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INFLUENCE OF NANO–SILICA ON WHEAT PLANTS GROWN IN SALT–AFFECTED SOIL

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ABSTRACT

A pot experiment was carried out at the Faculty of Technology and Development greenhouse farm in the winter agricultural season 2018–2019. The experiment was planned to study the role of nano–SiO_2 on improving the wheat growth and productivity under salinity conditions. Six treatments (two grades of water quality are: tap water and saline water; three additional methods for silica nanoparticles are; 0, Si–soil, foliar) in three replicates. The soil was fertilized by nano–SiO_2 before sowing at a rate of 80 mg $kg^{-1}$and NPK recommended was added uniformly for all treatments. Wheat plants were sprayed five times by nano–silica after the month of sowing every ten days by 600 mg Si L^{-1} (10 mL pot^{-1}). The wheat plant was irrigated with tap water (0.4 dS m^{-1}) and saline–water (8 dS m^{-1}).

The nano–SiO_2 was analyzed by some analysis as Fourier Transform Infrared (FTIR), the scanning electron Microscopy Coupled with Energy Dispersive X–Ray analysis (SEM–EDAX), the Transmission Electron Microscopy (TEM), particle size, Specific Surface Area (SSA), Brunauer–Emmett–Teller (BET), X–Ray Diffractometer (XRD). The obtained results indicated a significant clear increase in wheat yield under salinity stress conditions compared with the check treatment. Nano–silica use led to the improvement of nutrients absorption e.g., N, P, K and Si contents under salinity stress conditions. In contrast, Na was reduced with Si increasing in plant tissues.

Conclusively, *nano–SiO_2 improves wheat plants on the growth and tolerance of salt stress up to 80 mg Kg^{-1} for soil addition and 600 mg L^{-1} for foliar spray.*

Keywords: Nano– SiO_2; Wheat growth; Salinity; Saline–soil; SiO_2.

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 the inadequacy of food to feed the world's population (Glick, 2012). Additionally, the available current data have shown that the world's salinity affected area of soil is about 1125 million hectares (FAO, 2019) of which approximately 76 million ha affected by agricultural human–practices led to salinization and sodification. Salt–affected soil is around 6% of the world's all out arable land zone (Munns, 2005). Locally, saltiness influenced soils spread roughly 32% of the all–out arable land region in Egypt (Ibrahim and Lal, 2013). If the salinization of soils continues in such a way, 50% of cultivable lands will be lost by 2050 especially with decreasing of water resources (UN, 2013). Hence, salt–affected soils have gained a major global–national– ecosystem–level concern. Yearly, the world's irrigated soil is decreasing by 1– 2% (FAO, 2019). However, the world population is increasing rapidly and will reach 9.6 billion by 2050. Hence, global food production will need to be increased 38 and 57% by 2025 and 2050, respectively to maintain the current level of food supply (Abrol and Wild, 2004).

The silicon element is ubiquitous in the earth's crust and considered the second most abundant after oxygen. Recently, the benefits of silicon for some crops, especially the *Poaceae* family, have been reported in the impedance against biotic and abiotic stress. Most researchers pointed out that the silicon has been recently candidates as a plant benefit element particularly for the *Poaceae* family plants (*e.g.* rice, wheat, corn, sugarcane...*etc*.). supplementation of Si has been proved as beneficial to plants in several ways such as increasing yield, resistance against diseases, and alleviation of abiotic stresses. The amendment of Si nutrition has been reported against various stresses under salinity and drought conditions (Liu *et al.,* 2009). The Si– available form is silicic acid H_4SiO_4, mono or polysilicic acids. Si is easily taken up by the roots and accumulated in plant tissues, with concentrations ranging from 1 to 100 g Si kg' dry matter (Pati *et al.,* 2016). (Heckman, 2013), and (Tubana *et al.,* 2016) reported the estimated shoot Si uptake for the wheat plants to be approximately 108 kg Si ha^{-1}.

Many studies reported that nano–silicon treatments can reduce the adverse effects of salinity on faba bean plants by enhancing the activity of antioxidant enzymes (Abdul Qados, 2015). Under salinity stress conditions, 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 (Siddiqui and Al-whaibi, 2014) (Kalteh et *al.,* 2018). Silicon nanoparticles have been implicated in crop improvements. Many reports indicate that appropriate concentrations of nano–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 some plants, (Haghighi *et al.,* 2012), length roots of the lentil and shoots (Sabaghnia and Janmohammadi, 2015). The importance of Si for improving plant growth was also reported by (Roohizadeh *et al.,* 2015) for faba bean and this is attributed to increase the water use efficiency in the 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. The function of Si and its concentration varies for plant species (Pilon-Smits *et al.,* 2009).

Overall, the main objectives of this current research use nano–silica under the saline conditions to examination the role of nano–silica for alleviating soil and water quality hazardous effects and draw the main mechanisms of the nano–silica for enhancing wheat plant growth and productivity.

MATERIALS AND METHODS

1. Experimental setup and treatments:

Soil material was collected from San EI–Hajer–Sharkia governorate, Egypt (latitude 30° 58' 37'' N and longitude 31° 52' 48'' E (Geohack, 2020)), Soil samples were taken at a depth of 0–20cm from a newly reclaimed soil. Soil samples were transported at the Faculty of Technology & Development greenhouse farm Zagazig University, Egypt (latitude 30° 35' 23.7'' N, longitude 31° 28' 53.2'' E (Geohack, 2020)), air–dried, ground passed through a 2–mm sieve, and the soil mixed by the nano-SiO_2, then filled into pots (25cm in diameter and 30cm in height). Uniformly with a 6 kg soil pot^{-1}, and nano–silica was added up to 80 mg Si kg^{-1}. The recommended doses of N, P, and K were added to the pots. Soil basic properties were measured in the laboratory (Table 1). Seeds of wheat (*Triticum aestivum* L. CV. Giza–68) were obtained from the Wheat Research Department, Crops Research Institute, Agriculture Research Centre, Giza, Egypt. The experiment was a split–plot design in randomized complete plot design. Water quality was considered as the main plots, silicon addition methods were assigned to the subplots. The treatments were as two water types tap water and saline–water (Table 2) and three addition method of nano–silica treatments (0, addition to soil, foliar–sprayed application) with three replicates. Before sowing, pots were irrigated with about 150% field capacity of freshwater to leach salts from 0 to 20 cm depth soil layer through progressive

Table (1): Some physio–chemical analyses for the tested soil.

Analysis	Result
Bulk density (g cm $^{-3}$)	1.26
Particles density (g cm $^{-3}$)	2.43
Porosity %	48.15
Water–holding capacity (g hg^{-1})	50.00
Soil color (dried soil)	10YR3/1
Practical size distribution (g hg^{-1})	
Sand	29.50
Silt	30.33
Clay	40.17
Texture	Clay loam
pH (soil paste suspension)	7.87
EC (dS m^{-1}) in soil paste extract	5.72
$CaCO_3$ (g kg^{-1})	15.47
Organic matter (g kg^{-1})	9.18
CEC (cmol$_{(+)}$ kg^{-1})	41.04
NH_4OAc–Na (g kg^{-1})	0.51
NH_4OAc–K (g kg^{-1})	0.68
KCl–N (mg kg^{-1})	19.25
$NaHCO_3$–P (mg kg^{-1})	17.21
$CaCl_2$–Si (mg kg^{-1})	20.02
Na^+ (meq. L^{-1})	7.39
K^+ (meq. L^{-1})	1.13
Ca^{2+} (meq. L^{-1})	34.70
Mg^{2+} (meq. L^{-1})	13.90
Cl^- (meq. L^{-1})	37.10
HCO_3^- (meq. L^{-1})	7.40
CO_3^{2-} (meq. L^{-1})	0.00
SO_4^{2-} (meq. L^{-1})	12.62

ponding. Subsequently, soil moisture of each pot was controlled within 70–80% field capacity until sowing to ensure the germination and initial establishment. Fifteen grains were sown in each pot on 15th November 2018. Fifteen days after sowing, seedlings were thinned to 10 per pot uniformly. Wheat plants were sprayed five times with a silicon solution of 600 mg L^{-1} in an amount of 10 mL pot^{-1} every two weeks after a month from sowing. Pots were irrigated by tap water and saline–water about 70% of soil water–holding capacity during the season. At harvest, plants were collected from each pot to estimate 1000–grain

Table (2): Some water quality parameters of the two used water.

Water type	EC dS m^{-1}	pH	Soluble ions meq. L^{-1}								SAR $(meq.L^{-1})^{0.5}$	RSC meq. L^{-1}
			Cations				Anions					
			Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	CO_3^{2-}	HCO_3^-	SO_4^{2-}		
Tap water	0.41	7.65	1.67	0.56	1.06	0.81	1.53	=	1.21	1.36	1.38	−0.66
Saline–water	8.00	7.42	44.05	3.43	20.36	12.16	60.04	=	12.81	7.15	8.57	−19.71

weight. The grain and straw yields were estimated based on 14% of moisture content and, then, the recorded values converted into g pot^{-1}.

***2. Analytical techniques*:**

Some physio-chemical characteristics of the SiO_2 were examined by using X–ray diffractometer (XRD) (X' Pert Pro, PANalytical, Netherland) using Cu Kα (λ = 1.5406 Å) as a radiation source over the 2θ range of 10°–80° at 293 K was employed to explore the crystalline nature of the silica. The peaks of silica functional groups from Fourier transform infrared spectra (FTIR) has been obtained in the wavenumber region of 4,000–400 cm^{-1} using FTIR spectrometer (Spectrum 100, Perkin Elmer, USA). The scanning electron microscopy coupled with energy dispersive X–ray analysis (SEM–EDAX) (JEOL JSM–6390LV, Japan) was used to determine the chemical composition of the nano–SiO_2. The morphology and size of the synthesized nano–SiO_2 were examined by transmission electron microscopy (TEM) (CM 200, Philips, USA). The specific surface area (SSA) of the prepared nano–SiO_2 was analyzed using the BET surface area analyzer (Autosorb AS–1MP, Quantachrome, USA). The physical sorption analysis was done with N_2 adsorption–desorption measurements at liquid N_2 temperature (–196 °C). Mean diameter was determined using the particle size analyzer (Particle Sizing Systems, Inc. Santa Barbara, Calif., USA)

Some properties in the previous Table of the investigated soil sample, water samples and silica were analysed according to (Estefan *et al.,* 2013). Samples of tested plant parts of the wheat crop were oven–dried at 70°C to a constant weight. The oven–dried samples were ground in a stainless–steel blade blender. Set powders of the ground materials were wet–digested in a mixture of H_2SO_4 and H_2O_2 at 420°C for the defined plant chemical analysis according to (Parkinson and Allen, 1975).

4. Statistical analysis:

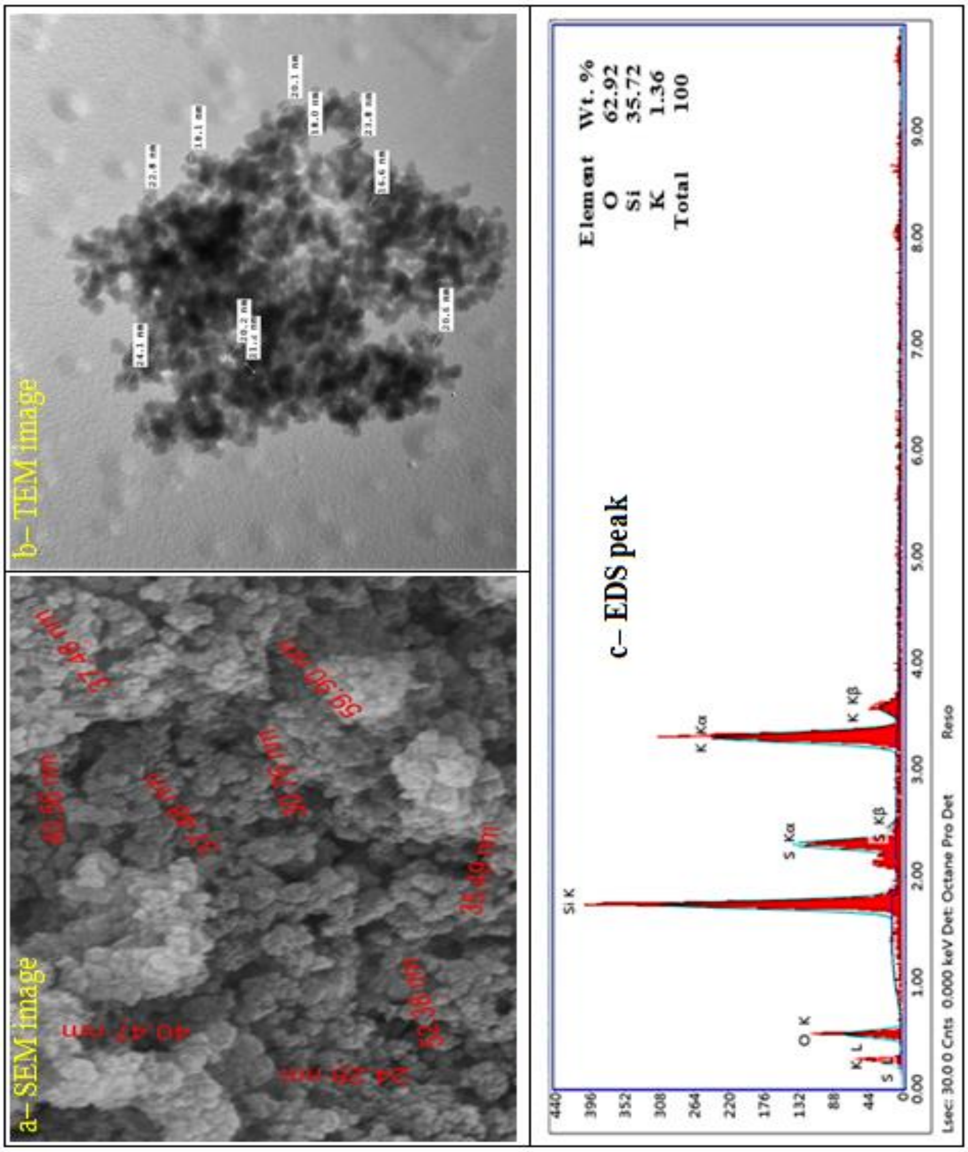
All data were statistically analyzed according to the variance analysis technique for the split-plot design using the MSTATC software package. The significant differences between the mean values of treatments were achieved by the LSD method.

RESULTS & DISCUSSION

1. Evaluation and characterization of used nano–silica:

The obtained results from the used nano–silica analyzes shown in Figures (1a – 1g) indicate that the diameters of the nano–silica particles in SEM and TEM images ranged between 24.28 – 59.90 and 16.6 – 24.1nm as shown in the Figures (1a, 1b), respectively. Additionally, EDS peak of nano–SiO_2 is shown in Figure (1c). In general, the majority of the content of elements present in the silicate products are 62.92, 35.72, 1.36% for O, Si and K, respectively.

Nano–SiO_2 XRD patterns of the silica is shown in Figure (1d). A broad diffuse peak appears at $2\theta \sim 22^{\circ}$, confirming the amorphous nature of the silica and this result is agree with (Premaratne *et al.*, 2014). Therefore, it can be concluded that nano–SiO_2 is purely amorphous type. Moreover, nano–silica was analyzed with FTIR technique to determine the prescience and densities of the major surface chemical groups (Figure 1f). It can be seen from FTIR spectra that the broad, intensity and positions of the absorption peaks varied nano–SiO_2. Generally, absorption peaks indicate the presence of surface groups belonging to silica structures (470–1150 cm^{-1}) and others going to the existing impurities and/or O–H groups and adsorbed H_2O (1640–3440 cm^{-1}). A large number of former researchers, including Sankar *et al.* (2016) and Nghiem *et al.* (2017) agreed to allocate the absorption peaks in the range of 438–475 cm^{-1} to Si–O– bond rocking, 796–805 cm^{-1} to symmetric Si–O– bending (silanol), 1050–1150 cm^{-1} to asymmetric Si–O–Si (siloxane) stretching in SiO_4 tetrahedra, 1633–1643 cm^{-1} to O–H bending, and 3437–3456 cm^{-1} to O–H stretching and adsorbed water. Nevertheless, Yuvakkumar *et al.* (2014) assigned the absorption beaks of 497, 623, and 795 cm^{-1} for Si–O–Si bending, Si–H, and symmetric Si–O–Si stretching modes of vibrations, respectively. The peaks of silica structures (silanol and siloxane groups) were stronger and broader. The specific surface area (SSA) of nano–SiO_2 was measured using a multiple–point BET surface area analyzer. The results of SSA measurement are shown in Figure (1e). The SSA of the nano–SiO_2 is found to 361.92 m^2 g^{-1}. Additionally, the result of mean diameter was about 44.2 nm as shown in Figure (1g). This result is confirmed and corroborated by the resultant analysis of SiO_2–SEM, TEM, BET and mean diameter. Moreover, this high value of the SSA of this nano–silica product suggests that it contains external and internal surfaces and is porous, and thereby highly reactive.


a– SEM image
b– TEM image
c– EDS peak
Element Wt. %
O 62.92
Si 35.72
K 1.36
Total 100

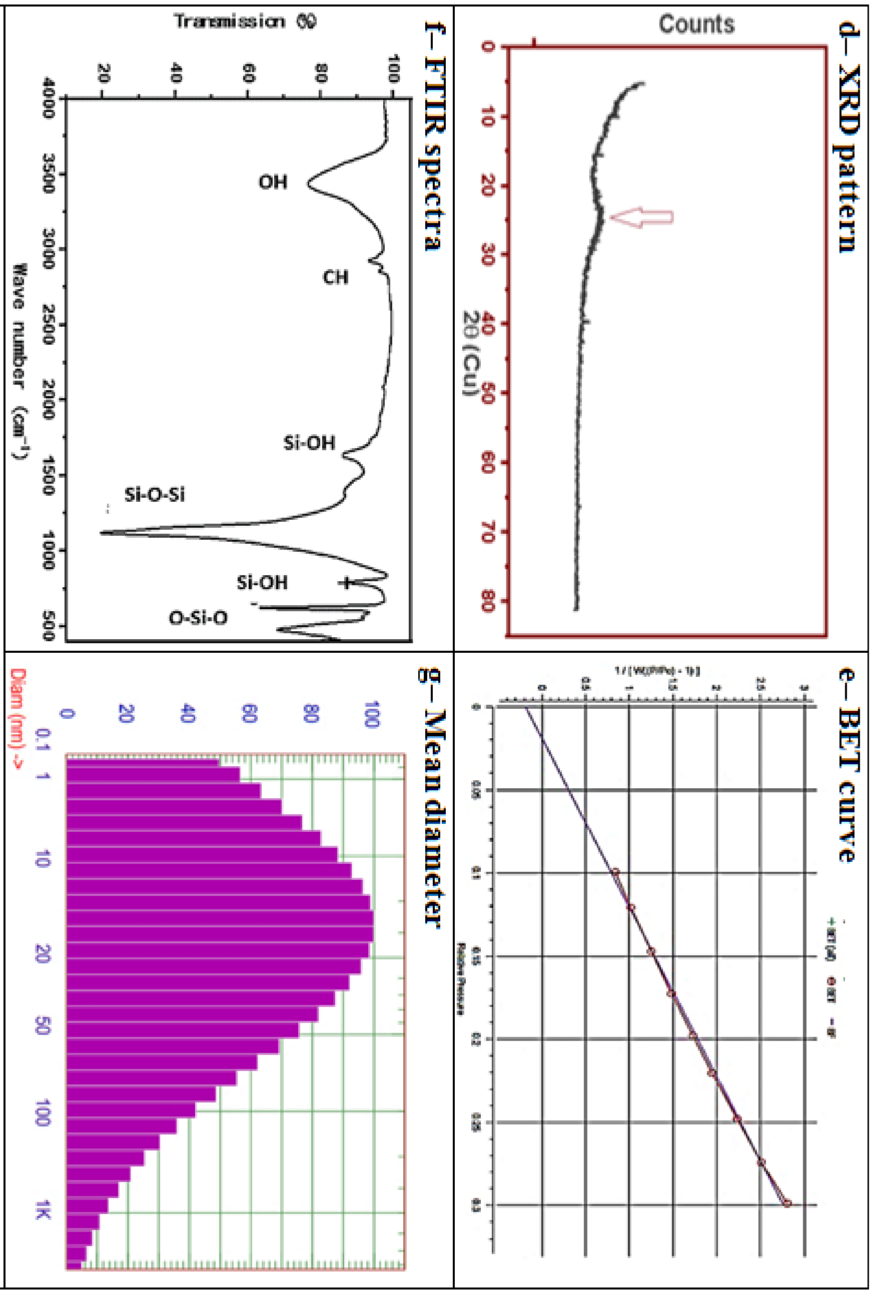


Figure (1): Characterization of used nano-SiO2 SEM (a), TEM (b), EDS (c), XRD (d), BET (e), FTIR (f) and mean diameter (g).

2. Influence of nano−SiO_2 on wheat yield components and N, P, K, Si and Na contents in wheat straw and grains:

Data presented in Table (3) show to wheat yield and its components. Biomass of wheat significantly increased by about 25.62, 33.47, 38.97 g pot^{-1} for 0, Si–soil, Si–foliar, respectively. The effect of saline water was limited in wheat biomass with nano–SiO_2 addition while it was a cleared in the check treatment. Additionally, grains yield was improved significantly and the increase for Si–soil and Si–foliar by 25.59, 21.54% for tap water and 65.53, 127.47% for saline water. Weight of one–thousand grains increased with nano–SiO_2 addition.

Generally, the superior treatments were Si–foliar, Si–soil compared with the check treatment in yield parameters. In related context, N content increased in wheat straw and grains by 0.28, 0.29, 0.3% and 2.37, 2.56, 2.64% for 0, Si–soil, Si–foliar, respectively. Additionally, data presented in Table (4) indicates some elements contents in both wheat straw and grains. N-content reduced in wheat straw and grains irrigated by saline water. While P slightly increased when wheat irrigated by saline water. K-content in straw and grains increased by Si–addition. This increase was about 34.21 to 63.08% for both wheat straw and grains. Also, Si content significantly increased with nano–SiO_2 addition. In contrast, Na reduced in straw and grains yield significantly by Si addition to soil or by spraying on wheat shoots. Additionally, Figure (2) showing K/Na and Si/Na ratios which increased due to the increase of K and Si with reducing of Na in wheat-growing under salt stress. These ratios increased in both conditions with tap and saline water. These results in an agreement with those of (Yuvakkumar *et al.,* 2011) and (Siddiqui and Al–whaibi, 2014) whose reported that the application of nano− SiO_2 showed significantly increased the growth traits of plants. Also, (Epstein, 2001) presented that nano−SiO_2 nutrition decreased the inhibitory outcome of salinity on plant growth by decreasing the Na^+ content, increasing the cell wall peroxidase activities. The results showing the efficiency of SiO_2 in wheat growth and productivity and these results were the same observation detected for nano silica that increased plant growth as reported by (Yuvakkumar *et al.,* 2011), and plant resistance to hydroponic conditions as reported by (Suriyaprabha *et al.,* 2012), as well as increased root length in plants, as stated by (Haghighi *et al.,* 2012) (Sabaghnia and Janmohammadi, 2015), and induced an improvement in photosynthesis as mentioned by (Liang *et al.,* 2003). Additionally, observed the same trend as other studies which showed the effects of nano−SiO_2 with mineral fertilizers in many crop plants, such as maize as stated by (Suriyaprabha *et al.,* 2012; Yuvakkumar *et al.,* 2011; Ayman *et al.,* 2016) a common bean as reported by (Alsaeedi *et al.,* 2017), tall wheatgrass as

Table (3): Influence of nano–SiO_2 on some yield parameters of wheat crop grown in saline soil.

Water source	Si– addition methods	Biomass (g)	Grains (g)	1000–grains weight (g)
Tap water	Check	26.65	7.66	17.41
	Soil	32.34	9.62	22.13
	Foliar	38.40	9.31	22.43
Saline water	Check	24.59	5.86	14.44
	Soil	34.60	9.70	21.48
	Foliar	39.53	13.33	23.09
Statistical analysis				
Factor		**Biomass**	**Grains**	**1000–grains weight**
Main factor:	**TW**	32.46	8.86	20.65^{a}
Water quality	**SW**	32.91	9.62	19.67^{b}
Sub–factor:	**LSD 0.05**	NS	NS	0.55
Si–addition methods	**Check**	25.62^{c}	6.76^{b}	15.93^{c}
	Soil	33.47^{b}	9.66^{a}	21.81^{b}
	Foliar	38.97^{a}	11.32^{a}	22.76^{a}
	LSD 0.05	4.02	1.69	0.89
Interaction	**W*Si**	*	*	*

Table (4): Influence of nano–SiO_2 on N, P, K, Si and Na contents (%) of wheat crop grown in saline soil.

Water source	Si– addition methods	Straw					Grains				
		N	P	K	Si	Na	N	P	K	Si	Na
Tap water	Check	0.33	0.03	0.76	1.16	0.09	2.57	0.52	1.13	0.21	0.03
	Soil	0.38	0.04	1.09	3.84	0.05	2.69	0.52	1.77	0.02	0.03
	Foliar	0.35	0.07	1.02	4.15	0.04	2.66	0.62	1.37	0.2	0.05
Saline water	Check	0.22	0.04	0.65	1.76	0.25	2.18	0.39	1.27	0.21	0.11
	Soil	0.20	0.08	1.06	4.21	0.1	2.60	0.46	1.73	0.09	0.06
	Foliar	0.27	0.1	0.99	4.84	0.08	2.46	0.42	1.4	0.2	0.06
Statistical analysis											
Factor		N	P	K	Si	Na	N	P	K	Si	Na
Main factor: Water quality	TW	0.35^{a}	0.05^{b}	0.96	3.05^{b}	0.06^{b}	2.64^{a}	0.56^{a}	1.42	0.14	0.03^{b}
	SW	0.23^{b}	0.07^{a}	0.89	3.60^{a}	0.14^{a}	2.41^{b}	0.42^{b}	1.46	0.16	0.07^{a}
Sub–factor:	LSD 0.05	0.06	0.01	NS	0.09	0.02	0.14	0.01	NS	NS	0.02
Si–addition methods	Check	0.28	0.03^{c}	0.70^{b}	1.46^{c}	0.17^{a}	2.37^{b}	0.46^{c}	1.20^{c}	0.21^{a}	0.07^{a}
	Soil	0.29	0.06^{b}	1.01^{a}	4.03^{b}	0.07^{b}	2.56^{a}	0.49^{b}	1.38^{b}	0.05^{b}	0.05^{b}
	Foliar	0.31	0.09^{a}	1.07^{a}	4.49^{a}	0.06^{b}	2.64^{a}	0.52^{a}	1.75^{a}	0.19^{a}	0.04^{b}
	LSD 0.05	NS	0.01	0.06	0.05	0.01	0.11	0.02	0.08	0.07	0.01
Interaction	W*Si	*	NS	NS	NS	*	NS	*	NS	NS	NS

described by (Azimi *et al.*, 2014), tomato as outlined by (Lu *et al.*, 2015), faba bean as mentioned by (Qados and Moftah, 2015), wheat as described by (Tahir *et al.,* 2006), rice as disclosed by (Yeo *et al.*, 1999), Glycine max as mentioned by (Lu *et al.*, 2002), and sweet pepper as displayed by (Tantawy *et al.*, 2015). Also, others showed the effective role of nanomaterial fertilizers on plant growth and productivity. On the other hand, several research works have been carried out to prove the positive impact of silica nanoparticles to the crops, such as (Rastogi *et al.*, 2019) who reported the benefits of nano− SiO_2 on physiological features of the plant in which that, they allow them to enter plants and affect its metabolic activities. The same group also claim that the mesoporous nature of silica nanoparticles can also direct them to be good applicants as nanocarriers for several molecules that may support in agriculture. Also, 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 the 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). Additionally, increasing the Si–absorption by nano− SiO_2 particles addition in saline soil, increase absorption of N, P, K, Si and reduce Na in plant, increase in plant antioxidants, Si helps wheat plant on tolerance of salt stress by reducing of Na uptake and set of turgor pressure inside the plant and increase the efficiency of the photosynthesis process. Many studies indicated to some or/and these reasons such as (Heckman, 2013; Qados and Moftah, 2015; Ayman *et al.*, 2016; Pati *et al.*, 2016; Tubana *et al.*, 2016; Rastogi *et al.*, 2019).

CONCLUSION

Results confirmed to the used of nano–silica by the application rate in this study for soil addition and spraying helped wheat plants growing in saline soils irrigated with saline water to the tolerance of the of soil and water salinity hazards. Additionally, increase of the absorption of nutrients *e. g.,* N, P, K, Si and reducing the Na uptake. Subsequently, this was reflected in improvements in wheat crop and its components.

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تَأْثِير النانوسيليكا عَلَى نَبَاتَاتُ الْقَمْح النَّامِيَة فِي التُّرْبَة المتأثرة بالأملاح

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أُجْرِيَت تَجْرِبَة أصُص فِي صوَّبه كُلِّيَّةُ التكنولوجيا وَالتَّنْمِيَة - جَامِعَةُ الزقازيق - مِصْر خِلَال الْمَوْسِمِ الزِّرَاعِيِّ الشِّتْوِيّ 2018 – 2019 خُططت هَذِه التَّجْرِبَة لِدِرَاسَة دُور النانوسيليكا فِي تَحْسِينِ نُمُوّ وإنتاجية الْقَمْح تَحْت ظُرُوف الْمُلُوحَة. كَانَتَ مُعَامَلَات التَّجْرِبَة هي سِتَّة مُعَامَلَات (درجتان مِنْ جَوْدَةِ الْمِيَاه هُمَا: مَاء الصُّنْبُور وَمِيَاه ملحية؛ ثَلَاثُ طُرُق إضَافَة لجزيئات النانوسيليكا؛ بدون ، سيليكون للتربة ، سليكون ورقي) فِي ثَلَاثِ مكررات. سُمدت التُّرْبَة الْمِلْحِيَّة بالنانوسيليكا قَبْلَ الزِّرَاعَةِ بمعدل 80 مجم/كجم وأضِّيفت الجرعات الْمُوصَى بِهَا مِنْ النيتروجين والفوسفور والبوتاسيوم بِشَكْل مُوَحَّد لِجَمِيع الْمُعَامَلَات. رُشت نَبَاتَاتُ الْقَمْح خَمْسَ مَرَّاتٍ بِوَاسِطَة النانوسيليكا بَعْدَ شَهْرٍ مِنْ الزِّرَاعَةِ كُلِّ عَشَرَةِ أَيَّام بمحلول سيليكون 600 مجم/لتر وبكمية 10مليلتر/أصيص. روُيت نَبَاتَاتُ الْقَمْح بِمَاء الصُّنْبُور (0.4 ديسيسيمنز/متر) أَوِ المِيَاهِ الْمِلْحِيَّة (8 ديسيسيمنز/متر) . وَصَفْت النانوسيليكا مِنْ خِلَالِ بَعْضِ التحليلات مِثْل تَحْلِيلِ فورييةِ للأشعة تحْتَ الحَمْرَاء ، المجهر الإلِكْتُرُونِيِ الْمَاسِح إِلَى جَانِبِ تَحْلِيل الأَشِعَّةُ السِّينِيَّةُ الْمُشَتَّتَة للطاقة والمجهر الإلِكْتُرُونِيّ النَّافِذ، حَجْم جُزَيْئَات السليكا، مِسَاحَة السَّطْح ، حُيود الأَشِعَّةُ السِّينِيَّةُ . أَشَارَت النَّتَائِج الْمُتَحَصِّل عَلَيْهَا إِلَى زِيَادَةِ مَعْنَوِيَّةٌ فِي مَحْصُول الْقَمْح تَحْت ظُرُوف الْإِجْهَاد الملحي مُقَارَنَة بِمُعَامَلَة التَّحَكُّم. أيضاً، أَدَّى اسْتِخْدَامٌ النانوسيليكا إِلَى تَحْسِينِ مُحْتَوِي العَنَاصِر الغِذَائِيَّة مِثْل النيتروجين، الفوسفور، البوتاسيوم، السيليكون تَحْت ظُرُوف الْمُلُوحَة. عَلَى الْعَكْسِ، اِنْخَفَض تَرْكِيز الصُّوديوم فِي قَشّ وَحُبُوب الْقَمْح مَعَ إضَافَةِ السليكون.
التوصية: ونوجز بِأَن اسْتِخْدَامٌ النانوسيليكا حَتَّى 80 مجم/كجم لِلْإِضَافَة الْأَرْضِيَّة و 600مجم/لتر للتسميد الورقي تُسَاعِد نَبَاتَاتُ الْقَمْح بفاعلية عَلَى النُّمُوِّ وَتُحْمَل الْمُلُوحَة.