EFFICIENCY OF SULFUR FERTILIZER ON YIELD AND SOIL PROPERTIES OF SALT STRESSED PADDY FIELDS

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Abstract

Two field experiments were conducted at the farm of El-Sirw Agriculture Research Station during 2008 and 2009 seasons to find out the impact of sulfur (S) fertilization on rice grain yield and some physical and chemical properties of salt stressed paddy fields. In this study four sulfur rates 0, 50, 100, and 150 Kg S ha^{-1} were tested using Giza 178 rice variety. Soil at the experimental site was clay with salinity level 5.3 and 5.0 $dS.m^{-1}$ in 2008 and 2009 seasons, respectively. Results indicated that sulfur application significantly improved rice grain yield and all attributing characters in both seasons. Interestingly, the rice grain yield and yield component responded to sulfur application up to 100 kg S ha^{-1} under the present study. Sulfur fertilization showed significant and effective role in increasing the availability of N, K, Zn, and Fe up to 100 Kg S ha^{-1} .In contrast, sulfur fertilizer did not increase the availability of phosphorus. Sulfur fertilizer significantly decreased pH values and positively improved the bulk density, aggregates (%), and porosity (%).

Key words: sulfur fertilizer, soil properties, soil nutrients availability and rice yield.

INTRODUCTION

Salinity is a major obstacle to the sustainability of irrigated agriculture in arid and semi arid regions of the world, since Egypt belong to semi –arid zones. However, paddy production in salt affected soils can be improved by cultivating salt tolerant genotypes of rice and by developing site specific practices including appropriate application of plant nutrition to reduce nutritional imbalance effects and improving soil properties under such area (Aslam *et. al.*, 1996).

Under the intensive cropping system in Egypt, low soil organic matter content, high and intensive use of blended materials such as urea and triple phosphate might be lead to sulfur deficiency in paddy fields in Egypt .Sulfur limits plant growth when the soil supply of S is low or adverse soil conditions which prevent plant uptake of S. In such cases, S should be applied as required. Other nutrients need to be applied in balanced amounts to ensure a high crop response to S fertilizer application and to achieve a healthy and productive crop. The secondary nutrient sulfur is found to be absorbed by rice crop in amounts equal to phosphorus and is considered essential for attainment of 90 percent of the optimum yield of rice .Aulakh and Chhibba (1992), Nair (1995), Channabasavanna *et. al.* (1996), Grobler *et. al.* (1999), Sakal et al., (1999) Sudha, and Chandini (2002), Rasheed *et. al.* (2004), Indira (2005), Rahman *et. al.* (2007) stated that sulfur fertilizer significantly raised grain yield of cereal crops including rice by significant improvement in all yield contributing characters and rice growth traits such as leaf area index and dry matter production. Furthermore, they stated that the application of sulfur significantly improved nutrients availability in the soil. Aulakh and Chhibba (1992) observed synergistic effect of P and S on the uptake of both when the nutrients were supplied at lower rates. A higher P level of 52.5 kg ha^{-1} had an antagonistic effect on S uptake in rice as reported by Nair (1995).

Sulfur like nitrogen is a mobile nutrient moving rapidly downward through the soil whereas, sulfate seldom accumulate in the plow layer because it leaches to B horizon. Sulfate often accumulate in the subsoil where soluble sulfates are absorbed by iron and aluminum oxides. Sulfur accumulation rises as acidity in the subsoil increases. If roots of the plant can go down to the subsoil, the plant will be able to use this sulphate. Therefore, plants can not get an adequate amount if this accumulation occurs at 17-20 inches of soil. Application of S is sometimes used to depress the pH of alkaline soils (Jolivet 1993). Wani (1980) stated that the application of calcium sulphate significantly increased the aggregates tensile strength. Samani and Kasraian (2004) found that elemental sulfur application improved physical properties of saline – sodic soils

The present study was, therefore, carried out with the objectives to improve the properties of newly reclaimed saline soil and find out an appropriate rice growth and yield under saline soil by applying sulfur fertilizer

MATERIALS AND METHODS

The current trial was carried out at the Experimental Farm of El Sirw Agriculture Research Station, Dammietta Governorate, at the northern part of Delta, Egypt in 2008 and 2009 seasons. The soil was clay and the soil chemical properties are listed in Table (1). The treatments studied the response of Giza 178 rice cultivar and some soil physical and chemical properties to various rates of sulfur fertilizer namely 0, 50, 100, and 150 kg S ha-1. The experiment was laid out in a randomized complete block design, with four replications. 30 day seedlings of Giza 178 rice cultivar was transplanted at 3 seedlings hill-1, spaced 20 x 20 Cm on May1, and harvested on September1. Nitrogen fertilizer was imposed in 4 equal doses 15 days after transplanting (DAT), mid-tillering stage, panicle initiation, and the end of booting stages as recommended under saline soil. All plots received 36 kg P2O5 ha-1 and 24 K2O ha-1. Sulfur treatments were applied in dry soil in the form of elemental sulfur (80% S). Plot area was 10 m2. At heading, ten hills from each plot were taken to estimate the dry mater flag leaf area cm-2/leaf and leaf area index (LAI).

At harvest, ten hills per each plot were counted to determine the number of panicles m^{-2} and also, plant height (cm) was measured. Ten main panicles from each subplot were packed to the laboratory to determine panicle length (cm), filled and unfilled grains panicle $^{-1}$,

Table 1. Soil chemical properties at the experimental sites during 2008 and 2009 seasons.

season	pH	EC dS m^{-1}	Cation meq L^{-1}			Anion Meq L^{-1}		
			Ca^{++} + Mg^{++}	Na^{+}	K^{+}	$SO^{=}_{4}$	Cl^{-}	HCO^{-}_{3}
2008	8.3	5.3	29.0	54.0	0.32	48.5	29.3	8.0
2009	8.2	5.0	28.0	48.0	0.31	30.0	38.0	7.0

	Available nutrients mg kg^{-1}						
	N	**P**	**K**	**Zn**	**S**	**Fe**	**Cu**
2008	28.0	8.12	240.0	1.22	9.7	5.00	6.2
2009	26.0	8.35	200.0	1.16	9.5	5.13	6.0

Panicle and 1000-grain weight. Plants of the six inner rows of each subplot were harvested, dried, threshed, then grain and straw yields were determined at 14 % moisture content and converted into t ha-1. Soil was sampled at harvest, the part of it stored in the refrigerator for chemical analysis and the other for physical analysis according to Piper,1950, Cottein *et. al.* (1982) and Page *et. al.* (1982) and Kemper and Rosenau (1986) as well as Black and Hartge (1986) .

All data collected except ph values were subjected to standard statistical analysis following the procedure described by Gomez and Gomez (1984) using the computer program (IRRISTAT). The treatment means were compared using Duncan's multiple range test (Duncan, 1955). * and ** symbol used in all tables indicate the significance at 5% and 1% levels of probability, respectively, while NS means not significant.

RESULTS AND DISCUSSION

A. Soil physical and chemical properties:

Data presented in Table 2 indicated that sulfur application was effective in improving soil physical properties such as bulk density, aggregates%, and total porosity % as well as pH values in both seasons. Obviously, the gradual increase of sulfur rates from zero up to the highest level of 150 kg S ha^{-1} significantly reduced the bulk density and improved other soil physical properties (Table 2). Furthermore, increasing sulfur rates significantly increased aggregates % and total porosity in both seasons of study. Sulfur application reduced soil pH values compared with the initial values to be around the equilibrium value resulting in improving soil prosperities. In addition, increasing sulfur rates up to 150 kg ha^{-} reduced pH values in both years of study. The reduction in pH values with increasing the rate of S applied may be due to the increase sulfuric acid and H_2SO_3 formation. The Egyptian soils tend to be alkaline in terms of high pH values thereby, sulfur application might provide more acidity resulting in reducing pH values. It is evident that low pH values might contribute to more nutrient availability and improve drainage system. Also, sulfur application had high affinity to improve soil aggregates providing an improving of drainage system. Improving drainage system in the Egyptian soils especially in the northern part of Egypt is important to reclaim such kind of soils for obtaining high crop production. As mentioned above, sulfur application in the rate of 150 kg was associated with the highest values of soil aggregates and porosity % in both seasons, while it gave the lowest values of bulk density and pH as well as electrical conductivity (EC). Both rates of 100 and 150 kg S ha^{-1} were at par regarding aggregates % and total porosity % in both years of study.

Sulfur application was also effective in reducing soil salinity levels at the highest rate of 150 kg S ha^{-1}. This might be due to its favorable effect on improving soil infiltration and increasing the availability of some nutrients, which contribute to removing or reducing sodium chloride from such soil. Sulfur application increase the acidity, which help for prevent calcium phosphate formation that increased available Ca^{++} leading to remove considerable amount of Na^{+} resulted in reducing salinity level and improving soil reclamation.

Table 2. Some soil physical properties and pH values as affected by various rates of sulfur fertilization under newly reclaimed saline soil during 2008 and 2009 seasons.

Treatment Kg S ha^{-1}	Bulk density g cm^{-3}		Aggregates %		Porosity %		pH	
	2008	2009	2008	2009	2008	2009	2008	2009
0	1.295	1.290	74.48	74.23	62.83	59.35	8.33	8.26
50	1.207	1.177	74.96	75.25	64.78	63.39	8.16	8.09
100	1.170	1.155	76.54	76.71	70.11	66.52	8.02	7.90
150	1.120	1.105	76.76	76.92	72.33	69.40	7.78	7.70
F test	**	**	*	*	**	**	-	-
LSD0.05	0.025	0.032	1.53	1.32	4.92	4.1	-	-

Sulfur application might increase calcium ions in the soil leading to more sodium leaching resulted in improving soil aggregates and total porosity. Results are in a good harmony with those reported by Wani, (1980), Jolivet (1993) and Samani and Kastaian (2004).

Data listed in Tables 3 and 4 showed that sulfur application had pronounced positive effect on nutrients availability under the current study in both years of study. Increasing sulfur rates up to 150 kg S ha^{-1} significantly boosted up the nitrogen, potassium, sulfur, zinc, iron and manganese availability in both years of study. The increase in availability of these nutrients might be resulted from the acidity resulted from S application which, decreased the losses of these nutrients. Regarding P availability, phosphorous significantly increased as sulfur application increased up to 50 kg S ha^{-1} and beyond this level sulfur application decreased the availability of phosphorous that might be due to the antagonism between phosphorous and sulfur. No significant differences were detected between 100 and 150 kg S ha^{-1} for nitrogen, potassium, and zinc availability in both years. Eventually, it is clear that sulfur application provided distinct effective role in improving soil physical prosperities and reducing the soil pH values which improved the availability of mentioned nutrients. Results confirm earlier finding reported by Nair (1995), Indira (2005) and Rahman *et. al.* (2007)

B.1-Growth traits:

Data documented in Table 5 indicated that sulfur fertilizer had significant desirable effect on rice growth characteristics in both seasons. Flag leaf area, LAI, and dry matter content of Giza 178 rice cultivar at heading stage significantly responded to sulfur levels up to 150 kg S ha^{-1}. The highest values of dry matter, LAI, and flag leaf area were recorded, when rice plants were fertilized by higher sulfur level of 150 kg S ha^{-1} in the two years of study. No significant differences were detected between 100 and 150 kg S ha^{-1}. The favorable effect of sulfur might be mainly due to its activation to the enzyme system leading to fast and healthy rice growth. Interestingly, sulfur had positive effect on nutrients availability, which improves soil properties and rice growth under saline soil. The current results are in a similarity with those reported by Nair (1995), Grobler *et. al.* (1999), Sudha and Chandini (2002) and Rahman *et. al.* (2007).

Table 3. The EC values and the availability of some micronutrients as affected by various rates of sulfur under newly reclaimed saline soil during 2008 and 2009 seasons.

Treatment Kg S ha^{-1}	Ec dSm^{-1}		N mg kg^{-1}		P mg kg^{-1}		K mg kg^{-1}	
	2008	2009	2008	2009	2008	2009	2008	2009
0	4.51	4.09	29.08	29.49	8.08	6.95	248.61	209.88
50	3.71	3.22	29.37	30.19	10.53	9.82	275.77	219.32
100	3.5	3.06	31.40	31.55	8.40	7.16	309.00	272.04
150	3.39	2.98	31.98	31.58	7.21	6.02	313.20	278.00
F test	**	**	**	**	**	**	**	**
LSD	0.20	0.23	1.04	0.97	1.06	1.19	21.53	36.00

Table 4. The availability of some nutrients as affected by various rates of sulfur under newly reclaimed saline soil during 2008 and 2009 seasons.

Treatment Kg S ha^{-1}	S mg kg^{-1}		Zn mg kg^{-1}		Fe mg kg^{-1}		Mn mg kg^{-1}	
	2008	2009	2008	2009	2008	2009	2008	2009
0	9.23	10.08	1.73	1.47	5.92	5.27	5.84	5.66
50	9.93	10.74	1.71	1.66	7.21	7.08	7.43	6.55
100	10.73	11.23	1.90	1.84	10.92	8.14	7.77	7.73
150	11.43	11.79	1.98	1.81	12.89	8.96	8.05	8.32
F test	**	**	**	**	**	**	**	**
LSD	0.45	0.5	0.19	0.12	1.83	0.43	0.35	0.347

Table 5. Dry matter g m^{-2}, flag leaf area cm^2 and Leaf area index of Giza 178 rice cultivar as affected by sulfur rate under newly reclaimed saline soil during 2008 and 2009 seasons.

Treatment Kg S ha^{-1}	Dry matter (g m^{-2})		Flag leaf area (cm^2)		Leaf area index	
	2008	2009	2008	2009	2008	2009
0	582.32	592.81	30.00	31.97	5.62	5.83
50	622.54	631.32	31.18	33.19	6.04	6.33
100	722.77	705.51	32.35	34.09	6.36	6.64
150	747.09	759.06	32.76	35.34	6.79	6. 92
F test	**	**	**	**	**	**
LSD 0.05	15.39	24.96	1.01	0.89	0.19	0.23

B.2-Yield attributing characteristics:

The impact of sulfur on yield contributing characteristics revealed that sulfur was found to be more fruitful in improving yield attributes of Giza 178 rice cultivar under saline soil. Sulfur application significantly increased plant height, number of panicles, panicle weight, filled grains $panicle^{-1}$ but decreased sterility % of rice under saline soil in both seasons (Tables 6 and 7). Sterility (%) was significantly decreased by sulfur fertilization up to 150 kg S ha^{-1}. It was found that plant height and number of panicles were markedly increased by sulfur fertilizer application up to 100 Kg S ha^{-1}. On the other hand, panicle weight and filled grains $panicle^{-1}$ were significantly increased as sulfur increment rate increased up to 150 kg S ha^{-1} which coincided with the response of flag leaf area, leaf area index and dry matter production to sulfur fertilizer. Results indicated that improving dry matter production in the terms of assimilate products at pre heading might be resulted in improving grain filling leading to higher filled grain and heavier panicles. As previously detected, sulfur fertilizer was found to be more effective in improving yield contributes, enhancing nutrients availability and reducing soil pH which improves soil chemical and physical properties that might contribute to improving rice growth and health under such condition.

Table 6. Panicle numbers $hill^{-1}$, plant height cm and panicle weight g of Giza 178 rice cultivar as affected by sulfur rates under newly reclaimed saline soil during 2008 and 2009 seasons.

Treatment	Panicle numbers $hill^{-1}$		Plant height (cm)		Panicle weight (g)	
Kg S ha^{-1}	2008	2009	2008	2009	2008	2009
0	13.45	13.06	90.89	91.92	2.24	2.47
50	17.00	15.52	92.98	93.96	2.43	2.51
100	18.96	18.20	96.24	97.44	2.49	2.55
150	19.75	19.07	97.14	98.39	2.64	2.70
F test	**	**	**	**	**	**
LSD 0.05	1.16	1.10	1.54	1.49	0.15	0.17

The above mentioned sulfur benefits might be attributed to improvement of yield attributing characteristics. Improving dry matter production by sulfur fertilizer was found to be efficient in improving grain filling process resulted in lower sterility and higher fertility. Interestingly, sulfur application had high affinity to relief the high grain sterility of rice induced by salinity stress whereas the sterility or fertility is the most affected trait by salt stress. The lowest values of all yield attributes were produced when rice plants were received zero level of sulfur in both seasons (Tables 6,7). On the other hand, zero level of sulfur produced the highest values of sterility % of Giza 178 rice cultivar. The findings data are in a good harmony with those reported by Aulakh and Chhibba (1992), Nair (1995), Channabasavanna *et. al.* (1996), Grobler *et. al.* (1999), Sakal *et. al.* (1999), Sudha, and Chandini (2002), Rasheed *et. al.* (2004), Indira (2005), Rahman et al. (2007).

B.3 Grain yield:

Results in Table 7 showed that sulfur application was found to be more efficient in increasing rice grain yield under saline soil condition in the two seasons of study. Increasing sulfur fertilizer significantly increased grain yield of Giza 178 rice cultivar up to 150 kg S ha^{-1} in both years of study. The highest values of grain yield of Giza178 were produced by the higher level of sulfur of 150 kg S ha^{-1} in both seasons (Table 5) without any significant differences with those produced by sulfur level of 100 kg S ha^{-1}. On the other hand, the lowest values of grain yield of rice were produced when rice plants did not receive any sulfur fertilizer.

The obtained data and soil analysis might confirm the importance of sulfur fertilizer application in reducing soil pH values, which improve nutrients availability and soil physical prosperities and rice grain yield. It is mentioning here the highest grain yield of 9 - 10 t ha^{1-} were completely coincided with initial salinity levels of 5.3 & 5.0 dS m^{-1}, and final ones, of 3.39 and 2.98 dS m^{-1} in the first and second seasons , respectively (Tables 1&3). The threshold of salinity tolerance in rice crop is 3 dS m^{-1}.

Table 7. Filled grains, sterility % and grain yield of Giza178 rice variety as affected by sulfur rates under newly reclaimed saline soil during 2008 and 2009 seasons.

Treatment	Filled grain panicle^{-1}		Sterility %		Grain yield t ha^{-1}	
Kg S ha^{-1}	2008	2009	2008	2009	2008	2009
0	119.61	123.37	15.38	14.70	8.10	8.16
50	127.44	130.80	13.87	13.62	8.63	9.03
100	134.79	137.7 0	12.11	11.70	9.23	9.66
150	140.27	143.64	11.60	10.53	9.35	10.00
F test	**	**	**	**	**	**
LSD 0.05	2.48	3.75	0.78	0.72	0.46	0.45

Sulfur has a direct role in some amino acids formation, activation for some very important metabolism enzymes and improved some soil chemical and physical prosperities as well as soil pH. Furthermore, improving soil nutrients availability, particularly under saline soil, improved rice salt tolerance, rice growth and health, and yield attributing characteristics of Giza 178 rice cultivar, which resulted in high grain yield under such salt stress. The present results are in a good similarity with those reported by Aulakh and Chhibba (1992), Nair (1995), Channabasavanna *et. al.* (1996), Grobler *et. al.* (1999), Sakal *et. al.* (1999), Sudha, and Chandini (2002), Rasheed *et. al.* (2004), Indira (2005), Rahman et al., (2007).

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كفاءة السماد الكبريتي علي المحصول و خواص التربة في حقول الأرز المتأثرة بالأملاح

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مركز البحوث والتدريب في الأرز- معهد بحوث المحاصيل الحقلية- مركز البحوث الزراعية- سخا - كفر الشيخ - مصر .

أقيمت تجربتان حقليتان بمحطة البحوث الزراعية بالسرو بدمياط موسمي ٢٠٠٨ ، ٢٠٠٩ لدراسة تأثير التسميد بالكبريت على محصول الأرز و كذلك على بعض الخواص الفيزيائية و الكيماوية لأراضى الأرز المتأثرة بالأملاح. تم استخدام ٤ معدلات من سماد الكبريت و هى صفر (بدون إضافة) و ٥٠ و ١٠٠ و ١٥٠ كجم كبريت للهكتار و كان الصنف المنزرع جيزة ١٧٨. و قد أوضحت النتائج ان استخدام سماد الكبريت أدى إلى زيادة محصول الأرز و مكوناته فى موسمى الدراسة . كذلك أدى التسميد بالكبريت إلى حدوث زيادة معنوية فى يسر النتروجين و البوتاسيوم و الزنك و الحديد حتى مستوى إضافة ١٥٠ كجم للهكتار بينما لم يزداد يسر عنصر الفوسفور مع هذا المستوى. ادى استخدام سماد الكبريت إلى نقص معنوى لقيم رقم الحموضة وكذا أدى إلى تحسن الكثافة الظاهرية و نسبة تجمع الحبيبات و النفاذية.