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Response of Rice Yield and Soil to Sulfur Application under Water and Salinity Stresses

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TWO FIELD experiments were conducted at El-Sirw Agricultural Research Station, Damietta Governorate, Egypt during summer seasons of 2015 and 2016 to investigate the effect of three irrigation intervals (3 , 6 and 9 days) and four soil application of sulfur rates (0 , 200 , 400 and 600 kg S/ ha) and their interaction on the soil properties , growth characters, yield and yield components as well as water productivity of rice under saline soil conditions. In each experiment , strip plot design with four replications was used , where the horizontal plots were devoted to the irrigation intervals and the vertical plots were allocated by the sulfur rates. Irrigation every 3 days significantly decreased the values of the soil chemical properties studied , i.e. soil acidity (pH) , electrical conductivity (EC) and bulk density but significantly increased growth characters , i.e. chlorophyll content, leaf area, dry matter production and number of tillers/ hill and plant height as well as yield and yield components, i.e. number of panicles/ hill , panicle length , panicle weight, number of filled grains/ panicle , fertility % , 1000-grain weight , grain and biological yields/ ha and harvest index as compared with irrigation every 6 and 9 days. However , irrigation every 9 days significantly increased the number of unfilled grains/ panicle. Increasing soil application of sulfur rates up to 600 kg S/ ha decreased the values of soil properties (pH , EC and bulk density) as well as significantly and gradually increased the aforementioned growth characters as well as yield and yield components but significantly decreased number of unfilled grains/ panicle. The interaction effect between irrigation intervals and sulfur application rates , indicate that grain and biological yields/ ha were increased by the application of sulfur rates up to 400 kg S/ ha under short irrigation interval (3 days) and up to 600 kg S/ ha under medium and and long irrigation intervals (6 and 9 days). The irrigation of rice plants every 3 days consumed the largest amount of irrigation water, while prolonging the irrigation intervals up to 6 and 9 days led to a gradual decrease in the amount of irrigation water consumed by 12.99 and 37.31% , respectively compared with the irrigation every 3 days. Irrigation of rice plants every 6 days with the application of sulfur at a rate of 600 kg S/ ha produced the highest values of water productivity (0.296 kg/ m^3 water) as an average of both seasons, indicating to the beneficial effect of the application of sulfur for improving soil properties , growth , yield and yield components as well as water productivity especially under prolonged irrigation interval in saline soil condition.

Keywords: Salinity, Irrigation, Sulfur, Rice.

Introduction

Rice (*Oryza sativa* L.) is a major food crop for more than half of the world's population and consider one of the important food crops in Egypt next to wheat. Rice is reclaiming crop for saline and saline-sodic soils. Rice is sensitive to salinity at different growth stages (Zeng, 2004).

Salinity is a major environmental stress that drastically affects plants growth by creating low osmotic potential outside the plants (Khajeh-Hosseini et al., 2003). Increasing salinity of agricultural land had a negative impact on food production. Enhancing tolerance to salinity stress in crop plants is necessary in order to increase productivity with limited water supplies and high salinity.

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Irrigation practices under saline sodic is continuously recommended to leach salts from rice root zone area to ensure healthy growth. Furthermore, using poor quality water need specific management and over water as leaching requirement. El-Sharkawy et al. (2006) and Zayed et al. (2013) found that prolonging irrigation interval under such condition significantly increased soil salinization and subsequently reduced rice yield and its component. Therefore, they stated that shortened the period of irrigation interval in the terms of 4 day intervals must be improved under such condition

Nutrients deficiency is very common under salt stress owing to high pH. nutrient deficiency limit productivity trends observed in rice growing countries (Zhu et al., 2004). Ahmed et al. (2016) suggested that the application of sulfur is an effective option in improving the chemical properties, like pHs, electric conductivity (EC) and Sodium absorption rate (SAR) of salt affected soils by decreasing their values and subsequently yield attribute of rice crop. Application of S fertilizer in saline soils is a viable procedure to counteract uptake of unnecessary toxic elements (Na^+ and Cl^-), which encourage selectivity of K/Na and ability of calcium ion to decrease the harmful impacts of sodium ions in plants (Zaman et al., 2002) .Sulfur is essential plant nutrients it consider a key enzymes and vitamins in the plant and is necessary for the formation of chlorophyll, it accumulates in dry matter basis by about 0.2 to 0.5% in plant tissue (Ali et al., 2008 and Mazhar et al., 2011). Sulfur deficient plants have also less resistance under stress conditions (Doberman & Fairhurst, 2000). Sulfur deficiency has become widespread in many countries, many soils are declining their sulfur fertility due to an intensive agriculture using fertilizers highly enriched in NPK (Zhao et al., 1999). S-deficiency results in general inhibition of photosynthesis and protein synthesis (Dubousset et al., 2010). S-deficiency reduces chlorophyll and rubisco content , and provokes chlorosis of young leaves (Muneer et al., 2014). Sulfur application decreased the hazardous effect of salinity and had favorable effect on growth and nutrient contents of rice. Sulfur used as a soil amendments for enhancing the rice productivity (Helmy et al., 2013). The aim of this investigation was studied the effect of irrigation intervals and sulfur application on growth , yield and water productivity of rice under saline soil.

Materials and Methods

Two field experiments were conducted at El-Sirw Agricultural Research Station, Damietta Governorate, Egypt during summer seasons of 2015 and 2016 to investigate the effect of three irrigation intervals , i.e. 3 (contionous flooding), 6 and 9 days and four soil application of sulfur rates (0 , 200 , 400 and 600 kg S/ ha) and their interaction on the soil properties , growth characters , yield and yield components as well as water productivity of rice under saline soil conditions. In each experiment , strip plot design with four replications was used , where the horizontal plots (from north to south direction) were devoted to the irrigation intervals and the vertical plots (from east to west direction) were allocated by the sulfur rates. The experiment was done in different land in each year of the study. Soil samples were taken before land preparation at the depth of 0 – 15 cm from soil surface to soil chemical analysis. The experimental soil was salinity clay and the chemical analysis are presented in Table 1.

Rice grains (Sakha 106 cultivar) were sown in the nursery at a rate of 120 kg/ ha on April 29th in both seasons. All normal agricultural practices of growing rice plants in the nursery were applied during the two growing seaons. After 30 days from sowing, the seedlings were transplanted in the permanent plot at a rate of 3 seedlings/ hill 20 X 20 cm apart. At each vertical plot, sulfur fertilizer (Agricultural sulfur 98 % S as super fine) was soil applied at the same time of soil preparation before transplanting according to the tested sulfur rates. Each plot size was 10 m^2 (2 m width X 5 m length) and fertilized with phosphorus fertilizer as calcium superphosphate (15.5 % P_2O_5) at a rate of 37 kg P_2O_5 kg/ ha and added during land preparation. The potassium fertilizer as potassium sulphate (48 % K_2O) was added at a rate of 50 kg K_2O/ ha at two doses , one of them was added at land preparation and the other one at the panicle initiation. Nitrogen fertilizer as urea (46.5 % N) was applied at a rate of 160 kg N/ ha in three doses , i.e. 15 , 30 and 45 days after transplanting. Zinc fertilizer at a rate of 24 kg zinc sulphate was manually broadcasted at the beginning of flooding. The weeds were controlled chemically using Saturn 50 % at 7.5 litre/ ha four days after transplanting. Each horizontal plot was tightly surrounded by deep ditches with 2 m width and 1 m depth to isolate each other and irrigated according to the tested aforementioned irrigation intervals.

Characters studied

Growth characters

At heading stage, plant samples from each plot were taken to estimate :

1- Colorophyll content (SPAD value) according to Yoshida et al. (1972)

2- Leaf area/ hill (cm^2)

3- Dry matter production (g/hill)

4- Plant height (cm)
5- Number of tillers/ hill

Yield and yield components

At harvest (130 days after sowing) , ten plants from each plot were counted to determine:

1- Number of panicles/hill
2- Panicle length (cm)
3- No. of filled grains/ panicle unfilled
4- No. of unfilled grains/ panicle
5- Fertility %: it was determined by the following fomula

$$\text{Fertility \%} = \frac{\text{No. of filled grains/ panicle}}{\text{No. of total spikelets/ panicle}} \times 100$$

6- 1000- grain weight (g)
7- Panicle weight (g)

The plants in the central six rows at 10 m^2 of each plot were harvested, dried and threshed to determine :

8- Grain yield (ton/ ha)
9- Biological yield (grain + straw) (ton/ ha)
10- Harvest index =

$$\frac{\text{Grain yield/ ha}}{\text{Biological yield/ ha}} \times 100$$

Soil properties

Also , After rice harvest , soil acidity (pH) and electrical conductivity (EC) was determined according to the methods described by Page et al. (1982) as well as bulk density according to the methods described by Black et al. (1965).

Water requirement and productivity

The following water measurements were determined

1- Total applied water (m^3/ ha) :- Water pump provided with calibrate water meter was used for irrigation and calculation the total water used.
2- Saved water % =

$$\frac{\text{Water of irrigation every 3 days – water of irrigation every 6 or 9 days}}{\text{Water of irrigation every 3 days}} \times 100$$

3- Water productivity (kg grains/ m^3 water) was calculated using the following Equation (Michael, 1978)

Water productivity =

$$\frac{\text{Grain yield (kg/ ha)}}{\text{Total applied water (m}^3\text{/ ha)}}$$

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

Results and Discussion

Soil properties

The data of soil properties studied , i.e. soil acidity (pH), electrical conductivity (EC) and bulk density of soil cultivated by rice as affected by irrigation intervals (3 , 6 and 9 days) , the application of sulfur rates (0 , 200 , 400 and 600 kg S/ha) and their interaction in 2015 and 2016 seasons are presented in Table 2.

The data show that shortining irrigation intervals from 9 up to 3 days significantly decreased the values of pH, EC and bulk density of the soil in both seasons. These results indicate that the irrigation interval may be ensured sufficient water addition to the soil which caused high effective leaching of sodium element (Na) from soil to drainage water and consequently improved the soil properties studied . On the other hand , the prolonging irrigation intervals show the opposite pattern . Similar results were obtained by El-Sharkawy et al. (2006).

Application of 600 kg S/ha significantly decreased the values of pH and EC as shown in Tables 1 and 2 as well as bulk density as shown in Table 2 compared to unfertilized plants (Zero kg S/ ha) in the two seasons. The reducing of pH soil by the sulfur application may be due its undergo oxidation to sulfuric acid which in turn reacts with limepresent in the soil to soluble calcium form which remove Na^+ from soil absorption complex leading to reduce bulk density in improving soil aggregates and drainage system against soil depression. Similar results were obtained by Helmy et al. (2013).

With regard to the interaction effect between irrigation intervals and sulfur application rates, the differences among interaction treatments were not great enough to reach the 5 % level of significance for the three soil properties studied in both seasons.

Growth characters

The data presented in Table 3 show the effect of irrigation intervals , sulfur application rates and their interaction on growth characters studied , i.e. total chlorophyll content , leaf area/ hill and dry matter/ hill, plant height and number of tillers / hill in 2015 and 2016 seasons.

TABLE 1. Soil chemical properties of experimental soils in 2015 and 2016 seasons.

Season	pH	ECe dS m^{-1}	Cation $meqL^{-1}$				Anion $meqL^{-1}$		
			Ca^{+2}	Mg^{+2}	Na^{+}	K+	$SO4^{-2}$	CL^{-}	HCO^{-3}
2015	8.5	7.1	19.9	17.9	38.1	0.31	32.1	40.1	11.1
2016	8.54	7.0	21.0	17.1	37.1	0.32	30.1	43.1	12.1

TABLE2. Effect of irrigation intervals , sulfur rates and their interaction on pH, EC and bulk density of soil during 2015 and 2016 seasons.

	pH		EC (dS/m)		Bulk density (g/cm^3)	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**
Irrigation intervals (days)						
3	7.90	7.92	5.51	5.42	1.66	1.64
6	8.22	8.13	6.21	6.02	1.71	1.68
9	8.37	8.36	8.42	8..53	1.75	1.76
F test	**	**	**	**	**	*
LSD at 0.05	**0.005**	**0.008**	**1.01**	**1.20**	**0.02**	**0.01**
Sulfur rates (kg S/ha)						
0	8.46	8.50	8.22	8.33	1.77	1.76
200	8.25	8.30	7.11	7.00	1.74	1.72
400	8.03	8.14	6.31	6.20	1.68	1.68
600	7.83	7.81	5.21	5.02	1.64	1.62
F test	**	**	**	**	**	**
LSD at 0.05	**0.003**	**0.01**	**0.9**	**1. 0**	**0.01**	**0.01**
Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

The data indicate that the highest significant values of all growth characters studied herein were get when the plants were irrigated by the shortest period of irrigation interval (3 days) followed by medium irrigation interval (6 days) without significant differences between them for leaf area/ hill (in the first season), plant height and no. of tillers/ hill (in the second season) and dry matter/ hill (in both seasons). However, the lowest significant values of the abovementioned growth characters were obtained by the largest period of irrigation interval (9 days) in both seasons. The depression in the growth of rice plants by prolonging irrigation interval (water stress) may be due to the reduction of plant capacity in building metabolites owing to reduce leaf expansion and total chlorophyll and consequently the photosynthetic efficiency. The harmful effect of water stress on the growth of rice plants are in harmony with the results obtained previously by El-Refaee et al. (2012), Ghazy (2015) and Ibrahim et al. (2017).

The data revealed that increasing sulfur application rates from 0 up to 600 kg S/ ha gradually and significantly increased all growth characters studied in both seasons. There are no significant differences betweem the two rates of 400 and 600 kg S/ ha for total chlorophyll content, leaf area/ hill and no.of tillers/ hill in the first season as well as dry matter production / hill and plant height in the second season.

The enhancing of growth character obtained herein may be due to improve chemical properties of saline soil owing to sulfur application as previously discussed. These finding are in agreement with those obtained by Kineber et al. (2004), El-Eweddy et al. (2005) and Mazhar et al. (2011).

The interaction between irrigation intervals and sulfur rates had significant effect on no. of tillers / hill in both seasons (Table 3). However, the other growth characters were not significantly affected by that interaction in the first and / or second seasons. The data in Fig. 1 show that the highest numbers of tiller / hill (18.68 and 18.49) were obtained by the application of highest sulfur rate (600 kg S/ ha) under shortest period of irrigation intervals (3 days) in both seasons. On the other hand , the plants irrigated every 9 days and untreated with sulfur produced the lowest values (10.11 and 10.00 tillers/ hill) in the first and second season, respectively.

Yield and yield component

The effect irrigation intervals and sulfur rates and their interaction on yield components , i.e. no. of panicles/ hill , panicle length , no. of grains/ panicle (filled and unfilled grain) , fertility % , 1000- grain weight and panicle weight are presented in Table 4.

TABLE 3. Effect of irrigation intervals , sulfur rates and their interaction on some growth characters in 2015 and 2016 seasons.

Traits	Chlorophyll content (SPAD value)		Leaf area/ hill (cm^2)		Dry matter production (g/hill)		Plant height (cm)		No. of tillers/hill	
Seasons	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Irrigation intervals (days)										
3	41.29	42.6	1800	1760	35.03	39.91	83.60	87.00	17.09	16.80
6	40.28	40.3	1684	1280	32.64	38.53	80.42	86.63	16.32	16.56
9	34.65	36.2	1328	1040	27.64	30.65	74.54	80.90	12.29	12.65
LSD at 0.05	**0.74**	**0.89**	**240**	**120**	**3.49**	**2.00**	**1.700**	**3.96**	**0.36**	**0.32**
Sulfur rates (kg S/ ha)										
0	30.32	32.4	1448	1120	26.43	31.24	76.83	84.01	11.47	11.77
200	37.95	40.3	1640	1280	30.12	35.28	77.99	84.88	13.34	12.74
400	42.45	43.8	1640	1484	33.04	38.92	80.14	85.14	14.61	14.43
600	42.95	44.8	1560	1564	37.55	40.11	83.12	85.33	14.43	15.36
LSD at 0.05	**0.73**	**0.80**	**128**	**56**	**2.64**	**1.42**	**1.428**	**2.48**	**0.22**	**0.26**
Interaction	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**	**NS**	**	**

TABLE 4. Effect of irrigation intervals , sulfur rates and their interaction on yield components of rice during 2015 and 2016 season.

Yield components	No. of panicles/hill		Panicle length (cm)		No. of grains/panicle filled		No. of grains/panicle unfilled		Fertility %		1000- grain weight (g)		Panicle weight (g)	
Seasons	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Irrigation intervals (days)														
3	15.30	15.52	18.92	19.73	87.07	99.49	11.72	12.37	88.13	88.94	22.16	22.94	2.091	2.760
6	14.86	14.68	18.06	18.04	81.19	96.07	18.12	20.26	81.75	82.58	24.13	22.47	1.781	2.030
9	10.97	10.54	15.31	16.02	68.60	76.36	20.73	31.26	76.79	70.95	23.46	24.37	1.564	1.820
LSD at 0.05	**0.31**	**0.34**	**0.64**	**0.30**	**11.15**	**2.40**	**0.74**	**2.30**	**6.80**	**1.80**	**0.66**	**0.49**	**0.145**	**0.259**
Sulfur rates (kg S/ha)														
0	12.63	11.77	15.46	18.49	65.52	77.78	22.29	27.20	74.61	74.09	23.03	23.79	1.633	2.110
200	13.39	12.74	16.58	18.64	74.82	87.90	19.36	22.62	79.44	79.53	23.80	22.92	1.730	2.060
400	14.68	14.43	18.28	19.11	82.10	97.00	13.77	19.65	85.63	83.15	24.18	22.42	1.900	2.210
600	14.99	15.36	19.40	20.07	93.38	99.88	12.01	15.73	88.60	86.39	22.80	22.90	1.974	2.440
LSD at 0.05	**0.22**	**0.26**	**0.55**	**0.43**	**6.64**	**2.74**	**1.16**	**1.04**	**3.22**	**1.48**	**0.87**	**0.73**	**0.103**	**0.186**
Interaction	**	**	**	**	NS	**	**	**	NS	*	NS	NS	**	**

2015 Season **2016 Season**

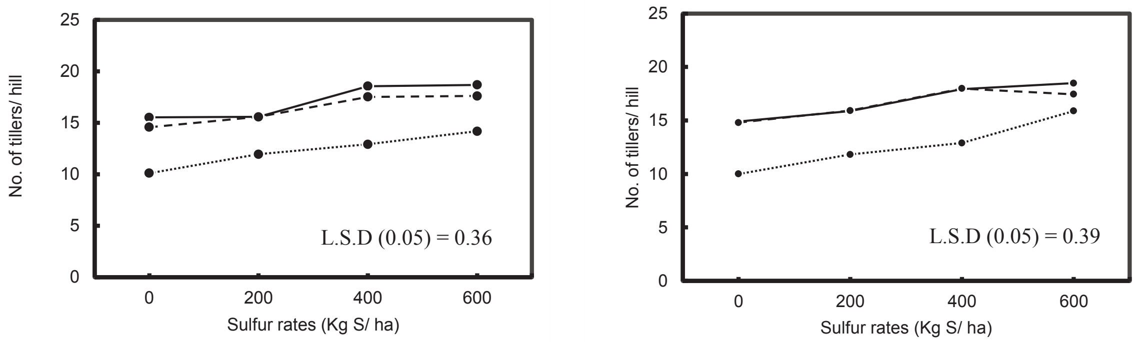

Fig. 1. Effect of the interaction between irrigation intervals and sulfur rates on the number of tillers /hill during 2015 and 2016 seasons. (Irrigation intervals 6 ---•-- ,3— •— and ……•.….. 9 days

The data indicated that the plants irrigated with shortest irrigation intervals (3 days) significantly increased no. of panicles/ hill , panicle length, no. of filled grains/ panicle , fertility % , 1000- grain weight and panicle weight. On the other hand, prolonged irrigation intervals (9 days) significantly decreased in the abovementioned yield components but increase the unfilled grain/ panicle in the two seasons. The depression in the values of yield components obtained under water stress condition may be due to the decrease in the dry matter production as previously discussed as well as due to the decrease in the germinated pollen on stigmas resulted in flower sterility and this in turn decrease the fertility % and consequently increase unfilled grains / panicle . Similar finding were obtained by Rang et al. (2011).

Among the sulfur rates, the data show that the application of of 600 kg S/ ha produced the highest significant values of no. of panicles/ hill, panicle length , no. of filled grains/ panicle, fertility % , 1000-grain weight and panicle weight but the lowest values of unfilled grains / panicle as compared with the other tested sulfur rates (0, 200 and 400 kg S/ha) in both seasons. The superiority of most yield components obtained herein owing to sulfur application may be due to its effect on improving the soil properties and enhancing growth characters as previously discussed.

The interaction between irrigation intervals and sulfur rates had significant effects on the number of panicles/ hill, panicle length , panicle weight and unfilled grain/ panicle in the two seasons (Table 4). The data illustrated in Fig. 2 show that the highest values of number of panicle/ hill, panicle length and weight were obtained when the rice plants were irrigated every 3 days and applied with 600 kg S/ha in both seasons. Reversly, the plants irrigated every 9 days without sulfur application produced the highest values of unfilled grains/ panicle. This trend was fairly true in the two seasons. However , the other yield components were not significantly affected by that interaction in the first and/ or second season, therefore their data were neglected .

Yield performance

Table 5 included the data of grain and biogical yields/ ha as well as harvest index as affected by irrigation intervals, sulfur rates and their interaction in 2015 and 2016 seasons.

The data show that shortening irrigation intervals from 9 to 6 and 3 days caused a significant increasing in each of grain and biological yield/ ha as well as harvest index. This increase amounted to (9.80 and 61.70 %) for grain yield/ ha , (2.67 and 38.90 %) for biological yield/ ha and (6.96 and 16.45 %) for harvest index when the plants were irrigated every 3 days compared to when those irrigated every 6 and 9 days, respectively (as an average of the two seasons). This superiority may be due to the shortest irrigation intervals (3 days) mitigated the harmful effect of soil salinity in that experiments (Table 2) and consequently improved growth characters (Table 3) and yield component, i.e. no. of panicles/ hill , panicle length, no. of filled grains/ panicle, fertility %, 1000- grain weight and panicle weight (Table 4) and this in turn improved grain and biological yields/ ha. Moreover, it can be noticed that also that there are a sharply and dratistically reduction in grain and biological yields/ ha as well as harvest index when the plants were irrigated every 9 days more than those irrigated every 6 days.

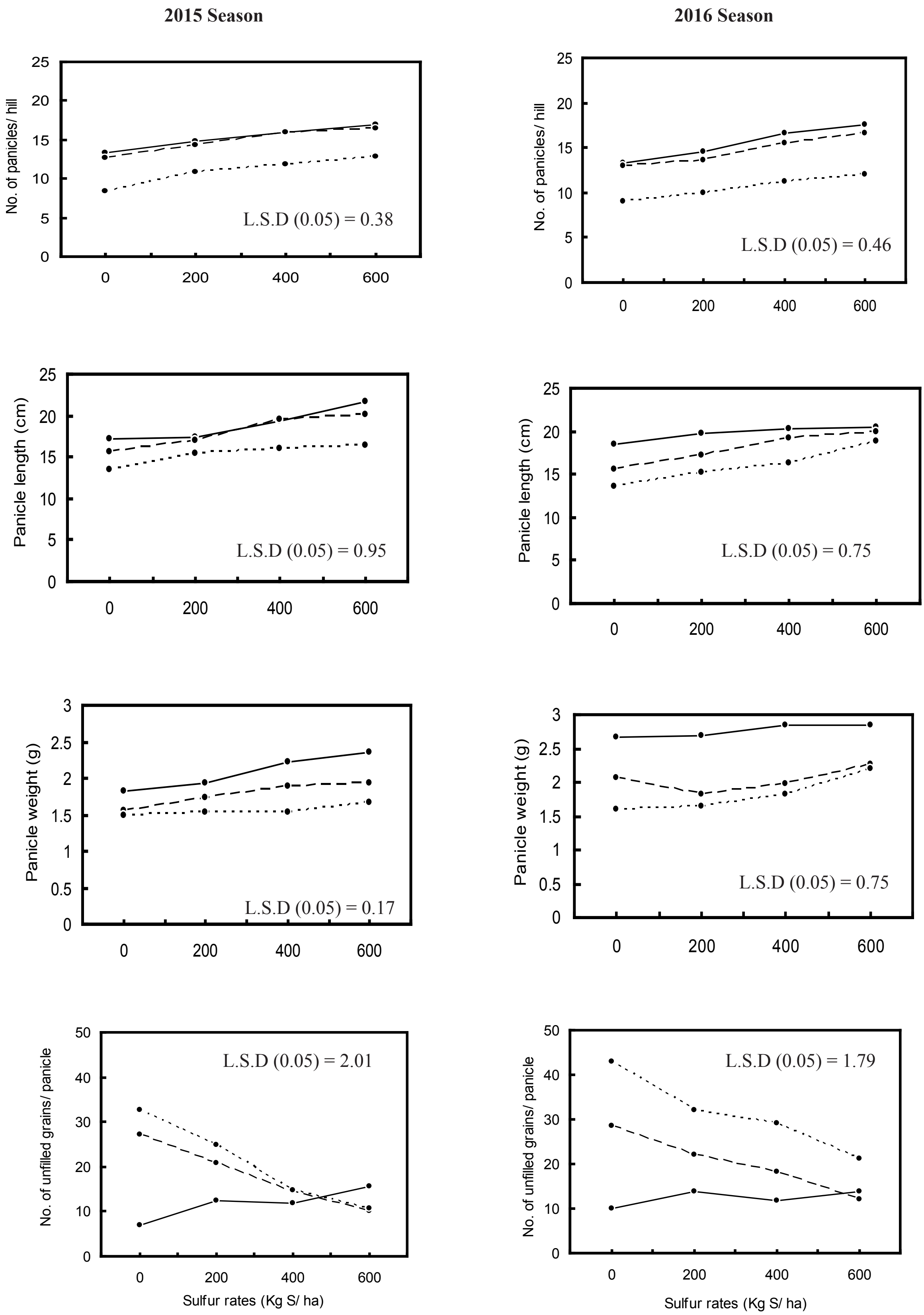

Fig. 2. Effect of the interaction between irrigation intervals and sulfur rates on some yield components of rice during 2015 and 2016 seasons. (Irrigation intervals 6 ---•-- ,3— •— - and … • … 9 days)

TABLE 5. Effect of irrigation intervals , sulfur rates and their interaction on grain and biological yields/ ha as well as harvest index % of rice during 2015 and 2016 seasons.

Characters	Grain yield (ton/ ha)		Biological yield (ton/ ha)		Harvest index (%)	
Seasons	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Irrigation intervals (days)						
3	4.10	4.30	9.04	9.10	45.35	47.25
6	3.73	3.92	8.91	8.76	41.86	44.75
9	2.43	2.78	6.56	6.50	37.04	42.77
LSD at 0.05	**0.32**	**0.35**	**0.45**	**0.43**	**3.00**	**1.90**
Sulfur rates (kg S/ha)						
0	2.86	2.95	7.28	7.03	39.29	41.96
200	3.27	3.44	8.07	7.64	40.52	45.03
400	3.66	4.00	8.51	8.72	42.30	45.87
600	3.83	4.19	8.86	9.07	43.23	46.20
LSD at 0.05	**0.22**	**0.24**	**0.31**	**0.42**	**1.30**	**0.90**
Interaction	**	**	**	**	**NS**	**NS**

The data show that the application of sulfur at a rate of 600 kg S/ ha produced the maximum values of grain yield (3.83 and 4.19 ton/ ha), biological yield (8.86 and 9.07 ton/ ha) and harvest index (43.23 and 46.20 %) in the first and second seasons, respectively. However, it can be noticed that there are not significant differences between 400 and 600 kg S/ ha for grain yield/ ha and harvest index in both seasons. The superiority of grain and biological yields/ ha as well as harvest index by the application of sulfur may be due to its effect on reducing soil pH and improving soil structure as well as beneficial role in plant metabolism and consequently increase the yield components as previously discussed (Table 4). Similar results were observed by Lunde et al. (2008).

The interaction between irrigation intervals and sulfur rates were significant on grain and biological yields/ ha in the two seasons as shown in Table 6. However , harvest index was not significantly affected by such interaction in both seasons. The data show that increasing sulfur application rates gradually increased the values of grain and biological yields/ ha up to 400 kg S/ ha under irrigation every 3 days and up to 600 kg S/ ha under irrigation every 6 and 9 days. Moreover, it can be noticed that the sulfur application under the stress conditions (irrigation every 9 days) was more effective and pronounced for enhancing the increase percentage of grain and biological yields/ ha than that under the normal conditions (irrigation every 3 days).

Water applied and productivity

The data in Table 7 show that the plants irrigated every 3 days received the highest amounts of total water (14555 and 15185 m^3/ ha) in both seasons. Moreover, it can be noticed that the total water applied was decreased and saved with increasing irrigation intervals from 3 to 6 days by about 1610 and 2265 m^3/ ha (11.06 and 14.92 %) as well as from 3 to 9 days by about 5215 and 9295 m^3/ ha (35.82 and 38.79 %) in the first and second season, respectively. Similar results were nearly obtained by El-Refaee et al. (2012) and Ibrahim et al. (2017).

Data presented in Table 8 show that the values of water productivity was increased by increasing irrigation intervals up to 6 days (0.288 and 0.303 kg grains/m^3) and also by increasing sulfur rates up to 600 kg S/ha (0.320 and 0.350 kg grains/m^3) in the first and second season, respectively. Moreover, the interaction effect between irrigation intervals and sulfur rates indicate that the highest values of water productivity (0.334 and 0.391 kg grains/m^3) were obtained when the rice plants were irrigated every 9 days and fertilized with 600 kg S/ ha in the two seasons. This means that the application of sulfur to rice plants cultivated in salinity soil raised the water productivity particulary when the plants were irrigated every 9 days . Similar results were obtained by Helmy et al. (2013).

TABLE 6. The interaction between irrigation intervals and sulfur rates on grain and biological yields during 2015 and 2016 seasons

Irrigation intervals	Sulfur rates (kg S/ ha)	Grain yield				Biological yield			
		ton / ha		Increase %		ton / ha		Increase %	
		2015	2016	2015	2016	2015	2016	2015	2016
3 days	0	3.56	3.63	-	-	8.57	7.97	-	-
	200	3.96	4.11	11.24	13.22	8.97	8.55	4.67	7.28
	400	4.54	4.82	27.53	32.78	9.37	9.96	9.33	24.97
	600	4.35	4.65	22.19	28.10	9.35	9.89	9.10	24.09
6 days	0	3.20	3.29	-	-	8.19	7.73	-	-
	200	3.57	3.76	11.56	14.29	8.92	8.23	8.91	6.47
	400	3.94	4.07	23.13	23.71	9.05	9.34	10.50	20.83
	600	4.22	4.56	31.88	38.60	9.49	9.72	15.87	25.74
9 days	0	1.82	1.94	-	-	5.08	5.40	-	-
	200	2.28	2.45	25.27	26.29	6.31	6.14	24.21	13.70
	400	2.50	3.11	37.63	60.31	7.11	6.95	39.96	28.70
	600	3.12	3.63	71.42	87.11	7.74	7.51	52.36	39.07
L.S.D at 0.05		**0.30**	**0.41**	**-**	**-**	**0.44**	**0.40**	**-**	**-**

TABLE 7. Effect of irrigation intervals on the amounts of total applied and saved water (m^3/ha) during 2015 and 2016 seasons.

Irrigation interval (days)	2015 season			2016 season		
	Applied water (m^3/ha)	Saved water		Applied water (m^3/ha)	Saved water	
		(m^3/ha)	%		(m^3/ha)	%
3	14555	-	-	15185	-	-
6	12945	1610	11.06	12920	2265	14.92
9	9340	5215	35.83	9295	5890	38.79

TABLE 8. Effect of irrigation intervals and sulfur rates and their interactions on water productivity (kg grains / m^3 water) during 2015 and 2016 seasons.

Irrigation intervals (days)	Sulfur rates (kg S/ha)									
	2015 season					2016 season				
	0	200	400	600	Mean	0	200	400	600	Mean
3	0.245	0.272	0.312	0.299	0.282	0.239	0.271	0.317	0.306	0.283
6	0.247	0.276	0.304	0.326	0.288	0.255	0.291	0.315	0.353	0.303
9	0.195	0.244	0.268	0.334	0.260	0.209	0.264	0.335	0.391	0.300
Mean	**0.229**	**0.264**	**0.295**	**0.320**		**0.234**	**0.275**	**0.322**	**0.350**	

Conclusion

Finally, it can be concluded that shortest Irrigation interval (3 days) was more effective and increased most of growth characters and yield and its components studied. However, increasing irrigation intervals up to 9 days was unfavorable and decreased the grain productivity of rice , followed by irrigation interval every 6 days under salinity stress . Sulfur application significantly increased the ability of rice plants to tolerant the harmful effect of salinity and water stress together by decreasing the values of EC, pH and bulk density which led to improve the soil chemical properties in this study . Moreover, sulfur application increased water productivity as well as improved growth parameters and yield of rice.

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استجابة محصول الأرز لإضافة الكبريت تحت ظروف الإجهاد المائي والملحي

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أجريت تجربتان حقليتان بمزرعة محطة بحوث السرو- دمياط- مصر خلال موسمي الزراعة ٢٠١٥ ، ٢٠١٦ وذلك لدراسة تأثير ثلاث فترات ري وهي الري كل ٣ أيام (الغمر المستمر) ، ٦ ، ٩ ايام وأربعة معدلات إضافة أرضية للكبريت (٠ ، ٢٠٠ ، ٤٠٠ ، ٦٠٠ كجم كبريت / هكتار) على بعض صفات الأرض الطبيعية والكيميائية (درجة الحموضة ، درجة التوصيل الكهربي ، كثافة التربة) وصفات نمو النبات (محتوى الكلوروفيل الكلي ، مساحة الأوراق وكمية المادة الجافة وعدد الفروع للجورة ، طول النبات) وصفات المحصول ومكوناته (عدد السنابل في الجورة ، طول السنبلة ، عدد الحبوب الممتلئة والفارغة في السنبلة ، النسبة المئوية للخصوبة في السنبلة ، وزن ١٠٠٠ حبة ، وزن السنبلة ، محصول الحبوب والبيولوجي للهكتار ، دليل الحصاد) وكذلك كمية المياه المضافة وكفاءة استخدام المياه وذلك لمحصول الأرز صنف سخا ١٠٦ تحت ظروف الأراضي الملحية .هذا وقد استخدم تصميم الشرائح المتعامدة في تنفيذ التجربة حيث وضعت معاملات الري في القطع الأفقية بينما وضعت معدلات الكبريت في القطع الرأسية ويمكن ايجاز اهم النتائج المتحصل عليها كما يلي :

١- أدى رى نباتات الأرز كل ٣ أيام إلى تخفيف التاثير الضار لملوحة الأرض عن طريق تقليل قيم صفات الأرض الطبيعية والكيميائية المدروسة وزيادة صفات النمو ومحصول الحبوب ومعظم مكوناته بالمقارنة بفترتي الري المتوسطة (كل ٦ أيام) والطويلة (كل ٩ أيام) بينما أدى رى نباتات الأرز على فترات طويلة (كل ٩ أيام) إلى زيادة معنوية في عدد الحبوب الفارغة في السنبلة

٢- أدت زيادة معدلات الكبريت المضافة حتى ٦٠٠ كجم كبريت / هكتار إلي تقليل الأثر الضار لملوحة التربة عن طريق تقليل قيم صفات الأرض الطبيعية والكيميائية المدروسة بينما أدت إلى زيادة تدريجية في صفات النمو ومحصول الحبوب ومعظم مكوناته بينما إلى نقص في عدد الحبوب الفارغة في السنبلة

٣- تشير نتائج التفاعل إلى زيادة إنتاجية محصول الحبوب والمحصول البيولوجي للهكتار وذلك باضافة الكبريت حتي ٤٠٠ كجم كبريت / هكتار في فترة الري القصيرة (كل ٣ أيام) وحتى ٦٠٠ كجم كبريت / هكتار تحت فترتي الري المتوسطة (كل ٦ أيام) والطويلة (كل ٩ أيام)

٤- تشير النتائج إلى أن ري نباتات الأرز كل ٣ أيام قد استهلك اكبر كمية مياه ري في حين أن زيادة فترات الري حتي ٦ او ٩ أيام بين الرية والاخري قد أدى إلى انخفاض تدريجي في كمية مياه الري المستهلكة تقدر بحوالي ٩٩,١٢ و ٣٧,٣١ ٪ علي التوالي مقارنة بالري كل ٣ أيام هذا وقد أدى ري نباتات الأرز كل ٦ أيام مع إضافة الكبريت بمعدل ٦٠٠ كجم كبريت / هكتار إلى إعطاء اعلى قيم لكفاءة استخدام مياه الري (٢٩٦,٠ كجم حبوب / م٣ مياه) كمتوسط لموسمي الزراعة مما يشير إلى أهمية إضافة الكبريت في تحسين صفات التربة وزيادة نمو وانتاجية محصول الأرز ورفع كفاءة استخدام مياه الري في حقول الأرز وخاصة تحت ظروف الاجهاد المائي في الأراضي الملحية