	15.58	27.03	255	2.742	2.74	0.172	0.910	109.60	45.20	53.30	32.50
		M2	12.18	14.72	26.41	249	2.598	2.70	0.159	0.881	103.40	39.80	44.90	30.70
SR+	25%	M1	10.58	13.32	25.15	231	2.418	2.66	0.139	0.834	96.20	30.40	29.30	28.50
		M2	9.13	12.16	23.78	222	2.302	2.64	0.132	0.783	91.90	22.60	56.60	25.60
SMR-	25%	M1	12.14	14.68	26.38	247	2.593	2.70	0.158	0.878	103.10	39.20	44.20	30.30
		M2	10.56	13.78	25.10	230	2.416	2.66	0.138	0.818	95.60	29.70	32.50	27.20
SMR		M1	13.47	16.27	27.51	261	2.812	2.81	0.181	0.936	114.20	50.40	59.60	34.80
		M2	12.47	15.39	26.87	254	2.658	2.71	0.168	0.900	108.20	44.30	51.10	31.20
SMR+	25%	M1	11.36	14.02	25.78	236	2.461	2.67	0.147	0.852	98.50	33.10	25.70	29.10
		M2	9.75	13.11	24.44	225	2.356	2.65	0.135	0.792	93.20	25.10	26.30	26.50
L.S.D.	at	5%	0.51	0.63	0.44	4.12	0.036	0.14	0.007	0.018	4.54	4.36	4.02	4.63
		1%	0.70	0.86	0.59	5.61	0.049	0.19	0.010	0.024	6.17	5.93	5.45	6.33
Site 2														
Control			8.42	10.86	22.72	214	1.889	2.50	0.118	1.075	88.20	18.80	23.20	24.30
SR-	25%	M1	11.97	13.52	24.93	236	2.402	2.56	0.139	0.842	93.90	29.10	39.50	30.00
		M2	10.92	12.05	23.81	223	2.302	2.53	0.126	0.782	90.60	21.60	28.40	27.30
SR		M1	12.95	15.26	26.32	250	2.691	2.62	0.162	0.915	104.90	41.10	50.40	31.80
		M2	12.41	14.42	25.69	244	2.484	2.58	0.149	0.873	97.70	35.20	44.20	30.60
SR+	25%	M1	11.39	12.67	24.41	229	2.321	2.54	0.129	0.799	91.50	22.40	33.60	29.10
		M2	10.22	11.06	23.04	218	2.218	2.52	0.122	0.768	82.30	19.20	23.60	25.50
SMR-	25%	M1	14.40	14.36	25.64	241	2.463	2.58	0.148	0.868	97.40	35.00	43.90	30.40
		M2	11.34	12.58	24.36	227	2.318	2.54	0.128	0.792	91.20	22.20	32.80	28.20
SMR		M1	13.36	15.85	26.86	255	2.722	2.78	0.172	0.943	111.30	46.90	54.80	33.60
		M2	12.80	15.02	26.17	248	2.564	2.60	0.158	0.902	104.20	41.00	48.70	31.20
SMR+	25%	M1	11.76	13.51	25.13	234	2.344	2.55	0.138	0.822	93.70	28.90	37.90	29.60
		M2	10.83	11.69	23.52	221	2.268	2.53	0.142	0.781	89.70	20.80	26.60	26.10
L.S.D.	at	5%	0.36	0.52	0.48	3.98	0.016	0.15	0.009	0.022	6.32	5.78	4.29	6.03
		1%	0.49	0.71	0.65	5.40	0.022	0.20	0.012	0.030	8.57	7.84	5.81	8.184

Although, the enhancement in most soil macro (NPK) and micro (Fe, Zn, Mn and Cu) nutrients due to the soil characteristics improvement by adding SR or SMR with M1, their values in "Valencia" orange leaves were generally within the normal range (Embleton *et al.*, 1978).

4. Yield:

(a) Preharvest fruit drop: Preharvest fruit drop percentage within the two application methods in the two studied seasons and both sites was progressively decreased with S or SM levels compared to the untreated trees. SR+25% or SMR+25% resulted in the highest fruit drop reduction. However, there were no significant differences with SR or SMR level.

This may be due to the increase in soil ca^{++} and other nutrient elements and consequently in plant leaves and orange neck (Lim *et al.*, 1993) (Table 6 and 7). Lisbon fruit set was highest and fruit drop was decreased by adding 0.7 Kg tree elemental sulfur (Mohmand *et al.*, 1994). Also, Malavolta *et al.* (1987) and Dawood (1996) are in agreement with these results.

(b) Yield weight and number: Yield weigh (Kgs) or number of fruit per tree was significantly increased (Table 6 and7) by adding S or SM at SR or SMR level broadcast method (M1). This may be due to some soil property improvement, the greatest fibrous root density with a more typical distribution, better vegetative growth, less preharvest fruit drop and most soil nutrient element improvement aforementioned. With respect to the two sulfur sources, SMR had the greatest yield followed by SR. thus SMR-M1 followed by SR-M1 were the most efficient treatments. On the other hand, fruit yield (Kgs or No/tree) was significantly decreased by adding SR+25% level comparing with other S or SM treatments particularly SR or SMR treatment. This may be due to the unfavorable soil conditions (Table 3) attained by adding more S or SM over SR or SMR level. Also, increasing ca^{++} solubility, which directly or indirectly affects fibrous root density and distribution (Martin *et al.* 1988). Generally, this was true for the two selected sites and studied seasons. These results are in accordance with those obtained by Malavolta *et al.* (1987); Koudounas (1994); Nunez-Moreno and Valdez-Gascon (1994) and Dawood (1996). They stated that soil chemical and physical properties had a greater effect on citrus yield than fertilizer and supplemental Ca or S which were found to mitigate the adverse effects of soil heavy texture, highly compact, highly alkaline, strongly saline, fixed P, high Na and Cl and high ESP on plant growth and yield.

Table 6. Yield and fruit quality of Valencia orange trees as affected by sulfur or sulfur mixture application at the selected sites in 1998 season (in April 1999).

Treatments		Fruit yield / tree (Kg)	Fruit yield / tree Number / tree	Preharvest fruit drop (%)	Fruit quality: Fruit weight (g)	Peel thickness (mm)	TSS	Acid (%)	TSS / acid ratio	V.C (mg / 100ml)
Site 1										
Control		44.63	241.94	11.96	186	3.63	11.12	1.18	9.42	42.21
SR-25%	M1	60.71	312.26	7.26	195	3.48	11.58	1.12	10.33	43.18
	M2	55.47	296.09	8.37	188	3.55	11.46	1.16	9.87	42.91
SR	M1	69.48	329.12	6.78	212	3.43	11.84	1.09	10.86	43.51
	M2	64.56	314.48	7.94	206	3.47	11.69	1.13	10.35	43.38
SR+25%	M1	58.02	306.66	6.63	190	3.58	11.32	1.14	9.93	42.72
	M2	53.61	288.49	7.79	187	3.62	11.28	1.15	9.81	42.52
SMR-25%	M1	64.32	316.36	7.08	204	3.46	11.61	1.10	10.55	43.36
	M2	57.43	307.94	8.18	189	3.49	11.52	1.12	10.29	43.12
SMR	M1	72.69	339.44	6.56	216	3.40	11.92	1.06	11.25	43.78
	M2	67.86	327.58	7.84	209	3.45	11.76	1.09	10.79	43.47
SMR+25	M1	59.92	308.96	6.31	194	3.56	11.46	1.13	10.14	42.82
	M2	54.48	291.52	7.34	188	3.61	11.38	1.14	9.98	42.71
L.S.D. at	5%	3.42	7.61	0.62	9.26	N.S	0.46	N.S	N.S	N.S
	1%	4.64	10.31	0.84	12.55	....	0.63	....	....	....
Site 2										
Control		37.28	209.32	13.21	17.90	3.72	10.68	1.12	9.54	41.89
SR-25%	M1	54.78	286.61	7.74	192	3.52	11.12	1.07	10.39	42.46
	M2	49.74	264.38	8.83	189	3.56	10.89	1.06	10.27	42.27
SR	M1	60.42	306.45	7.49	198	3.47	11.46	1.04	11.02	42.87
	M2	56.96	293.12	8.56	195	3.53	11.38	1.05	10.83	42.63
SR+25%	M1	52.77	280.63	7.32	189	3.58	10.82	1.09	9.93	42.16
	M2	46.26	256.39	8.39	181	3.63	10.71	1.11	9.65	42.91
SMR-25%	M1	56.41	289.98	7.28	195	3.49	11.28	1.05	10.74	42.52
	M2	51.18	268.76	8.32	191	3.54	11.09	1.07	10.36	42.38
SMR	M1	63.84	316.28	7.14	203	3.46	11.52	1.02	11.29	43.02
	M2	58.72	300.42	8.18	196	3.52	11.41	1.05	10.87	42.80
SMR+25	M1	52.82	284.21	7.08	186	3.54	11.02	1.08	10.20	42.22
	M2	47.01	260.19	7.12	182	3.50	10.82	1.09	9.93	42.06
L.S.D. at	5%	3.39	8.19	0.63	8.36	N.S	0.52	N.S	N.S	0.91
	1%	4.61	11.11	0.85	11.34	....	0.71	....	....	1.24

5. Fruit quality:

Data of tables (6 and 7) revealed that, adding S or SM at different levels enhanced most measured "Valencia" orange fruit quality characteristics, but the differences were not statistically significant in most measured parameters in both selected sites and experimental seasons. These results agree with those of Oh (1988) who found that S application improved the quality of citrus fruits by increasing the sugar contents of the fruits and are in line with those of Malavolta *et al.* (1987); Reddy *et al.* (1992) and Dawood (1996).

Table 7. Yield and fruit quality of Valencia orange trees as affected by sulfur or sulfur mixture application at the selected sites in 1999 season (in April 2000).

Treatments		Fruit yield / tree (Kg)	Number / tree	Preharvest fruit Drop (%)	Fruit quality: Fruit weight (g)	Peel thickness (mm)	TSS	Acid (%)	TSS / acid ratio	V.C (mg / 100ml)
Site 1										
Control		48.54	275.68	12.41	178	3.56	10.85	1.16	9.35	40.62
SR-25%	M1	67.18	253.19	6.82	193	3.48	11.03	1.09	10.11	41.25
	M2	59.30	326.98	8.29	182	3.51	10.93	1.11	9.85	41.16
SR	M1	77.04	394.16	6.22	197	3.43	11.22	1.05	10.69	41.56
	M2	72.56	375.92	7.94	194	3.47	11.16	1.06	10.53	41.36
SR+25%	M1	62.26	331.26	6.18	188	3.53	10.90	1.13	9.65	41.02
	M2	56.86	316.88	7.23	180	3.55	10.86	1.15	9.44	40.72
SMR-25%	M1	72.16	372.25	6.71	195	3.46	11.14	1.07	10.41	41.32
	M2	61.07	329.32	8.12	186	3.49	11.06	1.08	10.24	41.21
SMR	M1	81.26	413.40	6.08	198	3.38	11.36	1.06	10.72	41.73
	M2	76.25	392.52	7.64	195	3.45	11.28	1.07	10.54	41.41
SMR+25	M1	66.89	331.78	7.05	192	3.5Z	10.92	1.11	9.83	41.14
	M2	57.82	319.89	7.16	181	3.54	10.88	1.13	9.63	40.80
L.S.D at	5%	3.58	10.74	0.98	10.02	N.S	N.S	N.S	N.S	0.73
	1%	4.85	14.57	1.33	13.58	...	.....	....	....	0.99
Site 2										
Control		41.96	345.96	13.96	172	3.66	10.98	1.20	9.15	41.66
SR-25%	M1	56.81	304.26	7.68	188	3.52	11.36	1.15	9.88	42.34
	M2	51.87	289.32	8.72	180	3.58	11.28	1.16	9.72	42.24
SR	M1	68.13	352.26	6.99	194	3.46	11.58	1.12	10.34	42.56
	M2	62.97	331.58	8.41	191	3.54	11.49	1.13	10.17	42.41
SR+25%	M1	54.80	295.65	7.21	186	3.58	11.12	1.17	9.50	42.03
	M2	50.94	284.66	8.26	176	3.64	11.06	1.18	9.37	41.81
SMR-25%	M1	61.82	328.18	7.22	189	3.49	11.48	1.13	10.16	42.36
	M2	53.68	297.71	8.29	184	3.54	11.38	1.16	9.81	42.28
SMR	M1	71.81	369.76	6.98	195	3.43	11.66	1.10	10.60	42.68
	M2	65.09	341.09	8.14	192	3.48	11.54	1.11	10.40	42.54
SMR+25	M1	55.36	298.22	7.01	188	3.56	11.26	1.16	9.71	42.21
	M2	51.28	288.43	8.06	179	3.61	11.13	1.18	9.43	41.92
L.S.D at	5%	3.66	11.03	0.86	7.82	N.S	0.54	N.S	N.S	0.86
	1%	4.97	14.94	1.17	10.58	....	0.73	....	....	1.17

The following conclusion could be drawn:

It could be concluded that to improve or to conserve the alkaly orchard soils or to increase fertilizer use efficiency and may overcome salt effects, for increasing the productivity of "Valencia" orange trees with best fruit quality, gypsum requirements (GR) must be detected and SR or SMR must be added with broadcast method.

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تأثير مصادر و معدلات و طرق إضافة الكبريت على النمو ، المحصول ، صفات جودة الثمار ، محتوى الأوراق المعدنى وخواص التربة لحدائق البرتقال الفالنشيا فى بعض الأراضى المتأثرة بالاملاح

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أجرى هذا البحث خلال موسمين متتاليين (١٩٩٧/١٩٩٨ -١٩٩٨/١٩٩٩) على موقعين برتقال فالنشيا مختلفى التأثر بقلوية التربة (قلوية، قلوية ملحية) بمحافظة كفر الشيخ لمقارنة تأثير مصدرين من الكبريت على خواص التربة وتقدير الكمية اللازمة ، وأفضل طريقة إضافة للحصول على أكبر نمو ، وأعلى إنتاجية وأحسن صفات جودة للثمار .

ولذلك أستخدم :

(١) مصدرين من الكبريت :

أ- الكبريت المعدنى ٩٩,٥٪.
ب- مخلوط الكبريت: وهو عبارة عن كبريت عنصرى وبيئة بكتيرية + خامات سمادية معدنية + طفلة و مستخلصات طمى النيل.

(٢) معدلات الإضافة :

أ- مكافئ الاحتياجات الجبسية من الكبريت ومخلوط الكبريت -٢٥٪.
ب- مكافئ الاحتياجات الجبسية من الكبريت ومخلوط الكبريت.
ج- مكافئ الاحتياجات الجبسية من الكبريت ومخلوط الكبريت + ٢٥٪.

(٣) طرق الإضافة :

أ- النثر المتماثل على سطح التربة اسفل المجموع الخضرى على بعد ٥٠ سم من جذع الشجرة .
ب- الإضافة المتماثلة فى خندق سطحى يحدد نهاية المجموع الخضرى للشجرة.

وقد أظهرت النتائج المتحصل عليها ما يلى :

إضافة الكبريت ومخلوط الكبريت بمعدل مكافئ الإحتياجات الجبسية والنثر المتماثل تحت المجموع الخضرى للشجرة أدى إلى :

(١) خواص التربة :

أ- تحسنت بوضوح معظم خواص التربة الكيماوية (الـ SAR , EC, PH ونسبة الصوديوم للكالسيوم) والطبيعية (معامل التحبب ، معدل الترشيح ، معامل بناء التربة) وبالتالى

تحسن نفاذية وبناء التربة .

ب- زيادة ذوبان وصلاحية الفوسفور ، الحديد ، الزنك ، المنجنيز ،والنحاس خاصة فى الطبقة السطحية للتربة مع زيادة طفيفة فى ملوحة الطبقات السفلية .

(٢) المحصول ، النمو الخضرى ، وصفات جودة الثمار :

نتيجة للتحسن الواضح فى خواص التربة الكيماوية والطبيعية وزيادة ذوبان وصلاحية معظم العناصر الغذائية فقد زادت كثافة الجذور الليفية مع تحسن فى انتشارها كما لوحظ أكبر نمو خضرى(طول الأفرع وعددها ومساحة الورقة ووزنها الجاف) مع قلة فى تساقط ما قبل الجمع للثمار وبالتالى أمكن الحصول على أعلى محصول مع أحسن صفات جودة للثمار . وكانت معاملات مخلوط الكبريت أعلى نموا خضريا ومحصولا تبعتها معاملة الكبريت المعدنى.

(٣) الإضافة أكبر من مكافئ الإحتياجات الجبسية:

الإضافة أكبر من مكافئ الإحتياجات الجبسية بأى معامله أدى إلى تناقص التحسن فى خواص التربة الطبيعية والكيماوية بينما زادت النسبة المئوية للكالسيوم وملوحة التربة وتأثرت سلبيا صلاحية الكثير من العناصر الكبرى والصغرى ونتيجة لذلك تناقص النمو الخضرى وقل المحصول بالمقارنة بالمعاملات الكبريتية الأخرى .

(٤) العناصر المعدنية بالورقة :

تزايد قليلا محتوى الأوراق من النتروجين والفوسفور والحديد والمنجنيز والزنك والنحاس وتناقص البوتاسيوم بإضافة مكافئ الاحتياجات الجبسيه من الكبريت و مخلوط الكبريت بينما تناقصت هذه العناصر تدريجيا خاصة الصغرى بزيادة معدل الإضافة عن مكافئ الإحتياجات الجبسية بدون فروق معنوية واضحة بين معاملات الكبريت المعدنى أو مخلوط الكبريت بالمقارنة بالمعاملات الكبريتية الأخرى.

(٥) أفضل معاملة :

أفضل معاملة لإصلاح أو صيانة الأراضى القلوية لحدائق البرتقال الفالنشيا وزيادة الكفاءة السمادية ولإزالة أثر الأملاح للحصول على اكبر نمو خضرى وأعلى إنتاجية (محصول) مع أحسن صفات جودة للثمار هى إضافة مكافئ الإحتياجات الجبسية من مخلوط الكبريت أو الكبريت نثرا متماثلا تحت المجموع الخضرى للأشجار .