Effect of Sulphur Application on Wheat Production in Calcareous Soil under Saline Irrigation Water Conditions

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Abstract: A field experiment was conducted at Ras Sudr, South of Sinai. The experimental 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 investigated soil is irrigated with ground water (EC about 6.18 dSm^{-1}), which is considered to be the main source of irrigation water in this area. The effect of irrigation periods (7, 14, 21 days), phosphorus applications 200 kg and 400 kg/fed. superphosphate (30 and 60 kg P_2O_5/fed.) and sulphur levels (0, 100, 300 and 500 kg S/fed.) on the nutrient content of wheat at the vegetative, flowering and maturity stages of plant growth. The interaction effect of sulphur, phosphorus treatments and irrigation periods on the straw and grain yields of wheat plant was studied. The results indicated that sulphur application under 200 kg superphosphate (30 kg P_2O_5/fed) significantly increased of the grain and straw yields under different irrigation periods. In contrary, increasing sulphur application under 400 kg superphosphate (60 kg P_2O_5/fed) decreased grain yield gradually by increasing sulphur application more than 100 kg S/fed. While the straw yield increased by increasing sulphur application up to 500 kg S/fed.

Keywords: Sulphur, Phosphorus, Saline Water, Irrigation Period, Wheat

INTRODUCTION

The horizontal expansion of agricultural lands in Egypt depends on the reclamation of new lands which are mainly calcareous soils. Most of these soils are concentrated in the north western 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 seasonal nutrient elements to plants.

There are real needs in today's Egypt for increasing food production, for improving the utilization of land and water resources and for finding productive uses for waste water. Food production can be increased by either increasing yield per unit land area, or by expanding the base of production, there is insufficient fresh water available to develop all the potential irrigable land. However, an appreciable volume of underground, agricultural drainage water and treated sewage water is produced annually which could be used on this land. The use of low quality water may cause unfavorable effect on nutrients status beside side several physical and chemical problems may gradually appear.

Therefore, the utilization of elemental sulphur which can be biologically oxidized in the soil to sulphoric acid is considered to be very important way in reclaiming and improving the irrigated soils of the arid and semi-arid regions. The biologically produced sulphoric acid lowers the soil pH and increases the availability of certain elements of soil such as P, Fe and Mn.

This study aimed to investigate the role of sulphur on wheat production cultivated in highly calcareous soil of Ras Sudur, South of Sinai Governorate under conditions of saline water irrigation, and phosphorus levels.

MATERIALS AND METHODS

A field experiment was conducted in the Experimental Station of Desert Research Center at Ras Sudr South Sinai Governorate to study the effect of elemental sulphur and phosphorus applications on the growth, yield and mineral content of wheat plant (*Triticum Vulgare* L.) under irrigation periods.

Sulphur and phosphorus were applied at the rate of 0,100,300 and 500 kg/fed for sulphur (= 0, 238, 714, 1190 kg S ha^{-1}) and 30 and 60 kg P_2O_5/fed for phosphorus (= 47.6, 1421.8 kg P_2O_5 ha^{-1}) before cultivation. N and K were applied at rate of 75 kg N/frd. and 50 kg K_2O/fed. as ammonium nitrate and potassium chloride, respectively. The treatments were arranged in split randomized design with four replications. Saline underground water from a well in the Experimental with EC 6.18 $dSm^{-1}$was used for irrigation every 7, 14, 21days.

Soil, water and plant analysis

Particle size distribution was determined by pipette method according to Piper (1950). Chemical analyses of the soil as well as water samples were carried out according to Richards (1954). Total calcium carbonate was determined volumetrically using collin's calcimeter as described by Piper (1950). Organic matter was determined according to Jackson (1967). Dried materials of the straw and grains of wheat plant were digested by wet ashing using the method described by Richard (1954).

RESULTS AND DISCUSSION

Grain and Straw Yields

Table 2 shows the interaction effect of sulphur, phosphorus treatments and irrigation periods. It is clear that applying sulphur with 200 kg of superphosphate significantly increased the grain and straw yields under different irrigation periods. In contrary, increasing sulphur application with 400 kg superphosphate treatment, decreased grain yield more than 100 kg S/fed. While, the straw yield increased by increasing sulphur application up to 500 kg S/ fed. Similar results were obtained by Aulakh and Pasricha (1977), Kumar and Singh (1980), and Abdelhamid *et al.,* (2013). Irrespective, the treatments of superphosphate and irrigation periods, sulphur application as shown in Table (3) significantly increased grain and straw yields.

Table 1 Some physical and chemical properties of the investigated soil of Ras Sudr

Properties	**Value**
Sand %	68.5
Silt %	15.4
Clay %	15.9
Textural class	Sandy loam
Total carbonate (g kg^{-1})	539
Organic Matter (g kg^{-1})	20
ECe (dSm^{-1})*	29.6
pH**	7.5
Soluble Ca^{2+} (cmol kg^{-1})	1.9
Soluble Mg^{2+} (cmol kg^{-1})	1.1
Soluble K^{+} (cmol kg^{-1})	0.1
Soluble Na^{+} (cmol kg^{-1})	5.7
Soluble Cl^{-} (cmol kg^{-1})	7.8
Soluble SO_4^{2-} (cmol kg^{-1})	2.2

* In soil paste extract ** In soil-water suspension

The highest grain yield was obtained by increasing sulphur application up to 500 kg S/fed. The percentage of increment relative to (0 treatment) was more than 70%. While the highest straw yield was obtained by increasing sulphur application up to 300 kg S/fed., and the percentage of increment was not more than 9%. This result clearly shows the pronounced effect of sulphur application up to 500 kg S/fed. has doubled the grain yield.

In this respect, Heter (1985) who used sulphur application to Jordan's calcareous soil and found that the grain yield of wheat plant increased by more than 24% by increasing sulphur application up to 5000 kg S/ha. Similar conclusion was reported by Hilal *et al.* (1985) who found that the barley yield increased with increasing rates of sulphur up to 3 tons/acre.

Regarding the effect of phosphorus application, Table 4 shows that irrespective of other treatments, increasing phosphorus application, significantly decreased grain yield. This results was expected because under sulphur application treatments the availability of phosphate as mentioned before increased progressively by increasing sulphur application. Increasing amount of phosphate by fertilization will increase also the available pool of phosphate and subsequently will increase the phosphate uptake by plant. Increasing P uptake may reduce Zn uptake and this may decrease the grain and straw yields. This conclusion is supported by Olsen (1972) who reported that extremely high phosphate levels in the root medium can depress growth. In solution culture experiments Loneragan and Asher (1967) found that very high uptake rates of phosphate were associated with reduced growth rates in plant.

Table 2 The interaction effect of sulphur, phosphorus treatment and gation periods on the grain and straw yields of wheat.

Irrigation periods (day)	**Superphosphate Kg/fed.**	**Sulphur treatment Kg/fed.**	**Yield ($kg\ ha^{-1}$)**		**Harvest index (HI)***
			Grain	**Straw**	
7	200	0	1528	4653	0.32
		100	1975	5193	0.38
		300	3706	5681	0.65
		500	4884	4705	1.03
	400	0	2099	4522	0.46
		100	3101	5431	0.57
		300	1975	4610	0.42
		500	1933	4486	0.43
14	200	0	1254	5129	0.24
		100	1930	4860	0.39
		300	2735	5157	0.53
		500	3587	5241	0.68
	400	0	1676	4355	0.38
		100	2359	4479	0.52
		300	1947	5772	0.33
		500	1645	4717	0.34
21	200	0	1242	5058	0.24
		100	1985	4879	0.40
		300	2028	4724	0.42
		500	2589	5241	0.49
	400	0	1537	4289	0.35
		100	2194	5241	0.41
		300	1280	4593	0.27
		500	1273	5503	0.23
L.S.D. Interaction 5%			182.13	262.03	433

*Harvest index (HI) = Grain yield / Biological yield (grain + straw).

Table 3 Average of grain and straw yields as affected by sulphur application

Sulphur (kg/fed.)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index HI
0	1554	4665	0.33
100	2256	5012	0.45
300	2278	5088	0.44
500	2651	4981	0.53
L.S.D. 5%	177	255	

Table 4 Average of grain and straw yields as affected by superphosphate treatments

Superphosphate (kg/fed.)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index HI
200	2451.4	5040.84	0.48
400	1915.9	4831.4	0.39
L.S.D. 5%	133.637	N.S.	

Table 5 Average of grain and straw yields as affected by irrigation periods

Irrigation period (day)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index HI
7	2648.94	4909.94	0.53
14	2139.62	4962.3	0.43
21	1765.96	4938.5	0.35
L.S.D. 5%	137.683	N.S.	

They added that such effects may be dependent on phosphate retarding the uptake and translocation of some of the micronutrients including Zn, Fe and Cu. The decrease in grain yield also may be due to high amounts of available sulphur. Joshi *et al.* (1973) reported that with increasing phosphate application, grain yields decreased in all combinations with sulphur. From this result it could be concluded that under sulphur application up to 500 kg/fed. the maximum amount of superphosphate fertilizer must not exceed 200 kg/fed. for obtaining the maximum grain yield of wheat plant under calcareous soils and saline irrigation water conditions.

Table 5 shows the average of grain and straw yields as affected by irrigation periods. It shows clearly that irrespective of other treatments, increasing water stress significantly decreased the grain yield. The maximum grain yield was obtained from the treatment which was irrigated every 7 days, while the minimum grain yield was obtained from the treatment which was irrigated every 21 days. The percentage of decrement reached to 19% and 33% for the treatments of 14 and 21 days, respectively relative to 7 day irrigation period. On the other hand, the straw yield was slightly affected by the irrigation periods under condition of study. Similar results were obtained by Gad El-Rab *et al.,* (1988) who found that the maximum grain yield was obtained when 6 and 5 irrigations were applied, while the minimum grain yield was obtained with skipping two or three irrigations, were applied.

Nutrient concentration in plant

Table 6 shows the interaction effect of irrigation periods, phosphorus and sulphur treatments on the nutrient concentration in wheat plants. Generally, these treatments significantly affected the nutrients concentration in grain and straw yields. Whereas increasing sulphur application up to 500 kg/fed. under different treatments of phosphate and irrigation periods, increased phosphorus, potassium and sulphate concentration in each of grain and straw yields.

With regard to sulphur application, irrespective of other treatments, Table 7 shows clearly that increasing sulphur application up to 500 kg S/fed. significantly increased each of phosphorus and potassium concentration in the grain yield by 31% and 7% relative to the control treatment, respectively. Furthermore, sulphate concentration was significantly increased by 8% relative to the control treatment. It is worthy to note that the highest concentration of sulphate was at 100 kg S/fed., which reached 37% greater than control treatment. Increasing sulphur application more than 100 kg S/fed. significantly decreased sulphate concentration but still was higher than control treatment. This result was expected because sulphur has been found to interact with P as both being anions. Several investigators (Kamprath *et al.,* 1956; Aulakh and Pasricha, 1977; Singh, 1988, Ragab, *et al.,* (2008), Arshad *et al.,* 2012 and Abdelhamid *et al.,* 2013) reported that S interacts antagonistically with P but at the same time synergistic relationship was found between S and P. Tables (7, 8) indicate that S and P have synergistic relationship when they are in low concentrations in the growth medium, but if they are in high concentrations in the growth medium they act antagonistically. The antagonistic relationship between S and P as shown by their concentration in the wheat grains could be due to their competition for absorption as both are anions on the root absorption sites or for the same uptake pathway within the root.

The nutrients concentration of wheat straw as shown in Tables (8, 9) indicated that increasing sulphur application significantly increased phosphorus and sulphate concentration and as mentioned above the highest concentration of phosphate and sulphate were at the rate of sulphur application not more than 100 kg S/fed., while potassium concentration increased by increasing sulphur application but it was not significant. In this respect, Kashird and Bazargani (1972) and Joshi and Seth (1975) reported that uptake of potassium has increased significantly due to the application of P with and without S. They added that the increase of potassium uptake was low when S alone was applied and concluded that K uptake was closely related to P uptake rather than to sulphur uptake.

Table 9 shows the average nutrients concentration as affected by irrigation periods, irrespective of other treatments. Generally, the data indicated that as moisture stress increase by increasing the period of irrigation phosphorus, potassium and sulphate concentration in the grain and straw yields significantly decreased.

Table 6 The interaction effect of sulphur, phosphorus and irrigation period on the nutrient concentration (g kg^{-1}) of wheat plants.

Irrigation periods (day)	Super-phosphate (kg/fed.)	Sulphur treatments (kg/fed.)	Grain			Straw		
			Phosphorus (g kg^{-1})	Potassium (g kg^{-1})	Sulphate (g kg^{-1})	Phosphorus (g kg^{-1})	Potassium (g kg^{-1})	Sulphate (g kg^{-1})
7	200	0	0.30	0.49	18.7	0.145	0.018	9.0
		100	0.35	0.53	25.5	0.151	0.020	10.6
		300	0.40	0.58	26.0	0.086	0.026	8.4
		500	0.48	0.51	22.4	0.098	0.024	6.8
	400	0	0.35	0.64	15.0	0.088	0.022	7.5
		100	0.40	0.64	18.7	0.119	0.019	7.5
		300	0.48	0.66	35.0	0.120	0.017	8.5
		500	0.45	0.71	20.0	0.132	0.016	12.5
14	200	0	0.28	0.58	22.3	0.100	0.020	4.3
		100	0.28	0.61	36.9	0.122	0.019	8.1
		300	0.43	0.58	23.1	0.069	0.017	13.1
		500	0.40	0.58	22.8	0.070	0.018	11.2
	400	0	0.35	0.51	18.4	0.079	0.020	8.1
		100	0.38	0.53	26.5	0.095	0.012	15.0
		300	0.45	0.65	18.0	0.165	0.020	8.8
		500	0.40	0.55	19.4	0.083	0.018	10.0
21	200	0	0.30	0.54	18.0	0.050	0.015	3.7
		100	0.45	0.55	20.9	0.059	0.016	7.1
		300	0.40	0.55	16.5	0.068	0.018	9.3
		500	0.45	0.54	15.5	0.078	0.018	10.0
	400	0	0.35	0.56	12.5	0.074	0.017	7.5
		100	0.38	0.60	15.0	0.120	0.020	12.5
		300	0.35	0.57	14.3	0.075	0.015	10.6
		500	0.35	0.64	13.0	0.098	0.020	7.5
L.S.D. 5%			0.0254	0.0238	1.9	0.00111	0.0003	1.9

Table 7 Average nutrient concentration (g kg^{-1}) in wheat plant as affected by sulphur application

Sulphur (kg/fed.)	Grain			Straw		
	Phosphorus (g kg^{-1})	Potassium (g kg^{-1})	Sulphate (g kg^{-1})	Phosphorus (g kg^{-1})	Potassium (g kg^{-1})	Sulphate (g kg^{-1})
0	0.32	0.55	17.4	0.089	0.018	6.6
100	0.37	0.57	23.9	0.11	0.017	10.3
300	0.42	0.59	22.1	0.097	0.019	9.7
500	0.42	0.59	18.9	0.093	0.019	9.5
L.S.D.5%	0.0103	0.0097	0.7	0.005	N.S.	0.7

Table 8 Average nutrient concentration (g kg^{-1}) in wheat plant by superphosphate application

Superphosphate (kg/fed.)	Grain			Straw		
	Phosphorus (g kg^{-1})	Potassium (g kg^{-1})	Sulphate (g kg^{-1})	Phosphorus (g kg^{-1})	Potassium (g kg^{-1})	Sulphate (g kg^{-1})
200	0.37	0.55	22.3	0.09	0.019	8.9
400	0.39	0.60	18.8	0.11	0.018	9.1
L.S.D.5%	0.007	0.01	0.50	0.004	0.0004	N.S

Table 9 Average nutrient concentration (g kg^{-1}) as affected by irrigation period

Irrigation period (day)	Grain			Straw		
	Phosphorus (g kg^{-1})	Potassium (g kg^{-1})	Sulphate (g kg^{-1})	Phosphorus (g kg^{-1})	Potassium (g kg^{-1})	Sulphate (g kg^{-1})
7	0.40	0.592	22.6	0.12	0.022	8.8
14	0.37	0.572	23.5	0.98	0.018	9.8
21	0.38	0.567	15.7	0.78	0.017	8.5
L.S.D.5%	0.009	0.0146	0.3	0.005	0.001	0.6

In this respect, Watanabe *et al.,* (1960) found that uptake of phosphate decreases to 80% at 1 bar and to 50% at 3 bars moisture tension in relation to uptake at 1/3 bar. While Vass (1970) reported that as moisture stress increased the potassium content in the corn leaves decreased. Similar trend was found with respect to sulphate content in plant where Barber (1962) reported that mass flow of soil water to supply the transpiration stream transports most of the sulphate to roots, any restrictions in water supply will reduce sulphate uptake by plant.

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أثر اضافة الكبريت على انتاج القمح بالتربة الجيرية مع الرى بمياه ملحية

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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 حوالى (53.9٪) $CaCO_3$ وتركيز الأملاح الذائبة ($EC = 29.6\ dSm^{-1}$) ، تروى التجربة من المياه الجوفية حوالى ($6.18\ dSm^{-1}$) وتعتبر المصدر الرئيسي لمياه الري في المنطقة. تم دراسة تأثير فترات الري (7 و 14 و 21 يوما)، واضافة الفسفور بمعدل (200 و 400 kg) (سوبر فوسفات / فدان) وإضافة الكبريت بمعدل (0 و 100 و 300 و 500 كجم / S فدان) . تم دراسة تاثير اضافة الكبريت و الفوسفور و فترات الرى على محتوى العناصر الغذائية فى مراحل مختلفة من نمو نبات القمح . اوضحت النتائج ان زيادة اضافة الكبيريت و الفوسفور ادى الى زيادة كبيرة فى غلة المحصول و القش و محتواها من العناصر الغذائية بالمقارنة بمعاملة الكونترول تحت ظروف الرى بمياه ملحية . و على العكس من ذلك فان اضافة الكبريت تحت مستوى 400 كيلو جرام سوبر فوسفات للفدان ادى الى نقص محصول الحبوب مع اضافات الكبريت اكبر من 100 كيلو جرام كبريت للفدان. بينما محصول القش زاد مع اضافات الكبريت حتى مستوى 500 كيلوجرام للفدان.