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Productivity and Quality of Rice as Influenced by Foliar Spray of Different Silicon Sources and Rates Under Salinity Soil Conditions

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ABSTRACT

A field experiment was carried out at El-Sirw Agriculture Research Farm at Damietta governorate, Egypt in 2018 and 2019 seasons. This investigation aimed to be study the effect of foliar application of three silicon sources at three rates for each, i.e. nano silica at 50, 100 and 150 ppm and potassium silicate as well as magnesium silicate at 500, 1000 and 1500 ppm for both of them on the productivity of rice plants grown in saline soil. Foliar application of Si at different tested sources and rates significantly increased each of physiological characters (chlorophyll content and stomatal conductance), morphological characters (plant height, number of tillers/ m^2, leaf area index and dry matter production/ m^2), chemical composition in the leaf (K %, K / Na ratio and Si %), yield components (number of panicles/ m^2, panicle weight and length, number of filled grains/ panicle and 1000 - grain weight), yields/ ha (grain and straw), grain quality characters (hulling % , milling % , head rice %, protein and amylose %), while significantly decreased Na % in the leaf, number of unfilled grains/ panicle and chalkiness grains % as compared with untreated plants (control treatment) in both seasons. Spraying of nano silica at 150 ppm and potassium silicate at 1500 ppm were found to be more efficiency in increasing most abovementioned traits of rice plants grown in saline soil than the other tested silicon sources and rates.

Kewwords: Rice, silicon sources, growth, yield, quality, saline soil.

INTRODUCTION

It is well known that around 20% of irrigated land is salt-affected which represents one-third of all food-producing land. It has been estimated that about half of all fertile land will be affected by salinity by the middle of the 21st century (Ladeiro, 2012). To overcome salinity stress in the future, Si-mediated salt tolerance mechanisms will help to enhance salt stress tolerance in various crop plants. However, many determinants and regulatory mechanisms have not been studied in detail and thus need further elucidation.

Silicon (Si) is a considerable element in the soil that helps plants tolerate environmental stress conditions and can ameliorate soil conditions. In this respect, Abdel-Haliem *et al* (2017) showed that silicon ions significantly attenuated the detrimental physiological and biochemical effects of NaCl on plants. Moreover, Viciedo *et al* (2019) found that Si application helps to induce multiple biotic and abiotic stress tolerance in plants. Recently, many investigators reported that Si is well recognized as a vital nutrient and plays a significant role in the growth, development and productivity of many crops such as corn (Sousa *et al*, 2010) and sugar cane (De Camargo *et al*, 2019). In addition, other investigators reported that the rice plants were positively and beneficially affected by Si application in their growth characters (Ahmed *et al*, 2013 and Mohamed *et al*, 2015), yield attributes (Deren *et al*, 1994 and El- Temsah, 2017), grain and straw yields (Wang *et al*, 2020) and grain quality and technology (Zhang *et al*, 2007). Furthermore, Wang *et al* (2015) reported that nano-fertilizers may be more effective than regular fertilizers in improving plant nutrition, enhancing nutrition use efficiency, and protecting plants from environmental stress. Moreover, foliar application with nano silica improved the growth, Mg, Fe, and Zn nutrition and the contents of chlorophyll a of the rice seedlings under Cd stress. Nano silica application alleviated Cd toxicity in rice by decreasing Cd accumulation and its translocation from root to shoot. Also, Essa (2019) found that foliar application of silica nano-particles at mid tillering and panicle initiation stages of rice plant increased grain yield and quality as well as Si content under salinity soil condition.

Therefore, this investigation aimed to study the effect of silicon foliar application at different sources and rates on the growth, productivity and quality of rice under salinity soil conditions.

MATERIALS AND METHODS

The present investigation was carried out at the Experimental Farm of El-Sirw Agricultural Research Station, Damietta Governorate (Latitude: 31° 24' 84'' and Longitude: 31° 65' 34''), Egypt, in 2018 and 2019 seasons to study the growth, yield and its attributes as well as grain quality of rice salt tolerant variety (Giza 179) as affected by foliar application with different silicon sources and rates under salinity soil conditions. Every experiment included ten foliar treatments of silicon which were the combination of three silicon sources at three rates of each, i.e. Nano silica (SiO_2-NPs) at 50,100 and 150 ppm, potassium

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silicate (K_2SiO_4) at 500,1000 and 1500 ppm and Magnesium silicate ($MgSiO_4$) at 500,1000 and 1500 ppm as well as the control treatment (water). The ten treatments were arranged in randomized complete block design with four replications. The experimental soil was salinity clay and its chemical analysis properties described by Black *et al* (1965) are presented in Table 1.

Table 1. Chemical analysis of the experimental soil in 2018 and 2019 seasons.

Characteristic / Season	pH	EC dS m^{-1}	O.M. %	Soluble cations meq L^{-1}(soil paste) Ca^{++}	Mg^{++}	K^{+}	Na^{+}	Soluble anions meq L^{-1} (soil paste) HCO^{3-}	CL^{-}	$SO4^{--}$
2018	8.12	8.29	1.52	7.8	5.4	0.50	70	9.34	68.5	6.33
2019	8.10	7.92	1.56	6.4	6.2	0.70	66	8.64	64.6	5.33

Rice grains at the rate of 140 kg ha^{-1} were soaked in fresh water for 24 hours and incubated for another 48 hours. Thereafter, it was broadcasted with 2-3 cm standing water in the nursery in April 25th in both seasons. At 30 days from sowing, seedlings were carefully pulled from the nursery and manually transformed to plots (2 m width x 5 m length). Three seedlings were transplanted in each hill at 20 x 20 cm spacing among hills (land area of hill = 400 cm^2). Seven days after transplanting, the herbicide Saturn 50% was added at the rate of 4.8 L ha^{-1}. Nitrogen fertilizer was soil added at the rate of 165 kg N ha^{-1} in the form of ammonium sulphate (20% N) in three equal splits applications at 15, 30 and 45 days after transplanting. Potassium fertilizer in the form of potassium sulphate (48% K_2O) at rate of 60 kg K_2O ha^{-1} was soil added in two equal doses at 30 and 45 days after transplanting. All other agronomic practices were applied as recommended for rice under saline soil during the growing season.

Characters studied:

At heading stage (90 days after sowing), plants of m^2 were randomly taken from each plot to estimate the following characters:

A- Physiological characters:

1- **Chlorophyll content (Chl.):** using SPAD meter (SPAD 502, Minolta, Japan)

2- **Stomatal conductance (SC) (m mol m^{-2} s^{-1}):** using leaf porometer (Decagon Devices, Inc., Pullman, WA, USA) according to Zhu *et al* (2016)

B- Morphological characters:

1- Plant height (cm) 2- Number of tillers/ m^2

3- Leaf area index (LAI) 4- Dry matter production/m^2

C- Chemical composition in leaf:

1- Potassium (K) % and Sodium (Na) % were estimated using flame photometer as described by Jackson (1967).

2- Potassium / sodium ratio: It was calculated by dividing potassium % ÷ sodium %

3- Silicon (Si) %: It was determined according to the method of Wei- min *et al* (2005)

D- Yield and its components and yields/ ha:

At harvest (130 days after sowing), plants of m^2 included 5 rows were randomly taken from each plot to determine the following characters:

1- Yield attributes:

1- Number of panicles/ m^2 2- Panicle length (cm)

3- Number of unfilled grains panicle

4- Number of filled grains panicle

5- 1000-grain weight (g) 6- Grain weight/ panicle (g)

2- Yields/ ha:

Five inner rows of each plot were harvested, dried, threshed and the grain and straw yields were determined and then their yields/ ha were calculated and adjusted at 14% moisture content.

D- Grain quality characters:

After threshing, rough rice grains were cleaned and the following grain quality characters were measured

1- Hulling % = brown rice weight ÷ rough rice weight x 100

2- Milling % = milled rice weight ÷ rough rice weight x 100

3- Head rice % = whole milled rice weight ÷ rough rice weight x 100

4- Chalkiness % = chalky grain weight ÷ rough rice weight x 100

Hulling %, milling % and head rice % were estimated according to the methods described by Adair (1952) as well as chalkiness % which was determined by using SATAKE model KU 120

5- Protein % was estimated in rough rice grains by multiplied N % by factor of 5.75.

6- Amylose % was estimated in milled rice grains according to the method described by Juliano (1971).

Statistical analysis:

All Data obtained were statistically analyzed according to Gomez and Gomez (1984). Treatment means were compared by Duncan's Multiple Range Test (Duncan, 1955). The mean values designated by the same letter (s) in each column are not significantly at 5 % level. All statistical analysis was performed using analysis of variance technique using CoStat computer software package.

RESULTS AND DISCUSSION

1- Physiological and morphological characters:

Data in Table 2 show the mean values of physiological characters studied (chlorophyll content and stomata conductance) as well as morphological (plant height, number of tillers/ m^2, LAI and dry matter production/ m^2) as well as of rice plants as affected by foliar application of silicon (Si) at different sources, i.e. nano silica, potassium (K) silicate and Magnesium (Mg) silicate and their levels at heading stage during 2018 and 2019 seasons.

The data indicated that foliar application of various silicon sources at all tested levels caused an increase in the two physiological characters studied as compared with the control treatment (T_1) in both seasons. Moreover, the values of such characters were increased gradually with increasing the levels of Si up to 150 ppm for nano silica (T_4) and 1500 ppm for both K (T_7) and Mg (T_{10}). In comparison among the three tested Si sources, it can be noticed that the highest values for Chl (42.13 and 42.20) and for SC (882.3 and 902.1) were obtained by foliar application of nano silica at 150 ppm (T_4) in the first and second seasons, respectively. However, there are no significant differences among the higher rates of the three tested Si sources for both traits in the two seasons. From these results, it can be noticed that silicon treatments involving the three tested sources especially at higher rates had marked positive and significant increasing effect on

Chl and SC especially under salinity stress condition of the experimental soil as shown in Table 1. The improving of Chl content obtained herein by foliar application of Si at different tested sources (nano, K and Mg) may be due to the beneficial role of silicon in enhancing rice salt tolerance as well as the magnesium element which represents the central atom of chlorophyll compounds and consequently raised plant pigments formation in rice plants. In this respect, Khan *et al* (2019) found that exogenous application of Si under salinity stress significantly improved photosynthesis rates and plant pigments contents of different plant species. Moreover, it can be suggested that the enhancing effect of Si on the stomata conductance values, especially using potassium silicate source may be due to the beneficial role in keeping balance content of K element in guard cell of stomata and consequently regulated and encouraged the stomata opening. In this respect, Coskun *et al* (2016) found that Si mitigates saline stress by maintaining stomatal conductance, transpiration, net photosynthesis, membrane permeability and chlorophyll levels which is partly due to the higher K^+ ion concentration and lower Na^+ ion levels induced by the presence of Si in salt – stressed environments.

Table 2. Mean values of physiological and morphological characters of rice at heading stage as affected by foliar application of silicon in 2018 and 2019 seasons

Characteristic / Treatments	Chlorophyll content (SPAD value)	Stomata conductance (mmol m^{-2} s^{-1})	Plant height (cm)	Number of tillers/ m^2	LAI	Dry matter production (g/ m^2)
2018 season						
(T_1) Control	40.38 g	817.5 c	80.05 d	450.0 g	3.32 g	1568.8 f
(T_2) Nano silica 50 ppm	40.97 ef	833.6 c	84.83 ab	504.3 de	3.85 e	1662.5 de
(T_3) Nano silica 100 ppm	41.50 bc	865.3 ab	85.93 a	525.0 bc	4.20 bc	1766.3 abc
(T_4) Nano silica 150 ppm	42.13 a	882.3 a	85.87 a	540.0 ab	4.45 a	1819.3 a
(T_5) K silicate 500 ppm	40.98 def	831.2 c	82.83 bc	494.3 ef	3.62 f	161.03 ef
(T_6) K silicate 1000 ppm	41.40 cde	871.8 ab	84.37 ab	506.8 de	4.07 cd	1706.3 cd
(T_7) K silicate 1500 ppm	41.85 ab	868.9 ab	86.17 a	548.3 a	4.28 ab	1777.5 ab
(T_8) Mg silicate 500 ppm	40.60 fg	835.0 c	82.83 bc	480.8 f	3.55 f	1612.5 ef
(T_9) Mg silicate 1000 ppm	41.42 bcd	861.0 b	83.78 bc	497.5 def	3.90 de	1683.5 d
(T_{10}) Mg silicate 1500 ppm	42.10 a	865.0 ab	84.83 ab	512.5 cd	4.08 c	1757.0 bc
F test	**	**	**	**	**	**
2019 season						
(T_1) Control	41.25 c	828.7 f	81.75 d	431.3 c	3.62 e	1628.0 f
(T_2) Nano silica 50 ppm	41.40 bc	845.2 e	86.15 bc	498.8 bcd	3.84 de	1681.3 ef
(T_3) Nano silica 100 ppm	41.65 abc	878.3 bc	88.35 ab	537.5 ab	4.30 bc	1793.8 ab
(T_4) Nano silica 150 ppm	42.20 a	902.1 a	89.50 ab	553.8 a	4.60 a	1852.5 a
(T_5) K silicate 500 ppm	41.30 c	865.5 d	85.72 bc	502.5 bc	3.72 e	1707.5 de
(T_6) K silicate 1000 ppm	41.62 abc	873.3 cd	87.50 bc	531.3 ab	4.15 c	1756.3 bcd
(T_7) K silicate 1500 ppm	42.15 ab	895.5 ab	92.28 a	567.0 a	4.52 ab	1816.3 ab
(T_8) Mg silicate 500 ppm	41.88 abc	840.3 ef	85.75 bc	482.5 cd	3.82 de	1668.8 ef
(T_9) Mg silicate 1000 ppm	41.68 abc	870.3 cd	87.25 bc	503.0 bc	4.10 cd	1728.8 cde
(T_{10}) Mg silicate 1500 ppm	41.25 a	882.0 bc	88.00 abc	525.0 ab	4.18 c	1787.5 bc
F test	*	**	**	*	**	**

With regard to morphological characters, it can be noticed that plant height, number of tillers/ m^2, LAI and dry matter production/ m^2 were significantly increased by foliar application of various Si treatments at any source or rate compared to the control treatment (T_1) in both seasons. Moreover, it is obvious that increasing the rates of the tested varying silicon sources up to 150 ppm for nano silica (T_4) and 1500 ppm for each of K silicate (T_7) and Mg silicate (T_{10}) gradually increased the abovementioned traits in both seasons. The highest values were obtained when the rice plants were sprayed with K silicate at a rate of 1500 ppm (T_7) for plant height and number of tillers/ $m^2$and with nano silica at a rate of 150 ppm (T_4) for leaf area index and dry matter production/ m^2 without significant differences between the two treatments for those characters in both seasons. However, Mg silicate came in the third order in this concern. The pronounced efficiency of Si in improving the morphological characters studied herein may be because of elevating different physiological processes to alleviate the illness impact of salt stress condition (Lee *et al*, 2010). In this respect, other investigators found that the application of Si at different sources to rice plants caused an enhancements in their plant height and number of tillers/ m^2 (Ahmed *et al*, 2013) as well as leaf area index and dry matter production/ hill (Mohamed *et al*, 2015).

2- Chemical composition in leaf:

The data in Table 3 indicate that foliar application of different sources and levels of Si significantly decreased sodium (Na^+) content in the plant leaf but significantly increased potassium (K^+), K / Na ratio and Si contents compared to that obtained by control treatment (T_1) in the two seasons. Moreover, it can be noted that foliar application of rice plants with K silicate at a rate of 1500 ppm (T_7) produced the highest values of K content (1.425 and 1.442 %), K / Na ratio (1.73 and 1.78) and Si content (4.87 and 4.90 %) but the lowest values of Na content (0.425 and 0.410 %) in the first and second seasons, respectively compared to the other tested treatments. From these results, it can be suggested that application of silicon alleviate the adverse effects of salinity by preventing Na^+ uptake by the roots and subsequent movement to the shoots as well as increasing some beneficial nutrients uptake such as K and Si and consequently improving salinity tolerance in the plants. In this concern, Gong *et al* (2006) found that application of silicate on rice plants dramatically decreased the Na concentration but increased K / Na ratio in the shoots compared to plants grown without additional silicon. Moreover, Wang *et al* (2020) reported that silicon content in stem sheath of rice plant was increased with soil application of silicon fertilizer (SiO2).

Table 3. Mean values of chemical composition of rice leaves at heading stage as affected by foliar application of silicon in 2018 and 2019 seasons.

Characteristic / Treatments	Na %	K %	K / Na ratio	Si %
2018 season				
(T_1) Control	1.162 a	1.230 e	1.06 d	3.80 g
(T_2) Nano silica 50 ppm	1.110 b	1.251 de	1.13 cd	4.20 f
(T_3) Nano silica 100 ppm	1.088 bc	1.306 b-e	1.20 c	4.55 cd
(T_4) Nano silica 150 ppm	0.960 d	1.382 ab	1.44 b	4.78 ab
(T_5) K silicate 500 ppm	1.090 bc	1.325 bcd	1.22 c	4.35 e
(T_6) K silicate 1000 ppm	0.956 d	1.375 ab	1.44 b	4.65 bc
(T_7) K silicate 1500 ppm	0.825 e	1.425 a	1.73 a	4.87 a
(T_8) Mg silicate 500 ppm	1.112 b	1.285 cde	1.17 c	4.15 f
(T_9) Mg silicate 1000 ppm	1.000 b	1.298 b-e	1.30 b	4.47 d
(T_{10}) Mg silicate 1500 ppm	0.975 cd	1.350 abc	1.39 b	4.65 bc
F test	**	**	**	**
2019 season				
(T_1) Control	1.142 a	1.280 f	1.11 d	3.87 f
(T_2) Nano silica 50 ppm	1.090 b	1.370 cd	1.26 cd	4.35 de
(T_3) Nano silica 100 ppm	0.970 cd	1.333 e	1.37 c	4.60 c
(T_4) Nano silica 150 ppm	0.900 e	1.398 b	1.55 b	4.85 a
(T_5) K silicate 500 ppm	0.975 bc	1.360 d	1.40 bc	4.40 d
(T_6) K silicate 1000 ppm	0.955 de	1.390 bc	1.46 bc	4.72 b
(T_7) K silicate 1500 ppm	0.810 f	1.442 a	1.78 a	4.90 a
(T_8) Mg silicate 500 ppm	0.985 bc	1.323 e	1.34 c	4.26 e
(T_9) Mg silicate 1000 ppm	0.968 cd	1.325 e	1.37 c	4.59 c
(T_{10}) Mg silicate 1500 ppm	0.950 e	1.360 d	1.43 bc	4.72 b
F test	**	**	**	**

3- Yield and yield attributes:

The data presented in Table 4 show that yield attributes studied, i.e. number of panicles/ m^2 and panicle length as well as grain weight/ panicle and its main components (number of filled grains/ panicle and 1000-grain weight) were positively and significantly affected by the tested Si treatments involving different sources and rates compared to control treatment in both seasons.

Table 4. Mean values of yield and yield components of rice at harvest as affected by foliar application of silicon in 2018 and 2019 seasons

Characteristic / Treatments	Number of panicles/ m^2	Panicle length (cm)	Number of unfilled grains/ panicles	Number of filled grains/ panicles	1000-grain weight (g)	Grain weight/ Panicle (g)	Grain yield (t/ ha)	Straw yield (t/ ha)
2018 season								
(T_1) Control	379.25 e	17.75 f	27.00 a	83.88 e	22.14 d	2.39 f	4.75 f	6.17 c
(T_2) Nano silica 50 ppm	471.75 abc	19.07 c	17.98 bc	87.23 bcd	23.35 bc	2.67 cde	5.03 de	6.64 b
(T_3) Nano silica 100 ppm	483.25 abc	19.47 ab	13.66 e	88.83 ab	23.72 ab	2.86 ab	5.43 ab	7.22 a
(T_4) Nano silica 150 ppm	518.75 a	19.60 a	10.23 f	90.82 a	24.28 a	2.97 a	5.58 a	7.27 a
(T_5) K silicate 500 ppm	452.5 cd	18.68 d	18.83 b	85.23 de	23.32 c	2.60 de	4.93 e	6.50 bc
(T_6) K silicate 1000 ppm	470.75 abc	19.33 abc	15.25 d	88.42 abc	23.60 ab	2.77 bc	5.32 bc	6.67 b
(T_7) K silicate 1500 ppm	504.00 ab	19.43 ab	11.47 f	91.15 a	23.97 ab	2.85 ab	5.45 ab	6.83 ab
(T_8) Mg silicate 500 ppm	412.50 de	18.35 e	19.20 b	84.87 de	22.67 cd	2.57 e	5.03 de	6.48 bc
(T_9) Mg silicate 1000 ppm	437.50 cd	19.18 bc	17.33 c	85.93 cde	23.27 bc	2.72 cd	5.17 cd	6.67 b
(T_{10}) Mg silicate 1500 ppm	458.25 bcd	19.30abc	13.22 e	87.17 bcd	23.58 ab	2.78 bc	5.37 b	6.87 ab
F test	**	**	**	**	**	**	**	**
2019 season								
(T_1) Control	400.00 f	18.25 c	23.15 a	85.25 f	22.55 g	2.45 e	4.93 e	6.55 d
(T_2) Nano silica 50 ppm	456.25 cd	19.00 ab	15.25 bcd	89.10 de	22.97 f	2.75 cd	5.15 cd	6.90 bcd
(T_3) Nano silica 100 ppm	487.50 b	19.55 ab	13.00 de	92.15 abc	23.65 cd	2.88 abc	5.55 ab	7.25 ab
(T_4) Nano silica 150 ppm	528.75 a	19.75 a	10.15 e	95.12 a	24.35 a	3.00 a	5.72 a	7.50 a
(T_5) K silicate 500 ppm	463.75 c	18.85 bc	16.25 bc	87.25 ef	23.45 de	2.76 cd	5.05 de	6.89 bcd
(T_6) K silicate 1000 ppm	480.00 b	19.60 ab	14.12 cd	90.13 cde	23.65 cd	2.80 cd	5.46 b	6.95 bc
(T_7) K silicate 1500 ppm	527.50 a	19.65 a	10.50 e	93.50 ab	24.28 ab	2.95 ab	5.68 a	7.00 bc
(T_8) Mg silicate 500 ppm	428.75 c	19.23 ab	17.27 b	88.35 de	23.00 f	2.68 d	5.23 cd	6.75 cd
(T_9) Mg silicate 1000 ppm	455.00 d	19.25 ab	16.50 bc	9.20 bcd	23.40 e	2.80 cd	5.36 bc	6.88 bcd
(T_{10}) Mg silicate 1500 ppm	481.25 b	19.50 ab	13.00 de	92.15 abc	23.75 c	2.85 bc	5.54 ab	6.95 bc
F test	**	*	**	**	**	**	**	**

The highest values of all abovementioned yield attributes were attained when the rice plants were sprayed with nano silica at a rate of 150 ppm (T_4) in the two seasons. Furthermore, it can be noticed that both treatments nano silica at 150 ppm (T_4) and K silicate at 1500 ppm (T_7) had the same level of significance for most previous traits in both seasons. However, the highest values of number of unfilled grains/ panicle were obtained by control treatment (T_1). The superiority of yield attributes as a result of Si application in different forms may be due to improving each of salinity withstanding presented in the experimental soil as shown in Table 1 as well as physiological and morphological characters as shown previously in Table 2. In this respect, many investigators reported that the application of rice plant with Si at various sources and rates enhanced and increased grain yield attributes , i.e. number of panicles/ m^2 (El-Temsah, 2017), panicle length (Mohamed *et al*, 2015), number of filled grains/ panicle (Essa, 2019), 1000-grain weight (Ahmed *et al,* 2013) and grain weight/ panicle (Deren *et al*, 1994).

Grain and straw yields/ ha were significantly affected by foliar application at different silicon sources and levels compared to control treatment (T_1) in the two seasons as shown in Table 5. The highest values of the abovementioned were obtained when the plants were sprayed with nano silica at 150 ppm (T_4) without any significant differences with those obtained nano silica at 100 ppm (T_3) and K silicate at 1500 ppm (T_7) in the two seasons. The superiority of grain yield/ ha by the application of both Si sources (nano and K) may be due to such Si sources were useful in improving physiological and morphological traits (Table 2) and salinity tolerance by decreasing Na content (Table 3) and finally rice grain yield attributes as formerly discussed. In this concern, other investigators found that application of different Si sources to rice plants led to increase grain yield as reported by El-Temsah (2017), Flavia *et al* (2017) and Essa (2019) as well as straw yield/ unit area as recorded by Ahmed *et al* (2013) and Mohamed *et al* (2015).

4- Grain quality characters:

Data presented in Table 5 show that grain technology characters (hulling % , milling % and head rice %) as well as grain quality characters (protein % and amylose %) tented to a significant increase when the plants were sprayed with silicon at varying sources and rates as compared with the control treatment in both growing seasons. Moreover, it can be found that increasing rate of any Si source progressively increased the previous characters studied of grain technology and quality in both seasons.

Table 5. Grain quality and technology characters of rice as affected by foliar application of silicon in 2018 and 2019 seasons

Characteristic Treatments	Hulling %	Milling %	Head rice %	Chalkiness %	Protein %	Amylose %
			2018 season			
(T_1) Control	77.32 e	64.20 e	50.66 h	25.75 a	5.75 g	17.30 c
(T_2) Nano silica 50 ppm	78.85 d	65.80 cd	51.63 e	22.36 d	6.25 cde	17.45 c
(T_3) Nano silica 100 ppm	79.95 abc	66.32 abc	52.41 bc	20.20 f	6.45 bc	18.38 a
(T_4) Nano silica 150 ppm	80.50 a	67.35 a	53.54 a	18.85 g	6.90 a	18.10 a
(T_5) K silicate 500 ppm	79.00 cd	65.75 cd	51.37 f	23.50 c	6.00 efg	17.38 c
(T_6) K silicate 1000 ppm	80.25 a	66.20 bcd	52.00 d	21.25 e	6.40 bc	17.46 c
(T_7) K silicate 1500 ppm	80.75 a	67.10 ab	52.50 b	19.35 g	6.65 ab	17.90 ab
(T_8) Mg silicate 500 ppm	78.90 d	65.33 d	51.09 g	24.20 b	5.95 fg	17.35 c
(T_9) Mg silicate 1000 ppm	79.20 bcd	65.95 cd	51.96 d	23.00 c	6.12 def	17.40 c
(T_{10}) Mg silicate 1500 ppm	80.12 ab	66.00 cd	52.25 c	21.15 e	6.33 cd	17.75 b
F test	**	**	**	**	**	**
			2019 season			
(T_1) Control	77.92 d	65.00 d	51.50 d	25.10 a	5.88 e	17.44 d
(T_2) Nano silica 50 ppm	79.30 c	66.45 bc	51.78 cd	21.75 d	6.15 d	17.50 cd
(T_3) Nano silica 100 ppm	80.20 bc	67.10 abc	52.75 b	20.10 f	6.50 b	18.25 a
(T_4) Nano silica 150 ppm	81.80 a	67.70 a	53.66 a	18.25 g	6.85 a	17.96 ab
(T_5) K silicate 500 ppm	79.50 c	66.25 c	51.67 cd	23.00 b	6.08 d	17.55 cd
(T_6) K silicate 1000 ppm	80.15 bc	66.50 bc	52.50 b	22.15 cd	6.52 b	17.69 bcd
(T_7) K silicate 1500 ppm	81.90 a	67.65 a	53.54 a	18.50 g	6.73 a	17.93 ab
(T_8) Mg silicate 500 ppm	79.45 c	66.25 c	51.71 cd	23.35 b	6.10 d	17.50 cd
(T_9) Mg silicate 1000 ppm	80.25 bc	66.88 abc	52.21 bc	22.30 c	6.25 cd	17.62 cd
(T_{10}) Mg silicate 1500 ppm	80.55 bc	67.00 abc	52.62 b	20.75 e	6.40 bc	17.90 abc
F test	**	**	**	**	**	*

The maximum values of those characters were gradually produced when the rice plants were sprayed by nano silica at a rate of 150 ppm (T_4) with identical statistical with those brought by K silicate at a rate of 1500 ppm (T_7) in both seasons. Reversely, chalkiness % character was significantly decline either with application of different Si sources or with increasing their different rates. However, the higher rates of Mg silicate occupied the third rank in this concern. From these results, it can be suggested that Si element can ameliorate the rice eating quality and nutritional quality of rice. The benefit role of silica exogenous application in various forms on grain quality is due to direct and indirect ways. Direct way is due to increasing potassium leaf content and other nutrient uptake that increased the stored carbohydrate in the terms of starch in rice grain. The increasing stored starch against grain husks in rice grain raised hulling, milling and head rice too. An abundance of starch as results of silica application could fill all of starch cell minimizing cracks formation and inducing few broken grains leading to huge head rice grain. With more clear benefit of silica exogenous application that might increase starch particularity in straight form for in the terms of amylose. In addition, applying silica in different sources might be increased nitrogen uptake which increased amino acid formation and subsequently protein content of grain. Indirect useful effect of silica exogenous application is mainly due to enhancing rice salinity tolerance resulted in improving rice growth, photosynthesis and different metabolism activities as well as development process which finally improved rice grain quality and nutrition. In this concern, many researchers found that application of Si caused an increment in grain qualities of rice, i.e. hulling and milling % (Essa, 2019), head rice and amylose % (Zhang *et al,* 2007) and protein % (El-Temsah, 2017).

CONCLUSION

Finally, it could be concluded that foliar application of nano silica at 150 ppm (T_4) or potassium silicate at 1500 ppm (T_7) were found to be more efficiency for increasing the growth, productivity and grain quality of rice by improving salinity tolerance under the experimental conditions.

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انتاجية وجودة محصول الأرز تحت تأثير الرش بمصادر ومعدلات مختلفة من السيليكون تحت ظروف الأراضي الملحية

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أجريت تجربتان حقليتان بالمزرعة البحثية بمحطة البحوث الزراعية بالسرو محافظة دمياط خلال موسمي الزراعة 2018 و 2019 وذلك لدراسة تأثير الرش بثلاث مصادر مختلفة من السيليكون وثلاث معدلات مختلفة لكل منها : نانو سيليكا (50-100-150 جزء في المليون) ، سيليكات البوتاسيوم (500-1000-1500 جزء في المليون) ، سيليكات الماغنسيوم (500-1000-1500 جزء في المليون) علي نمو وانتاجية محصول الأرز (صنف جيزة 179) تحت ظروف الأرض الملحية. ويمكن ايجاز النتائج المتحصل عليها في الاتي: 1- أدى رش نباتات الأرز بجميع مصادر ومعدلات السيليكون المختبرة إلي زيادة معنوية في كل من الصفات الفسيولوجية (محتوى الكلوروفيل – التوصيل الثغري) ، الصفات المورفولوجية (طول النبات ، عدد الفروع القاعدية/ م2 ، دليل مساحة الأوراق ، كمية المادة الجافة/م2) ، التحليل الكيماوى للأوراق (النسبة المئوية لكل من البوتاسيوم والسيليكون ومعدل البوتاسيوم إلي الصوديوم) ، مكونات المحصول (عدد السنابل/ م2، طول ووزن السنبلة ، عدد الحبوب الممتلئة بالسنبلة ، وزن 1000 حبة) ، محصول الهكتار لكل من الحبوب والقش ، الصفات التكنولوجية للحبوب (النسبة المئوية لكل من التقشير والتبييض والحبوب السليمة) ، صفات جودة الحبوب (النسبة المئوية للبروتين والاميلوز) وذلك مقارنة بمعاملة الكنترول التي لم ترش بالسيليكون. 2- لوحظ نقص معنوى في كل من النسبة المئوية لعنصر الصوديوم في الأوراق والحبوب الجيرية وعدد الحبوب غير الممتلئة في السنبلة وذلك عند رش النباتات بأى صورة من صور السيليكون المختبرة وبأى معدل لها. 3- تم الحصول علي افضل النتائج لمعظم الصفات المدروسة عند رش النباتات بالنانو سيليكا بمعدل 150 جزء في المليون ويليها سيليكات البوتاسيوم بمعدل 1500 جزء في المليون وذلك مقارنة بباقي المعاملات المختبرة الأخرى، مما يشير الي ان هاتين المعاملتين كان لهما التأثير الافضل في تحسين صفات النمو والمحصول والجودة لمحصول الارز تحت ظروف التجربة.