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Impact of Foliar with Nano-silica in Mitigation of Salt Stress on Some Soil Properties, Crop-Water Productivity and Anatomical Structure of Maize and Faba Bean

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IMPROVING soil productivity, enhancing nutrition use efficiency, and protecting plants from environmental stress, can be ascertained by nanofertilizers. Lysimeter experiments were conducted at Sakha Agriculture Research Station Farm during two successive summer 2017 and winter 2018 growing seasons to study the effect of foliar application with different concentrations with nano-silica and different salinity of irrigation water on some soil properties and productivity of maize and faba bean plants. For soil properties, results showed that there are no variations between soil salinity and foliar application with different concentrations with nano-silica. But, there is a remarkable variation in mean of soil salinity between irrigation with fresh water and blended with well water treatments, which T_4 (1.36 dS m^{-1}), recorded 4.32 and 4.47 dS m^{-1}, compared with T_2 (2.45 dS m^{-1}), recorded 5.07 and 5.28 dS m^{-1}, at 0-20 cm depth for maize and faba bean plants, respectively. Also, the mean values of Exchangeable sodium percent after harvesting of maize was 12.55, 14.97, 14.72 and 13.85 % with different irrigation water treatments T_1 (0.51 dS m^{-1}), T_2 (2.45 dS m^{-1}), T_3 (1.84 dS m^{-1}), and T_4 (1.36 dS m^{-1}), respectively, at 0-20 cm depth. The same trend was exhibited by faba bean plants. Anatomical structure in roots of maize and faba bean plants recorded increment (22.75% and 15.54%) with 300 mg L^{-1} nano-Si more than the control. Also, all of the anatomical characters of roots were decreased by increasing of the salinity irrigation water and recorded lowest values up to T_2 (2.45 dS m^{-1}) and without nano-Si. Treatment T_2 showed a significant reduction in grain yield (39.28 and 80.13 %), and in straw yield (38.84 and 78.06%) for maize and faba bean plants, respectively, in comparison with the control treatment, T_1. On the other hand, T_4 recorded the highest values 4.22 and 5.32 Mg $Fed.^{-1}$ in grain and straw yield of maize plants and 1.74 and 1.84 Mg fed^{-1} in grain and straw yield of faba bean plants, respectively, under foliar application with 300 mg L^{-1} of nano-silica compared with other concentrations. The same trend was observed in chlorophyll content, nitrogen uptake and nitrogen use efficiency of maize and faba bean. Based on these results, foliar application with 300 mg L^{-1} of nano-silica is the proper concentration to mitigate the salt stress for maize and faba bean plants.

Keywords: Nano-silica; Salinity; Maize; Faba bean; Anatomical structure; Crop water productivity.

Introduction

Recently, the total available land for agriculture has been reduced by the increasing worldwide population, industrialization and urbanization and if these global problems are not resolved in time, it will lead to inadequacy of food to feed the world’s population (Glick 2012). Also, parallel to the problem of insufficient water resources, that of desertification is looming, certainly dependent on irrational anthropic activities and climatic variations but also linked to the uncontrolled use of poor quality waters and as a consequence agriculture is facing the difficult problem of producing more with ever more limited and worse water resources (El-Shahawy and Ragab 2005).

Direct use of saline irrigation water varying from 0.50 to 3 dS m^{-1} is common in the districts of Northern Delta where there are no other alternatives or in areas of limited better water quality supply with traditional farming practices.

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Yield reductions of 25 to 30 percent are attributed to water logging and salinization due to the poor management of agriculture, soil and water (FAO, 1992). According to Ministry of Water Resources and Irrigation, it referred that the quantity of salinity irrigation water used in Kafr El-Sheikh up to 2.5×10^9 m^3/year by 2017. Silicon (Si) is the second most abundant element in the soil, and it's not considered an essential element. The Si treatments were considered beneficial to plant growth and production. Recently, some studies have shown that treatment with silicon significantly alleviated salt, drought, chilling and freezing stress in plants (Liang et al. 2007; Ma and Yamaji 2008), plays a key role in a number of metabolic and physiological activities in plants **(**Bao et al. 2004). In addition, Hashemi et al. **(2010)** observed that silicon nutrition reduced the inhibitory effect of salinity on plant growth by reducing the Na^+ content, increasing CAT and cell wall peroxidase activities, and maintaining the membrane integrity of root cells, as demonstrated by reduced lipid peroxidation. In addition, nano-SiO_2 mediates the synthesis of protein, amino acids, nutrient uptake and stimulates antioxidant enzyme activity (Li et al. 2012). According to Epstein (2009), silicon plays an astonishingly large number of diverse roles in plants and does so primarily when the plants are under stressful conditions. Thus, we postulate that the application of nano-SiO_2 improves plant tolerance to salt stress.

Maize (*Zea mays* L.) ranks third in global cereal production and is used as food, feed, and fodder. The percent reduction of grain yield was 0, 10, 25, and 50% due to EC of irrigation water of 1.1, 1.7, 2.5, and 3.9 dS m^{-1}, respectively (Ayers 1977). Also, grain yield was reduced by 20% for each unit increase in electrical conductivity of the irrigation water and the soil solution above 1.7 and 4.6 dS m^{-1}, respectively (Flávio et al 2008). Also, faba bean (*Vicia faba* L.) is an important legume crop in Egypt and many parts of the world. concluded that grain yield reduction of faba bean (%) was 0, 10, 25, and 50% due to EC of irrigation water and were 0.7, 1.0, 1.5, and 2.4dsm^{-1}, respectively for faba bean (Ayers 1977)

It is reported that nano-silicon treatments can reduce the adverse effects of salinity on *V. faba* plants by enhancing the activity of antioxidant enzymes (Abdul Qados 2015). Under salinity stress, nano-SiO_2 might improve leaf fresh and dry weight, chlorophyll content and proline accumulation. It is also reported that, an increase in the accumulation of proline, free amino acids, content of nutrients, antioxidant enzymes activity due to the nano-SiO_2, thereby improving the tolerance of plants to abiotic stress (Kalteh et al. 2014; Siddiqui et al. 2014). Silicon nanoparticles (N-Si) have been implicated in crop improvements. Many reports indicate that appropriate concentrations of N-Si increase plant growth (Yuvakkumar et al. 2011), plant resistance to hydroponic conditions (Suriyaprabha et al. 2012), and alleviation of the adverse effects of salt stress, increased root length and dry weight of tomato plants, (Haghighi et al. 2012), length roots of the lentil and shoots (Sabaghnia and Janmohammadi 2014). The importance of Si for improving plant growth was also reported by Roohizadeh et al. (2015) for *V. faba*, and this is attributed to increase the water use efficiency in plant (Romero-Aranda et al. 2006) and improve the competence of photosynthesis (Liang et al. 2003). Parveen and Ashraf (2010) found that exogenously applied Si significantly enhanced plant water use efficiency and slightly increased photosynthetic rate under saline stress condition in maize. Function of Si and its concentration varies for plant species (Pilon-Smits et al. 2009).

Yet, no studies were found on the effect of nano silica application under different levels of salinity irrigation water on growth, anatomical structure and yield of maize and faba bean plants. So, this study was conducted to compare the effectiveness of applying nano-silica to reduce the negative effects of salinity irrigation water on growth, anatomical structure and crop-water productivity of maize and faba bean.

Materials and Methods

Experimental site and treatments

Two lysimeter experiments were conducted at Sakha Agric. Res. Station Farm, Kafr El-Sheikh Governorate, Egypt during two seasons (summer of 2017 and winter of 2017/2018), to study the effect of foliar application with different concentrations of nano-silica (nano-Si) and different levels of salinity of irrigation water on some soil properties and yield both of maize (*Zea mays,* cv. Giza 10) and faba bean (*Vicia faba*, cv. Sakha 3). The lysimeter experiment (82 cm diameter x 110 cm depth), were designed as split- plot with three replicates. The main plots were occupied by water irrigation as: T_1: fresh water (0.51 dS m^{-1}), T_2: well water (2.45 dS m^{-1}), T_3: blended fresh water with well water (1.84 dS

m^{-1} at ratio of 1:1), and T_4: blended fresh water with well water (1.36 dS m^{-1} at ratio of 2:1). For sub plot, different concentrations of nano-silica were devoted to: 0,100, 200 and 300 mg L^{-1} were evaluated as foliar application at 25 and 50 days from sowing. Used nano-silica was provided by National Research Center (NRC), and have characterized by specific surface area (300-330 m^2g^{-1}), pH (4.0-4.5), and mean diameter (10 nm). The meteorological data from Sakha Agric. Res. Station Farm during the two growing seasons are presented in Table 1.

Maize was sown on May 20th and harvested on September 10th, 2017 while faba bean was sown October 20th, 2017 and harvested on April 6th, 2018. All lysimeter units received 100 kg fed^{-1} mono-super phosphate (15.5% P_2O_5), 50 kg fed^{-1} potassium sulphate, (48% K_2O). For nitrogen fertilizer, the recommended N for maize (120 kg N fed^{-1}) and faba bean (40 kg N fed^{-1}) were added. Other agricultural practices were carried out as recommended by the Ministry of Agriculture and land reclamation.

Soil samples and analysis

Soil samples were taken at depths (0-20, 20-40 and 40-60 cm) in the initial and after harvesting of maize and faba bean plants. Exchangeable cations Ca^{++}, Mg^{++}, K^+ and Na^+, soluble cations and anions as well as soil pH, EC, exchangeable sodium, organic matter and total calcium carbonate were determined according to Page et al. (1982). Also, SO_4^{-2} was calculated from the difference between sum of the cations and the anions according to Jackson (1958). Soil bulk density was determined according to Campbell (1994). Field capacity and wilting point were determined by using the pressure plate extractor with regulated air pressure (Garcia 1978) as shown in Table 2. Also, chemical analysis of fresh water, well water and blended irrigation water salinity Table 3.

TABLE 1. Climatological data for the growing seasons in 2017/2018.

Month	Temp. (C°) Max.	Temp. (C°) Min.	R.H. (%)	W.V. (Km day^{-1})	P.E. (mm day^{-1})	Rain (Mm)
			2017			
May	30.6	25.8	61.65	106.5	659.1	0.0
Jun.	32.5	28.1	65.75	102.6	709.5	0.0
Jul.	34.2	29.0	71.0	80.9	644.2	0.0
Aug.	33.9	28.3	70.6	70.2	603.9	0.0
Sep.	33.3	25.9	68.30	48.95	560.15	0.0
Oct.	28.7	24.0	67.90	73.2	326.4	0.0
Nov.	23.7	19.7	74.85	53.5	256.1	0.0
Dec.	21.2	18.5	77.2	47.1	150.3	1.8
			2018			
Jan.	19.3	13.9	76.05	49.3	185.1	4.9
Feb.	21.6	14.6	75.5	34.7	277.5	16.6
Mar.	25.4	16.6	65.3	46.4	421.9	0.0

Temp.: Temperature; **R.H**.: Relative Humidity; **W.V**.: Wind Velocity (at 2 m height); **P.E**.: Pan Evaporation.

TABLE 2: Some physical and chemical characterization of the experimental soil.

Soil depth(cm)	F.C (%)	W.P. (%)	A.W. (%)	B.D. (kg m^{-3})	Sand	Salt	Clay	Soil texture
	Physical characterization							
	Soil moisture characteristics				**Particle size distribution (%)**			
0-20	43.5	21.2	22.3	1.28	17.0	32.5	50.5	clay
20-40	44.2	21.9	22.3	1.29	16.7	31.9	51.4	clay
40-60	42.5	21.3	21.2	1.31	17.9	32.8	51.3	clay

Chemical characterization

Soil depth(cm)	pH	EC (dS m^{-1})	ESP (%)	CEC (cmole kg^{-1})	OM (g kg^{-1})	$CaCO_3$ (%)
0-20	7.95	3.10	11.70	41.2	11.54	1.91
20-40	7.98	3.45	12.47	40.6	10.78	1.88
40-60	8.01	3.81	13.00	40.1	10.59	1.81
mean	-	3.45	12.39	40.63	10.97	1.86

F.C.: Field Capacity**; W.P.:** Welting Point; **A.W.**: Available Water; **B.D.**: Bulk Density; **PH**: was determined in soil water suspension (1:2.5); **EC**: was determined in saturated soil paste extract; **ESP:** Exchangeable Sodium Percent; **CEC:** Cation Exchange Capacity; **OM**: Organic Matter.

TABLE 3: Chemical analysis of different irrigation water treatments.

Treatment	pH	EC dS m^{-1}	SAR	Cations (meq L^{-1})				Anions (meq L^{-1})			
				Na^+	K^+	Ca^{++}	Mg^{++}	$CO_3^=$	HCO_3^-	Cl^-	$SO_4^=$
F.W	7.35	0.51	3.50	3.50	0.6	1.1	0.8	-	1.5	2.4	2.1
W.W	7.91	2.45	7.70	16.70	0.8	5.4	3.9	-	3.5	11.7	11.6
F.W+W.W (1:1)	7.81	1.85	6.70	12.60	0.8	4.1	3.0	-	3.1	8.8	8.6
F.W+W.W (2:1)	7.46	1.36	5.80	9.20	0.6	3.0	2.2	-	2.5	6.5	6.0

F.W: Fresh Water; **W.W**: Well Water.

Plant sampling and analysis

Anatomical structure

Root samples of maize and faba bean were taken after 30 and 35 days from sowing to study the anatomical structure, respectively. The sections were computerized morphometrical analysis, the morphmetrical analysis was done by Research Microscope type Axiostar plus made by Zeiss transmitted light bright field examinations upgradable to professional digital image analysis system (Carl Zeiss Axiovision Product Suite DVD 30). Two samples of root per plot were collected. Each sample measured 0.5 cm of the tip portion of the primary root. All samples were killed and fixed for 48 h in FAA (10 ml formalin; 5 ml glacial acetic acid; 50 ml ethyl alcohol and 35 ml water). The dehydrated samples were infiltrated and embedded in paraffin (52-54°C m.p.). The embedded samples were sectioned on a rotary microtome at a thickness of 5-7 µm. Sections were mounted on slides and deparaffinized. Staining was accomplished with safranine and light green, cleared in xylem and mounted in Canada balsam (Geriach, 1977). Slides were microscopically examined and measurements and counts were taken and averages of 9 readings of 3 slides were calculated.

Yield and nitrogen uptake

At physiological maturity growth stage, plants were taken to determine grain yield (Mg fed^{-1}), stalk yield (Mg fed^{-1}) and N-uptake in both maize and faba bean. Nitrogen concentration was determined according to Page et al. (1982), but nitrogen use efficiency was calculated according to (Barbar, 1976), as follows: N use efficiency (NUE) = [(Grain yield from N-fertilizer – grain yield from control) / added N-fertilizer] = kg grains / kg N.

Water requirements

a) The total irrigation water for maize plants was 2800 m^{3}fed.$^{-1}$ which equalizes 7 irrigation times and resulted from field irrigation water 2800 m^3 season^{-1}, and amount of rainfall 0.0 m^3 season^{-1}.

b) The total irrigation water for faba bean plants was 1703.5 m^{3}fed^{-1}, which equalizes 4 irrigation times and resulted from field irrigation water 1635 m^3 season^{-1} and amount of rainfall 68.5 m^3 season^{-1}.

TABLE 4: Reference evapotranspiration (ET_0) and maximum evapotranspiration (ET_m) for maize and faba bean crops during growing season (2017/2018).

Crop	Month	Period day^{-1}	P.E. cm day^{-1}	P.E. cm period^{-1}	ET_0	Kc	(ETm) cm	(ETm) m^3
Maize	**May**	10	0.659	6.59	4.94	0.5	2.47	103.74
	Jun.	30	0.710	21.30	15.98	0.9	14.38	603.96
	Jul.	31	0.644	19.96	14.97	1.2	17.97	754.74
	Aug.	31	0.604	18.724	14.04	1.15	16.15	682.5
	Sep.	10	0.660	6.60	2.1	1.10	2.31	97.02
Total season							53.28	2241.96
Faba bean	**Oct.**	11	0.326	3.26	2.45	0.40	0.98	41.16
	Nov.	30	0.256	7.68	5.76	0.8	4.608	193.54
	Dec.	31	0.150	4.65	3.49	0.8	2.79	117.26
	Jan.	30	0.185	5.55	4.16	1.2	4.992	209.664
	Feb.	28	0.278	8.06	6.05	0.75	4.5375	190.575
	Mar.	30	0.422	12.66	9.50	0.75	7.125	299.25
	Apr.	6	0.541	3.24	1.62	0.3	1.62	68.04
Total season							26.65	1119.49

P.E.: Pan Evaporation; ET_0: Potential evapotranspiration; Kc: Crop coefficient; ETm: Maximum evapotranspiration. Pan coefficient (K pan) = 0.75; Effective rain fall = incident rain fall x 0.7 (Novica, 1979).

The reference evapotranspiration (ET_o) and maximum evapotranspiration (ET_m) for maize and faba bean are shown in Table 4. Water productivity (WP) is generally defined as crop yield per cubic meter of water consumption. According to Ali et al. (2007), it was calculated as follows:

1- WP = GY/ET
Where: WP= Water productivity (kg grains/m^3),
GY= Grain yield (kg $fed.^{-1}$), and
ET= Total water consumption of the growing season (m^3 $fed.^{-1}$).

2- PIW = Gy/I
Where: PIW= Productivity of irrigation water (kg grains/m^3),
Gy = Grain yield (kg $fed.^{-1}$), and
I = Irrigation water applied m^3 $fed.^{-1}$

Statistical analysis

The data were analyzed statistically by analysis of variance (ANOVA) using Cohort Computer Program according to Gomez and Gomez (1984). Differences among means within the samples were tested using Duncan's - test at the 5% probability level.

Results and Discussion

Soil properties

Soil salinity

Electrical conductivity of different soil depth (0-20, 20-40 and 40-60 cm) for the experimental soil as influenced by different salinity of irrigation water and foliar application with different concentrations of nano-silica after harvesting of maize and faba bean plants are illustrated in Tables 5. Generally, salinity of soil was increased with increasing of different soil depth. Also, there are no variations between soil salinity and foliar application with different concentrations with nano-silica during the two growing seasons. On contrast, there is a remarkable variation in mean of soil salinity between irrigation with fresh water and blended with well water treatments, which T_4 (blended fresh water with well water 1.36 dS m^{-1} at ratio of 2:1), recorded 4.32 and 4.47 dS m^{-1}, followed by T_3 (blended fresh water with well water 1.84 dS m^{-1} at ratio of 1:1), recorded 3.74 and 3.89 dS m^{-1}, compared with T_2 (well water 2.45 dS m^{-1}), recorded 5.07 and 5.28 dS m^{-1}, at 0-20 cm depth for maize and faba bean plants, respectively. A similar trend was also exhibited in the other soil depth. From our results, it can be noticed that increasing of values of soil salinity may be due to soluble cations and anions in well water and upon reuse of saline water in irrigating of soils in the terminal end resulted in a remarkable increase in soil salinity and sodicity as compared to soil irrigated with fresh water**.** These results are supported by (Amer et al. 2015).

TABLE 5: Impact of foliar application with different concentrations with nano-silica and different salinity of irrigation water on soil salinity (dS m^{-1}) after harvesting of maize and faba bean during growing seasons 2017/2018.

Treatments		Maize				Faba bean			
		Soil depth (cm)							
SW	N-Si	0-20	20-40	40-60	Mean	0-20	20-40	40-60	Mean
T1	0	3.15	3.55	3.91	3.54	3.21	3.61	3.98	3.60
	100	3.15	3.55	3.91	3.54	3.21	3.61	3.98	3.60
	200	3.15	3.56	3.93	3.55	3.21	3.62	3.97	3.60
	300	3.14	3.55	3.95	3.55	3.22	3.62	3.98	3.61
	Mean	3.15	3.55	3.93	3.54	3.21	3.62	3.98	3.60
T2	0	5.03	5.31	6.11	5.48	5.24	5.65	6.35	5.75
	100	5.03	5.31	6.11	5.48	5.24	5.65	6.35	5.75
	200	5.09	5.35	6.12	5.52	5.29	6.25	6.36	5.97
	300	5.10	5.36	6.13	5.53	5.31	6.31	6.37	6.00
	Mean	5.07	5.34	6.12	5.51	5.28	6.07	6.36	5.90
T3	0	4.31	4.55	5.31	4.72	4.45	4.84	5.91	5.07
	100	4.31	4.55	5.31	4.72	4.45	4.84	5.91	5.07
	200	4.35	4.56	5.36	4.76	4.48	4.85	6.10	5.14
	300	4.29	4.60	5.35	4.75	4.47	4.87	6.01	5.12
	Mean	4.32	4.57	5.34	4.74	4.47	4.85	6.01	5.11
T4	0	3.74	3.91	5.07	4.24	3.87	4.10	5.12	4.36
	100	3.74	3.91	5.07	4.24	3.87	4.10	5.12	4.36
	200	3.75	3.92	5.05	4.24	3.89	4.11	5.12	4.37
	300	3.74	3.92	5.06	4.24	3.9	4.12	5.13	4.38
	Mean	3.74	3.92	5.06	4.24	3.89	4.11	5.12	4.37

$\mathbf{T_1}$: fresh water (0.51 dS m^{-1}), $\mathbf{T_2}$: well water (2.45 dS m^{-1}), $\mathbf{T_3}$: blended fresh water with well water (1.85 dS m^{-1} at ratio of 1:1), and $\mathbf{T_4}$: blended fresh water with well water (1.36 dS m^{-1} at ratio of 2:1).

Exchangeable sodium percentage (ESP)

In lysimeter experiment, a noteworthy increase in exchangeable sodium percentage (ESP), was observed in irrigation with fresh water and blended with well water treatments with their corresponding control (fresh water only), after harvesting of maize and faba bean plants (Fig. 1). Data showed that the mean values of ESP after harvesting of maize was 12.55, 14.97, 14.72 and 13.85 % with different irrigation water treatments T_1 (0.51 dS m^{-1}), T_2 (2.45 dS m^{-1}), T_3 (1.84 dS m^{-1}), and T_4 (1.36 dS m^{-1}), respectively, at 0-20 cm depth. Also, for foliar application with different concentrations of nano-silica, ESP of the different soil depth unaffected under the same plant. However, under faba bean plants, soil samples were recorded the highest values of ESP for different soil depth (0-20, 20-40 and 40-60 cm) as compared to maize plants. These results may be due to sole application of saline water increased salt contents in soil and caused accumulation of toxic ions (Na+ and Cl^-) in soil. These results supported by Gandahi (2010) and Amer et al. (2015).

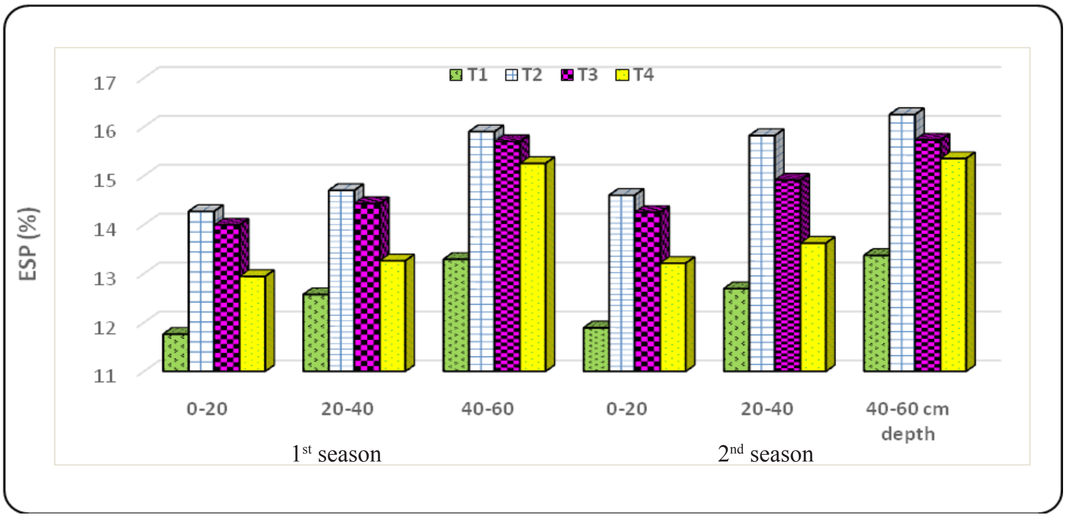

Fig. 1: Impact of foliar application with different concentrations of nano-silica and different levels of irrigation water salinity on exchangeable sodium percent(ESP) after harvesting during growing seasons (2017/2018)

Anatomical structure of maize and faba bean

Cross sections of maize and faba bean roots at 30 and 35 days after sowing of maize and faba bean plants, respectively are illustrated in Table 6 and Fig. 2, 3. Generally, blended fresh water with well water treatment (T_4) and foliar application with nano-silica 300 mg L^{-1} showed an increase in root diameter by 22.75% and 15.54% more than the control treatment (T_1). The increase in diameter of root was mainly due to the noticeable increment in root thickness of cortex (mm), diameter vascular cylinder (V.C.), no. of V.B/V.C and diameter of big xylem vessels. On the other hand, all of the anatomical characters of roots were decreased by increasing of the salinity irrigation water and recorded lowest values up to T_2 (2.45 dS m^{-1}) and without N-Si.

Under adverse climatic conditions, foliar application with nano-silica can stimulate the vegetative growth of plant as well as increase stem diameter, number of lateral shoots, root length, chlorophyll content (Sivanesan et al. 2010; Marafon and Endres, 2013). Also, foliar spray with potassium silicate (50 or 100 mg L^{-1}) helped the plants to overcome the adverse effect of salt and improvement of vegetative growth (Soundararajan et al. 2013). These observations were noticed by previous studies such as sunflowers (Kamenidou et al. 2008); cucumber (Huang et al. 2009); maize (Suriyaprabha 2012) and Salvia (Soundararajan et al., 2013). These results may be due to the role of nano silicon in anatomical structure in roots of maize and faba bean plants. These results were supported by (Chanchal et al. 2016).

Total chlorophyll

Table 7 depicted the results of total chlorophyll in leaves of maize and faba bean plants. Highly significant variations in total chlorophyll content were observed under both of foliar application with different concentrations with nano-silica and different salinity of irrigation water treatments. For irrigation water treatments, T_3 (irrigation

TABLE 6: Anatomical characteristics in roots of maize and faba bean plants as affected by foliar application with different concentrations with nano-silica and different salinity of irrigation water during growing seasons 2017/2018.

Characters	T1			T4		
	Cont.	N-Si 300	R.C. (±%)***	Cont.	N-Si 300	R.C. (±%)***
Maize						
Ø of root*	524.25	643.50	22.75	443.94	512.92	15.54
Ø of V.C**	374.16	403.89	7.95	300.77	319.80	6.33
Thickness of cortex (mm)	139.24	170.95	22.77	174.39	184.89	6.02
Ø of big X.V(mm)	31.90	33.29	4.36	24.96	31.89	27.76
Length of V. B (mm)	85.62	92.68	8.25	72.29	89.97	18.44
No. of V.B/v.c	70.00	76.0	8.57	33.00	44.00	33.33
Faba bean						
Ø of root (mm)*	330.93	343.94	3.93	299.25	317.13	5.97
Thickness of cortex (mm)	157.08	161.64	2.90	126.41	128.55	1.69
Ø of V.C**	175.91	179.14	1.84	170.11	175.14	2.96
Length of xylem arch/V.B (mm)	104.31	123.18	18.09	87.83	106.83	21.63
No. of V.B/V.C	10.00	11.00	10.00	8.00	8.33	4.13
Ø of big vesl/arch (mm)	7.00	13.66	95.14	6.00	9.33	55.50

Ø of root*=1/2 diameter of root (mm) Ø of V.C**= 1/2 diameter vascular cylinder in root (mm) R.C. (±%)*** = Relative of change (±%) T_1: fresh water (0.51 dS m^{-1}), and T_4: blended fresh water with well water (1.36 dS m^{-1} at ratio of 2:1).

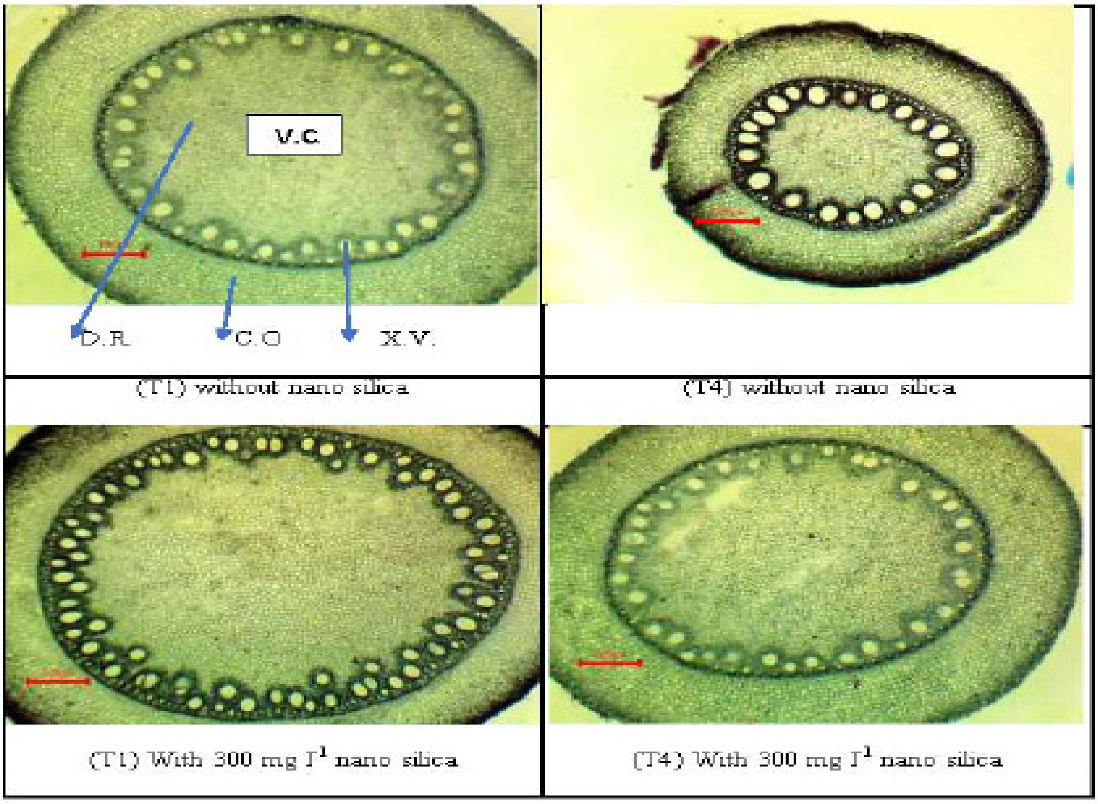

Fig. 2: Transfer section of maize root at 30days from sowing as affected by foliar application with different concentrations of nano-silica and different levels of irrigation water salinity during growing seasons 2017. Where abbreviations: T1: fresh water (0.51 dS m^{-1}) and T4: blended fresh water with well water (1.36 dS m^{-1} at ratio of 2:1); DR: Diameter of root (mm), VB: vascular bundles,X.V.: Big xylem vessels per vascular bundle; CO= Cortex tissue and VC = vascular cylinder, (X 32) Bar= 100µm.

water at ratio of 1:1), recorded the highest values in total chlorophyll content compared to the other blended treatment in both of maize and faba bean plants. Inversely, total chlorophyll content was increased with increasing of foliar application with nano-silica concentration, which the increasing percentage between the least concentration (N-Si 100 mg L^{-1}) and the highest concentration (N-Si 300 mg L^{-1}), increased to 58.30 and 26.17%, 100 and 34.10%, 94.56 and 10.14% and 99.12 and 7.94%, for T_1, T_2, T_3 and T_4 treatments for maize and faba bean plants, respectively.

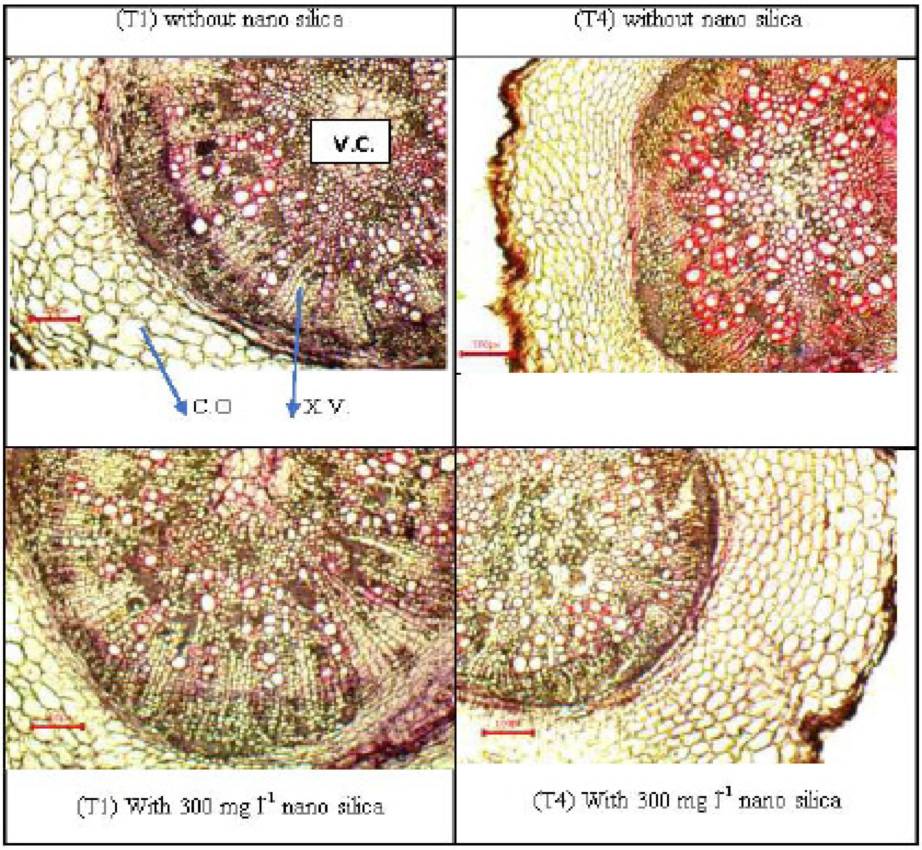

Fig. 3: Transfer section of faba bean root at 35 days from sowing as affected by foliar application with different concentrations of nano-silica and different levels of irrigation water salinity during growing seasons 2017. Where abbreviations: T1: fresh water (0.51 dS m^{-1}) and T4: blended fresh water with well water (1.36 dS m^{-1} at ratio of 2:1), VB.: Vascular bundles, X. V.: Big xylem vessels per vascular bundle, CO= Cortex tissue and VC = Vascular cylinder, (X 40) Bar= 100µm.

TABLE 7: Impact of foliar application with different concentrations with nano-silica and different salinity of irrigation water on chlorophyll leaf content of maize and faba bean during growing season 2017/2018

Treatments	Maize					Faba bean				
	Cont.	N-Si 100	N-Si 200	N-Si 300	F. test	Cont.	N-Si 100	N-Si 200	N-Si 300	F. test
T_1	28.1 i	33.1 g	44.6 d	52.4 a	**	36.1 e	40.5 c	41.8 b	51.1 a	**
T_2	19.7 m	21.1 k	33.4 g	42.2 e	**	18.5 p	21.4 o	22.6 n	28.7 l	**
T_3	20.2 l	22.8 j	40.5 f	45.4 c	**	27.8 m	30.2 k	31.5 j	32.6 i	**
T_4	21.2 k	23.9 h	44.5 d	46.5 b	**	31.2 j	34.5 f	36.4 e	38.0 d	**
F. test	**	**	**	**		**	**	**	**	

T_1: fresh water (0.51 dS m^{-1}), **T_2**: well water (2.45 dS m^{-1}), **T_3**: blended fresh water with well water (1.84 dS m^{-1} at ratio of 1:1), and **T_4**: blended fresh water with well water (1.36 dS m^{-1} at ratio of 2:1).

Yield of Maize and faba bean

Grain and straw yield (Mg fed^{-1}) of maize and faba bean plants as affected by different types of irrigation water (0.51, 2.45, 1.85 and 1.36 dS m^{-1}), and foliar application with different concentrations of nano-silica (0,100, 200 and 300 mg L^{-1}) are illustrated in Table 8. Treatment T_2 showed a significant reduction in grain yield (39.28 and 80.13%), and in straw yield (38.84 and 78.06%) for maize and faba bean plants, respectively, in comparison with the control treatment, T_1. On the other hand, T_4 (1.36 dS m^{-1}), recorded the highest values 4.22 and 5.32 Mg fed^{-1} in grain and straw yield of maize plants and 1.74 and 1.84 Mg fed^{-1} in grain and straw yield of faba bean plants, respectively, under foliar application with 300 mg L^{-1} of nano-silica as compared to the other concentrations. The reduction in yield of due to increasing of the salinity hazard (Amer et al. 2015) These results may be due to silicon reduces the adverse impact of abiotic stresses by the improved photosynthetic activity, enhanced K/Na selectivity ratio, increased enzyme activity and increased concentration of soluble substances in xylem, resulting in limited sodium absorption by plants (Chanchal et al. 2016). Silicon may alleviate salt stress by inhibition of transport of Na^+ to the leaves and specific accumulation of Na^+ in the roots (Tuna et al. 2008) and (Saqib et al. 2008).

Nitrogen uptake

It showed that nitrogen uptake by grain and straw yields of maize and faba bean were decreased with increasing the salinity of irrigation water (Table 9). On the other hand, positive effects were observed by application with different concentrations with nano-silica for maize and faba bean plants. Measurements of total N uptake yield (grain and straw) of maize and faba bean plants were can be arranged for the treatments irrigation water as follows: T_1 (0.51 ds m^{-1}), > T_3 (1.85 dS m^{-1}), > T_4 (1.36 dS m^{-1}), > T_2 (2.45 dS m^{-1}). These results were supported by (Yuvakkumar et al., 2011) and (Amer et al. 2015). Foliar application with 300 mg L^{-1} nano-silica attained the highest values of total N uptake (kgFed.$^{-1}$), 100.93, 86.04, 93.71 and 100.49 for maize plants and 57.19, 24.26, 49.54 and 60.36 for faba bean plants for T_1, T_2, T_3 and T_4 compared to the other nano-silica concentrations, respectively. This can be attributed to the nano size of silica which allows it to penetrate the leaf tissue causing changes in the physicochemical reactions in the cell and activate the growth hence reduce adverse effect of irrigation by saline water. These results may be due to nano-SiO_2 mediates the synthesis of protein, amino acids, nutrient uptake and stimulates antioxidant enzyme activity (Li et al. 2012). These results were supported by (Epstein, 2009)

TABLE 8: Impact of foliar application with different concentrations with nano-silica and different salinity of irrigation water on grain and straw yield (Mg fed^{-1}) of maize and faba bean during growing seasons 2017/2018

Treatment	Grain (Mg fed^{-1})					Straw (Mg fed^{-1})				
	Maize									
	Cont.	N-Si 100	N-Si 200	N-Si 300	F. test	Cont.	N-Si 100	N-Si 200	N-Si 300	F. test
T_1	2.75 j	3.12 g	3.86 d	4.29 a	**	2.91 k	4.15 g	4.65 d	5.36 a	**
T_2	1.67 n	2.61 k	3.14 g	3.70 e	**	1.78 n	3.45 j	4.16 g	4.37 f	**
T_3	2.42 m	2.84 i	3.68 f	3.95 c	**	2.58 m	3.87 i	4.56 e	4.98 c	**
T_4	2.56 l	3.00 h	3.86 d	4.22 b	**	2.65 l	4.01 h	4.64 d	5.32 b	**
F. test	**	**	**	**		**	**	**	**	
	Faba bean									
T_1	1.51 i	1.84 c	1.98 b	2.15 a	**	1.55 f	1.98 c	2.05 b	2.10 a	**
T_2	0.30 s	0.41 r	0.59 q	0.71 p	**	0.34 q	0.52 p	0.61 o	0.78 n	**
T_3	0.84 o	1.15 n	1.29 m	1.44 k	**	0.85 m	1.19 l	1.34 k	1.54 i	**
T_4	1.32 l	1.55 j	1.61 e	1.74 d	**	1.41 j	1.58 f	1.71 e	1.84 d	**
F. test	**	**	**	**		**	**	**	**	

T_1: fresh water (0.51 dS m^{-1}), **T_2**: well water (2.45 dS m^{-1}), **T_3**: blended fresh water with well water (1.84 dS m^{-1} at ratio of 1:1), and **T_4**: blended fresh water with well water (1.36 dS m^{-1} at ratio of 2:1).

TABLE 9: Impact of foliar application with different concentrations with nano-silica and different salinity of irrigation water on nitrogen uptake of grain and straw yield (kg fed^{-1}) of maize and faba bean during growing seasons 2017/2018.

Treatments		Maize			Faba bean		
SW	**N-Si**	**N-Grain**	**N-Straw**	**Total N uptake**	**N-Grain**	**N-Straw**	**Total N uptake**
T_1	**0**	49.5	21.18	70.68	49.53	3.72	53.25
	100	50.54	21.91	72.46	54.2	5.29	59.49
	200	63.57	27.83	91.40	62.96	6.17	69.13
	300	70.27	30.66	100.93	68.5	6.68	75.19
T_2	**0**	30.15	14.24	44.39	10.00	0.828	10.828
	100	42.28	18.52	60.80	11.97	1.07	13.04
	200	51.43	25.26	76.69	18.30	1.59	19.89
	300	60.27	25.77	86.04	22.18	2.08	24.26
T_3	**0**	43.56	20.64	64.2	27.72	2.04	29.76
	100	47.63	20.77	68.40	33.57	2.66	36.23
	200	60.61	27.69	88.30	40.34	3.57	43.91
	300	64.35	29.36	93.71	45.3	4.22	49.54
T_4	**0**	46.08	21.2	67.28	43.3	3.38	46.68
	100	50.22	21.53	71.75	45.52	3.8	49.33
	200	63.57	28.17	91.75	51.73	4.71	56.43
	300	69.12	31.37	100.49	55.13	5.22	60.36

T_1: fresh water (0.51 dS m^{-1}), **T_2**: well water (2.45 dS m^{-1}), **T_3**: blended fresh water with well water (1.85 dS m^{-1} at ratio of 1:1), and **T_4**: blended fresh water with well water (1.36 dS m^{-1} at ratio of 2:1).

Nitrogen use efficiency

The nitrogen use efficiency of maize and faba bean plants under different levels of salinity of irrigation water and different concentrations of nano-silica are shown in Fig. 4 and 5. Under irrigation with fresh water (0.51 dS m^{-1}) and foliar application with nano-silica (300 mg L^{-1}) treatment, the highest values of nitrogen use efficiency were 35.8 and 53.8 kg grain kg^{-1} N, whereas the lowest values were 14.0 and 7.6 kg grain kg^{-1} N, which attained by irrigation with saline water (2.45 dS m^{-1}) of maize and faba bean plants, respectively. These results are supported by (Li et al. 2012).

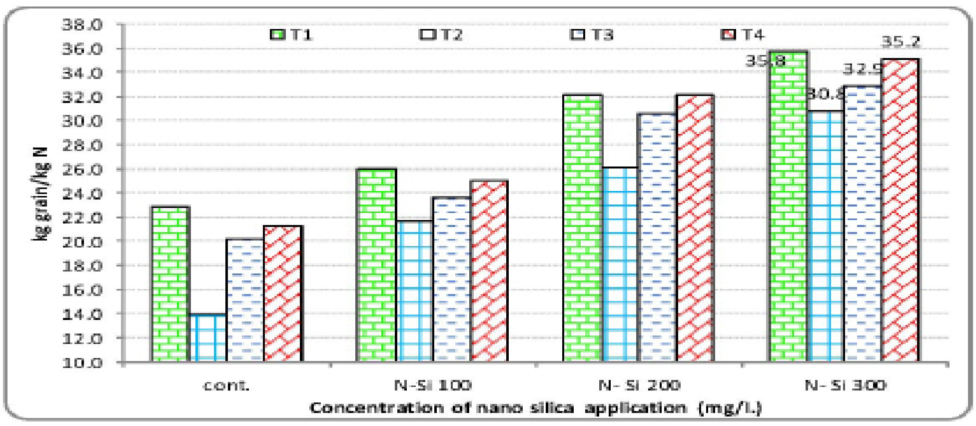

Fig. 4: Nitrogen use efficiency by grain yield of maize as affected by different levels of irrigation water salinity and different foliar application with nano-silica.

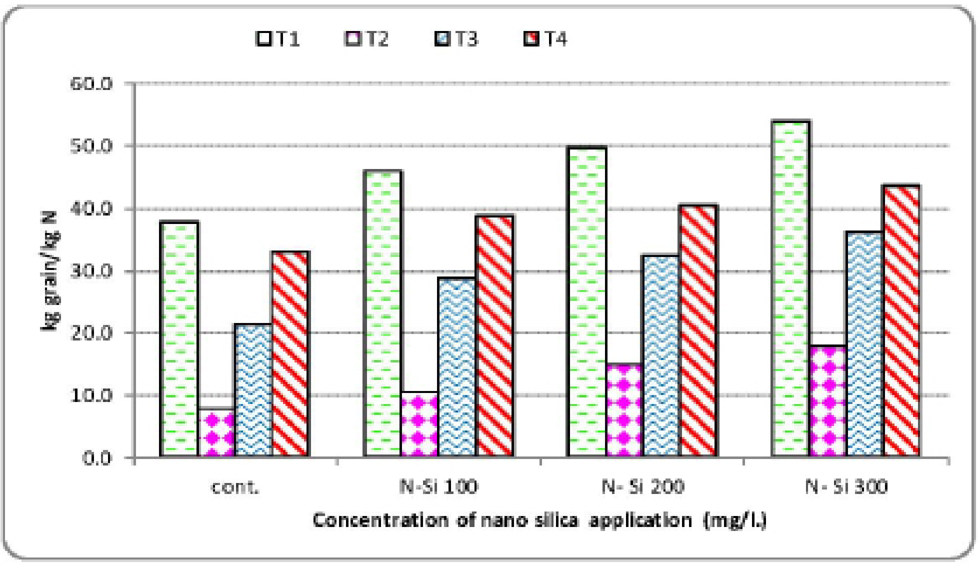

Fig. 5: Nitrogen use efficiency by grain yield of faba bean as affected by different levels of irrigation water salinity and different foliar application with nano-silica.

Water productivity and productivity of irrigation water

Data in Table 10 showed that WP of maize was decreased (0.75 kg grain m^3) due to increasing salinity of irrigation water up to (2.45 dS m^{-1}) and without foliar application of nano-silica during summer season 2017. Also, the same data illustrated that WP of maize was positive increased (1.91 kg grain m^3) by increasing of nano-silica foliar application up to (300 mg L^{-1}) by fresh water irrigation. Similar trend was also exhibited in faba bean plants. Productivity of irrigation water of maize, results showed that the lowest value (0.60 kg grain m^3) by irrigation of salinity water (2.45 dS m^{-1}) and without foliar application of nano-silica sized during summer season 2017. Also, the same data revealed that PIW of maize was positive increased up to (1.53 kg grain m^3) by increasing of nano-silica application up to (300 mg L^{-1}) by fresh water irrigation. The same results were observed in faba bean plants.

TABLE 10: Water productivity (WP) and productivity of irrigation water (PIW) of maize and faba bean (kg grains/m^3) as affected by foliar application with nano-silica and different levels salinity of irrigation water during growing seasons 2017/ 2018.

Treatments	WP				WIP			
	Cont.	N-Si 100	N-Si 200	N-Si 300	Cont.	N-Si 100	N-Si 200	N-Si 300
Maize								
T1	1.23	1.39	1.72	1.91	0.98	1.11	1.38	1.53
T2	0.75	1.16	1.40	1.65	0.60	0.93	1.12	1.32
T3	1.08	1.27	1.64	1.76	0.86	1.01	1.31	1.41
T4	1.14	1.34	1.72	1.88	0.91	1.07	1.38	1.51
Faba bean								
T1	1.35	1.64	1.77	1.92	0.89	1.08	1.17	1.26
T2	0.27	0.37	0.53	0.63	0.18	0.24	0.35	0.42
T3	0.75	1.03	1.16	1.29	0.50	0.67	0.76	0.85
T4	1.18	1.38	1.44	1.56	0.77	0.91	0.94	1.02

T_1: fresh water (0.51 dS m^{-1}), T_2: well water (2.45 dS m^{-1}), T_3: blended fresh water with well water (1.85 dS m^{-1} at ratio of 1:1), and T_4: blended fresh water with well water (1.36 dS m^{-1} at ratio of 2:1).

Generally, Water productivity WP is defined as crop yield per cubic meter of water consumption. Concept of water productivity in agricultural production systems is focused on producing more food with the same water resources or producing the same amount of food with less water resources. These increases in WP and PIW maybe due to the positive effects with nano-silica application on increasing of grain yield of maize and faba bean and reduce adverse effects of salinity of irrigation water on growth and yield of maize and faba bean. These results are supported by Romero-Aranda et al. (2006) and Roohizadeh et al. (2015). And may be due to the role of silicon in the water conservation in the plants has been observed (Meyer and Keeping, 2000).

Conclusion

In agriculture system, nanoparticles have been proved its vital role. In this present work, nano-silica proved its significant importance for anatomical characteristics, grain and straw of maize and faba bean. All measured yield parameters such as grain and straw were positively affected by nano-silica having higher values compared to without application of nano-silica under irrigation by different level of salinity of water. Among four elevated nano-silica doses (i.e., 0, 100, 200, and 300 mg L^{-1}), treatment of 300 mg L^{-1} nano-silica had the highest values of anatomical characteristics and yield. Based on these results, it could be concluded that 300 mg L^{-1} of nano-silica suspension is the ideal concentration that maize and faba bean plants should be treated under irrigation by saline water.

References

Abdul Qados A. M. (2015) Mechanism of Nano silicon-Mediated Alleviation of Salinity Stress in Faba Bean (*Vicia faba L.*) Plants. *American Journal of Experimental Agric.,* **7**(2), 78-95.

Ali M.H., Hoque M.R., Hassann A.A. and Khair A. (2007) Effect of deficit irrigation on yield water productivity and economic returns of wheat. *Agric. Water Management.;* **92**(3),151-161.

Amer, M. M.; M. A. Aiad and S.H. Rashed. (2015) Effect of Algae and Compost Extracts on Some Soil Proprieties and Its Productivity Under Low Quality Irrigation Water in North Nile Delta Region, *J. Soil Sci. and Agric. Eng., Mansoura Univ.,* **6** (11), 1365 - 1380

Ayres, R.S. and D.W. Westcot. (1977) Water Quality for Agriculture. Irrigation and Drainage Paper No. 29. *Food and Agric.* Organization of the United Nations. Rome.

Bao-Shan L, Shao-qi D, Chun-hui L, Li-jun F., Shu-chun Q. and Min Y. (2004) Effect of TMS (nanostructured silicon dioxide) on growth of Changbai larch seedlings. *J. Forest Res.***15,**138–140

Barbar, S. A. (1976) Efficient fertilizer use In: Patterson. F. L. Ed. *Agronomic Res. for Food.* American Society of Agronomy Special Publication, 26, Madison, USA pp.13-29

Campbell, D.J. (1994) Determination and use of bulk density in relation to soil compaction. In Soane and Ouwerk (Eds). *Soil Compaction in Crop Production.* Elsevere, London, Amsterdam.

Chanchal M. C.H., RitiThapar Kapoor and G. Deepak (2016). Alleviation of abiotic and biotic stresses in plants by silicon supplementation. *Sci. Agri.***13** (2), 59-73

El-Shahawy, M. I. and M.M, Ragab (2005) Demonstration of Sustainable Safe Reuse of Drainage Water in Agric. at North Delta, Agric. Res. Center, Regional Council for Agric. Res. and Extension, *Annual Report*

Epstein E. (2009) Silicon Its manifold roles in plants. *Ann. Appl. Biol* **155,** 155–160.

FAO. (1992) The use of saline waters for crop production *Irrigation and Drainage* Paper 48 Chapter 3 - Examples of use of saline waters for irrigation

Flávio F. B.; V. F. Marcos; R. G. Hans and D. F. Pedro (2008) Growth and yield of corn irrigated with saline water. *Sci. Agric. (Piracicaba, Braz.),* **65**(6) 574-580.

Gandahi, A. W. (2010) Integrated Saline Water Management in maize (*Zea mays* L.) fodder Production. *Ph.D. Thesis,* Sindh Agric.Univ., Tando Jam.

Garcia, I. (1978) *Soil Water Engineering Laboratory Manual.* Department of Agric. and Chemical Engineering. Colorado State univ., Fortacollin Colorado, USA.

Geriach, D. (1977) Botanshe micotechnik. Eine einfuhrung theime veriag, Stuttgart. BRO

Glick B.R. (2012) Plant growth-promoting bacteria: mechanisms and applications. Scientifica :1–15

Gomez, K.A. and A.A, Gomez (1984) *Statistical Procedures for Agric. Res.*, 2nd edition. John Wiley and Sons, New York, 680.

Haghighi M, Afifipour Z, M., Mozafarian (2012). The effect of N-Si on tomato seed germination under salinity levels. *J Biol Environ Sci*. **6**(16),87–90

Hashemi A, Abdolzadeh A and Sadeghipour H.R. (2010). Beneficial effects of silicon nutrition in alleviating salinity stress in hydroponically grown canola, Brassica napus L., plants. *Soil Sci Plant Nutr* **56,** 244–253.

Huang S, Li R, Zhang Z, Li L and X. Gu (2009). The genome of the cucumber, *Cucumissativus L. Nature Genet.* **41,** 1275-1281

Jackson, M.L. (1958) *Soil Chemical Analysis.* Constable. Co. Ltd.London

Kalteh M., Alipour Z.T., Ashraf S., Aliabadi M.M. and A.F. Nosratabadi (2014) Effect of silica nanoparticles on basil (*Ocimumbasilicum*) under salinity stress. *J. Chem Health Risks* **4,** 49–55

Kamenidou S, Cavins T.J., S.M. Marek (2008) Silicon supplements affect horticultural traits of greenhouse-produced ornamental sunflowers. *Hort Science.* **43,** 236-239.

Li B., Tao G., Xie Y. and X. Cai (2012) Physiological effects under the condition of spraying nano SiO2 on to the Indocalamus barbatus McClure leaves. *J Nanjing For Univ (Natural Science Edition)* **36,**161–164

Liang Y., Sun W., Zhu Y.G., P. Christie (2007). Mechanisms of silicon mediated alleviation of abiotic stresses in higher plants: a review. *Environ Poll.***147,**422–428.

Liang Y.C., Chen Q.I.N., Liu Q., Zhang W. and R. Ding (2003) Exogenous silicon (Si) increases antioxidant enzyme activity and reduces lipid peroxidation in roots of salt-stressed barley (*Hordeum vulgare* L.). *J. Plant Physiol* **160,**1157–1164

Ma, J.F., and N. Yamaji (2008) Functions and transport of silicon in plants. *Cell Mol. Life Sci.* **65,** 3049-3057.

Marafon A.C. and L. Endres (2013) Silicon: fertilization and nutrition in higher plants. *Amaz.J. Agric. Environ. Sci.* **56,** 380–388

Meyer, J.H. and M.G. Keeping (2000) Review of Research Into the Role Of Silicon For Sugarcane Production, *Proc S Afr Sug Technol Ass* (2000) 74

Novica, V. (1979) *Irrigation of Agric.crops* Fac.Agric. press, Novi sad, Yogoslavia

Page A.L.R., Miller, H. and D.R., Keeney (1982) *Methods of soil analysis. Part 2: Chemical and Microbiological Properties*. 2nd Edition. Agronomy Monograph, No. 9, ASA, CSSA, CSSA and SSSA, Madiso.

Parveen N. and M., Ashraf (2010) Role of silicon in mitigating the adverse effects of salt stress on growth and photosynthetic attributes of two maize (Zea Mays L.) cultivars grown hydroponically. *Pak J. Bot.* **42**(3),1675–1684.

Pilon-Smits E. A.H., Quinn CF., Tapken W., Malagoli M. and M. Schiavon (2009). Physiological functions of beneficial elements. *Current Opinion in Plant Biology.* **12,** 267-274.

Romero-Aranda M.R., Jurado O. and J. Cuartero (2006) Silicon alleviates the deleterious salt effect on tomato plant grow by improving plant water status. *J. Plant Physiol* **163,** 847–855

Roohizadeh G., Majd A. and S. Arbabian (2015) The effect of sodium silicate and silica nanoparticles on seed germination and some of growth indices in the Vicia faba L. *Trop Plant Res* **2**(2), 85–89

Sabaghnia N and M Janmohammadi (2014) Graphic analysis of nano-silicon by salinity stress interaction on germination properties of lentil using the biplot method. *Agr Forest* 29-40,. (3)60, .

Saqib M, Zorb. C, S. Schubert (2008) Silicon-mediated improvement in the salt resistance of wheat (*Triticum aestivum*) results from increased sodium exclusion and resistance to oxidative stress. *Functional Plant Biology.* **35**, 633-639.

Siddiqui M.H., Al-Whaibi M.H., Faisal M. and A.A. Al Sahli (2014) Nano-silicon dioxide mitigates the adverse effects of salt stress on Cucurbita pepo L. *Environ Toxicol Chem* **33**(11),2429– 2437. doi:10.1002/etc.2697

Sivanesan I, Son M.S, Lee J.P. and B.R. Jeong (2010) Effects of silicon on growth of Tagetespatula L. Boy orange and Yellow boy seedlings cultured in an environment-controlled chamber. *Propag.Ornam. Plants.* **10,** 136-140.

Soundararajan P, Sivanesan I, Jo E.H. and B.R. Jeong (2013) Silicon promotes shoot proliferation and shoot growth of Salvia splendens under salt stress in vitro. *Hort. Environ. Biotechnology*. **54,** 311-318

Suriyaprabha R, Karunakaran G, Yuvakkumar R, Rajendran V and N. Kannan (2012). Silica nanoparticles for increased silica availability in maize (Zea mays L) seeds under hydroponic conditions. *Curr Nano Sci.***8,**1–7

Tuna A.L, Kaya C, Higgs D, Murillo-Amador B, Aydemir S and A.R. Girgin (2008). Silicon improves salinity tolerance in wheat plants. *Environ Exp Bot.* **62,**10-16

Yuvakkumar R, Elango V, Rajendran V, Kannan N. S and P. Prabu (2011). Influence of Nanosilica Powder on the Growth of Maize Crop (*Zea mays L*.). *Inter J Green Nanotechn.*;**3,**180-190.

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