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Impacts of Sulfur Fertilization as Soil Addition, Potassium Foliar Application and their Interactions on Rice Plant under Saline Condition

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ABSTRACT

Rice (*Oryza sativa L.*) grades a must-have cereal crop it rates the second weighty cereal crop moreover it's a salt-defenseless crop. Sulfur plays a basic role in plant development and growth processes. Potassium is the most rich cationic and essential nutrient. It is very important for crop yield and its tolerance to abiotic stresses. Is it possible that the effect of the interaction between them will be more effective in resisting salinity?. Two field experiments were operated on a clayey soil for two summer seasons .The treatments are a split-plot design included the influences of using agricultural sulfur without addition, 300 Kg ha^{-1} and 650 Kg ha^{-1} were applied on soil, while the sub plots were occupied by foliar applications of potassium as potassium citrate without addition, 36% and 45% . Sulfur application in soil and potassium foliar levels were improving plant height, no. of productive tillers hill^{-1}, dry weigh, 1000-grains weight, grain yield, straw yield and NPK uptake of rice plant. Soil addition of sulfur was attributed positively in modifying bulk density (g cm^{-3}) by reduced it, modifying total porosity % by increased it and features via decreasing pH, EC and ESP% in the soil. The interaction between sulfur and foliar potassium showed that applying sulfur (650 Kg ha^{-1}) with potassium citrate (45%) together showed an effective impact on rice under salinity condition by improving growth, yield, N P K uptake and improving soil properties.

Keywords: sulfur application, potassium foliar and rice

INTRODUCTION

Rice (*Oryza sativa L.*) grades a must-have cereal crop whereas it stands a certain eats for more than half of the world's inhabitants. It rates the second weighty cereal crop moreover it's a salt-defenseless crop. (Deivanai *et al.* 2011 and Rad, Aref and Rezaei 2012) mentioned that soil salinity impacts rice yield seriously. Salt purity through water or soil is usually be moderate or rather high in both arid and semi-arid zones. As a result it brings adverse effects on plant processes at the physiological and molecular levels involving overall derangements on plants nourishment, osmotic stress, and ion-specific toxicity at the hands of sodium concentration Na^+ and chloride Cl^- ions. In nearly all saline soils, sodium rates one of the crucial toxic cautions which generally abuses plants through wrecking potassium ion (K^+) uptake (Tester and Davenport, 2003 and Nazar *et al.* 2011). Sulfur becomes the fourth elemental macronutrient ingredient since it plays a basic role in plant development and growth processes i.e the synthesis of amino acids cysteine and methionine, vitamins, proteins, and enzymes. Furthermore its elementary part in combining with the defense compounds as their presence is vital for plant survival under abiotic stress conditions (Nazar *et al.* 2011). These protective compounds involve strictly necessary sulfur, hydrogen sulfide, glutathione, phytochelatins, S-rich proteins, and types secondary metabolites (Capaldi *et al.* 2015). The provided S-led increments in the cellular S- restraining compounds (such as GSH, thioredoxins, methionine, coenzyme A, and vitamins) and GSH-mixed antioxidant enzymes were reported for raising antioxidant defense system in salinity-endangered plants. Sulfur part (or its provider) is very obvious in managing Na^+/K^+ balance (Rasheed *et al.* 2020). In the other side salt stress damages plant but applying sulfur on soil has enhanced plants growth even under saline circumstances. Obviously sulfur was attributed positively in modifying soil features via decreasing exchangeable sodium, pH, and electrical conductivity in the soil extract (Stamford *et al.* 2002). Sulfur enhances basic plant nutrients uptake, particulary , nitrogen (N), phosphorus (P), and potassium (K) moreover it lowers toxic elements absorption i.g. chlorine and sodium (Zhang *et al.* 1999; Salvagiotti *et al.* 2009). It is well known that potassium is the most rich having a valence of one cationic and essential nutrient. It is very important for crop yield and its tolerance to abiotic stresses. Besides K considers as a stimulator for various enzymes, it is involved in the intracellular osmotic regulation and membrane protein transport. Furthermore it is considered as a basic factor on rice nutrition, it progresses root growth and plant vigor, regarding restricting lodging and improving rice defense against pests and diseases. In addition K also acts a significant task in carbohydrate transport in rice .It is also very important for the plant metabolism and stress resistance (Krishnakumar *et al.*, 2005; Wang and Wu, 2013 and Nieves-Cordones *et al.*, 2019).During the initial stages of plant growth, the root

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system may not be enhanced enough to absorb sufficient nutrients from soil and in such a condition the fertilizers foliar application could be a perfect choice to provide the must-have nutrients like potassium K^+ to the plants (Mallarino *et al*., 2001). Applying K^+ Fertilizing on plants so that it could advance the K^+/Na^+ ratio effectively to enhance plants tolerance against salinity stress (Elhindi *et al*., 2016).Potassium promotes salinity tolerance as it has aggressive nature to sodium limiting and maintaining plant water status (Capula-Rodríguez *et al*., 2016).

MATERIALS AND METHODS

The experimental area

At El-Serw Agricultural Research Station, Agricultural Research Center, Damietta Governorate (latitude: 31 14 43.693 ’N and longitude: 31 48 14.245 ’E) in north Egypt, field experiments were operated on a clayey soil for two summer seasons (2017and 2018). Irrigation from El-Serw drain by drainage water (EC ranged from 2.62 to 2.02 ds m^{-1} and SAR 11.74:9.83).

Experimental design, treatments, and crop administration.

A split plot design was operated with four replicates, the plots were managed to study the influences of using three agricultural sulfur (S) 98% as super fine without addition (S0), 300 Kg ha^{-1} (S1) and 650 Kg ha^{-1} (S2) were applied on soil and it was mixed perfectly with the soil in the time of soil preparation prior to transplanting according to the examined sulfur rates. While the sub plots were occupied by foliar applications of potassium as potassium citrate $K_3C_6H_5O_7$ - commercial product- in three levels without addition (FK0), 36% (FK1) and 45% (FK2). Foliar application was applied at panicle initiation and flowering stages. The plot size was 10 m^2 (5 m X 2 m) all usual agricultural practices of growing rice plants in the nursery were employed by way of both growing seasons. After 30 days from planting, the seedlings were transplanted in the permanent plot by the rate of 3 seedlings $hill^{-1}$ 20 X 20 cm apart. Rice (*Oryza sativa, L.*,), Giza 178, was cultivated in 1st season on 10th May , transplanting on 15th June and harvesting on 1st October while, in the 2nd season rice was cultivated on 13th May, transplanting on 19th June and harvesting on 3st October. Other agricultural practices were done as followed by farmers.

Rice features and crop yields.

Samples of plants were gathered randomly from each plot to figure out plant height (cm), no. of productive tillers $hill^{-1}$ and dry weight (g). The rice was harvested at maturity on October during both seasons. After the signs of being fully grown come out, the plants in the middle six rows at 10 m 2 of each plot were taken, dried and threshed to obtain 1000-grains weight (g), grain yield (t ha^{-1}) and straw yield (t ha^{-1}).

Nutrient uptake by rice plant.

After finding out N, P and K concentration, in grain and straw uptake of N, P and K in of rice by using the following formula like mentioned by Sharma *et al.* (2012). Nutrient uptake (kg ha^{-1}) =Nutrient content (%)*yield (kg ha^{-1})/100.

Soil physical and chemical properties.

Before planting, soil samples were analyzed at a depth of (0 to 30 cm) table (1,2). After harvest, soil samples were collected from the experimental plots and a statistical analysis was carried out for the results of the physical and chemical analysis. It was analyses as follows: particle size distribution (%), soil bulk density (g cm^{-3}) and total porosity % were settled according to Dewis, and Freitas, (1970). Walkley-Black organic carbon and available nitrogen by the Kjeldhal method (Hesse, 1971), NaHCO3-extractable P (Olsen *et al*., 1954), NH4OAc-extractable K (Jackson, 1973), Sodium were detected using flame photometer as described by (Jackson, 1973), Calcium and magnesium were determined using the versenate method as mentioned by (Jackson, 1973), chloride was titrated with silver nitrate, as described by (Jackson, 1973), exchangble sodium percentage figured out according to (Hesse, 1971),soluble carbonate , bicarbonate and sulphates anions were figured out according to Dewis, and Freitas, (1970).

Table 1. Some physical properties of soil samples before rice cultivation in both seasons.

Seasons	Particle size distribution (%)				Texture Class	Bulk density (g cm^{-3})	Total porosity %
	Coarse Sand %	Fine Sand %	Silt %	Clay %			
1st	10.4	20.1	15.6	53.9	clayey	1.47	48.57
2st	10.5	20.3	15.8	53.2	clayey	1.46	58.65

Table 2 .Some chemical properties of soil samples before rice cultivation in both seasons.

Seasons	pH (1:2.5)	EC dSm^{-1}	ESP%	OM %	Soluble Cations (meq $100g^{-1}$)				Soluble Anions (meq $100g^{-1}$)				Available		
					Ca^{++}	Mg^{++}	K^+	Na^+	CO_3^-	HCO_3^{--}	Cl^-	SO_4^{--}	N mg kg^{-1}	P mg kg^{-1}	K mg kg^{-1}
1st	8.4	8.58	11.22	0.75	13.30	12.81	0.22	34.66	-	1.37	33.40	26.22	30	7.95	474
2st	8.3	8.33	11.15	0.83	13.39	12.90	0.21	35.23	-	1.41	33.76	26.65	33	8.11	434

Statistical analysis.

Data were statistically study closely, and the standard error was known. Mean values at levels of ($p< 0.05$) and ($p< 0.01$) were made via LSD test. It was also for variance analysis (ANOVA), According to (Snedecor and Cochran 1981).

RESULTS AND DISCUSSION

1-Growth parameters:

Table 3 illuminate the influence of sulfur fertilization on mean plant height, no. of productive tillers $hill^{-1}$, and its reaction on dry weight through the couple seasons. Treatment of distinctive rates of sulfur covering induce a significant ($p<0.01$) influences on plant height and dry weight since the outcome of sulfur fertilization on no. of productive tillers $hill^{-1}$ had a significant effect at ($P<0.05>0.01$) in the studied of both periods. Escalating standards of sulfur fertilization resulted in advance in plant height, no. of productive tillers $hill^{-1}$, and dry weight. Maximal plant height, no. of productive tillers $hill^{-1}$, and dry weight were registered with S2 and S1 interactions, respectively.

Data mentioned in table 3 clears a significant ($p<0.01$) outcome on plant height, no. of productive tillers $hill^{-1}$, with using potassium foliar in the couple seasons.

Applying potassium foliar induces best values of the preceding growth parameters unlike unusing potassium foliar in the couple periods. Additionally, applying potassium foliar in both seasons didn't adjust dry weight ($p>0.05$).

Table 3 Data notes a significant interplay ($p<0.01$) between sulfur fertilizer and potassium foliar on rice plant height and dry weight. In contrast a non-significant interaction ($p>0.05$) result on no. of productive tillers hill^{-1} were gained. Actually, the maximal values (Figure2) were obtained with (S2 + FK2), (S2 + FK1) and (S2 + FK0) on rice plant height, no. of productive tillers hill^{-1} and dry weight, respectively.

It`s apparent that using sulfur fertilizer had significantly enhanced plant height, no. of productive tillers hill^{-1} and dry weight by growing it (table 3). As it has an important role on plant enhancement and growth likewise the synthesis of amino acids cysteine and methionine, vitamins, proteins, and enzymes. Moreover it has a fundamental part in the synthesis of the defense compounds where their existences are crucial to maintain plant alive under abiotic stress cases and improve saline soil chemical properties by the favor of sulfur application (Nazar *et al.* 2011).Relating to results of Stamford *et al.* 2002; Mazhar *et al.* (2011) and Helmy *et al.*, 2013.

In addition table 3 illustrates that potassium foliar also raised the plant height no. of productive tillers hill^{-1} and dry weight of rice plant. That is treated as a vital element in rice nutrition since it advances root growth and plant vigor. Increasing K^+/Na^+ ratio is impressive for advancing plant defense system against salinity stress (Krishnakumar *et al.*, 2005 and Elhindi *et al.*, 2016). These results are in agreement with those reported by Mohiti *et al.*, 2011 and Bhiah *et al.*, 2010.

(Figure1) mentioned that the best outcomes of plant height, no. of productive tillers hill^{-1} and dry weight were obtained (S2 + FK2) > (S2 + FK1) > (S2 + FK0) respectively. This determined that using the high rate of sulfur and high level of potassium was more dynamic than high rate of sulfur and low rate to of potassium in resisting salinity in growth parameters of rice plant

2-Yields and yield attributes characteristics

Table 3 data remarks that applying sulfur fertilizer on rice plant had resulted in a significant ($p<0.01$) profit on the weight of 1000-seed in the couple seasons. Significant best values of the former parameters were obtained by applying sulfur fertilizer comparing to unusing sulfur fertilization in both seasons. The best results were obtained on S2 > S1 treatments, respectively. Moreover a significant ($p<0.01$) outcomes on these parameters were gained with potassium foliar application in both seasons. Actually using potassium foliar on rice plant produces the best values on the weight of 1000-seed comparing to avoiding potassium foliar (table 4). The best significant values of the prior parameters were gained via FK2 > FK1 applications, respectively during the couple periods.

(Table 3) mentions a significant treatment ($p<0.01$) among applying sulfur fertilizer and potassium foliar on the weight of 1000-seed rice plant. The best results of 1000-seed weight (Figure2) were gained by (usage of S2 + FK2), (usage of S2 + FK1), and (the application of S2 + FK0), respectively. Moreover, a significant profit of sulfur fertilizer was observed for grain yield and straw yield (table 4 $p<0.01$) in the couple cropping years. The best grain yield was achieved by applying S2 (5.89 and 6.07 t ha^{-1}) and S1 (5.34 and 5.41 t ha^{-1}) treatments unlike the unfertilized control treatment (4.75 and 4.82 t ha^{-1}), respectively in the couple periods. Concerning straw yield, the maximal yield was profited with the application of S2 (7.22and 7.46 t ha^{-1}) and S1 (6.82and 7.05 t ha^{-1}) treatments differs from unusing control treatment (6.11and 6.29 t ha^{-1}), respectively, in the couple periods.

Table 4 notes a significant ($p<0.01$) outcomes on grain yield and straw yield in both seasons by the favor of potassium foliar application. Actually, potassium foliar interaction FK2 resulted in the best grain yield (5.61 and 5.77 t ha^{-1}) > FK1 (5.33 and 5.43) comparing to un-applying control treatment (5.05 and 5.10 t ha^{-1}), respectively in both seasons. Concerning, straw yield the maximal yield was gained by applying FK2 (7.09 and 7.33t ha^{-1}) and FK1 (6.77 and 7.01 t ha^{-1}) interactions compared to the unusing control treatment (6.30 and 6.47 t ha^{-1}), respectively, in the couple seasons.

1000-seed weight, grain yield and straw yield of rice plant had significantly advanced by applying sulfur fertilizer table 2**,** 3. This outcome is attributed to sulfur vital role since it modifies soil properties by decreasing ESP%, pH, and EC in the soil. As the role of sulfur is very clear in demonstrating Na^+/K^+ balances and in progressing growth properties, (Rasheed *et al.* 2020 and Stamford *et al.* 2002).

Table 3. Effects of sulfur fertilizer and potassium foliar usage on plant height, no. of productive tillers hill, dry weight, and 1000-grains weight in rice plant during both seasons.

Treatments	Plant height (cm)		No. of productive tillers hill^{-1}		Dry weight (g)		1000-grains weight (g)	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
S fertilization in-soil								
S0	73.9	75.2	12.67	14.00	62.92	60.78	17.33	18.50
S1	78.9	80.1	15.08	15.42	66.33	68.51	22.25	23.83
S2	80.9	81.6	17.00	18.58	74.58	77.42	23.50	24.33
Total	77.9	78.9	14.92	16.00	67.94	68.90	21.03	22.22
P Value	0.0	0.0	0.04	0.02	0.00	0.00	0.00	0.00
Foliar K fertilization								
FK0	75.0	76.1	12.17	12.92	65.58	65.87	18.08	19.08
FK1	78.5	79.7	15.00	16.17	67.17	68.75	22.00	23.50
FK2	80.3	81.1	17.58	18.92	71.08	72.08	23.00	24.08
Total	77.9	78.9	14.92	16.00	67.94	68.90	21.03	22.22
P Value	0.0	0.0	0.00	0.00	0.15	0.20	0.01	0.00
S×FK								
P Value	0.0	0.0	0.04	0.02	0.00	0.00	0.00	0.00

Table 4. Effects of sulfur fertilizer and potassium foliar application on grain yield, and straw yield in rice plant during two seasons.

Treatments	Grain yield (t ha^{-1})		Straw yield (t ha^{-1})	
	1st	2nd	1st	2nd
S fertilization in-soil				
S0	4.75	4.82	6.11	6.29
S1	5.34	5.41	6.82	7.05
S2	5.89	6.07	7.22	7.46
Total	5.33	5.43	6.72	6.93
P Value	0.00	0.00	0.00	0.00
Foliar K fertilization				
FK0	5.05	5.10	6.30	6.47
FK1	5.33	5.43	6.77	7.01
FK2	5.61	5.77	7.09	7.33
Total	5.33	5.43	6.72	6.93
P Value	0.10	0.05	0.00	0.00
S×FK				
P Value	0.00	0.00	0.00	0.00

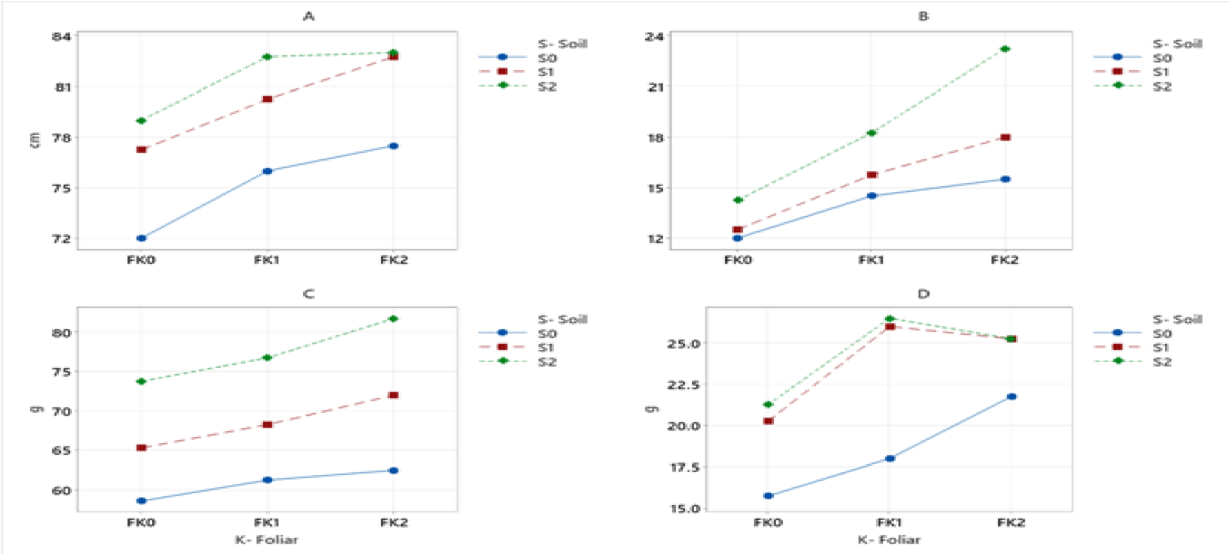

Fig. 1. interaction plot between S fertilization in soil rates and K foliar fertilization levels on Plant height (A), No. of productive tillers hill^{-1} (B), Dry weight (C) and 1000-grains weight (D).

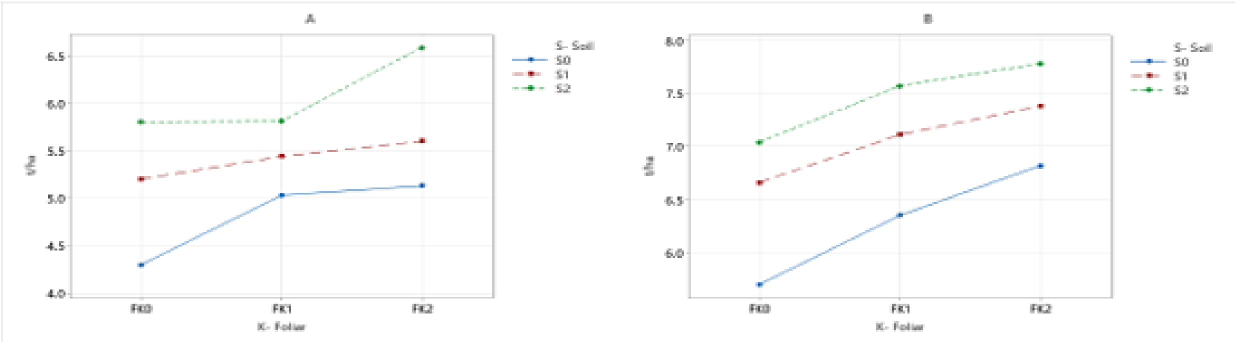

Fig. 2. interaction plot between S fertilization in soil rates and K foliar fertilization levels on rice grain yield (A) and straw yield (B).

Table 5 data indicates a significant treatment ($p<0.01$) between sulfur fertilizer and potassium foliar applications on rice grain and straw yield. The best values (figure3) were profited by (S2 + FK2) > (S2 + FK1) > (S2+ FK0) on rice grain and straw yield in the couple seasons, respectively.

In the other side using potassium foliar significantly raised 1000-seed weight, grain yield and straw yield of rice plant (table 3, 4). This could be caused by increasing K^+/Na^+ ratio is a successful way for advancing plants defense against salinity stress moreover potassium has a vital role in mechanism of stomata movement, photosynthesis and osmoregulatory adaptation of plants to water stress in saline soils (Elhindi *et al*., 2016 and Flowers, *et al* 1991).

According to (figure 1 and 2), the perfect outcomes of 1000-seed weight, grain yield and straw yield were gained via the usage of (S2 + FK2) > (S2 + FK1). This outcome cleared that usage of sulfur at high rate with applying high rate of potassium had more impressive outcome than using high rate of sulfur and low rate of potassium.

3-Nutreint uptake:

Nitrogen uptake by grain and straw yield.

It is mentioned that the uptake of nitrogen on rice plant grain and straw yield was significantly ($p<0.01$) enhanced by the application of sulfur fertilizer in the two cropping seasons. The best rate of nitrogen uptake in grain and straw yield was noted by applying S2 > S1 interactions comparing to unusing control treatment respectively, in the couple periods (table 5).

Nitrogen uptake in grain yield of rice plant had a non-significant influence ($p>0.01$) in the 1st season. In contrast, it had a significant ($p<0.05>0.01$) progress with potassium foliar application comparing to the control treatment in the 2nd season (table 4).Nitrogen uptake in rice plant straw yield during both seasons was enhanced with potassium foliar application comparing to the control in the couple periods it had a significant ($p<0.05>0.01$)outcome. The best rates of nitrogen uptake in rice grain and straw yield was gained via applying FK2 > FK1 treatments comparing to the unfertilized control treatment respectively, in the two periods.

Table 5 mentions a significant interplay ($p<0.01$) between sulfur fertilizer and potassium foliar application on nitrogen uptake in rice grain and straw yield. The maximal rates of nitrogen uptake in rice grain and straw yield (fig. 3) were achieved with (S2 + FK2) > (S2 + FK1) > (S2+ FK0), respectively.

Actually applying sulfur in fertilization resulted in a significant progress in nitrogen uptake in rice plant grain and straw yield (table 5). Similar results were observed by (Haneklaus *et al*. 2007; Carciochi *et al*. 2020), they also concluded that sulfur application has been reported to enhance nutrient uptake. It has been confirmed that sulfur application contributes towards better nutrients uptake and carbohydrate synthesis in the crop plants due to synergistic effects with other nutrients such as N, P, and K.

Applying potassium fertilization caused a significant increment in nitrogen uptake in grain and straw yield by rice plant (table 5). Alike the results were mentioned by Rahman *et al*. (2005) who also summarized that using potassium had advanced nutrients uptake on rice under saline condition as it kept proper shoot and root growth.

(Figure 3) marked perfect outcomes of nitrogen uptake in grain and straw yield with using (S2 + FK2) > (S2 + FK1). This result noted that using sulfur at high rate with using high rate of potassium had more impressive result than high rate of sulfur and low rate of potassium.

Table 5. Effects of applying sulfur fertilization and potassium foliar on N-uptake in rice plant grain and straw through the couple periods.

Treatments	Grain N-uptake ($kg\ N\ ha^{-1}$)		Straw N-uptake ($kg\ N\ ha^{-1}$)	
	1st	2nd	1st	2nd
S Fertilization in-soil				
S0	57.56	59.04	27.33	28.41
S1	67.82	69.50	40.94	43.09
S2	77.71	81.07	47.03	49.27
Total	67.69	69.87	38.44	40.26
P Value	0.00	0.00	0.00	0.00
Foliar K fertilization				
FK0	63.50	64.42	32.06	33.66
FK1	67.49	69.57	39.74	41.60
FK2	72.09	75.61	43.51	45.51
Total	67.69	69.87	38.44	40.26
P Value	0.12	0.05	0.01	0.01
S×FK				
P Value	0.00	0.00	0.00	0.00

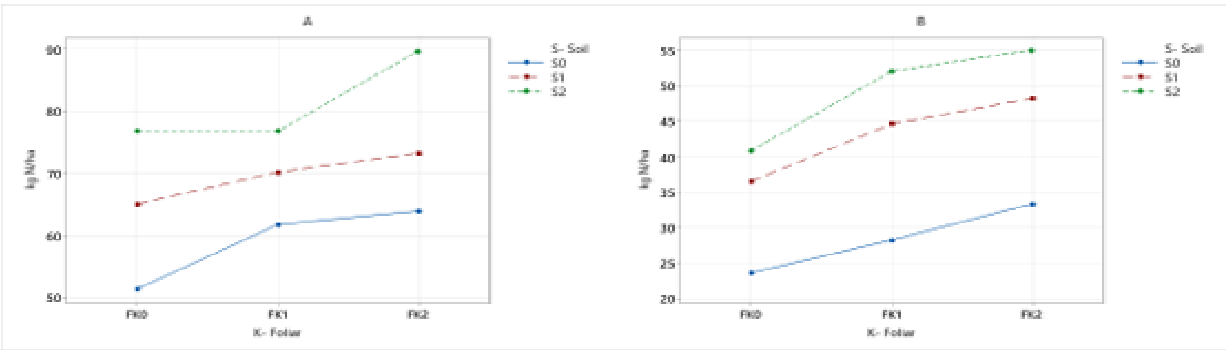

Fig. 3. interplay plot between S fertilization in soil rates and K foliar application levels on N-uptake in both rice grain (A) and straw (B).

Phosphor uptake by grain and straw yield.

Phosphor uptake in grain and straw yield of rice plant was significantly ($p<0.01$) progressed by using sulfur fertilizer in the two cropping seasons. Best phosphor uptake rates in grain and straw yield were done by applying S2 > S1 treatments compared to the unfertilized control treatment respectively, in the couple seasons.

Phosphor uptake in rice plant grain yield had a non-significant result ($p>0.01$) in the 1st season. Although it had a significant ($p<0.05>0.01$) outcome with potassium foliar application compared to the control treatment in the 2nd season (table 6). Actually phosphor uptake rates in rice plant straw yield through both seasons were influenced by potassium foliar compared to the control treatment in the couple seasons, it had a significant ($p<0.05>0.01$) progress. Best phosphor uptake rates in grain and straw yield was achieved by using FK2 > FK1 treatments compared to the unfertilized control treatment respectively, in both seasons.

Table 6 mentions a significant treatment ($p<0.01$) between applying sulfur fertilization and potassium foliar on phosphor uptake in grain and straw yield. The best rates of phosphor uptake in grain yield (fig. 4) were profited with (S2 + FK2) > (S2 + FK1) > (S2+ FK0). The maximum rates of phosphor uptake in straw yield (fig. 5) were achieved with (S1 + FK2) > (S1 + FK1) > (S1+ FK0), respectively.

Using sulfur in fertilization resulted in a significant progress in phosphor uptake in rice grain and straw yield (table 5). Alike data were recorded by (Zhang *et al*. 1999; Salvagiotti *et al*. 2009).

Applying potassium fertilization resulted in a significant enhancement in phosphor uptake on grain and straw yield of rice plant (table 6). These outcomes are in agreement with Singh *et al*. (2013) that phosphor percentage had concentrated increasingly in plant due to adding potassium fertilizer.

As shown in (figure 4), The perfect rates of phosphor uptake in grain yield were achieved with (high rate of sulfur and a high rate of potassium) but the highest rates of phosphor uptake in straw yield were profited with (low rate of sulfur + a high rate of potassium).

Table 6. Effects of sulfur fertilizer and potassium foliar applications on P-uptake in both rice grain and straw in the couple seasons.

Treatments	Grain P-uptake ($kg\ P\ ha^{-1}$)		Straw P-uptake ($kg\ P\ ha^{-1}$)	
	1st	2nd	1st	2nd
S fertilization in-soil				
S0	10.13	10.54	1.84	2.02
S1	13.00	13.42	3.94	4.34
S2	15.36	15.93	3.50	3.82
Total	12.83	13.30	3.09	3.39
P Value	0.00	0.00	0.00	0.00
Foliar K fertilization				
FK0	11.71	11.96	2.59	2.78
FK1	12.62	13.14	2.96	3.31
FK2	14.16	14.78	3.73	4.10
Total	12.83	13.30	3.09	3.39
P Value	0.06	0.03	0.04	0.02
S×FK				
P Value	0.00	0.00	0.00	0.00

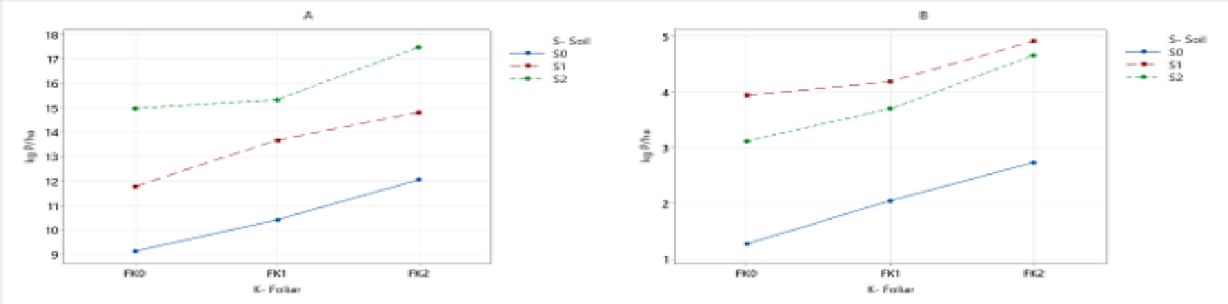

Fig. 4. interaction plot between applying S fertilization in soil rates and K foliar usage levels on rice grain P-uptake (A) and straw P-uptake (B).

Potassium uptake by grain and straw yield.

Actually potassium uptake in grain and straw of rice plant was significantly ($p<0.01$) enhanced by sulfur fertilization in both cropping seasons. The best rates of potassium uptake in grain and straw was showed with applying S2 >S1 interplays compared to the unfertilized control treatment respectively, in both periods.

In addition, potassium uptake in grain and straw yield of rice plant was significantly ($p<0.01$) improved with potassium foliar application compared to the control treatment in the couple periods (table 7). Best rates of potassium uptake in grain and straw yield was achieved by using FK2 > FK1 interactions compared to the unfertilized control treatment respectively.

Table 6 marks a significant interplay ($p<0.01$) between sulfur fertilizer and potassium foliar applications on potassium uptake in grain and straw yield. The highest rates of potassium uptake in grain and straw yield (fig. 5) were achieved with (S2 + FK2) > (S2 + FK1) > (S2+ FK0), respectively.

Applying sulfur fertilization caused a significant increment in potassium uptake in grain and straw yield by rice plant (table 7). Similar results were noted by (Zhang *et al.* 1999; Salvagiotti *et al.* 2009).

Using potassium in fertilization resulted in a significant progress on potassium uptake in grain and straw yield of rice plant (table 7). These outcomes were also in agreement with Singh *et al.* (2013) that nutrient concentration in plant was escalated because of adding potassium fertilizer.

(Figure 5) mentions that the maximal results of potassium uptake in grain and straw yield were profited via the application of S2 + FK2 > S2 + FK1. These results indicate that applying high rate of sulfur with high rate of potassium are more efficient than using high rates of sulfur with low rate of potassium.

Table 7. Influences of sulfur fertilization and potassium foliar on K-uptake in grain and K-uptake in straw on rice plant through both seasons.

Treatments	Grain K-uptake (kg K ha^{-1})		Straw K-uptake (kg K ha^{-1})	
	1st	2nd	1st	2nd
S fertilization in-soil				
S0	9.30	9.68	71.88	74.27
S1	12.28	13.07	84.01	87.05
S2	16.70	16.59	90.68	94.64
Total	12.76	13.11	82.19	85.32
P Value	0.00	0.00	0.00	0.00
Foliar K fertilization				
FK0	9.60	9.94	73.67	75.85
FK1	12.61	13.18	83.66	86.88
FK2	16.07	16.23	89.24	93.23
Total	12.76	13.11	82.19	85.32
P Value	0.00	0.00	0.00	0.00
S×FK				
P Value	0.00	0.00	0.00	0.00

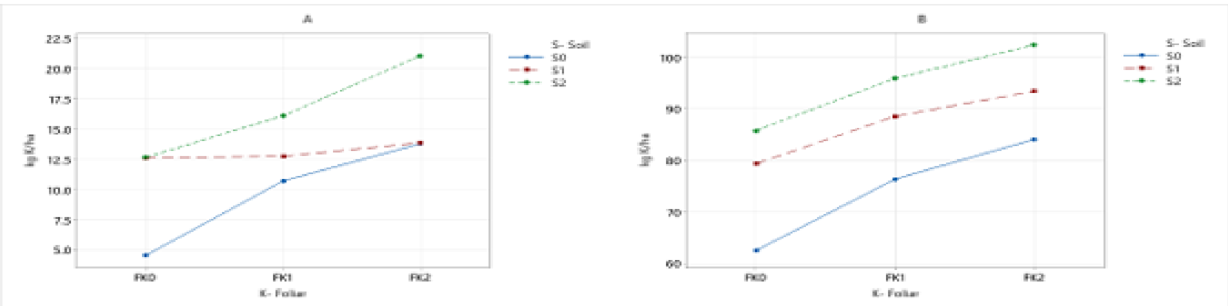

Fig. 5. interaction plot between S fertilization in soil rates and K foliar fertilization levels on rice grain K-uptake (A) and straw K-uptake (B).

4- Impactes of sulfur on some soil properties:

Impactes of sulfur on some soil physical properties

Data in table 8 point out a significant lose in bulk density value because of sulfur application unlike un-applying sulfur (control treatment) in the two seasons. These outcomes figure out that the maximum level of sulfur application (650 Kg ha^{-1}) decline the rate of bulk density more than lowered level of sulfur application (300 Kg ha^{-1}). The diminution of bulk density by sulfur application may be a result of its oxidation to sulfuric acid which in turn respond with lime exist in the soil to soluble calcium form which take out Na^+ from soil absorption complex causing decrease of bulk density in progressing soil aggregates and drainage system against soil depression. Similar results were mentioned by Helmy *et al.* (2013).

Data in table 8 explain that the percentage of total porosity of soil was significantly raised by sulfur application compared to avoiding application of sulfur (control treatment) in both seasons. These results explain that a high level of sulfur application (650 Kg ha^{-1}) was more effective than a low level of sulfur application(300 Kg ha^{-1}) in increasing the percentage of total porosity. This may be due to declining soil pH and ESP% and improving exchangeable Ca^{++} and Mg^{++} in the soil which effected positively particles aggregates then total porosity. Similar results were noted by El-Ghamry,*et al* (2005).

Impactes of sulfur on some soil chemical properties

using sulfur significantly declined the rates of pH, EC and ESP% as shown in Table 9 compared to avoiding sulfur application (control treatment) in the two cropping periods. These outcomes highlights that a high level of sulfur application (650 Kg ha^{-1}) was more effective than a low level of sulfur application (300 Kg ha^{-1}) in decreasing pH, EC and ESP%. pH, EC and ESP% decline on soil by sulfur application may be due its oxidation to sulfuric acid, which in turn respond with lime exist in the soil to soluble calcium form which take out Na^+ from soil absorption complex. These outcomes were also in agreement with (Stamford *et al.* 2002) that obviously sulfur was attributed positively in modifying soil features via decreasing ESP%, pH, and electrical conductivity in the soil .

Significantly raised available N, P and K in the soil as result of using sulfur in both seasons table 9. These results indicate that a high level of sulfur application (650 Kg ha^{-1}) was more effective than a low level of sulfur application (300 Kg ha^{-1}) in going up available N, P and K in the soil. These obtained results could connected with the effect of sulfur on lowering soil pH, EC and ESP% which hasten nitrification process furthermore, using of sulfur as soil conditioners would increment the availability of nutrients El-Ghamry,*et al* (2005).

As showed in table 9 using sulfur in the soil significantly raised OM % in both seasons. These results point out that a high level of sulfur application (650 Kg ha^{-1}) was more effective than a low level of sulfur application(300 Kg ha^{-1}) in going up OM % this may be ascribe sulfur application oxidation to sulfuric acid, which dissolves organic matter in the soil .

Table 8. Effect of sulfur application in-soil on some physical properties after harvesting of rice in both seasons.

Treatments	Bulk density (gcm^{-3})		Total Porosity %	
	1st	2st	1st	2st
S_0	1.42	1.41	1.41	58.66
S_1	1.35	1.35	63.17	63.23
S_2	1.29	1.26	64.98	65.12
F.Test	**	**	**	**
LSD5%	0.044	0.035	0.056	0.054
LSD1%	0.066	0.054	0.086	0.082

S_0 without sulfur application S_1=300 Kg ha^{-1} sulfur S_2=650 Kg ha^{-1} sulfur

Table 9. Effect of sulfur application in-soil on some chemical properties after harvesting of rice

Treatments	pH (1:2.5)		EC dS m^{-1}		ESP %		OM %		`Available N (mg kg^{-1}soil)		P (mg kg^{-1}soil)		K (mg kg^{-1}soil)	
	1st	2st	1st	2st	1st	2st	1st	2st	1st	2st	1st	2st	1st	2st
S_0	8.4	8.3	8.4	8.28	11.20	11.13	0.736	0.766	30.33	32.33	7.946	7.973	473.33	474.66
S_1	8.2	8.1	7.9	7.86	10.97	10.91	0.826	0.846	33.33	35.66	7.996	8.053	478.66	480.33
S_2	8.1	8.0	7.8	7.72	10.87	10.77	0.853	0.876	36.66	37.00	8.056	8.153	484.66	489.66
F.Test	*	*	**	**	**	**	**	**	*	ns	*	**	*	*
LSD5%	0.199	0.199	0.047	0.050	0.044	0.038	0.047	0.041	3.460	----	0.078	0.070	6.920	8.860
LSD1%	0.303	0.303	0.071	0.076	0.067	0.057	0.072	0.063	5.243	---	0.118	0.106	10.486	13.424

S_0 without sulfur application S_1=300 Kg ha^{-1} sulfur S_2=650 Kg ha^{-1} sulfur

CONCLUSION

In general, it was possible to be proof against the negative effect of salinity in rice plant by applying sulfur and folair potassium. Where the interaction between sulfur and foliar potassium showed that applying sulfur (650 Kg ha^{-1}) with potassium citrate (45%) together showed an effective impact against salinity by improving growth, yield, a better NPK uptake and improving soil properties.

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تأثيرالاضافة الارضية للكبريت، والرش الورقى بالبوتاسيوم والتفاعل بينهما على الأرز تحت الظروف الملحية.

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الملخص

يعتبر الأرز من محاصيل الحبوب الحيوية وثانى محصول هام لأنه غذاء أساسي لأكثر من نصف سكان العالم ، وهو من المحاصيل الحساسة للملوحة ، وتؤثر الملوحه على محصوله بشكل كبير. يلعب الكبريت دورا أساسيا فى نمو النبات, وعمليات النمو.البوتاسيوم هو أكثر المغذيات الموجبة أحادية التكافؤ وفرة, وهو ضروري لإنتاج المحاصيل, وتحمل الضغوط الملحية .هل من الممكن أن يكون تأثير التفاعل بينهما أكثر فعالية في مقاومة الملوحة؟. تم إجراء تجربتين حقليتين على تربة طينية لمدة موسمين صيفيين ، حيث تم تصميم القطع المنشقة مرة واحدة حيث كانت القطع الشقية الرئيسة تأثيرات استخدام الكبريت الارضى الزراعي بمعدل (دون إضافة ، واضافة 300 كجم هكتار $^{-1}$ و 650 كجم هكتار$^{-1}$) على التربة ،. وتم استخدام الرش الورقى بالبوتاسيوم فى القطع التحت رئيسة على هيئة سترات بوتاسيوم بمعدل (بدون إضافة, 36٪ و 45٪). أدى إضافة الكبريت في التربة , ومستويات البوتاسيوم الورقي إلى تحسين طول النبات ، وعدد الاشطاء فى الجورة، الوزن الجاف ، وزن 1000 حبة ، محصول الحبوب ، محصول القش ,وامتصاص NPK من نبات الأرز.إضافة الكبريت للتربة اعطى قيما ايجابية في تعديل قيمة الكثافة الظاهرية (جم سم 3) من خلال تقليلها, وتعديل النسبة المئوية للمسامية الكلية بزيادتها , كما ادى اضافة الكبريت الى تقليل درجة الحموضة ، وقيمة التوصيل الكهربى ، والنسبة المئوية للصوديوم المتبادل في التربة. أظهر التفاعل بين الكبريت الارضى والبوتاسيوم الورقي أن استخدام الكبريت الارضى بمعدل (650 كجم هكتار$^{-1}$) مع سترات البوتاسيوم (45 ٪) أظهرا تأثيرا فعالا على الأرز تحت الظروف الملحية عن طريق تحسين النمو ، ومحصول الحبوب ,والقش ,وامتصاص النيتروجين, والفوسفور, والبوتاسيوم ، إلى جانب تحسين خصائص التربة.

الكلمات الداله: إضافة الكبريت الارضى ، الرش بالبوتاسيوم, والأرز