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Article

Soil salinity and nutrient availability influenced by silicon application to tomato irrigation with different saline water

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Abstract: Silicon can be used as a soil amendment to reduce deleterious soil salinity and improve nutrient availability under different irrigation water salinity levels. Four treatments of Si (0,150 and 300 kg Si ha^{-1} as nano-silica and 300 kg Si ha^{-1} as potassium silicate) along with four salinity levels of irrigation water (1.65,3,6and 9 dSm^{-1}) were used to investigate their effect on soil salinity at three soil depth (0-15, 15-30 and 30-45 cm) and availability of N, P and K in soil cultivated with tomato. The experiment was conducted under greenhouse conditions using a random complete block design with three replicates. According to the results, increasing irrigation water salinity level increased soil salinity and decreased available N, P and K to tomatoes. Si treatments decreased soil salinity and increased available amounts of N, P and K . Using 300 Kg Si ha^{-1} of nano-silica caused the lowest soil salinity of 1.89, 2.51 and 3.23 dSm^{-1} for 0-15, 15-30, and 30-45cm depth, respectively and increased availability of N, P and K with a percent of 19.4, 14.1 and 82.7 %, respectively.

Keywords: nano-silica, soil salinity, available nitrogen, irrigation water salinity, tomato.

INTRODUCTION

Agriculture in arid and semi-arid regions faces the problem of insufficient pure water resources for irrigation caused by anthropic climate changes and human activities. Using poor quality water in such regions is a common practice where there is limited good quality water supply for irrigation. The reduction in yields of 25-30% is attributed to waterlogging and salinization results from poor agriculture, soil and water management [1]. Tomatoes are an important vegetative crop in Basrah province, with a total cultivated area of 15372 Donums in 2021. Tomatoes are classified as moderately tolerant to salinity. The percentage reduction of fruit yield was 4, 18, 25 and 31% for EC of irrigation water of 2.4, 4.8, 7.2 and 9.6 dSm^{-1}, respectively [2] . [3] also found fruit yield of tomato reduced by about 50% when EC of irrigation water rise from 0.6 to 6 dSm^{-1}.

Silicon(Si) is abundant in soils and is the second element in the soil. Recently, several studies stated that treating soil or plants with silicon will alleviate environmental stresses such as drought, salt, freezing, heavy metals, and biotic stresses. Improvement of salt tolerance by adding Si may start from enhancing soil properties related to salinity stress. It has been reported that the addition of Si significantly reduced salt concentration in soil and that could be due to the low level of cations and anions in soil solution resulting from either Si increased the solubility and mobility of nutrients in the soil making it readily to uptake or to improvement in the plant growth which enhanced nutrient uptake [4]. [5] stated that the accumulated Na in the soil due to root absorption selectivity under silicon treatment could be leached and weakens bond outside the root zone. However, some studies obtained increasing [6] or no effect [7] of soil salinity due to silicon application.

Silicon substances usually have very high adsorption capacity due to their large surface area, so increase the soil adsorption capacity. The specific surface area of sandy loam soil increased by 80% due to using nano-silica, leading to changes in many physicochemical properties [4]. Silicon application reduced the leaching of mobile nutrients from the soil, such as phosphorus [8], nitrogen [9] and potassium [10]. Sadgrov(2006) found a reduction in leaching of N, P and K for 60,30 and 6%, respectively, after using Si-rich organic materials. The enhancement of nutrient availability can justified by increasing soil CEC, improving water and air regimes and changing soil mineral composition. Nitrogen and phosphorus are weakly adsorbed on Si-rich materials and remain in available form.

Locally, few and limited studies were found on the effect of Si application on soil properties. So, this work was conducted to study the effect of applying Si(nano-silica or potassium silicate) through the soil on soil salinity under different irrigation water salinity levels and the availability of some macronutrients for tomato plants.

MATERIALS AND METHODS

The experimental Site

An experiment was conducted in greenhouses at Agricultural Research Station - College of Agriculture - University of Basrah, Iraq located in Karmat Ali region (47º44'40"E and latitude 30º33'44" N) rising 3 m above sea level and 9.78 km from the city center in 2020-2021 to clarify the role of nano-silica in improving the resistance of tomato plant REDFLORA F1 hybrid to salinity of irrigation water and its comparison with conventional silicon. Random samples were taken from the soil layers (0-15, 15-30 and 30-45) cm, mixed well, air-dried, then crushed and passed through a sieve of 2 mm diameter for analysis of some chemical and physical properties according to the standard methods mentioned in [11] and [12] and included in table 1.

Treatments

The experiment includes two factors :

The first factor is the salinity of the irrigation water, which includes four treatments:

1. Freshwater with a salinity of 1.65 dSm^{-1} (W1)
2. Water with a salinity of 3 dSm^{-1} (W2)
3. Water with a salinity of 6 dSm^{-1} (W3)
4. Water with a salinity of 9 dSm^{-1} (W4)

Salinity levels of 3, 6 and 9 dSm^{-1} are prepared from the dilution of drainage water with tap water using the following equation [13]:

$$EC1=[ECa*a]+[ECb(1-a)]$$

Where:
EC1 = electrical conductivity of the water to be obtained (dS m^{-1})
ECa = electrical conductivity of water used in dilution (dS m^{-1})
ECb = electrical conductivity of drainage water (dS m^{-1})
a = percentage of water used for dilution (liters)

property		Value	unit
pH (1:1 in water)		7.60	-
Electrical conductivity (EC)	0-15 cm	3.25	dSm^{-1}
	15-30 cm	2.50	
	30-45 cm	2.13	
CEC		14.43	$Cmol^{+}$ kg^{-1}
total solid carbonates		162.00	g kg^{-1}
Organic matter (O.M)		2.50	g kg^{-1}
total nitrogen		0.127	g kg^{-1}
Available phosphorus		22.00	mg kg^{-1}
Available potassium		184.00	mg kg^{-1}
Available silicon		118.43	mg kg^{-1}
Soluble cations	Calcium	2.30	mmol L-1
	magnesium	1.04	
	Sodium	23.45	
	potassium	0.75	
Soluble anions	Carbonate	0.00	
	bicarbonate	1.65	
	sulfate	9.00	
	chloride	13.65	
Sodium exchangeable percentage (ESP)		33.26	
Soil particles Size	sand	38.80	%
	loam	40.00	
	clay	21.20	
Soil texture		loam	

Table 1. Some chemical and physical properties of the greenhouse soil.

The irrigation water characteristics are listed in Table 2.

2.2.2. The second factor is the addition of silicon, which includes the following treatments:-

1. 0 kg Si ha^{-1} (S1)
2. 150 kg Si ha^{-1} in the form of nano-silica (98.5% (SiO_2) (S2)
3. 300 kg Si ha^{-1} in the form of nano-silica (98.5% (SiO_2) (S3)
4. 300 kg Si ha^{-1} in the form of potassium silicate (26.5% SiO_2) (S4)

Used nano-silica was provided by FADAK complex new technology / Iran and is characterized by a specific area of 220-250 m^2 g^{-1} and a mean diameter of 20-30nm.

Adjective	EC dSm^{-1}	Ca	Mg	Na	K	CO_3	HCO_3	SO_4	Cl	pH	SAR	water class*
		mmol L^{-1}								-	-	
W1	1.65	3.70	3.30	1.08	0.05	0.00	0.6	3.41	8.00	7.6	0.41	**C3S1**
W2	3	4.60	3.40	13.04	0.19	0.00	1.00	4.52	20.00	7.4	4.62	**C4S2**
W3	6	9.70	7.50	26.08	0.25	0.00	2.40	9.68	38.00	7.5	6.29	**C4S2**
W4	9	11.70	10.10	43.46	1.02	0.00	2.80	10.80	66.00	7.7	9.32	**C4S3**

Table 2. Irrigation water characteristics *According to Richards (1954).

Experimental design

The field was plowed thoroughly and divided into 6 rows extending along the length of the plastic house, with a distance of 1m between the rows. Rows were fertilized with cattle manure at a rate of 5 tons ha^{-1}. The field was divided into 3 blocks, and the individual plots within a block were designed according to the treatments at a row size of 3.5 ×0.5m with a factorial experiment. The drip irrigation system was designed to be connected to four plastic tanks of a capacity of 3 tons dedicated to each type of irrigation water salinity from the middle of the plastic house to supply the drip holders on both sides. A leaching requirement of 20% was used for all treatments.

Tomato (Solanum Lycopersican Mill.) seedlings, REDFLORA F1 hybrid, were transferred to the field in October 2020 at a rate of 16 plants for each plot, with a distance of 0.4 m between plants. Nitrogen in the form of urea (46% N), phosphorous in the form of DAP (21% P) and potassium in the form of potassium sulfate (43% K) were added at the rate of 300 kg N ha^{-1}, 65 kg P ha^{-1} and 250 kg K ha $^{-1}$, respectively. All fertilizers were added to the soil along the plant line under drippers.

Nano-silicon and potassium silicate were mixed with distilled water by a mixer for 30 minutes, then mixed with a small amount of field soil to ensure the homogeneity of nano-silica particles with the soil. After that, each level of nano-silicon or potassium silicate was added to the soil in two doses after 2 and 4 weeks of transplanting the seedlings. Other agricultural practices were carried out according to local recommendations of the region.

Soil samples and analysis:

Soil samples were collected at different depths (0-15, 15-30 and 30-45 cm) at the end of the season by taking composite samples from the center of the plots, air-dried, crushed and passed through a sieve of 2 mm diameter. Electrical conductivity (EC) was determined in 1:1 soil extract according to [12]. The available amounts of N, P and K were also estimated in soil samples of surface layer (0-15 cm). For nitrogen, samples were extracted with 2M KCl according to the method of [14] and then determined by steam distillation [15]. For phosphorous, samples were extracted with a solution of 0.5 M$NaHCO_3$ according to the Olsen method. Then P was estimated by a Spectrophotometer at a wavelength of 700 nm, according to the blue color method [16]. Available potassium was extracted with 1N NH_4OAC and measured by a Flame photometer as stated in [12].

Statistical analysis

The experiment was a factorial experiment with two factors (irrigation water salinity levels × silicon treatments) in a random complete block design RCBD with three replications. Data were subjected to analysis of variance (ANOVA) using the GenStat procedure Library Release PL 18.2 program. Differences among means were compared using the least significant difference (RLSD) test at a probability level of 0.05 [17].

RESULTS

Soil salinity (Electrical conductivity) of different soil depths (0-15,15-30 and 30-45 cm) as influenced by irrigation water salinity and silicon application at the end of tomato season are presented in Tables 3,4, and 5. Generally, increasing the salinity of irrigation water significantly increases soil salinity for all depths. Irrigated tomatoes with irrigation water 9dSm^{-1} (W4) recorded the highest soil salinity values of 3.19, 3.52 and 5.18 for 0-15,15-30 and 30-45cm depths, respectively. Increasing soil salinity values may be due to soluble ions in irrigation water, which leads to an increase in soil solution because the soil retains a portion of the water equivalent to the field capacity. This result is supported by [18, 19]. [20] stated that increasing sodium chloride salt led to an increase in the osmotic pressure of soil solution.

Silicon treatment	**Irrigation water Salinity(dSm^{-1})**				**Mean**
	W1	W2	W3	W4	
S1	1.24±0.01	1.67±0.12	2.99±0.13	3.45±0.12	2.34±0.95
S2	1.01±0.06	1.49±0.09	2.26±0.11	3.23±0.03	2.00±0.88
S3	0.91±0.07	1.46±0.04	2.20±0.04	3.00±0.08	1.89±0.82
S4	1.09±0.05	1.93±0.11	2.42±0.04	3.08±0.04	2.13±0.76
Mean	1.06±0.05	1.64±0.09	2.47±0.08	3.19±0.07	
R.L.S.D$_{0.05}$	Water salinity =0.055		Silicon=0.056	Interaction=0.117	

Table 3. The effect of irrigation water salinity and silicon treatments on soil salinity (dSm^{-1} ± SD) at depth 0-15 cm. W1 : 1.65 dSm^{-1}; W2: 3 dSm^{-1}; W3 : 6 dSm^{-1}; W4: 9 dSm^{-1}; S1: 0 kg Siha^{-1}; S2: 150 kg Si ha^{-1} as nano-silica; S3: 300 kg Si ha^{-1} as nano silica; S4: 300 kg Si ha^{-1} as potassium silicate.

Silicon treatment	Irrigation water Salinity(dSm^{-1})				Mean
	W1	W2	W3	W4	
S1	1.85±0.13	3.51±0.15	3.56±0.22	3.61±0.27	3.13±0.79
S2	1.78±0.11	2.22±0.13	3.45±0.11	3.34±0.21	2.70±0.76
S3	1.38±0.10	1.86±0.14	3.24±0.16	3.54±0.09	2.51±0.95
S4	1.40±0.02	3.04±0.51	3.19±0.13	3.57±0.12	2.80±0.90
Mean	1.60±0.09	2.66±0.23	3.36±0.16	3.52±0.17	
L.S.D$_{0.05}$	Water salinity =0.141		Silicon=0.150	Interaction=0.300	

Table 4. The effect of irrigation water salinity and silicon treatments on soil salinity (dSm^{-1} ± SD) at a depth of 15-30 cm.W1 : 1.65 dSm^{-1}; W2: 3 dSm^{-1}; W3 : 6 dSm^{-1}; W4: 9 dSm^{-1}; S1: 0 kg Siha^{-1}; S2: 150 kg Si ha^{-1} as nano-silica; S3: 300 kg Si ha^{-1} as nano silica; S4: 300 kg Si ha^{-1} as potassium silicate.

Silicon treatment	Irrigation water Salinity(dSm^{-1})				Mean
	W1	W2	W3	W4	
S1	3.09±0.17	2.90±0.04	5.21±0.51	5.27±0.74	4.12±1.24
S2	2.52±0.09	2.66±0.17	5.20±0.52	5.28±0.44	3.92±1.42
S3	2.12±0.16	2.25±0.11	4.13±0.07	4.42±0.21	3.23±1.10
S4	2.25±0.07	2.66±0.05	5.22±0.66	5.74±0.20	3.97±1.63
Mean	2.50±0.12	2.62±0.09	4.94±0.44	5.18±0.40	
L.S.D$_{0.05}$	Water salinity =0.244		Silicon=0.259	Interaction=NS	

Table 5. The effect of irrigation water salinity and silicon treatments on soil salinity (dSm^{-1} ± SD) at depths 30-45 cm.W1 : 1.65 dSm^{-1}; W2: 3 dSm^{-1}; W3 : 6 dSm^{-1}; W4: 9 dSm^{-1}; S1: 0 kg Siha^{-1} ; S2: 150 kg Si ha^{-1} as nano-silica; S3: 300 kg Si ha^{-1} as nano silica; S4: 300 kg Si ha^{-1} as potassium silicate.

For silicon application, soil salinity of the different soil depths decreased as compared with corresponding control (S1) tables 3,4 and 5. The lowest values were recorded at the treatment of nano silica at a rate of 300kg Si ha^{-1} (S3), confirming the superiority of nano-silicon in reducing soil salinity.

Analysis of variance showed the significant effect of the interaction of water salinity and silicon treatments in soil salinity at depths of 0-15 and 15-30 cm Tables 3 and 4. Nano silicon at a rate of 300kg Si ha^{-1}(S3) reported the lowest values of soil salinity at all water salinity levels with a decrease of 1.4-61.7% for depth 0-15cm and 9.9-73.6% for depth 15-30 cm. That means using nano-silica in reducing soil salinity did not change with changing salinity levels of irrigation water.

Available Nitrogen

Data in Table 6 showed the effect of irrigation water salinity and silicon's addition on the soil's available nitrogen. The results showed that the increase in soil salinity led to a significant decrease in the amount of available nitrogen in the soil; the values were 78.34, 71.62, 70.98 and 65.41 mg kg^{-1} soil for treatments W1, W2, W3 and W4, respectively, with significant differences between all levels, except for the W2 and W3 treatments. The accumulated salts in soil solution due to irrigation with saline water could be reduced.

Silicon treatment	**Irrigation water Salinity(dSm^{-1})**				**Mean**
	W1	W2	W3	W4	
S1	70.43±6.67	66.26±3.23	63.46±5.82	60.00±5.17	65.04±6.08
S2	78.80±3.10	77.00±4.27	75.63±4.60	69.99±2.54	75.36±4.68
S3	84.41±3.84	78.83±2.77	77.62±7.52	69.12±1.66	77.49±6.89
S4	79.73±5.82	64.40±7.40	67.20±2.80	62.53±5.82	68.46±8.53
Mean	78.34±6.81	71.62±7.79	70.98±7.67	65.41±5.69	
R.L.S.D$_{0.05}$	Water salinity =3.77		Silicon=3.77	Interaction=NS	

Table 6. The effect of irrigation water salinity and silicon treatments on soil's available nitrogen (mg kg^{-1}soil ± SD).W1 : 1.65 dSm^{-1}; W2: 3 dSm^{-1}; W3 : 6 dSm^{-1}; W4: 9 dSm^{-1}; S1: 0 kg Siha^{-1} ; S2: 150 kg Si ha^{-1} as nano-silica; S3: 300 kg Si ha^{-1} as nano silica; S4: 300 kg Si ha^{-1} as potassium silicate.

Table 6 showed that adding silicon significantly increased the available nitrogen compared to the no-addition treatment. The increase percents were 15.8, 19.14 and 5.25% for S2, S3 and S4 treatments, respectively.

Treatment S3 showed a significant recorded available nitrogen compared to S2 and S4 treatments. This could be since the large surface area of silicon can absorb water, nutrients and heavy elements, thus saving nitrogen from loss. Sadgrov(2006) obtained a decrease in nitrogen leaching rates of 60% when treated with silicon from an organic source because of its good porous structure.

Available phosphorus:

The increase in the salinity of the irrigation water led to a significant decrease in available phosphorus content Table 7. These results were similar to those of [32 and 33], who found a decrease in available phosphorus with an increase in the salinity of irrigation water. Twenty-four indicated that the low concentration of phosphate in the soil solution is not only due to the effects of ionic strength that reduce phosphate activity but also to the high control of phosphorous concentrations in the soil solution through the absorption processes and low solubility of Ca-P compounds.

Silicon treatment	**Irrigation water Salinity(dSm^{-1})**				**Mean**
	W1	W2	W3	W4	
S1	46.73±2.79	45.78±0.58	40.99±1.51	39.34±2.68	43.21±3.71
S2	45.52±1.86	45.00±0.54	44.50±2.13	43.81±1.87	44.71±1.60
S3	55.68±2.79	50.60±1.60	44.50±2.13	46.51±2.50	49.32±4.88
S4	51.50±2.06	48.61±2.52	43.26±3.48	42.28±1.01	46.41±4.48
Mean	49.85±4.69	47.50±2.68	43.31±2.55	42.98±3.25	
R.L.S.D$_{0.05}$	Water salinity =1.60		Silicon=1.66	Interaction=4.21	

Table 7. The effect of irrigation water salinity and silicon treatments on soil's available phosphorus (mg kg^{-1}soil ± SD).W1 : 1.65 dSm^{-1}; W2: 3 dSm^{-1}; W3 : 6 dSm^{-1}; W4: 9 dSm^{-1}; S1: 0 kg Siha^{-1} ; S2: 150 kg Si ha^{-1} as nano-silica; S3: 300 kg Si ha^{-1} as nano silica; S4: 300 kg Si ha^{-1} as potassium silicate.

The results shown in Table 7 demonstrated that the addition of silicon significantly increased the available phosphorus compared to the non-addition treatment, with an increased percent of 4, 12 and 7% for treatments S2, S3 and S6, respectively. Moreover, Sadgrov(2006) concluded that the decrease in phosphate losses after the addition of Si-rich materials is due to the highly porous structure of these materials, which preserves water in large quantities.

Regarding nano-silica superiority, [30] explained the superiority of nano-silica over sodium silicate in increasing the available phosphorus in soil. The fact that nanoparticles have a large surface area and reduced concentration of soluble calcium (Data not published) could justify their high effect in increasing the amount of phosphorus in soil compared to potassium silicate in the present study.

Data analysis of the effect of water salinity along with silicon treatments showed that the highest values were obtained with S3 treatment at all salinity levels, with the highest value of 55.68 mg kg^{-1} soil when interacted with W1 level, which is 8-42% higher than others.

Available Potassium

Table 8 indicates a significant decrease ($p \leq 0.05$) in available potassium content by increasing the salinity level of irrigation water. [39] found that irrigation with dilute seawater decreases the proportion of nutrients such as calcium and potassium due to an increase in sodium concentration in the soil.

The available potassium in soil significantly increases from 241mgkg^{-1} soil for control to 294.26, 441.26 and 349.92 mg kg^{-1} soil for S2, S3 and S4 treatments, respectively. Thus, the available potassium is about doubled in the presence of 300 kg Si ha^{-1} at nano-silica. [7] indicated a significant difference between soil treated with silicon and those that did not increase the potassium concentration. The role of silicon in increasing the availability of nutrients, including potassium, can be summarized by increasing the ability of soil to retain water, increasing CEC and holding ions [38]. Sadgrov(2006) obtained a decrease in potassium leaching by 60% when using Si-rich materials due to their highly porous structure, resulting from increasing water retention.

Silicon treatment	Irrigation water Salinity(dSm^{-1})				Mean
	W1	W2	W3	W4	
S1	338.39±9.84	258.45±16.24	190.53±16.28	178.46±9.67	241.46±67.54
S2	489.27±30.54	321.80±40.20	244.85±6.89	121.13±10.33	294.26±141.10
S3	547.61±88.03	579.80±37.16	356.58±23.42	281.06±10.48	441.26±138.03
S4	497.21±5.91	329.83±4.523	298.88±.5614	273.76±1.729	349.92±91.26
Mean	468.12±90.93	372.47±130.62	272.71±65.69	213.60±70.38	
R.L.S.D$_{0.05}$	Water salinity =20.79		Silicon=20.79	Interaction=44.17	

Table 8. The effect of irrigation water salinity and silicon treatments on soil's available potassium (mg kg^{-1}soil ± SD). W1 : 1.65 dSm^{-1}; W2: 3 dSm^{-1}; W3 : 6 dSm^{-1}; W4: 9 dSm^{-1}; S1: 0 kg Siha^{-1} silica; S2: 150 kg Si ha^{-1} as nano-silica; S3: 300 kg Si ha^{-1} as nano silica; S4: 300 kg Si ha^{-1} as potassium silicate.

S3 treatment had the highest available potassium of all water salinity treatments, and this superiority could be a result of the highly active surface of nanoparticles and their impact on soil properties such as water retention, CEC and retention in the form of colloids.

DISCUSSION

[7] indicated that the available amount of nutrients such as calcium and sulfur increased with the addition of silicon to the soil due to enhanced soil CEC and water holding, resulting in higher uptake by the plant. [4] also indicated that the addition of silicon decreased soil salinity due to Si increasing the solubility and mobility of nutrients, making it readily available for plant uptake. Si also improves plant growth and metabolism, increasing nutrient uptake by plant roots. However, decreasing the activity of some ions, such as calcium, due to forming Si-Ca complexes may reduce the soluble amount in soil solution and decrease soil salinity [21]. [22] stated that silica nanoparticles are small and have a highly specific surface area, so they have great absorption capacity by plants and reducing ions in soil solution. Silica minerals are basic in nature, and it is easy to adsorb cations with higher adsorbing capacity for nano-silica compared with conventional silica due to higher density [23]. From our results, it can be noticed that soil salinity increased with increasing soil depth. This may be attributed to the leaching rate of ions to the deeper layer(30-45cm), confirmed by using the leaching requirement in the experiment and by soil properties treated with manure. This result is in harmony with those of [19] who found that soil salinity increased with increasing soil depth from 20 to 60 cm under corn or bean covers. [24] attributed this decrease to the competition of Na^+ and Cl^- with nutrients such as K^+, Ca^{+2} and NO_3^- in saline soils. [25] indicated that the excessive increase of soluble ions due to salinity would provide osmotic stress and thus uptake of certain ions compared to other ions. It is well documented that Cl^{-1} reduces the

uptake of NO_3^- by plant [26]. Organic N mineralization [27] and urease activity [28] results in low available nitrogen in the soil. The enhancement of available nitrogen in soil may be attributed to silicon's positive effect on the microorganisms in the soil [40] and to the positive effect of silicon in reducing NO_3^- leaching [9] and ammonia volatilization [29] due to increasing CEC and retaining more water. Treatment S3 showed a significant recorded available nitrogen as compared with S2 and S4 treatments; this may be because nano-silica is converted to silicon colloids in soil because of hydrogen bonds, making it more active molecules as well as does not affect soil pH, maintaining optimum pH for microorganisms growth and availability of NPK [30]. Moreover, the presence of a suitable water layer on the surface of the nano-silica could facilitate the attraction of silicon on the microbial surface [31], which results in an increase in the activity of microbes and an increase in the availability of nutrients, including nitrogen. [34] indicated a significant correlation between soil salinity and Ca-P compounds, which results in a significant negative correlation (r = -0.64) between soil salinity and available phosphorus. Calcium and other salt ions accompany the orthophosphate ion and adsorbate on clay particles [35]. [36] justified the relationship of salinity with the availability of phosphorus to the fact that mono-salts such as sodium chloride encourage the dissolution of calcium carbonate in calcareous soils, releasing more calcium, which accelerates phosphorus adsorption. [9] indicated an increase in the availability of phosphorus in soil after silicon fertilization due to a series of reactions that include monosilicic acids adsorption on slightly soluble phosphates of calcium, magnesium, iron or aluminum, then exchange of phosphate-anion by silicate-anion followed by desorption of phosphate-anion leading to increase phosphorus in soil solution. This also could be because application of Si-rich material could decrease P leaching by 40-70 %, and phosphorus absorbed by this material remained in plant–available form [8]. [37] who found that potassium in the soil decreased after irrigation with drainage water compared to river water. He explained by the fact that the increase in the concentration of Ca, Mg and Na was greater than the increase in potassium concentration, which allows displacing potassium from the exchange sites and may be subjected to leaching. The result is in agreement with the findings of [30], who obtained an increase in the available potassium as a result of adding nano silica compared to sodium silicate.`

CONCLUSIONS

It can be concluded from this study that the addition of nano-silica or potassium silicate led to a reduction in soil salinity at all soil depths and for a wide range of irrigation water salinity (1- 9 dSm^{-1}), Proving its important role in improving soil properties. Nutrient (N, P and K) availability were positively affected by silicon application with higher value at nano-silica compared to potassium silicate under different level of irrigation water salinity. It is possible that the addition of nano-silica at a level of 300 kg Si ha^{-1} is the best level for reducing soil salinity and preparing a suitable medium for tomato plants with sufficient available quantities of nutrients, especially since the cost of obtaining the nano-source is low and does not constitute a burden on the inputs of the agricultural process.

References

1. FAO. The use of saline waters for crop production Irrigation and Drainage Paper 48 Chapter 3 - Examples of using saline waters for irrigation. **1992**.
2. Alsadon, A.;S. Monther and M. Wahb-Allah. Responsive gene screening and exploration of genotypes responses to salinity tolerance in tomato. *AJCS*. **2013**; *7(9)*:1383-1395.

3. Arslan, A.; A. Abdelgawad .; A. Gaibeh and F. Kadouri. The effects of saline irrigation water management and salt tolerant tomato varieties on the sustainable production of tomato in Syria (1999–2002). Agricultural Water Management • j.agwat..04.024,54-66. **2005**.
4. Al-Saeedi,A.H. Contribution of Nano-Silica in Affecting Some Physico-Chemical Properties of Cultivated Soil with the Common Bean (Phaseolus vulgaris). *Journal of the Advances in Agricultural Researches (JAAR):* **2021**; *25 (4)*.389-400.
5. Matthew, A and A. Akinyele. Sodium and Calcium Salts Impact on Soil Permeability. *Journal of Earth Sciences*. **2014**;*4(3)*, 37– 45.
6. Ali, B.M.K. Role of Silicon in Decreasing Salinity of Irrigation Water and Toxicity of Some Heavy Metals in Growth of Corn Crop(*Zea mays* L.).MSc.Thesis of. College of Agriculture , University of Basrah.Iraq.(In Arabic). **2006**.
7. Greger, M. ID , L. Tommy, and V. Marek. Silicon Influences Soil Availability and Accumulation of Mineral Nutrients in Various Plant Species. *Plants*, **2018**; *7*, 41:1-16.
8. Cherepanov K.A.; G.I. Chernish.; V.M. Dinelt and J.L. Suharev. The Utilization of Secondary Material Resources in Metallurgy, Moscow, Metallurgy. **1994**.
9. Matichenkov, V.; E. Bocharnikova and J.Campbell. Reduction in nutrient leaching from sandy soils by Si-rich materials: Laboratory, greenhouse and field studies. *Soil and Tillage Research*, **2020**; *196*, 104450.
10. Matichencov V. V., and E. A. Bocharnikova. The relationship between silicon and soil physical and chemical properties. In: Silicon in Agriculture, Vol. 8, Studies in Plant Science. Datnoff L. E., G. H. Snyder, and G. H. Korndörfer (eds.). Amsterdam, The Netherlands: Elsevier, **2001**; 209–219.
11. Richards, L.A. Diagnosis And Improvement Of Saline And Alkaline Soils. Usda Hand Book60. Usda, Washington Dc. **1954**.
12. Page, A.L. ;R.H. Miller and D.R. Keeney. Methods of soil analysis part(2).2nd.E.d. Published by J. Agronomy Soc. **1982**.
13. Ayers, R.S.; D.W. Westcot. Water quality for agriculture. Irrigation and Drainage Paper No. 29, FAO, Rome. 174 p. **1985**.
14. Bremner, J.M . and A.P. Edwards. Determination and isotope-ratio analysis of different forms of nitrogen in soils:I.Apparatus and procedure 159 for distillation and determination of ammonium.*Soil Sci.Soc Amer. Proc*., **1965**;*29*:504 507 .
15. Bremner, J. M. and D. R. Keeney. Determination and isotope-ratio analysis of different forms of nitrogen in soils.3-Exchangeable ammonium, nitrate and nitrite by extraction-distillation methods.*Soil Sci. Soc. Amer. Proc*., **1966**; *30*: 577 - 582.
16. Murphy, T. and J. R. Riley. A modified single solution method for the determination of phosphate in natural waters.*Anal.Chem. Acta*., **1962**; *27*:31-36.
17. Al-Rawi. K.M and A.M. Khalaf- Allah. Design and analysis of agricultural experiments Al-Mousel Univ. press Iraq488pp.(In Arabic). **1980**.
18. Abdulkareem, M.A. and Al-Delfi, H.F.K. Role of organic residues in reducing the effect of irrigation water salinity on corn(*Zea mays* L.) growth.*Assiut J.Agric.Sci*. **2017**;*48*:231-254.(In Arabic).
19. E l- Emary F. A. A. and M. M. Amer. Role of Nano-Silica in Amelioration Salt Stress Effect on some Soil Properties, Anatomical Structure and Productivity of Faba Bean (Vicia faba L.) and Maize (Zea mays L.) Plants. *J. Plant Production, Mansoura Univ*. 2018. *9 (11)*: 955 -964.
20. Amacher, J. K.;R Koenig and B. Kitchen .Salinity and Plant Tolerance. All Archived Publications. Paper 43. **2000**.
21. Bosnic, P.; M. Pavlicevic, N. Nikolic, and M. Nikolic. High mono silicic acid supply rapidly increases Na accumulation in maize roots by decreasing external Ca^{2+} activity. *J. Plant Nutr. Soil Sci*.**2019**; *182*, 210–216.
22. Nair ,R.; S.H. Varghese.; B.G. Nair.; T. Maekawa.; Y.Yoshida and D.S. Kumar . Nanoparticulate material delivery to plants. *Plant Sci*,**2010**; *179(3)*:154–163.
23. Ma *,J.F*. Silicon uptake and accumulation in higher plants. Soil, *fertilizer and plant Silicon Research*, **2002**;*11*,no .8.
24. Monica, N.; V.Roxana .; R. Ioan.; S. Vlad.; P. Rodica and M. Raluca . Plant Nutrition Affected by Soil Salinity and Response of Rhizobium Regarding the Nutrients Accumulation. **2014**; *7*:71 – 75.

25. Agarwal ,S. and Z. Ahmad. Contribution of the Rhizobium inoculation on plant growth and productivity of two cultivars of Berseem (*Trifolium alexandrinum* L.) in saline soil, *Asian. J. of Plant Sci*, **2010**; *9(6)*, 344-350.
26. Soussi, M.; A.Ocana and C.Lluch. Effects of Salt Stress on Growth, Photosynthesis and Nitrogen Fixation in Chick-Pea (Cicer arietinum L.). *Journal of Experimental Botany*, **1998**; *49*, 1329-1337.
27. Al-Jaberi ,M.M. Nitrification and urea hydrolysis in some southern Iraqi soils .MSc. Thesis , College of Agriculture, University of Basrah,Iraq.116p (In Arabic). **1989**.
28. AL-Ansari. A.S. characteristics of enzymes in recently reclaimed land IV. Effect of salinity on behavior and Kinetic parameters of urease enzyme .*Iraq.Agric*. **2002**;*7*:202-209.
29. Kerr,G. Second report on the potential use of diatomaceous earth as a soil conditioner in vegetation of overburden in the hunter Value, South Cross University. **2007**.
30. Karunakaran G, R. Suriyaprabha.; P. Manivasakan.; R. Yuvakkumar.; V. Rajendran.; P. Prabu and N. Kannan. Effect of nano-silica and silicon sources on plant growth promoting rhizobacteria soil nutrients and maize seed germination. *IET Nanobiotechnol*. **2013**; *7(3)*: 70-77.
31. Gordienko, A.S and I.K. Kurdish. Electrical properties and interaction with silicon dioxide particles of Bacillus subtilis cells’, *Biofizika*, **2007** ;*52*, pp. 314–317.
32. Jarallah , A. K. A. ; J. K. Al Ugail and A. A. Al Hadethi. Using drainage water for bare production . *Iraqi Journal of Agricultural Sciences,* **2001**;*32 (1)* : 227- 233.
33. Al-Delfi, H.F. Role of organic residues in reducing the effect of irrigation water salinity on soil properties and corn (Zea mays L.) growth. MSC. Agriculture college . Basrah university .(In Arabic). **2013**.
34. Al-Tameemi, H.J and R.K. Hiba. Effect of Phosphatic and organic fertilization on Phosphate forms in some calcareous soils.*J.Wasit*. **2016**;*9(2)*:60-72.
35. Prasad, R and F. Power. Soil fertility management for sustainable agriculture.Lewis pub.New York,347p. **1997**.
36. Buehrer,T.F. Evaluation of phosphorus sources soil ,*J.Tech,Bull*. **2001**;*3(3)*:42-58.
37. Prism, T.H. Influence of sewage sludge levels and irrigation water quality on behavior of some nutrients in soil and corn yield.ph. D. dissertation. Agriculture college .Univ. Baghdad.(In Arabic). **2006**.
38. Agri power. A review of silicon and its benefits for plants.BFA registered prod.Sydney,Australia.pp70. **2010**.
39. Hue, N. V. and W. W. McCall. Soil salinity and the growth of macadamia seedlings. *J. of Plant Nutrition*; **1989**; *12 (4)*: 449 – 464.
40. Xu, D., Gao, T.; X. Fang.; H. Bu.; Q. Li.; X. Wang and R. Zhang. Silicon addition improves plant productivity and soil nutrient availability without changing the grass:legume ratio response to N fertilization. *Scientific Reports*, **2020**; *10(1)*, 1–9.

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