EFFECT OF NANO- SILICON ON GROWTH ,FRUITS YIELD AND ANTIOXIDANTCAPACITY OF TOMATO PLANTS UNDER SALT STRESS

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ABSTRACT

Salinity is the major problem for agriculture in arid and semi-arid regions , as it negatively affected plants growth and yield. The use of silicon has been observed to mitigate salt stress effects by increasing the tolerance of plant. Therefore , the aim of this study is to evaluate the application of Nano-silicon and K_2SiO_3 on dry weight ,fruits yield and antioxidant capacity (proline ,phenols and lycopene contents) of tomato plant irrigated with different levels (1.65 , 3 ,6 and 9 dSm^{-1}) of water salinity .Nano-silicon was applied either to soil or spraying on plant canopy . Results indicated that there is a remarkable variations in dry weight ,fruits yield ,proline ,phenols and lycopene contents among irrigation with different levels of water salinity ,which the dry weight decrease with increased salinity levels , and the rest parameters increased up to 6dSm^{-1}then decreased at 9dSm^{-1} .The application of silicon had positive effects on the plants that were subjected to salt stress, alleviated the negative effects of oxidative stress caused by salt.The application of Nano-silicon is more effective than K_2SiO_3 in increasing response of tomato to salt stress .Among other treatments , addition of 300kg Si ha^{-1} Nano - silicon spraying on plant had the more positive effect on mitigation salt stress enhancing fruits yield of 65.58$Mgha^{-1}$. 5469

Keywords: antioxidants ,Nano-silicon ,salinity , tomato ,stress

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INTRODUCTION:

Agriculture in arid and semi-arid regions is facing the problem of in sufficient pure water resources for irrigation caused by anthropic climate changes and human activities. Using of poor quality waters in such regions is common practice where there are limited good quality water supply for irrigation. The reduction in yields of 25-30% are attributed to water logging an salinization results from poor agriculture , soil and water management (FAO., 1992).Tomatoes is an important vegetative cropin Basrah province with a total cultivated area of 15372 Donums in 2021. Tomatoes classified as moderate tolerant to salinity. The percentagereduction 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 (Alsadon *et al*., 2013).Arslan *et al*. (2005) also found fruit yield of tomato reduced for about 50% when EC of irrigation water rise from 0.6 to 6 dSm^{-1} .

Silicon(Si) was thought to be a nano-essential element for plant growth ,but recently , many studies confirmed that silicon providing several benefits for several crop plants particularly under stress conditions (Liang *et al*.,2015;Zargar *et al*.,2012).Several studies showed that silicon alleviated environmental stresses such as salt. Silicon can reduce salt stress in plants by different mechanism involved a reduction in ion toxicity ,maintenance of plant water balance , increase nutrient uptake and assimilation ,regulation of biosynthesis of compatible solutes and phytohormones ,reduction in oxidative stress ,modification of gas exchange attributes and modification of gene expression (Zargar *et al*.,2019). Silicon application enhances salt tolerance in plants by adjusting the content of some solutes such as proline ,free amino acids and glycine betaine in okra (Abbas *et al*.,2005). Dantoff *et al*.(1997) stated that silicon accumulation leads to a production of phenols and phytoalexines that provides tolerance against plant pathogens. According to Muneer and jeong (2015) tomato under salt stress can increase expression of genes related to antioxidants (leAPX, leSOD and CAT). Stamatakis *et al*.(2003) and Marodin *et al*.(2014) found an increase of lycopene content in tomato fruits treated with silicon .

Using the nanotechnology in agriculture has developed in last years ,since nanoparticles have different characteristics from their bulk form due to the less size (<100nm) and high surface area ,so enter the plant easily and participate in plant metabolisms. Silicon nanoparticles have been involved in tomato improvement and increase growth and yield (Elsadek *et al*.,2019 ;Guerrero *et al* .,2020). Haghighi *et al* .(2013) observed that Nano-silicon alleviated the adverse effects of salinity on tomato plants and increased growth parameters .The present study was conducted to examined the impact of wide range of irrigation water salinity on antioxidants capacity ,dry weight and fruits yield of tomato plant and the role of Nano-silicon added with different level and methods to induce the tolerance of plant to the adverse effects of salinity .

MATERIALS AND METHODS:

The experimental Site :-

Anexperiment was conducted in greenhouses at Agricultural Research Station- College of Agriculture - University of Basrah , Iraq located in Karmat Ali region (47^{o}44'40"E and latitude30^{o}33'44"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 analyze of some chemical and physical properties according to the standard methods mentioned in Richards (1954)and Page*et al*.(1982) and included in table 1.

Treatments :

The experiment includes two factors The first factor: the salinity of the irrigation water which includes four treatments :-

1- water with 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 9dSm^{-1} (W4)Salinity levels of 3, 6 and 9 dSm^{-1} were prepared from dilution of drainage water with tap water using the following equation(Ayers and Westcot,.1985):$EC1=[ECa*a]+[ECb(1-a)]$ where :-

EC1= electrical conductivity of the water to be obtained(dSm^{-1})

ECa=electrical conductivity of water used in dilution ($dS\ m^{-1}$) .

Table 1 : some chemical and physical properties of the greenhouse soil.

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		

ECb = electrical conductivity of drainage water ($dS\ m^{-1}$). a = percentage of water used for dilution (liters). The irrigationwater characteristics were listed in table 2 .

Table 2: irrigation watercharacteristics

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

*According to Richards(1954).

The second factor : addition of silicon which included the following treatments :

1- 0 Kg Si ha^{-1} (S1)
2- 150 Kg Si ha^{-1} in the form of nano-silica (98% SiO_2) added to soil (S2).
3- 300 Kg Si ha^{-1}in the form of nano silica (98% SiO_2) added to soil (S3).
4- 150 Kg Si ha^{-1}in the form of nano silica (98% SiO_2) added as foliar application(S4) .
5- 300 Kg Si ha^{-1} in the form of nano silica (98% SiO_2) added as foliar application(S5) .
6- 300 Kg Si ha^{-1} in the form of potassium silicate (26.5% SiO_2) added to soil (S6).

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

Experimental design :

Field was ploughed 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}. Field divided to 3 blocks , and the individual plots within block were designed according to the treatments at row size of 3.5× 0.5m with factorial experiment. The drip irrigation system was designed 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. Leaching requirement of 20% were used for all treatments. Tomato (*Solanum Lycopersican* Mill.) seedlings, REDFLORA F1 hybrid, were transferred to the field on October 2020 at a rate of 16 plants for each plots, with a distance of 0.4 mbetween plants. Nitrogen in the form of urea (46% N), phosphorous in the form of DAP (21% P) and potassium in The form of potassiumsulfate (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 in soil along theplant line under drippers.For soil application treatments,Nano silicon and potassium silicate were mixing with an amount of distilled water by a mixer for 30 minute, then mixing with 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. For foliar application treatments ,nano silicon with a mentioned level was mixed thoroughly with a sufficient water for full wetness of the plants and plants were sprayed using hand sprayer ,The spraying was carried out in the early morning at two doses as for soil application treatments.Other agricultural practices were carried out according to local recommendations of the region.

plant samples and analysis:

At the vegetative growth period of tomato plant , the upper fully developed leaves of four randomly selected plants per treatment were taken ,washed , oven – dried at 70°C and grinded for proline analysis. Proline was determined according to the method of Troll and Lindesly (1955)by using 95% Ethyl alcohol for extraction and carried out spectrophotometrically at 520 nm wave length . At stage of flowering –early maturity ,whole shoot of two plants for each treatment were selected ,and dry weights were recorded after drying at 70°C. Tomatoes of four plants per treatment were selected and harvested in fully red .Four fruits were selected randomly ,washed ,oven – dried at 70°C and grinded .Phenols were determined using Folin – Denis method as described in Dalaly and Al-Hakeem(1987) by using Folin-Denis indicator and 6% sodium carbonate ,then carried out the total phenolsspectrophotometrically at 760 nm. Lycopene content were determined according to the method of Nagata and Yamashita (1992) after extracting by 4:6 of Acetone:Hexane solution and reading the absorbance spectrophotometrically at 505 nm and 663 nm .For total fruits yield the fruits were harvested weekly ,counted and weighted of each plot.

Statiscal analysis:

For each the evaluated variables , three replicates per treatment were used .An analysis of variance (ANOVA) was employed using GenStat procedure Liberary Release pL 18.2 program .Revised Least significant difference test was performed at a probability level of 0.05 (Al-rawi and khalaf Alla,1980).

Results and Discussion:

Plant growth and yield:

Plant dry weight reduced by 5.54,15.02 ,17.88% for W2,W3 and W4. respectively as compared with W1(table 3).On the other hand ,fruits yield of tomato plants behaves differently than dry weight which indicated an increase till W3(6 dSm-1) then significantly decreased at W4 (9 dSm-1) (table 4) .the mean values were 50.90 ,62.21 ,69.06 and 55.28Mgha-1 for salinity levels W1, W2, W3 and W4 respectively. That meaning ,the toxic threshold of salinity differed with different plant part examined. It can be concluded thatfruits yield was more tolerance to salinity than shoot growth .However, treatment W4showed the lowest values of both parameter ,especially without silicon addition .Under salt condition ,plants exposed to low external water potential and ion toxicity ,due to accumulation of ion such as Na^+ and Cl^- inside the cells resulting in low accumulative carbohydrates and inhabited the formation of chloroplasts whichsignificantly reduced dry weight (Ghassemi-Golezani,2012).The toxic reactive oxygen radicals which generated during salinity conditions affect chloroplasts and degrade chlorophyll . Saline ions are transported

Table 3: Effect of irrigation water salinity and silicon treatments on dry weight ($Mgha^{-1}$ ± SD) of tomato .

Silicon treatment	Irrigation water Salinity(dSm^{-1})				Mean
	W1	W2	W3	W4	
S1	4.59±0.004	4.56±0.208	4.28±0.198	3.73±0.134	4.29±0.384
S2	5.47±0.184	4.84±0.081	4.36±0.192	4.21±0.114	4.72±0.529
S3	6.34±0.188	6.04±0.136	4.36±0.135	4.27±0.071	5.25±0.992
S4	5.93±0.109	5.56±0.040	5.50±0.060	5.41±0.071	5.60±0.217
S5	6.29±0.026	5.81±0.041	5.54±0.070	5.48±0.080	5.78±0.338
S6	4.94±0.235	4.86±0.280	4.44±0.054	4.46±0.078	4.68±0.285
Mean	5.59±0.124	5.28±0.131	4.75±0.118	4.59±0.091	
$R.L.S.D_{0.05}$	Water salinity =0.079		Silicon=0.097	Interaction=0.207	

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-silicato soil; S3: 300 kg Si ha^{-1} as nano silicato soil ;S4:150kg Si ha^{-1}as nano silica foliar,S5:300kg Si ha^{-1}as nano silica foliar,S6: 300 kg Si ha^{-1} as potassium silicateto soil.

Table 4: Effect of irrigation water salinity and silicon treatments on fruits yield ($Mgha^{-1}$ ± SD) of tomato.

Silicon treatment	Irrigation water Salinity(dSm^{-1})				Mean
	W1	W2	W3	W4	

S1	50.33 ±4.92	55.97±1.76	66.52 ±0.85	47.30 ±3.17	55.03 ±8.09
S2	51.55 ±0.88	56.83 ±6.36	67.74 ±3.63	46.99 ±1.44	55.78 ±8.69
S3	51.56± 1.06	61.83 ±6.09	70.89 ±6.33	52.10 ±4.79	59.10 ±9.34
S4	40.63±5.84	67.56 ±7.21	72.38 ±1.81	65.33 ±1.56	61.48±13.48
S5	56.07±4.74	68.11 ±0.78	71.22 ±3.01	66.93 ±3.79	65.58 ±6.64
S6	55.29±6.56	62.96 ±3.40	65.63 ±4.82	53.04 ±3.38	59.23 ±6.77
Mean	50.90±4.00	62.21 ±4.27	69.06 ±3.41	55.28 ±3.03	
R.L.S.D$_{0.05}$	Water salinity =2.507		Silicon=3.345	Interaction=7.067	

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-silicato soil; S3: 300 kg Si ha^{-1} as nano silicato soil ;S4:150kg Si ha^{-1}as nano silicafoliar,S5:300kg Si ha^{-1}as nano silicafoliar, S6: 300 kg Si ha^{-1} as potassium silicateto soil

to the top of plant by transpiration force ,inducing harmful effects in tissues when
these ions reaches a toxic threshold. The toxic effects of salinity on growth and yield of tomato plant have been widely described (Romero-Aranda *et al*.,2006) . The yield of plant positively correlated with accumulated dry matter in shoot ,El-Emary and Amer (2018) stated that growth behavior, metabolie activity (chlorophyll and carbohydrate content) , the anti-oxidants such as carotenoids and the anatomical performance positively correlated with yield ,especially under salinity conditions.

Shoot dry weight (table3) and fruits yield(table4) were significantly increased with addition of silicon at all treatments .Dry weight increased by 10.02 ,22.37 .30.53 , 34.73 and 9.09% for S2 ,S3 ,S4, S5 and S6 treatments, respectively .The same trend ,fruits yield increased by 1.36 ,7.39 ,11.72 ,19.17 and 7.63% for S2 , S3 , S4 . S5 and S6 treatments , respectively .These results supported by Marodin *et al*.(2014); Elsadek *et al.*(2019) and Guerrero (2020) who obtained higher tomatoes yield after addition of silicon . These results clearly indicated that addition of nano-silicon at different levels and methods (foliar or soil application)as well as potassium silicate can enhanced plant growth and yield . Treatment S5(foliar application of nano-silicon atrate 300KgSiha^{-1}) recorded the highest values of dry weight and fruits yield compared to the silicon treatments.

Tomato plants irrigated with water salinity of 9dSm^{-1} without silicon reduced their dry weight and fruits yield by 19.38 and 6.02% , respectively . However, when plants irrigated with 9dSm^{-1} water salinity plus 300 KgSiha^{-1} nano-silicon as foliar application ,the dry weight and fruits yield increased by 19.39 and 32.98% , respectively. This is true also for treatment S4 in regard to dry weight and treatments S3,S4 and S6 in regard to fruits yield . That meaning ,addition of silicon in most treatments reduced the adverse impact of water salinity , and its role was so clear in lowsalinity level (W1).These results are in a great interest because they are highlight the direct effect of silicon on production of dry matter and fruits yield by different treatments .The simulative effect of silicon might be due to its anti-oxidant effect to protect chloroplasts and prevented chlorophyll degradation and improved photosynthetic activity (El-Emary and amer.,2018) as well as enhanced K/Na selectivity ratio, increased enzyme activity and concentration of soluble substances in xylem, resulting in limited sodium absorption by plants (Chanchal *et al*.,2016) . However Romero-Aranda et al (2006) stated that the benefits of silicon addition under saline stress are due to its role in water status concerning the ability of the plant to retain water under saline condition by depression of excessive by transpiration and improve tissue tolerance by dilution effect of saline ions. Neuman and De Figueiredo(2002) have shown that silicon complexes with high molecular weight can be transported into the vacuoles through an endocytotic process , resulting in low ψ_w in cell. Richmond and Sussman (2003) also stated that the hydrophilic nature of silicon (SiO_2-nH_2O) could help to keep water in cell and then dilute salts ions .Nano particles have different characteristics from their bulk form due to the small size less than 100 nm ,so have more active surfaces and easy salinity level of W3 as compared with W1 salinity level. Similar results were observed by Krauss *et al*.(2006) ; Klados and Tzortzakis (2014) and Martinez *et al*.(2020). The plant under salinity stress change its metabolism to overcome the stress condition and one of the mechanisms to be used by plant is accumulation of compatible osmolytes in the cytoplasm, such as proline and soluble sugar (Zahra *et al*.,2010) .High production of abcissic acid in plants under salt stress increases proline and defensive proteins (Shairova and Sakhabutdinova , 2003). It is common to observe an accumulation of phenolic compounds inplant at salt stress condition to play an important role in protecting molecules against oxidation condition associated with salinity (Petropoulos *etal*.,2017).Kubota *et al*. (2006) also stated that increasing ethylene content in plant due to saline condition results in lycopene accumulation in tomato fruits.

to entering the plant cells by pores and stomatas and interact with plant metabolisms as well alter the anatomical structure of plant parts (Siddiqui and Al-Whaibi,2014; Schroffenegger and Reimhult,2019).The more positive response to foliar application methods as compared to soil application method might be due to the plant makes the most of silicon dose without any negative interference in soil , as well as addition of materials through leaves stimulates the high response of plant, so the effect is greater in the vocabulary of plant growth .

Antioxidant Capacity :

Salinity significantly increased proline ,phenols and lycopene contents up to level W3 ,then a significant decreases have been recorded at level W4 (table 5,6 and 7) . These results were similar to the result of fruits yield (table 4). However ,the depressions in these parameter at salinity level of 9 dSm^{-1} (W4) remained with a values over W1 salinity levels . The proline , phenole and lycopene contents were increased by 145.52 ,436.53 ,and 58.85%with the

Differences were observed in the contents of proline ,phenols and lycopene after application of silicon (table 5 ,6 and 7) .The proline content was increased by 39.86 ,49.20 ,38.80 ,51.71 and 17.62 % for treatments S2 ,S3 ,S4 ,S5 and S6.respectivly .This result similar to those of Ali *et al*.(2018) who found an accumulation of proline in more salt sensitive varieties of tomato .Silicon application can enhance salt tolerance by adjusting the levels of some solutes such as proline ,glycine , betaine and free amino acids in different plantparts (Abbas *et al* .,2015) and activated the genes related to the antioxidants response in salt – stressed tomato (Muneer and Jeong,2015). The phenols content was not affected by silicon application at treatments S4 and S6 and remained with insignificant less values ,while addition silicon at treatments S2,S3 and S5 significantly increasedphenols by 12.26 ,24.53 and 53.98% ,respectively. This finding is in agreement with

Guerrero et al.(2020) who found an increase of phenols contents in tomato fruits treated with silicon . Datnoff *et al*.(1997) stated that accumulation of silicon in plant tissues leads to the production of phenols and phytoalexines which provided tolerance to plant. The lycopene content in fruits

Table 5: Effect of irrigation water salinity and silicon treatments on proline (µg.g^{-1}DW ± SD).) in tomato leaves.

Silicon treatment	Irrigation water Salinity(dSm^{-1})				Mean
	W1	W2	W3	W4	
S1	2317.78±167.77	2506.88±66.34	5040.00±218.58	1673.33±88.19	2884.50±1345.26
S2	2295.55±107.96	3940.00±120.18	5395.56±423.39	4506.67±88.19	4034.44±829.45
S3	2184.44±167.77	4406.67±145.29	5473.33±185.59	5151.11±117.06	4303.89±566.12
S4	2117.77±157.52	5651.11±50.92	5884.33±183.26	2362.22±69.39	4002.86±1611.63
S5	2351.09±50.95	5784.44±236.60	6251.11±69.39	3117.78±171.06	4376.11±1350.24
S6	2351.11±157.53	3262.22±107.00	5395.55±50.70	2562.22±183.58	3392.78±1152.63
Mean	2269.96±134.92	4258.55±121.06	5573.31±188.48	3228.89± 119.58	
R.L.S.D$_{0.05}$	Water salinity =94.30		Silicon=115.49	Interaction=236.27	

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-silicato soil; S3: 300 kg Si ha^{-1} as nano silicato soil ;S4:150kg Si ha^{-1}as nano silica foliar,S5:300kg Si ha^{-1}as nano silica foliar, S6: 300 kg Si ha^{-1} as potassium silicateto soil.

Table 6: Effect of irrigation water salinity and silicon treatments on phenols (% ± SD) in tomato fruits.

Silicon treatment	Irrigation water Salinity(dSm^{-1})				Mean
	W1	W2	W3	W4	
S1	0.050±0.010	0.183±0.015	0.253±0.006	0.163±0.006	0.163±0.077
S2	0.050±0.017	0.187±0.015	0.273±0.006	0.220±0.010	0.183±0.067
S3	0.060±0.010	0.233±0.012	0.290±0.017	0.230±0.010	0.203±0.049
S4	0.057±0.015	0.157±0.015	0.290±0.010	0.097±0.012	0.150±0.093
S5	0.053±0.006	0.303±0.015	0.333±0.015	0.160±0.010	0.251±0.069
S6	0.043±0.006	0.210±0.010	0.233±0.015	0.150±0.010	0.159±0.041
Mean	0.052±0.011	0.212±0.014	0.279±0.012	0.170±0.010	
R.L.S.$D_{0.05}$	Water salinity =0.011		Silicon=0.014	Interaction=NS	

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-silicato soil; S3: 300 kg Si ha^{-1} as nano silicato soil ;S4:150kg Si ha^{-1}as nano silica foliar,S5:300kg Si ha^{-1}as nano silica foliar, S6: 300 kg Si ha^{-1} as potassium silicateto soil. 5477

Table 7: Effect of irrigation water salinity and silicon treatments on lycopene (mg.$100g^{-1}$DW ± SD)in tomato fruits..

Silicon treatment	Irrigation water Salinity(dSm^{-1})				Mean
	W1	W2	W3	W4	
S1	12.79±0.47	13.27±0.31	14.36±1.60	7.38±0.65	11.95±2.92
S2	12.88±0.36	17.51±1.23	19.56±1.20	11.02±0.63	15.24±3.43
S3	13.51±0.99	20.49±0.57	21.69±1.87	14.99±0.67	17.67±2.82
S4	13.05±1.05	21.27±0.98	23.03±1.03	16.83±1.10	18.55±2.53
S5	13.34±0.62	25.39±1.72	27.04±2.20	23.73±1.82	22.38±2.11
S6	11.99±1.79	18.21±0.42	17.52±1.86	13.80±1.56	15.38±2.98
Mean	12.92±0.88	19.36±0.87	20.53±1.63	14.63±1.07	
R.L.S.$D_{0.05}$	Water salinity =0.742		Silicon=0.888	Interaction=2.091	

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-silicato soil; S3: 300 kg Si ha^{-1} as nano silicato soil ;S4:150kg Si ha^{-1}as nano silica foliar,S5:300kg Si ha^{-1}as nano silica foliar, S6: 300 kg Si ha^{-1} as potassium silicateto soil

significantly increased by addition of silicon over control (table 7).Treatments S2,S3,S4,S5 and S6 caused an increasing of 27.53 ,47.86 ,55.23 ,87.28 and 28.70% ,respectively .This result is in agreement with Stamatakis *et al*.(2003) and Marodin *et al*.(2006).

The high proline ,phenols and lycopene values were observed at treatment S5(300 kgSiha^{-1} as nano-silicon added as foliar application) which indicated thesuperiority of nano-silicon over potassium silicate as well as the superiority of foliar application method as compared with soil applicationmethod .Furthermore ,it could be observed that treatment S5 gave the highest values at most of irrigation water salinity (table 5,6 and7).This result was similar to the previously mentioned results of dry weight and fruits yield.

Without silicon application ,increasing water salinity level from W1 to W4 decreased the proline content from 2317.78 to 1673.33 µg.g^{-1} DW while, under S5 treatment the proline content increased from 2317.78 to 3117.78 µg.g^{-1} DW . A same trend was observed for lycopene. however there is no significant differences of interaction effect were recorded for phenols. Nano-silicon can alleviate the negative effect of oxidative stress caused by salts through antioxidant compounds (Guerrrero *et al*.,2020) . An increase in accumulation of proline ,free amino acids ,nutrients content and antioxidant enzymes due to the nano-silicon will improving the tolerance of plant to abiotic stress (Siddiqui *et al* .,2014). In the present study , the simulative effect of silicon on different examined parameters might be due to its anti-oxidantal role to be protected plants and enhanced their growth and fruits yield.

CONCLUSION:

Silicon (Si) proved its role for en hancement antioxidant capacity , growth and fruits yield of tomato . Mentioned parameters were positively affected by silicon with higher values as compared to control (without silicon) under irrigation by different levels of water salinity .Treatment of 300kgSi ha^{-1}of nano-silicon added as foliar application method had the superiority effect to mitiga of salt stress and enhanced plant growth and yield .So, it could be concluded that this treatment is the most suitable for tomato plant under or related conditions of the experiment.

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