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Treating Rice Plants with Zeolite Soil Addition and Foliar Application of Potassium Silicate to Mitigate the Expected Water Scarcity in North Nile Delta, Egypt

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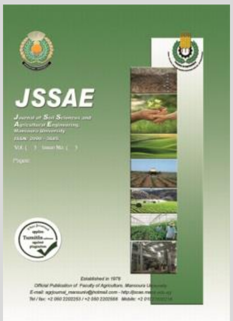

ABSTRACT

Due to limited water resources in Egypt, the researchers should find various ways to save irrigation water without a reduction in rice yield. So, two field experiments were conducted to evaluate the impact of three irrigation intervals as main plots [irrigation every 6, 8 and 10 days], three addition levels of zeolite as sub-plots [0.0 (without addition), 7.0 and 10.0 ton fed^{-1}], foliar application of potassium silicate as sub-sub plots [0.0 (without foliar application) and 2.0 g K_2SiO_3 L^{-1}] and their interactions on performance and yield of rice plant. Also, post-harvest soil analysis was done. The results indicated that water stress (irrigation every 8 and 10 days) led to raising phenol content and superoxide dismutase activity in rice plant leaves, while zeolite and potassium silicate led to a decline of the plant's requirement from these antioxidants. Both zeolite and potassium silicate beneficially affected rice growth, yield and its components. Soil addition of zeolite at rate of 7.0 and 10 ton fed^{-1} before sowing under watering rice plants every 8 days realized better results for growth, yield and its components than non- soil addition of zeolite under watering every 6 days (traditional irrigation) in presence and absence of K_2SiO_3. Usage of zeolite improved soil total porosity, CEC and FC values.It can be concluded that both potassium silicate as a foliar application and zeolite amendment represents an attractive option to mitigate the expected water scarcity.

Keywords: Rice plant, zeolite, irrigation intervals, potassium silicate and antioxidants.

INTRODUCTION

Rice (*Oryza Sativa* L.) is one of the most important cereals in the world. Rice crop consumes so much irrigation water comparing with other crops. Nowadays, due to the scarcity of water, Egypt faces a challenge in rice productivity. Therefore, there is an urgent need to find new irrigation regimes aiming to save the irrigation water without a decline of rice crop productivity.

Soil amendments such as zeolite is one of the most eco-friendly techniques to enhance water use efficiency by reducing water leaching. Kulikova *et al.* (2020) indicated that zeolite amendment is an environmentally friendly product. Zeolite improves soil properties such as CEC and holding both water and nutrients and release them for plants at the need time, thereby improving plant growth with water scarcity (Bernardi *et al.* 2009; Bernardi *et al.* 2010; Azarpour *et al.* 2011; Gomah, 2015 and Khalifa, *et al.* 2019). Khalifa, *et al.* (2019) showed that using zeolite could increase available water values, available nutrients (N, P, and K), CEC and total porosity. Beside, El-Sherpiny *et al.* (2020) found that zeolite improved bulk density, total porosity, CEC and FC of soil.

Potassium silicate (K_2SiO_3) is a source of high potassium and silicon nutrients, so it is used in agricultural purposes as a silicon source and has supplying small amounts of potassium to improve the quality of rice yield (Tarabih *et al.* 2014).

Therefore, the aim of the current study is to assess response of rice plants in terms of growth and yield as well as some soil properties to zeolite soil addition and foliar spraying with potassium silicate under deficit irrigation water.

MATERIALS AND METHODS

1. Experiment Design and Crop Management.

Two field experiments were carried out in a split-split plot design at a private farm located in Met Antar village, Talkha district, Dakahlia governorate, Egypt during the summer rice-growing seasons of 2019 and 2020 to evaluate the impact of three irrigation intervals as main plots [irrigation every 6, 8 and 10 days], three addition levels of zeolite as sub-plots [0.0 (without addition), 7.0 and 10.0 ton fed^{-1} as soil addition at 30 days before sowing], foliar application of potassium silicate as sub-sub plots [0.0 (without foliar application) and 2.0 g K_2SiO_3 L^{-1}] and their interactions on attributes of rice plants growth (*Oryza sativa* L.) "Sakha 104 cultivar". The experiment included 18 treatments; each treatment was replicated three times. The experimental unit size was 18m^2 (3×6). Starting from first irrigation, the studied irrigation intervals were applied (as continuous flooding) until rice crop harvest using main canal near the experimental site (Nile River). At the start of the experiment (before transplanting the rice seedlings in the permanent field), soil sample at depth of 0-30 cm was taken and analyzed according to Buurman *et al.*, (1996), where the soil texture was clay with pH value 8.00 (1: 2.5 soil: water suspension) having low organic matter content (1.28%), available N of 55.2 mg kg^{-1}, available P of 7.75 mg kg^{-1} and adequate available K with 305.1 mg kg^{-1}. Zeolite (from Alex Zeolite Company) contained SiO_2 (64.75%), K_2O (5.20%),

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FeO (6.0%), P_2O_5 (1.05%), AlO_3 (12.5%) , Na_2O (1.50%) and CaO (9.0%) as well as its CEC value was 158.50 cmol kg^{-1} and EC of 2.35 dSm^{-1}.The rice seedlings were transplanted on 8th June in both seasons. The experimental field was prepared (plowed two times and well dry leveled).The traditional agricultural practices and mineral fertilization were done for the rice production according to the recommendations of Ministry of Agri. and Land Reclamation. Each irrigation treatment was isolated from another with 2.5 meter to prevent water seepage.

2.Data Recorded.

1.Measurements at panicle initiation and heading stage.

- **Plant height (cm).**
- **Chlorophyll content (SPAD value).**
- **Phenols (mg.g^{-1} F.W)** were determined calorimetrically using the modified Folin-Ciocaltue colourimetric method (Eberhardt *et al.* 2000).
- **Superoxide Dismutase activity (SOD enzyme, Unit.min^{-1}.mg^{-1})** in leaves of rice plant was determined by measuring inhibition of photochemical reduction of NBT as described by Peixoto *et al.* (1999).

2.Yield and its components at harvest stage.

- Panicle length (cm) and weight (g).
- No. of grains $panicle^{-1}$ and No. of filled grain.
- 1000 seeds weight (g) and grain yield (Mg ha^{-1}).

a.Grain quality parameters.

- Grain protein content (%) was calculated using the following formula: Crude protein % = Nitrogen (N)% × 5.75. N (%) of rice grain was determined by Micro-Kjeldhal method as mentioned by Anonymous, (1990).
- Total carbohydrates (%) in rice grains were determined according to Hedge and Hofreiter (1962).

b. Soil analyses.

After harvest stage, soil samples (0-30 cm depth) from each sub sub-plot were taken and analyzed according to Buurman *et al.* (1996) to evaluate the effect of studied treatments on some soil properties, where the cation exchange capacity (CEC, cmol.kg^{-1}), electric conductivity (EC,dSm^{-1}),total porosity (TP,%) and field capacity (FC,%) were determined.

3.Statical Analysis.

Data obtained were statistically analyzed according to Gomez and Gomez (1984) using CoStat (Version 6.303, CoHort, USA, 1998–2004).

RESULTS AND DISCUSSION

1. Phenol (mg.g^{-1} F.W) and SOD enzyme (Unit.g^{-1} F.W).

Data in Table 1 indicate that water stress (irrigation every 8 and 10) led to raising phenol (mg.g^{-1} F.W) content and superoxide dismutase activity (SOD, Unit.g^{-1} F.W) in rice plant leaves, where increases of irrigation intervals from 6 to 8 and 10 days caused raising self-production of the plant from antioxidants such as phenols and SOD enzyme to resist water deficit. Generally, irrigation every 10 days recorded the highest values of the studied antioxidants followed by irrigation every 8 days, while the lowest values were recorded with plants irrigated every 6 days. On the other hand, the plants grown without soil addition of zeolite produced the studied antioxidants in leaves of rice plants more than that with zeolite, where the lowest values of phenols and SOD enzyme were realized with zeolite at rate of 10.0 ton fed^{-1} followed by 7.0 and 0.0, respectively. Also, the rice plants treated with potassium silicate at rate of 2g L^{-1} produced phenols and SOD enzyme less than untreated plants. Generally, it can be said that rice plants may up-regulate various scavenging mechanisms like antioxidants to mitigate stress-induced damage. Also, zeolite and potassium silicate have a beneficial role in increasing rice plant resistance to water stress, thus the plant's requirement from antioxidants such as phenol and SOD enzyme were reduced. This result is in accordance with those of Goud and Kachole, (2011); Yi *et al.*, (2014); Palanivell *et al.* (2016); and Hellal *et al.* (2020). This trend was found in both growing seasons.

2. Agronomic Parameters.

Data in Tables 1, 2 and 3 show the effect of irrigation intervals, zeolite soil addition, foliar spraying with potassium silicate and their interactions on plant height (cm) and chlorophyll (SPAD Reading) as well as yield and its components [panicle length(cm), No. of grains $panicle^{-1}$, No. of filled grain, 1000 seed weight (g), grain yield (Mg ha^{-1})] and some quality traits of grain [protein and carbohydrates (%)] of rice grains during two growing seasons of 2019 and 2020.

It is clear that all aforementioned traits were significantly affected due to studied irrigation intervals, where the values significantly increased as irrigation intervals decreased. Hence, the highest values were recorded with rice plants irrigated every 6 days followed by that irrigated every 8 and 10 days, respectively. These results confirm that rice grown under drought stress possess slow growth and low yield compared to that grown under traditional flooding irrigation (irrigation every 6 days). Generally, the increases of all agronomic parameters under irrigation every 6 days might be due to sufficient water and nutrients that are essential for biological and physiological processes including cell division and cell elongation compared to other intervals (8 and10 days). This result is in accordance with those of Zulkarnain *et al.* (2009) and Sultan *et al.* (2013).

Regarding soil addition of zeolite, results showed pronouncedly significant differences among additives zeolite, where soil addition at rate of 10 ton fed^{-1} was the superior treatment followed by 7.0 ton fed^{-1}, while untreated plants gave the lowest values. The promotional effect of zeolite is due to its role in preventing soil moisture losses in addition its high content from adsorbed nutrients (as mentioned in the material section).This result is in accordance with those of Ahmed *et al.* 2010; Ozbahce *et al.* 2015 and Khalifa, *et al*. 2019 and El-Sherpiny *et al.* (2020).

Concerning foliar application of potassium silicate, the data in same Tables showed that foliar spraying with potassium silicate at rate of 2 g L^{-1} gave results better than non-foliar. This may be attributed to potassium silicate (K_2SiO_3) as source of high soluble potassium and silicon; therefore foliar spraying with it caused improvement of all aforementioned traits. On the other hand, it is known that silicon nutrition alleviates many abiotic stresses like water deficit in addition to that silicon reduces plant transpiration (Epstein, 1994; Ma and Yamaji, 2006). Also, silicon in rice shoots may be enhance the thickness of the culm wall and the size of the vascular bundles that result in a reduction in lodging. These results are in agreement with those obtained by Abdel-Haliem *et al.* (2017).

The combination of irrigation every 6 days, treating with 10 ton zeolite fed^{-1} and foliar application of 2.0 g

K_2SiO_3 L^{-1} realized the highest values of all aforementioned traits, while the lowest values were recorded when rice plants irrigated every `0 days without both zeolite and K_2SiO_3. Taking into account that soil addition of zeolite at rate of 7.0 and 10 ton fed^{-1} before sowing with irrigation of rice plants every 8 days realized better results than non-addition of zeolite with irrigation every 6 days (traditional irrigation) in presence and absence K_2SiO_3. This trend was found in both growing seasons.

3.Soil Properties.

Table 4 shows that soil properties such as EC (dSm^{-1}), CEC ($cmol.kg^{-1}$), total porosity (%) and F.C (%) pronouncedly differ as a result of studied treatments, where the values are means of both seasons.

Soil EC values at harvest stage were more than that before transplanting and this may be attributed to residual salts in the soil due to fertilization processes during growing season. Soil addition of zeolite caused increasing soil EC.

On the contrary, irrigation every 6 days caused a slight decrease in soil EC values compared to 8 and 10 days, respectively. This may be attributed to irrigation every 6 days takes more water, thus leaching of salts out of the soil root zone is more far. The effect of foliar application of K_2SiO_3 on soil EC values is positive, where the values were reduced with foliar application of K_2SiO_3 compared to control treatment (0.0 g K_2SiO_3 L^{-1}) and this may be due to the role of potassium silicate in improving plant uptake.

As for cation exchange capacity (CEC, $cmol.kg^{-1}$), total porosity (TP,%) and field capacity (FC,%), the most effective factor affected these properties is zeolite. Irrigation intervals and foliar application have a slight impact on these physical properties. So, results presentation will be confined to zeolite impact. The soil CEC increased as zeolite rate increased and these increases may be due to the high CEC value of used zeolite (158.5 cmol kg^{-1}). Appling zeolite before transplanting at rate of 7.0 and 10.0 ton fed^{-1} led to an increase of soil total porosity and these Increases may be attributed to the role of zeolite in aggregation process which caused improving soil structure which reflects positively on soil physical properties. F.C of soil after harvesting rice gradually increased with raising rate of zeolite. This behavior might be due to that zeolite holds a high quantity of water in its pores, where zeolite can retain more irrigation water in the root zone to be uptaked by plants as need, thus zeolite helps in tolerance the water stress (irrigation every 8 and 10 days).

Table 1. Impact of irrigation intervals, zeolite soil addition and foliar application with potassium silicate on plant height as well as chlorophyll, SOD and phenol contents of rice plants during two growing seasons of 2019 and 2020.

Characters			Plant height ,cm		Chlorophyll SPAD Reading		SOD, $Unit.min^{-1}.mg^{-1}$		Phenol, $mg.g^{-1}$ F.W	
Treatments			2019	2020	2019	2020	2019	2020	2019	2020
Irrigation intervals										
Irrigation every 6 days			100.76a	115.50a	33.00a	33.71a	21.71c	22.06c	31.91c	31.97c
Irrigation every 8 days			95.31b	107.48b	28.23b	28.75b	25.47b	25.81b	38.40b	38.40b
Irrigation every 10 days			89.79c	99.54c	23.45c	23.97c	29.11a	29.53a	44.90a	44.91a
LSD at 5%			0.25	2.32	0.57	0.08	0.04	0.13	0.15	0.36
Zeolite application										
Without zeolite			89.76c	99.52c	23.43c	23.93c	29.17a	29.59a	44.89a	44.91a
7 ton Zeolite fed^{-1}			97.48b	110.68b	30.12b	30.64b	23.87b	24.21b	35.85b	35.85b
10 ton Zeolite fed^{-1}			98.62a	112.33a	31.13a	31.87a	23.26c	23.60c	34.47c	34.52c
LSD at 5%			0.19	0.46	0.11	0.06	0.06	0.13	0.13	0.45
Potassium silicate										
0.0 g K_2SiO_3 L^{-1}			94.31b	106.24b	27.37b	27.97b	26.02a	26.40a	39.55a	39.59a
2.0 g K_2SiO_3 L^{-1}			96.26a	108.78a	29.08a	29.66a	24.84b	25.21b	37.25b	37.26b
LSD at 5%			0.27	0.92	0.25	0.08	0.09	0.09	0.08	0.26
Interaction										
Irrigation every 6 days	Without zeolite	0.0 g $K_2SiO_3L^{-1}$	94.72j	108.78g	27.66j	28.25j	25.90i	26.55h	39.09i	39.12i
		2.0 g $K_2SiO_3L^{-1}$	95.95i	109.36fg	28.76i	29.34i	25.36j	25.70i	37.67j	37.68j
	7 ton Zeolite fed^{-1}	0.0 g $K_2SiO_3L^{-1}$	101.75d	116.16bc	33.92d	34.80d	20.18o	20.56n	30.76o	30.76o
		2.0 g $K_2SiO_3L^{-1}$	104.03b	119.53a	35.91b	36.30b	19.62p	19.91o	28.03q	28.02q
	10 ton Zeolite fed^{-1}	0.0 g $K_2SiO_3L^{-1}$	102.87c	118.20ab	34.84c	35.57c	20.38o	20.47n	29.24p	29.60p
		2.0 g $K_2SiO_3L^{-1}$	105.22a	120.98a	36.90a	38.02a	18.84q	19.19p	26.66r	26.64r
Irrigation every 8 days	Without zeolite	0.0 g $K_2SiO_3L^{-1}$	87.63p	95.44jk	21.53p	22.00p	30.52c	30.66c	47.48c	47.50c
		2.0 g $K_2SiO_3L^{-1}$	88.75o	97.59ij	22.56o	23.25o	29.77d	30.08d	46.09d	46.10d
	7 ton Zeolite fed^{-1}	0.0 g $K_2SiO_3L^{-1}$	97.12h	111.67ef	29.80h	30.12h	24.36k	24.69j	36.26k	36.25k
		2.0 g $K_2SiO_3L^{-1}$	99.50f	112.46de	31.82f	32.13f	22.66m	23.31l	33.43m	33.43m
	10 ton Zeolite fed^{-1}	0.0 g $K_2SiO_3L^{-1}$	98.25g	112.95de	30.78g	31.50g	23.57l	24.01k	34.94l	34.95l
		2.0 g $K_2SiO_3L^{-1}$	100.63e	114.79cd	32.88e	33.52e	21.96n	22.12m	32.16n	32.15n
Irrigation every 10 days	Without zeolite	0.0 g $K_2SiO_3L^{-1}$	85.29r	92.81k	19.49r	19.72r	32.12a	32.76a	50.21a	50.19a
		2.0 g $K_2SiO_3L^{-1}$	86.23q	93.12k	20.58q	20.99q	31.35b	31.80b	48.79b	48.85b
	7 ton Zeolite fed^{-1}	0.0 g $K_2SiO_3L^{-1}$	90.05n	99.83i	23.61n	24.35n	29.00e	29.40e	44.69e	44.69e
		2.0 g $K_2SiO_3L^{-1}$	92.41l	104.42h	25.63l	26.15l	27.38g	27.42g	41.90g	41.92g
	10 ton Zeolite fed^{-1}	0.0 g $K_2SiO_3L^{-1}$	91.16m	100.31i	24.66m	25.39m	28.20f	28.50f	43.30f	43.27f
		2.0 g $K_2SiO_3L^{-1}$	93.58k	106.74gh	26.70k	27.22k	26.63h	27.33g	40.53h	40.51h
LSD at 5%			0.82	2.77	0.76	0.25	0.26	0.28	0.25	0.80

Table 2. Impact of irrigation intervals, zeolite soil addition and foliar application with potassium silicate on yield and its components of rice plants during two growing seasons of 2019 and 2020.

Characters / Treatments			Panicle length (cm)		Panicle weight (g)		No. of grains/panicle		No. of filled grains		1000 seeds weight (g)		Grain yield (Mg ha^{-1})	
			2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Irrigation intervals														
Irrigation every 6 days			24.83a	25.35a	2.74a	2.80a	139.06a	141.72a	98.06a	100.22a	27.75a	28.19a	8.98a	9.12a
Irrigation every 8 days			23.16b	23.57b	2.50b	2.56b	129.06b	131.11b	89.44b	91.83b	26.07b	26.62b	7.59b	7.70b
Irrigation every 10 days			21.50c	21.96c	2.25c	2.29c	117.72c	120.00c	81.72c	83.44c	24.28c	24.80c	6.06c	6.15c
LSD at 5%			0.06	0.03	0.03	0.01	0.76	3.26	2.61	0.83	0.05	0.37	0.08	0.01
Zeolite application														
Without zeolite			21.46c	21.88c	2.24c	2.29c	117.39c	120.00c	81.61c	83.72c	24.31c	24.83c	6.02c	6.11c
7 ton Zeolite fed^{-1}			23.83b	24.25b	2.60b	2.65b	133.17b	135.11b	92.78b	94.78b	26.70b	27.15b	8.16b	8.29b
10 ton Zeolite fed^{-1}			24.20a	24.75a	2.65a	2.70a	135.28a	137.72a	94.83a	97.00a	27.09a	27.64a	8.45a	8.57a
LSD at 5%			0.05	0.04	0.02	0.02	0.57	1.88	1.84	1.37	0.07	0.30	0.06	0.01
Potassium silicate														
0.0 g K_2SiO_3 L^{-1}			22.87b	23.33b	2.45b	2.50b	126.74b	129.04b	88.59b	90.48b	25.72b	26.28b	7.29b	7.40b
2.0 g K_2SiO_3 L^{-1}			23.46a	23.93a	2.54a	2.60a	130.48a	132.85a	90.89a	93.19a	26.35a	26.79a	7.80a	7.91a
LSD at 5%			0.07	0.07	0.02	0.03	0.69	1.36	1.10	0.82	0.07	0.24	0.07	0.2
Interaction														
Irrigation every 6 days	Without zeolite	0.0 g K_2SiO_3 L^{-1}	23.13j	23.58g	2.48ij	2.52g	125.00i	127.67f	89.00g	91.33fg	25.89j	26.41fg	7.42j	7.53j
		2.0 g K_2SiO_3 L^{-1}	23.45i	23.93f	2.54hi	2.62f	129.33h	132.33e	90.33fg	92.33f	26.25i	26.86ef	7.76i	7.90i
	7 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	25.05d	25.76c	2.78cd	2.84cd	142.33cd	144.33bc	99.67bc	102.33bc	28.02d	28.69bc	9.31d	9.48d
		2.0 g K_2SiO_3 L^{-1}	25.77b	26.02b	2.88ab	2.95ab	145.67ab	147.67ab	102.67ab	104.33b	28.78b	28.34bc	9.80b	9.94b
	10 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	25.43c	25.95bc	2.84bc	2.87bc	144.33bc	147.33ab	102.33ab	103.67b	28.40c	29.00b	9.53c	9.67c
		2.0 g K_2SiO_3 L^{-1}	26.13a	26.89a	2.93a	2.99a	147.67a	151.00a	104.33a	107.33a	29.17a	29.84a	10.06a	10.17a
Irrigation every 8 days	Without zeolite	0.0 g K_2SiO_3 L^{-1}	20.75p	21.15l	2.15op	2.20lm	112.67mn	116.33jk	78.67kl	81.00l	23.69p	24.26jk	5.41p	5.49p
		2.0 g K_2SiO_3 L^{-1}	21.12o	21.76k	2.21no	2.25kl	114.67m	117.67ij	80.33jk	82.67kl	24.05o	24.53j	5.84o	5.93c
	7 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	23.80h	24.05f	2.58gh	2.64f	132.33g	132.00e	92.33ef	93.67ef	26.59h	27.18e	8.08h	8.21h
		2.0 g K_2SiO_3 L^{-1}	24.41f	24.65e	2.69ef	2.76de	138.67e	140.67cd	94.33de	97.33d	27.38f	28.04cd	8.74f	8.86f
	10 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	24.12g	24.54e	2.63fg	2.70ef	135.67f	137.67d	93.67e	95.67de	27.03g	27.57de	8.44g	8.54g
		2.0 g K_2SiO_3 L^{-1}	24.76e	25.26d	2.74de	2.81cd	140.33de	142.33c	97.33cd	100.67c	27.70e	28.17cd	9.03e	9.17e
Irrigation every10 days	Without zeolite	0.0 g K_2SiO_3 L^{-1}	19.94r	20.07n	2.01q	2.04n	110.33o	112.33k	75.33m	77.33m	22.76r	23.19l	4.71r	4.81r
		2.0 g K_2SiO_3 L^{-1}	20.36q	20.78m	2.08p	2.13m	112.33no	113.67jk	76.00lm	77.67m	23.22q	23.71kl	4.97q	5.02q
	7 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	21.57n	22.20j	2.26mn	2.31jk	117.67l	121.33hi	82.33ij	83.67jk	24.34n	24.90ij	6.19n	6.27n
		2.0 g K_2SiO_3 L^{-1}	22.36l	22.82i	2.38kl	2.41hi	122.33jk	124.67fgh	85.33hi	87.33hi	25.10l	25.73gh	6.84l	6.97l
	10 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	22.01m	22.67i	2.33lm	2.38ij	120.33k	122.33gh	84.00i	85.67ij	24.75m	25.37hi	6.53m	6.60m
		2.0 g K_2SiO_3 L^{-1}	22.77k	23.22h	2.44jk	2.48gh	123.33ij	125.67fg	87.33gh	89.00gh	25.50k	25.88gh	7.13k	7.24k
LSD at 5%			0.20	0.19	0.07	0.08	2.06	4.10	3.30	2.46	0.20	0.74	0.21	0.08

Table 3. Impact of irrigation intervals, zeolite soil addition and foliar application with potassium silicate on some quality traits of rice grain during two growing seasons of 2019 and 2020.

Characters / Treatments			Protein %		Carbohydrates %	
			2019	2020	2019	2020
Irrigation intervals						
Irrigation every 6 days			8.19a	8.31a	68.76a	70.27a
Irrigation every 8 days			7.29b	7.40b	67.07b	68.49b
Irrigation every 10 days			6.39c	6.48c	65.33c	66.67c
LSD at 5%			0.02	0.05	1.45	0.14
Zeolite application						
Without zeolite			6.40c	6.50c	65.30c	66.75c
7 ton Zeolite fed^{-1}			7.64b	7.76b	67.75b	69.19b
10 ton Zeolite fed^{-1}			7.83a	7.92a	68.11a	69.48a
LSD at 5%			0.02	0.04	0.32	0.18
Potassium silicate						
0.0 g K_2SiO_3 L^{-1}			7.13b	7.24b	66.72b	68.25b
2.0 g K_2SiO_3 L^{-1}			7.45a	7.56a	67.38a	68.70a
LSD at 5%			0.02	0.08	0.56	0.18
Interaction						
Irrigation every 6 days	Without zeolite	0.0 g K_2SiO_3 L^{-1}	7.24j	7.42fg	66.79f-j	68.19f
		2.0 g K_2SiO_3 L^{-1}	7.43i	7.59ef	67.26e-i	68.82e
	7 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	8.33d	8.50b	69.18a-d	70.75b
		2.0 g K_2SiO_3 L^{-1}	8.73b	8.85a	69.78ab	71.18b
	10 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	8.51c	8.53b	69.36abc	70.91b
		2.0 g K_2SiO_3 L^{-1}	8.93a	8.95a	70.21a	71.78a
Irrigation every 8 days	Without zeolite	0.0 g K_2SiO_3 L^{-1}	6.04p	6.07k	64.62lmn	66.38i
		2.0 g K_2SiO_3 L^{-1}	6.25o	6.31j	65.03k-n	66.39i
	7 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	7.58h	7.69e	67.64d-h	69.13de
		2.0 g K_2SiO_3 L^{-1}	7.95f	8.18c	68.39b-f	69.76c
	10 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	7.79g	7.95d	67.97c-g	69.40cd
		2.0 g K_2SiO_3 L^{-1}	8.13e	8.20c	68.76a-e	69.87c
Irrigation every 10 days	Without zeolite	0.0 g K_2SiO_3 L^{-1}	5.64r	5.75l	63.84n	65.14j
		2.0 g K_2SiO_3 L^{-1}	5.79g	5.88kl	64.28mn	65.62j
	7 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	6.44n	6.53ij	65.35j-n	66.93h
		2.0 g K_2SiO_3 L^{-1}	6.81l	6.82h	66.14h-l	67.39gh
	10 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	6.61m	6.68hi	65.75i-m	67.42gh
		2.0 g K_2SiO_3 L^{-1}	7.03k	7.22g	66.59g-k	67.53g
LSD at 5%			0.06	0.23	n.s	0.53

Table 4. Some soil properties as affected by studied treatments after harvesting rice plants (combined data over both seasons).

Characters \ Treatments			E.C, $dS.m^{-1}$	C.E.C, $cmol.kg^{-1}$	Porosity, %	F.C, %
Initial soil before transplanting			1.40	42.90	52.00	34.75
Irrigation every 6 days	Without zeolite	0.0 g K_2SiO_3 L^{-1}	1.45	44.10	52.33	35.13
		2.0 g K_2SiO_3 L^{-1}	1.42	44.11	52.39	35.28
	7 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	1.65	45.92	53.22	36.44
		2.0 g K_2SiO_3 L^{-1}	1.61	46.00	53.31	36.55
	10 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	1.72	46.98	55.08	37.90
		2.0 g K_2SiO_3 L^{-1}	1.66	47.03	55.23	38.18
Irrigation every 8 days	Without zeolite	0.0 g K_2SiO_3 L^{-1}	1.51	43.88	52.03	34.79
		2.0 g K_2SiO_3 L^{-1}	1.47	43.90	52.14	34.91
	7 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	1.81	45.59	53.93	36.06
		2.0 g K_2SiO_3 L^{-1}	1.76	45.62	53.04	36.16
	10 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	1.87	46.59	54.79	37.37
		2.0 g K_2SiO_3 L^{-1}	1.85	46.63	54.90	37.55
Irrigation every 10 days	Without zeolite	0.0 g K_2SiO_3 L^{-1}	1.58	43.50	51.69	34.39
		2.0 g K_2SiO_3 L^{-1}	1.54	43.60	51.82	34.53
	7 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	1.95	45.25	52.64	35.67
		2.0 g K_2SiO_3 L^{-1}	1.90	45.25	52.71	35.80
	10 ton Zeolite fed^{-1}	0.0 g K_2SiO_3 L^{-1}	2.05	46.37	53.51	36.93
		2.0 g K_2SiO_3 L^{-1}	1.98	46.42	53.60	37.08

Generally, zeolite is one way to prevent soil moisture losses due to that aluminosilicates is scaffold structure and water molecules occupation in its cavities and removable in its structure so that ion exchange reactions and dehydration do as reversible (Habashy and Abdel-Razek 2011; and Ozbahce *et al.* 2015)

Generally, it can be said that zeolite led to improving soil properties due to its ability to hold water in its pores and adsorb nutrients on surfaces and this reflects on rice plant behavior under drought stress. On the other hand, all studied growth and yield measurements of rice plants under drought stress increased with potassium silicate compared to untreated plants (without K_2SiO_3) due to that potassium silicate is a source of high soluble potassium (K) and silicon (Si). K is associated with the interance of water, nutrients and carbohydrates in plant tissue. It's involved with enzyme activation within the plant, which affects protein, starch and adenosine triphosphate (ATP) production. The production of ATP can regulate the rate of photosynthesis. On the other hand, plants benefit from the presence of Si and it is found that Si can increase biomass production and increase the tolerance to abiotic and biotic stresses and it helps plant with stability and protection. These results are in agreement with those obtained by Pisarović *et al.*, (2003); Habashy and Abdel-Razek (2011); Khalifa *et al*., (2019); El-Habet (2020) and El-Sherpiny *et al.* (2020).

CONCLUSION

Results confirmed that;

1- Zeolite improves soil water holding capacity and other soil properties as well as prevent soil moisture losses, thus it can be said that its effect positively reflects on rice plants grown under drought stress.
2- Potassium silicate has a role in alleviating the hazard effect of water deficit.

It can be concluded that both potassium silicate as a foliar application and zeolite amendment represents an attractive option to mitigate the expected water scarcity in Egypt.

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Yi, H., Liu, X., Yi, M and Chen, G. (2014). Dual role of hydrogen peroxide in Arabidopsis guard cells in response to sulfur dioxide. Advances in Toxicology, Article ID 407368, pages1-9**.**

معاملة نبات الأرز بالزيوليت كإضافة أرضية مع الرش الورقي بسيليكات البوتاسيوم لمجابهة ندرة المياه المتوقعة في شمال دلتا النيل، مصر.

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معهد بحوث الأراضي والمياه والبيئة – مركز البحوث الزراعية – الجيزة – مصر

بسبب محدودية الموارد المائية في مصر، يجب على الباحثين إيجاد طرق مختلفة لتوفير مياه الري دون التقليل من محصول الأرز. لذلك، تم إجراء تجربتين حقليتين لتقييم تأثير ثلاث فترات ري كمعاملات رئيسية [الري كل ٦،٨،١٠ ايام]، وثلاثة معدلات من الزيوليت كمعاملات منشقة اولي [٠,٠(بدون إضافة)، ٧,٠، ١٠ طن/ فدان]، الرش الورقي بسيليكات البوتاسيوم كمعاملات منشقة ثانية [٠,٠ (بدون إضافة ورقية) و ٢,٠ جرام سليكات بوتاسيوم/ لتر) وتداخلاتها على أداء ومحصول نبات الأرز. كما تم إجراء تحليل للتربة بعد الحصاد. أشارت النتائج إلى أن الإجهاد المائي (الري كل ٨ و١٠ أيام) أدي إلى زيادة محتوى الفينول ونشاط انزيم SODفي أوراق نبات الأرز، بينما أدى الزيوليت وسيليكات البوتاسيوم إلى انخفاض احتياج النبات من تلك مضادات الأكسدة. أثر كل من الزيوليت وسيليكات البوتاسيوم بشكل مفيد على نمو الأرز والمحصول ومكوناته. أدت إضافة الزيوليت إلى التربة بمعدل ٧,٠ و١٠ طن /فدان قبل الزراعة مع ري نباتات الأرز كل ٨ أيام إلى نتائج أفضل بالنسبة لكل من النمو والمحصول ومكوناته مقارنة مع عدم إضافة الزيوليت مع الري كل ٦ أيام (الري التقليدي) في حضور وغياب سليكات البوتاسيوم. أدى استخدام الزيوليت إلى تحسين قيم المسامية الكلية والسعة التبادلية الكلية والسعة الحقلية للتربة. يمكن استنتاج أن الإضافة الورقية لسيليكات البوتاسيوم والاضافة الأرضية للزيوليت يمثلان خيارًا جذابًا لمجابهة ندرة المياه المتوقعة.