Effect of Sulphur Application and Saline Irrigation Water on Chemical Properties of Ras Sudr Calcareous Soil, South Sinai, Egypt

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Abstract: A field experiment was conducted at Ras Sudr, South of Sinai Governorate. The investigated soil was cultivated by wheat (*Triticum Vulgare* L.). Ras Sudr soil is calcareous in nature and is characterized by high content of $CaCO_3$ (53.9%) and total soluble salts (EC, 29.6 dSm^{-1}). The experimental soil was irrigated with a saline ground water 6.18 dSm^{-1} which considered the main source of irrigation water in this area. The effect of irrigation periods (7, 14 and 21 days), phosphorus application (20, 60 kg P_2O_5/ fed.) and sulphur application (0, 100, 300, 500 kg S/fed.) on the chemical composition of Ras Sudr soil during and after wheat growth season. The EC decreased gradually by increasing S application and increased progressively by increasing water stress. Sulphur application also decreased soil pH by 2.5% relative to the initial pH value and increased each of soluble –sulphate, available phosphate and potassium.

Keywords: Sulphur, Saline water, Irrigation periods, Wheat, Nutrient availability, Calcareous soil

INTRODUCTION

The horizontal expansion of agricultural lands in Egypt depends on the reclamation of new lands which are mainly in north eastern coastal zone and in Sinai Peninsula. These soils are characterized by high content of $CaCO_3$, alkalinity and salinity which affect to a large extent the availability of several nutrient elements to plants.

Due to insufficient fresh water available to develop all the potential irrigable lands, in this area the use of low quality waters such as underground and drainage waters as well as treated sewage water is a most. The use of such waters is expected to affect salt distribution throughout the soil profile, particularly within the root zone which is of more concern from the agricultural view point. Moreover, the use of low quality water may also cause unfavorable effect on nutrient status beside reversal physical and chemical problems may gradually appear.

The particular structure of calcareous soils is a major problem in farming processes. When they are subjected to irrigation cycle, crust formation occurs at surface, which impedes germination as well as their inadequate water retention and nutrients uptake. Therefore, the application of certain soil amendments for the reclamation of such soils becomes essential.

Most attention has been devoted to use elemental sulphur as a soil amendment for its acidulous effect on increasing the nutrient availability. Therefore, the utilization of elemental sulphur is considered a very important way out in reclaiming and improving the irrigated soils of the arid and semi arid regions.

The present study aimed to investigate the role of sulphur in the availability and uptake of some macronutrients by wheat plant grown in a highly calcareous soil under saline irrigation water conditions of Ras Sudr of Sinai Governorate.

MATERIALS AND METHODS

A field experiment was conducted in the experimental station of Desert Res. Center at Ras Sudr South Sinai Governorate, to study the effect of S application on the chemical composition of Ras Surd calcareous soil. The experiment was cultivated with wheat plant (*Triticum Vulgare* L.), and irrigated by saline water.

Sulphur treatments were 0, 100, 300 and 500 kg S/fed. (= 0, 238, 714, 1190 kg S ha^{-1}) and treated with 30 and 60 kg P_2O_5/fed. (= 71, 143 kg P_2O_5 ha^{-1}), 75 kgN/fed. as NH_4NO_3 and 50 kg K_2O/fed. as KCl. The irrigation periods during plant growth were 7, 14 and 21 days. Soil samples were taken at the vegetative, flowering and at harvesting and analyzed for the chemical composition.

Methods of soil and water analysis

Particle size distribution was determined after Piper (1950). Electrical conductivity (EC), soil pH, total cations and anions were determined in soil paste according to Richards (1954). Total carbonate was determined volumetrically as described by Piper (1950). Organic matter was determined according to Jackson (1958). Gypsum content was determined according to Beaker (1980). Soluble sulfate was determined according to Spencer and Freney (1960). Available-K was extracted by ammonium acetate and determined by a Flamephotometer after Jackson (1958). Available-P was extracted by 0.5 N $NaHCO_3$, pH 8.5 according to Olsen *et al.,* (1954) and determined colorimetrically according to Jackson (1958).

RESULTS AND DISCUSSION

Table 1 shows that Ras Sudr soils have high content of organic matter which reached to 2%. This result may be due to that Ras Sudr soil was used as a pasture for many years. This soil also characterized by high content of salinity (EC, 29.6 dSm^{-1}). This is attributed to that this soil was irrigated for reversal years by ground water which has salinity > 6.18 dSm^{-1}, and it is considered the main source of irrigation water.

To study the effect of sulphur application and saline water irrigation on nutrient availability in Ras Sudr calcareous soil, an experiment was conducted in the

Experimental Station of the Desert Institute at Ras Sudr, South of Sinai Governorate. The experimental soil was cultivated by wheat (*Triticum Vulgare* L.), which is considered one of strategic crops in Egypt. Tables (2, 3, 4) show the effect of irrigation periods, phosphorus and sulphur applications on some chemical composition of Ras Sudr soil during and after wheat growth season. The results will be discussed under the following headings:

Electrical Conductivity (EC):

Table 3 shows clearly that, irrespective of phosphate treatments and irrigation periods, the EC decreased gradually in the soil samples taken during wheat growth by increasing sulphur application rate. The reduction in the EC values reached to 66%, 70% and 72% relative to the initial EC values for the soil samples taken at vegetative, flowering and after harvesting, respectively. This result may be due to that the high EC of irrigation water (EC, 6.18 dSm^{-1}). These soluble salts will prevent the dispersion of the soil particles and subsequently enhance the water percolation in soil. This process will facilitate the leaching of soluble salts through the drainage water. Similar conclusion was reported by Rhoades and Invaglson (1969), Pupsky and Shainberg (1979) and Ahmed *et al.*, (2007) who reported that the concentration of salts in irrigation water is very important parameters which affect the hydraulic conductivity and permeability of soils. Also, many investigators such as Stremberg and Tisdale 1979, Ogata and Bower 1975, Dawood *et al.*, 1985, John *et al.*, 1985, Abd El Fattah and Hilal 1985, Ahmed *et al.*, 2007, Fatemeh *et al.*, 2012 found that the addition of elemental sulphur to calcareous soils improved the soil structure and increased hydraulic conductivity and water penetration and subsequently decreased the EC values of soils.

Another reason may be that, the addition of sulphur to calcareous soils may result in increases the gypsum concentration. In this respect, Shadfan and Hussen (1985) found that the X- ray diffraction pattern of the calcareous samples treated with 6000 kg^{-1} soil sulphur showed gypsum peaks at 0.75 nm. Reda and Modaihish (1990) also found that sulphur application to calcareous soil increased gypsum content in the surface soil layer.

On the other hand, irrespective of sulphur application and irrigation periods, superphosphate treatment increased the EC values in the soil samples which were taken at different stages of wheat growth as shown in Table 4. This may be due to that superphosphate addition to soil will increase the adsorption of cations such as Ca^{2+} and decrease the adsorption of anions such as SO_4^{2-}. Unlike phosphate, SO_4^{2-} is weakly held at the soil surface and is therefore more susceptible to leaching in soil. Thus, phosphate addition will increase the amount of SO_4^{2-} in the soil solution and subsequently increase the EC values. Similar finding was reported by Ryden *et al.*, (1987) and Abdou Soaud *et al.*, (2011).

Regarding to the effect of irrigation periods on the EC values data in Table 4 shows that irrespective of other treatments, the EC values increased progressively by increasing water stress in the soil samples which were taken at different stages of wheat growth. This result was expected because the water stress will reduce the amount of water which will percolate through the soil and subsequently reduce salt leaching. In this respect Marvin (1975) who studied the irrigation scheduling for salinity control found that the irrigation scheduling improved irrigation water management efficiency and reduced salt accumulation in some selected areas.

Soil Reaction (pH):

Table 4 indicates that irrespective of phosphate treatments and irrigation periods soil pH was affected especially by high rates treatment. The maximum reduction which reached to 2.5% relative to the initial pH values was obtained after harvest by addition of 500 kg/fed. of sulphur. This slight reduction in different sulphur treatments may be due to the high $CaCO_3$ content of the studied soil. It is known that the soils which have high content of $CaCO_3$ will also have high buffering capacity to change its pH values. Similar results were obtained by superphosphate treatments as shown in Table (4). In this respect Kashirad and Bazargani (1972), Heter (1985) and Abdou Soaud *et al.*, (2011) found that sulphur as soil amendment for calcareous soils showed insignificant in reducing the pH value after harvest.

On the other hand, increased the irrigation period slightly increased the pH values of soil samples at different stages of plant growth as shown in Table 5. It is interesting to note that from the Table 5 that pH values increased progressively by increasing the EC values.

Table (1): Some physical and chemical properties of investigated Ras Sudr Soil

Particle size distribution		Properties of Ras Sudr soil	
Sand (%)	68.5	Available – P (mg kg^{-1})	1.0
Silt (%)	15.4	Available- K (cmol kg^{-1})	10.0
Clay (%)	15.9	Soluble Ca^{2+} (cmol kg^{-1})	1.9
Textural class	Sandy loam	SolubleMg^{2+} (cmol kg^{-1})	1.1
Organic matter (g kg^{-1})	20	Soluble Na^{+} (cmol kg^{-1})	5.7
Total $CaCO_3$ (g kg^{-1})	539	Soluble K^{+} (cmol kg^{-1})	0.1
Gypsum content (g kg^{-1})	0.10	Soluble HCO_3^{-} (cmol kg^{-1})	0.1
pH *	7.5	Cl^{-} (cmol kg^{-1})	7.8
ECe (dSm^{-1})**	29.6	Soluble SO_4 (cmol kg^{-1})	2.2

* In soil-water suspension, ** in soil paste extract.

Table (2): Effect of irrigation periods, sulphur and phosphorus treatments on some chemical composition of Ras Sudr soil during plant growth season

Irrigation periods	7 days								14 days								21 days							
Super phosphate kg/fed.	**200**				**400**				**200**				**400**				**200**				**400**			
	0	**100**	**300**	**500**	**0**	**100**	**300**	**500**	**0**	**100**	**300**	**500**	**0**	**100**	**300**	**500**	**0**	**100**	**300**	**500**	**0**	**100**	**300**	**500**
First sample (during the vegetative stage)																								
EC (dSm^{-1})	9.2	8.3	7.9	7.2	11	9.6	8.5	8	15	13	9.8	8.5	17	14.5	10.5	9	18	16.5	15	13.8	20	18	16	13.9
pH	7.4	7.4	7.4	7.4	8.4	7.4	7.4	7.4	7.5	7.4	7.4	7.4	7.4	7.4	7.38	7.36	7.49	7.46	7.43	7.4	7.46	7.43	7.41	7.38
Soluble SO42- ($mg\ kg^{-1}$)	755	770	790	825	775	793	832	850	603	652	690	708	635	679	712	753	503	532	570	602	575	596	619	655
Available-P ($mg\ kg^{-1}$)	1.5	1.6	1.9	2.3	1.9	2.2	2.3	2.5	1.3	1.6	1.9	2.1	1	1.3	1.6	1.6	1	1.3	1.6	1.6	1.2	1.5	1.7	2
Available-K ($mg\ kg^{-1}$)	70	75	81	85	40	50	60	68	55	60	65	70	46	50	55	6	40	43	48	52	39	42	46	48
Second sample (after flowering stage)																								
EC (dSm^{-1})	8.9	8	7.6	6.9	9.8	9	8	7.3	14	12	9	8	14	13.7	10	8.2	16	15.3	13.1	12	17.2	15	13.1	10.5
pH	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.3	7.4	7.4	7.4	7.4	7.4	7.38	7.36	7.34	7.46	7.43	7.41	7.38	7.43	7.4	7.38	7.35
Soluble SO42- ($mg\ kg^{-1}$)	794	820	865	898	825	850	870	896	652	683	700	730	685	703	741	780	536	569	591	632	595	613	655	689
Available-P ($mg\ kg^{-1}$)	1.9	2.1	2.3	2.5	2.1	2.2	2.4	2.8	1.6	1.8	2	2.3	1.8	2	2.2	2.4	1.3	1.5	1.7	2.1	1.5	1.7	2	2.2
Available-K ($mg\ kg^{-1}$)	85	85	97	105	76	78	88	92	80	86	89	99	75	79	85	90	66	69	72	78	60	67	69	75
Third sample (after harvest)																								
EC (dSm^{-1})	7.9	7.3	7	6.4	9	8.5	7.4	7	13	12	8.5	7.5	14	13	10	7.8	15	14	12.5	11.5	16.5	14.8	12.9	10
pH	7.4	7.4	7.3	7.3	7.4	7.3	7.3	7.3	7.4	7.3	7.4	7.3	7.4	7.35	7.33	7.32	7.44	7.42	7.38	7.34	7.38	7.36	7.34	7.31
Soluble SO42- ($mg\ kg^{-1}$)	803	835	875	905	843	850	883	935	675	695	720	752	703	725	762	795	553	575	599	653	600	632	662	702
Available-P ($mg\ kg^{-1}$)	1.9	2	2.1	2.3	2	2.2	2.4	2.6	1.5	1.9	2	2.2	1.8	2	2.1	2.3	1.3	1.4	1.8	2	1.5	1.8	2	2.1
Available-K ($mg\ kg^{-1}$)	93	97	102	108	85	91	97	100	87	89	95	105	80	88	95	103	70	79	85	90	76	78	83	88
Gypsum content ($g\ kg^{-1}$)	1.3			2.8	1.7			5	1			2	1.6			2.5	0.12			0.33	0.16			0.56

Table (3): Effect of sulphur treatments on some soil characteristics of Ras Sudr soil during growth season and after harvesting

Sulphur treatment (kg/fed.)	EC (dSm^{-1})	pH	Soluble SO_4^{2-} (mg kg^{-1})	Available-P (mg kg^{-1})	Available-K (mg kg^{-1})
First sample (during the vegetative stage)					
0	14.9	7.44	641	1.38	48
100	13.2	7.42	670	1.63	53
300	11.2	7.39	702	1.88	59
500	10.0	7.37	732	2.11	63
Second sample (after flowering stage)					
0	13.2	7.41	681	1.70	73
100	12.1	7.39	706	1.88	77
300	10.1	7.37	737	2.10	83
500	8.8	7.35	770	2.38	89
Third sample (after harvest)					
0	12.4	7.38	696	1.60	80
100	11.5	7.36	718	1.80	87
300	9.7	7.34	750	2.06	92
500	8.3	7.31	790	2.25	99

Table (4): Effect of Superphosphate treatments on some soil characteristics of Ras Sudr soil during and after growth season

Superphosphate kg/fed.	EC (dSm^{-1})	pH	Soluble SO_4^{2-} (mg kg^{-1})	Available-P (mg kg^{-1})	Available-K (mg kg^{-1})
First sample (during the vegetative stage)					
200	11.8	7.41	666	1.65	62
400	12.9	7.39	706	1.80	50
Second sample (after flowering stage)					
200	10.8	7.40	705	1.92	84
400	11.3	7.37	741	2.10	77
Third sample (after harvest)					
200	10.1	7.36	720	1.86	116
400	10.8	7.33	757	2.06	88

Table (5): Effect of irrigation periods treatments on some soil characteristics of Ras Sudr soil during and after growth season

Irrigation period day	EC (dSm^{-1})	pH	Soluble SO_4^{2-} (mg kg^{-1})	Available-P (mg kg^{-1})	Available-K (mg kg^{-1})
First sample (during the vegetative stage)					
7	8.65	7.38	798	2.0	66
14	12.1	7.40	679	1.7	57
21	16.4	7.43	581	1.5	44
Second sample (after flowering stage)					
7	8.18	7.36	852	2.2	88
14	11.0	7.38	709	2.0	85
21	14.0	7.40	610	1.75	69
Third sample (after harvest)					
7	7.56	7.33	866	2.18	96
14	10.57	7.36	728	1.97	92
21	13.4	7.38	622	1.73	80

Soluble Sulphate (SO_4^{2-}):

Data in Table 3 shows that irrespective of irrigation periods and P application sulphur treatments progressively increased the soluble sulphate in the soil extract at each of the periods of wheat growth. The highest amounts of SO_4^{2-} were obtained after harvest under different treatments of sulphur application. The increment in SO_4^{2-} at the different stages were 13%, 20% and 23% relative to 0 treatment of sulphur at the vegetative, after flowering and after harvesting could be attributed to the oxidation of sulphur which increased with time of cropping. Similar result was obtained by Naseem and Nasrallh (1983) who found that the rate of oxidation sulphur was increased from 60% after one week to 82% after four weeks.

Similar trend was obtained by superphosphates as shown in Table 4. Increasing phosphate application increase SO_4^{2-} in the soil solution because PO_4^{3-} ions appear to decrease SO_4^{2-} adsorption. In this respect Joshi *et al.*, (1973) found that the SO_4^{2-} has increased due to application of sulphur and phosphorus.

On the other hand, SO_4^{2-} concentration proved to be decreased during irrigation periods as shown in Table 5. However, it increases during growth season under different irrigation periods. These results indicate that the moisture content is a factor that can affect sulphur oxidation. In this respect Murakami (1968) found that oxidation of sulphur to sulphate was slow at low moisture content, rapid at 40% maximum water-holding capacity and most rapid at 64% of maximum capacity.

Available Phosphorus:

Irrespective of irrigation periods and phosphorus application, Table 4 shows that sulphur treatments progressively increased the available phosphorus in the soil at extract at each period of wheat growth. The highest amounts of available phosphate were obtained from the highest sulphur treatment. The increment of available phosphorus in soil at different stages of wheat growth season was 52%, 72% and 53% relative to 0 sulphur treatment at the three stages, respectively. The decrease in soil content of available phosphate after harvesting may be due to high uptake of phosphorus by wheat plant. It is interesting to note that the increase of available phosphate in the soil was associated with the decrease in pH values at each period of soil sampling. This result may be due to that in calcareous soils inorganic phosphate as mostly bonded to Ca^{2+}, and acidification of these soils facilitates the conversion of unavailable phosphorus to available form. In this respect, Kashirad and Bazargani (1972) reported that application of sulphur at all levels significantly reduced soil pH and increased available phosphorus of soil.

Phosphate treatments as shown in Table 4 increased available- P in the soil samples which were taken under different stages of wheat growth. The increments were 9%, 9.3% and 10.7% at vegetative flowering and after harvest stages, respectively. The increments were expected because the increase of superphosphate application with sulphur application will increase phosphate solubility. Similar conclusion was reported by Joshi *et al.*, (1973).

On the other hand, irrigation periods, irrespective of other treatments decreased available – P by increasing water stress which increases the concentration of soil solution. It is known that Ca^{2+} ions were the dominant ions in soil solution of calcareous soils and subsequently will precipitate soluble phosphate to insoluble form. In this respect, Jacob *et al.*, (1916) reported that low moisture content reduces water soluble phosphate.

Available Potassium:

Irrespective of irrigation periods and phosphorus application, sulphur treatments increased the available-K in soil at each period of wheat growth. These increments were 31%, 85% and 106% relative to 0 treatment of sulphur at the first, second and third stage, respectively. This result indicates that there is a positive relationship between the rates of sulphur oxidation and availability of K in soil. The sulphoric acid formed from sulphur oxidation will react with the primary minerals which contain K such as mica, lucite, orthoclase.......*etc*, as well as the K adsorbed physically on the surface of $CaCO_3$. **Joshi** and **Seth (1975)** reported that uptake of K has increased significantly due to the applications of phosphorus and sulphur.

On the other hand, phosphate treatments decreased the available –K in the soil samples which were taken at different stages of wheat growth as shown in Table 4. However, the availability of K was increased by increasing the period of wheat growth. These increments were 43% and 82% in the soil samples taken after flowering and harvest stages, respectively.

Regarding the effect of water stress on the K availability, data in Table 4 shows that irrespective of other treatments, increasing water stress decreased the availability of K under different stages of wheat growth season. However, the available –K increased in soil samples taken after flowering and after harvest under different levels of moisture stress. The mean increments of available –K relative to vegetative stage were 55% and 71%, after flowering and after harvest, respectively. This result may be due to that increasing period of sulphur application which increased the K availability.

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أثر اضافة الكبريت وملوحة مياه الري على الخواص الكيميائية للتربة الجيرية برأس سدر، جنوب سيناء ، مصر

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أجريت تجربة حقلية بمنطقة رأس سدر، محافظة جنوب سيناء ، زرعت بنبات القمح ، تتميز منطقة رأس سدر بالتربة الجيرية و نسبة عالية من كربونات الكالسيوم حوالى53.9) $CaCO_3$ ٪ (ومجموع الأملاح الذائبة ($EC = 29.6\ dSm^{-1}$) ، تروى التجربة من المياه الجوفية حوالى (٦,١٨ dSm^{-1}) وتعتبر المصدر الرئيسي لمياه الري في المنطقة. تم دراسة تأثير فترات الري (٧ و ١٤ و ٢١ يوما)، واضافة الفسفور بمعدل (٢٠٠ و ٤٠٠ kg) (سوبر فوسفات / فدان) وإضافة الكبريت بمعدل(٠ و ١٠٠ و ٣٠٠ و ٥٠٠ كجم / S فدان) . تمت دراسة التركيب الكيميائي للتربة قبل و أثناء وبعد زراعة القمح. أوضحت النتائج انخفاض EC تدريجيا عند زيادة معدلات اضافة S وزادت تدريجيا مع الاجهاد المائى (زيادة فترات الرى) . كذلك ادت اضافة المستويات المختلفة من الكبريت إلى انخفاض حموضة التربة بمعدل حوالى ٢,٥٪ بالمقارنة مع قيمة الرقم الهيدروجيني للتربة قبل الزراعة وزيادة ذوبان الكبريتات، و كذلك الفوسفات والبوتاسيوم الميسرين فى التربة.