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The Contribution of Nano-Selenium in Alleviation of Salinity Adverse Effects on Coriander Plants

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ABSTRACT

Nanotechnology is the field of science that opens a large scope of novel application in various fields, especially agricultural biotechnology. Selenium (Se) is an essential trace element for humans and animals and appears to be a beneficial element for many plants. There is increasing evidence showing that low selenium (Se) concentrations may build resistance of plants to environmental stresses. For this purpose, a pot experiment was carried out at The Experimental Farm of the Faculty of Agriculture, Mansoura University, Dakahlia Governorate, Egypt, during the spring season of 2016, to investigate the potential alleviation of salinity adverse effects by Se application as a foliar spray in the form of selenium nanoparticles (Se-NPs) in two concentrations (0 and 50 ppm) on coriander (*Coriandrum sativum*) grown on a sandy soil irrigated with different concentrations of saline water S1 (EC_w=3.12 dS m^{-1}), S2 (EC_w =6.25 dS m^{-1}) and tap water as a control S0 (EC_w=0.45 dSm^{-1}). These experimental treatments were arranged in a split plot design in three replications. Salinity showed adverse effects on different plant growth parameters as well as total chlorophyll content. Selenium nanoparticles (Se-NP1) at 50 ppm showed the best effects on vegetative growth and total chlorophyll content of coriander plants under different salinity levels of irrigation water. Increasing salinity resulted in decreasing N and K contents in the leaves of coriander plants, but Na increased as a result of some sort of antagonism with K; in spite of that, N and K contents in coriander leaves increased with foliar application of selenium nanoparticles (Se-NP1) at rate of 50 ppm to be higher concentrations compared to distilled water added to the spray as a control 0 ppm (Se-NP0). Values of Na/K ratio in coriander leaves increased as the salinity levels increased while, K/Na ratio was decreased. On the contrary, the values of Na/K ratio decreased with (Se-NP1) spraying at rate of 50 ppm, but K/Na ratio was increased at the same spraying rate under all salinity levels. It is concluded that application of selenium nanoparticles can mitigate salt stress damages on coriander plants; it also leads to increasing in K concentrations and decreasing in Na concentrations under salt stress.

Keywords: Coriander, Growth, Salinity, Selenium nanoparticles, Total chlorophyll, Nutrient contents, Na/K ratio.

INTRODUCTION

Climate has an important environmental effect on ecosystems. Climate change has caused serious changes by increasing biotic and abiotic stresses, leading to changes in ecosystem processes (Robroek *et al.*, 2017). The shortage of fresh water resources is becoming an alarming crisis especially in arid and semi-arid regions (e.g. Egypt). Saline water may inhibit plant growth as it contains salts and ions that can have adverse impacts on the plant growth and development. Salinity is the environmental stress that causes many disorders in morphological, physiological and biochemical properties; resulted in reduction growth of different plants owing to increase of sodium and chloride ions. The excessive buildup of sodium and chloride decreases uptake of essential nutrients (e.g. Ca, P, K and Fe), thereby plants suffer from enzymatic inhibition, nutritional imbalance, membrane damage and inhibition crop yields and qualities (Grattan and Grieve, 1999). Salinity-induced-oxidative stress is also associated with the overproduction of ROS that calls reactive oxygen species vital damage to proteins, membrane lipids, nucleic acids and photosynthetic pigments (Hasanuzzaman *et al.*, 2013).

Recently, exogenous protectants such as several trace elements and antioxidants have been found helpful to mitigate the salt-induced damages (Hasanuzzaman *et al.*, 2013). One of the protective strategies is the utilization of selenium (Se), which can mitigate of salt damages and increment stress resistance by improving plant growth and enhanced nutritional status, thus reducing the adverse effects of salinity.

Selenium (Se) is an essential nutrient and food supplement for healthy life of animals and humans. It is contributing in the membranes protection and has anticancer action. Further, it is a cofactor of glutathione peroxidase and has a significant role against oxidative damage of tissues. Even though, Se isn't considered as an essential element for higher plants, metabolism and nutrition, several studies have appeared at low concentrations of Se that have stimulating effects for plants, especially under abiotic stress, where it has the ability to regulate the water status of plants, acts as an antioxidant, mitigating oxidative stress induced by environmental stresses, thus improving abiotic stress tolerance in plants (KeLing *et al.*, 2013 and Mozafariyan *et al.*, 2016).

Se application at low concentrations might stimulate vegetative growth, increases proline content, protecting cell membrane against lipid peroxidaseand increasing in the quality and production of vegetable crops under stress conditions. It has a plant resistance mechanism for salinity such as; Se has growth promoting effect and might reduce the osmotic potential and maintain turgor, promote the accumulation of free amino acids and total soluble sugars or the activity of antioxidant enzymes and improve the transpiration rate (Nawaz *et al.*, 2015). However, the optimal and effective dose of Se depends on plant species and cultivation conditions. Selenium enhances plant salt tolerance via enhancement in the photochemical efficiency of the salt-stressed plants, resulting in higher photosynthesis. It decreases Cl^- ion contents, reactive oxygen species (ROS) and membrane damage (Hawrylak-Nowak, 2009 and Djanaguiraman *et al.*, 2010). Additionally, it can cause increases in the K^+ accumulation and decreased in the Na^+ accumulation, thus reducing the adverse effects of salinity on plant (Walaa *et al.*, 2010; KeLing *et al.*, 2013 and Diao *et al.*, 2014). Hawrylak-Nowak (2009) found that low concentration of exogenous Se (5 and 10 μM) under NaCl treated cucumber seedlings stimulates growth as well as photosynthetic pigments accumulation. However, Se can adjust the uptake and redistribution of essential elements important for plant metabolism or maintain the ion balance and structural integrity of plant cells and may play a role in anti-oxidative reactions and hormone balance in plant cells (Feng *et al.*, 2013).

Selenium deficiency has a direct negative impact on human health; it can cause several diseases, for example, heart disease and numerous kinds of cancers (Rayman, 2002). Therefore, fortification of crops with Se can be useful for plants and is important for human nutrition. Foliar application of Se element is the most effective ecoenvironmental method for enriching the Se content of plant biomass (Feng *et al.*, 2013).

Nano-technology can present solution to increasing environmental problems and the value of agricultural products. Nano materials as a result of their minor size show unique characteristics. They can change physicochemical properties compared to their bulk materials, they have a great surface area than bulk materials. Due to these larger surface areas, their solubility and surface reactivity was higher (Moraru *et al.*, 2003).

Nano-selenium defined as nano elemental selenium, use in developed in nutritional supplements, medical therapy additionally Se-fertilization. Recently, selenium nanoparticles (Se-NPs) have been presented as alternatives for seleno-compounds and numerous researchers have focused on excellent characteristics of Se-NPs for example, higher antioxidant effects, lower toxicity, better biocompatibility and bio-efficacy (Zhang *et al.*, 2008). More applications for nanoparticles of Se are represented the development of safeSe vitamins and additives of food. Nano-Se can be utilized as a supplemental fertilizer for increasing productivity of agricultural soils. Thus, it was recorded that there are a good opportunities for the intervention of Se nanotechnology in the area of plant nutrition and fertilizers (Mastronardi *et al.*, 2015).

Coriander (*Coriandrum sativum*) is one of the most aromatic herbs in the market, the highest demand in worldwide, utilize in the food industry. However, it is important to consider that current demand in the food industry is oriented towards the consumption of high quality products and value added services, which provide greater benefits. Coriander has a place in the market of the Northeast region and tolerates high temperatures better than othervegetables and has attractive prices to the producer (Silva *et al.*, 2016). Coriander pants were found to resist salinity up to the concentration of 3000 ppm (Ewase *et al.*, 2013).

Therefore, in this work, the main objectives of this study were to find out a novel approach in alleviation of salinity negative effects on growth and mineral concentrations of coriander plants by using selenium nanoparticles (Se-NPs) as foliar application.

MATERIALS AND METHODS

During the spring season of 2016, a pot experiment was carried out at The Experimental Farm of the Faculty of Agriculture, Mansoura University, Dakahlia Governorate, Egypt to investigate the contribution of selenium nanoparticles (Se-NPs) in alleviation of salinity adverse effects on growth and mineral concentrations of coriander plants. The experimental design was a split plot with three replicates. Seeds were sown in plastic pots containing 20 kg air-dried sandy soil. The levels of saline water were assigned as main-plots and Se concentrations as sub-plots. Main treatments comprised three salinity levels: tap water as a control S0 (EC_w = 0.45 dS m^{-1}), S1 (EC_w = 3.12 dS m^{-1}) and S2 (EC_w = 6.25 dS m^{-1}). Subplots were assigned to foliar application of selenium nanoparticles (Se-NPs) treatments 50 ppm (Se-NP1) and distilled water as a control 0 ppm (Se-NP0) after three weeks of sowing, and the second application was two weeks after the first application.

Irrigation water analysis: Water samples were analyzed according to the standard methods of APHA, (1995) for conventional parameters presented in Table 1.

Table 1. Chemical composition of water used for irrigation.

EC_W (dS m^{-1})	pH	Water used for irrigation — Soluble ions, ($mmol_c$ / L)						
		Ca^{2+} + Mg^{2+}	Na^+	K^+	$^*CO_3^{2-}$	HCO_3^-	Cl^-	$^{**}SO_4^{2-}$
(S0)*** 0.45	7.95	3.45	2.35	0.17	N.D.	1.33	1.82	2.82
(S1) 3.12	7.97	11.16	10.56	0.53	N.D.	3.51	9.52	9.22
(S2) 6.25	8.23	25.03	28.43	2.46	N.D.	5.36	24.83	25.73

*** N.D. means not detected, **sulfate (SO_4^{2-}) ions were calculated as the difference between sum of cations and anions.**
***** (S0, S1 S2): Salinity levels.**

The physicochemical properties of soil showed that the soil of experimental site was sandy in texture and poorly fertile soil. Some physicochemical properties of the studied soil have been presented in Table 2.

Table 2. Some physicochemical properties of the soils collected from the experimental field.

Soil Properties		Method use	B: Chemical properties		
A: Particle size distribution					
Property	**2016 season**		**Analysis**	**Values**	**Method adopted**
Sand (%)	95.35	The international	Soil pH (1:2.5)	8.56	pH meter, Jenco (model 3173) Rowell, (1994)
Silt (%)	3.35	pipette method	$^{**}EC_e$ (dS m^{-1}) (1:5)	3.02	EC meter, Jenco (model 3173) Rowell, (1994)
Clay (%)	1.30	Piper, (1950)	O.M. (g kg^{-1})	4.1	Walkley and Black method, Jackson, (1967)
Texture class	Sandy				

C: Available macro and micro nutrient (mg kg^{-1})			D. Soluble cations and anions, ($mmol_c$ / L)		
			Ions	**Values**	**Methods**
N	22.04	The conventional method of Kjeldahl, Page *et al.*, (1982)	Ca^{2+}	2.12	Standard titration methods USSL, (1954)
P	4.62	Spectrophotometer, Page *et al.*, (1982)	Mg^{2+}	1.70	
K	86.57	Flame photometer, Page *et al.*, (1982)	Na^+	1.55	
Zn	0.10	DTPA extractable method, (Lindsay and Norvel, 1978)	K^+	0.17	
			$^*CO_3^{2-}$	N.D.	
Fe	0.24		HCO_3^-	0.26	
			CL^-	4.08	
Mn	0.02		$^{**}SO_4^{2-}$	1.20	

***N.D. means not detected.**sulfate ($SO4^{2-}$) ions were calculated as the difference between sum of cation and anions.**

Selenium Solution Preparation:

Nano-Se:

Se-nanoparticles were prepared biologically using *Lactobacillus casei* as bacteria strain at Sakha Agriculture Research Station, Kafr El-Shiekh Governorate, Egypt according to El-Ramady, (2015).

Plant Samples and Analysis:

A random sample of five plants at harvesting stagewere taken from each pot and subjected for vegetative growth parameters including plant height (cm), number of leaves per plant, leaves fresh and dry weight (g). Total chlorophyll (SPAD) content was measured by portable Chlorophyll Meter (model SPAD-502, Soil and Plant Analysis Development) of as described by Minolta Co. Ltd., Osaka, Japan (1989).

Chemical Composition:

The plant samples were dried at 70 ^{o}C; ground using stainless steel equipment to analyze nitrogen, phosphorous, potassium and sodium contents of coriander leaves. From each sample, 0.5 g was digested by the mixture of H_2SO_4: $HClO_4$ acids (1:1) for nitrogen, potassium and sodium determination. Total nitrogen was determined by Kjeldahl method, total potassium and sodium were determined by flame photometer as described by Cottenie *et al.,* (1982). Nutrient uptake was determined using the following formula:

Nutrient uptake (g/plant) = Nutrient concentration (%) x leaves dry weight (g)

Statistical Analysis:

Data of the experiment were subjected to statistical analysis according to Duncan's Multiple Range Test (DMRT) for analysis of variance (ANOVA) at 95% confidence using COSTAT software.

RESULTS AND DISCUSSION

Effect of salinity levels on plant growth, total chlorophyll, mineral content and uptake of coriander

Data in Table 3 showed that vegetative growth parameters of coriander plants expressed as plant height, number of leaves per plant as well as fresh and dry weight of leaves was significantly affected and adversely influenced by increasing levels of irrigation water salinity. The plant height decreased significantly ($P < 0.05$) by increasing salinity levels. The plant height of coriander decreased from 40.83 cm under control plants irrigated with tap water S0 (0.45 dS m^{-1}) to 34.00 cm under the highest level of salinity S2 (6.25 dS m^{-1}), as it decreased by 16.72 %. Similar results were also recorded by Ewase *et al.,* (2013) in coriander. The reduction of plant height may be owing to inhibitory behavior of salt stress on cell expansion and cell division (Hernandez *et al.,* 2003). The number of leaves is the very essential character for vegetative development as leaf is the main photosynthetic organ for plant growth. The higher salinity level reduced significantly and adversely affected the production of leaves number per plant in coriander compared to irrigation with tap water S0 (0.45 dS m^{-1}). Saberi *et al.,* (2011) who found reduce leaves number/plant under salinity stress. Ewase *et al.,* (2013) also reported that with the increase of NaCl concentration, the number of leaves per plant decreased in coriander. The leaves fresh weight was significantly reduced under salinity treatment and was agreed and hand by hand with the previous findings on the plant height and number of leaves per plant during the studied season. The leaves fresh weight of coriander decreased from 34.09 cm under control plants irrigated with tap water S0 (0.45 dS m^{-1}) to 26.19 under the highest level of salinity, as it decreased by 23.17 %. Under water stress condition, the reduction in fresh weight of coriander may be attributed to suppression of cell growth and cell expansion due to the low turgor pressure, lower chlorophyll content, less expansion of leaf area and reduction in the values of net assimilation rate (Rodriguez *et al.,* 2005).

Table 3. Vegetative growth and total chlorophyll content of coriander plants as affected by irrigation with diluted seawater and selenium nanoparticles (Se-NPs) spraying during the studied season.

Salinity levels, dS m^{-1} (A)	Selenium concentrations, ppm (B)		Mean (A)
	*(Se-NP0)	**(Se-NP1)	
	Plant height (cm),		
EC_w = 0.45	39.33 ab***	42.33 a	40.83 a
EC_w = 3.12	35.66 bc	38.33 ab	37.00 b
EC_w = 6.25	32.33 c	35.66 bc	34.00 c
Mean (B)	35.78 b	38.77 a	
	Number of leaves/plant,		
EC_w = 0.45	6.33 b	8.33 a	7.33 a
EC_w = 3.12	5.33 bc	6.33 b	5.83 b
EC_w = 6.25	4.00 c	5.33 bc	4.66 c
Mean (B)	5.22 b	6.66 a	
	Fresh weight (g),		
EC_w = 0.45	30.41 b	37.78 a	34.09 a
EC_w = 3.12	27.90 bc	31.44 b	29.67 b
EC_w = 6.25	24.48 c	27.90 bc	26.19 b
Mean (B)	27.59 b	32.37 a	
	Dry weight (g),		
EC_w = 0.45	7.03 b	8.34 a	7.69 a
EC_w = 3.12	4.64 cd	5.58 c	5.11 b
EC_w = 6.25	3.14 e	3.88 de	3.51 c
Mean (B)	4.94 b	5.93 a	
	Chlorophyll content, (SPAD)		
EC_w = 0.45	7.30 c	13.13 a	10.21 a
EC_w = 3.12	6.66 c	9.33 b	8.00 b
EC_w = 6.25	5.86 c	6.66 c	6.26 c
Mean (B)	6.61 b	9.71 a	

***(Se-NP0)): selenium nanoparticle at rate of 0 ppm; **(Se-NP1): selenium nanoparticle at rate of 50 ppm**

***** Different letters in the same column which indicate significant differences a cording to the Duncan Multiple Range Test (P < 0.05)**

A negative relationship was observed between dry weight of coriander plants and salinity. The leaves dry weight of coriander decreased from 7.69 cm under control plants S0 (0.45 dS m^{-1}) to 5.11 cm and 3.51 under 3.12 and 6.25 dS m^{-1}, respectively. Irrigation with highest salinity water level greatly decreased dry weight of leaves by 54.35 % comparison with non-saline water. Salinity of irrigation water resulted in excess Na^+ uptake, which can cause a disturbance to osmotic adjustment in plant tissue. In addition, the high Na^+ accumulation may cause inhibitory effects and severely reduce the vegetative growth characteristics, physiological activity and metabolic disturbances in plants due to ion toxicity, osmotic stress and ion imbalance and (Ewase *et al.,* 2013). Additionally, nutrient uptake by plant roots and water availability is limited due to toxic effect of Na and Cl ions and high osmotic potential (Kumar, 1995).

Chlorophyll is a green pigment that absorbs optical energy for use in photosynthesis, found in chloroplast of plant and relative chlorophyll content has a positive relationship with photosynthetic rate. Total chlorophyll content (SPAD reading) in response to irrigation water salinity in coriander leaves reduced significantly with increasing salinity levels. Results in Table 3 found that the highest salinity level S2 (6.25 dS m^{-1}) induced a significant reduction in the total chlorophyll content as compared to control plants S0 (0.45

dSm^{-1}). These results were also supported by (Guerfel *et al.*, 2009 and Farhood *et al.*, 2016). The chlorophyll pigment is sensitive to increased environmental stress, especially salinity, which led to reduce chlorophyll content (Guerfel *et al.*, 2009). The reduction in chlorophyll content may be due to an increase of chlorophyll degradation or to a decrease of chlorophyll biosynthesis under salinity stress, result in increasing the destructive specific enzymes chlorophylls activity that are responsible for the synthesis of photosynthetic pigments (Rahdari *et al.*, 2012) as well as reduce in the stomatal aperture, which affects on photosynthesis pathway (Munns and Tester, 2008).

Data in Table 4 showed the effect of irrigation with saline water on N content in leaves of coriander compared to non-saline water treatment during the studied season. Increasing salinity resulted in significantly decreased N content in the leaves of coriander plant by 69.01 %. Decreasing N content in leaves of coriander with increasing salinity of irrigation water may be due to increase the amino acids inside the plant with increasing the stress; amino acids also interact with phospholipids to adjust the osmotic potential according to (Abd El-Nasser *et al.*, 2010).

Table 4. Nitrogen, potassium and sodium concentrations as well as Na/K and K/Na ratio in coriander leaves as affected by irrigation with diluted seawater and selenium nanoparticles (Se-NPs) spraying during the studied season.

Salinity levels, dS m^{-1} (A)	Selenium concentrations, ppm (B) (Se-NP0)	(Se-NP1)	Mean (A)
	% N		
EC_w = 0.45	2.26 ab	4.26 a	3.26 a
EC_w = 3.12	1.05 b	3.00 ab	2.03 b
EC_w = 6.25	0.50 b	1.52 ab	1.01 c
Mean (B)	1.27 B	2.93 A	
	% K		
EC_w = 0.45	1.83 c	3.73 a	2.78 a
EC_w = 3.12	0.93 d	2.63 b	1.78 b
EC_w = 6.25	0.65 d	2.40 b	1.52 b
Mean (B)	1.14 B	2.92 A	
	% Na		
EC_w = 0.45	3.80 c	3.47 c	3.64 c
EC_w = 3.12	5.73 ab	4.60 bc	5.17 ab
EC_w = 6.25	6.73 a	5.51 ab	6.13 a
Mean (B)	5.42 A	4.52 B	
	% Na / K		
EC_w = 0.45	0.91 c	0.80 c	0.86 b
EC_w = 3.12	1.49 c	1.15 c	1.32 b
EC_w = 6.25	3.62 a	2.34 b	2.98 a
Mean (B)	2.01 A	1.43 B	
	% K / Na		
EC_w = 0.45	1.09 ab	1.25 a	1.17 a
EC_w = 3.12	0.68 c	0.91 b	0.79 b
EC_w = 6.25	0.31 d	0.45 d	0.38 c
Mean (B)	0.69 B	0.87 A	

The results of the potassium and sodium analysis presented in Table 4 showed that, irrigation with salinity water significantly decreased potassium concentration in coriander leaves ($P < 0.05$), whereas Na^+ concentration increased. Increasing salinity level from 3.12 to 6.25 dS m^{-1} resulted in a reduction in potassium concentration by 45.32 % and 35.97 %, respectively for coriander plants. Sodium concentration increased with increasing salinity levels, and the highest concentration of sodium and the lowest concentration of potassium were obtained with 6.25 dS m^{-1} treatment (Table 4). Na and K concentrations are good indicators of salinity tolerance and it can be utilized as an index for toxicity of sodium because of Na ion inhibits the activity of enzymes required in physiological processes (Taleisnik and Grunberg 1994). It is also noted that values of Na/K ratio increased significantly as the salinity level increased. On the contrary, K/Na ratio reduced with increasing salinity of irrigation water (Table 4). The potassium is the main cation in plant cells, and is an essential component of the cell osmotic potential (Reggiani *et al.*, 1995). Saqib *et al.*, (2004) found that excessive sodium content in root growth environment, under saline conditions lead to a reduction of K uptake due to the antagonism between sodium and potassium at sorption sites in the roots.

Effect of salinity levels and (Se-NPs) spraying on plant growth, total chlorophyll, mineral content and uptake of coriander

As illustrated in Table 3 and Figs. 1 & 2 show that, the foliar spraying of (Se-NP1) at rate of 50 ppm had non-significant effect on the plant height of coriander plants under non-saline and saline water irrigation but the plant height increased with the application of (Se-NP1). The plant height of coriander increased with the foliar addition of (Se-NP1) to 35.66 cm compared to distilled water added to the spray as a control 0 ppm (Se-NP0), plant height was then 32.33 cm under the highest level of salinity (6.25 dS m^{-1}) (Fig. 1). It increased by 10.30 %. Regarding the interaction between irrigation water salinity and (Se-NP1) spraying, the irrigation with the highest level of salinity and (Se-NP1) foliar application were found to give the increased number of leaves per plant (5.33); the irrigation water with 6.25 dS m^{-1} and foliar application with distilled water(Se-NP0) gave the lowest one (4.00) (Fig. 2). It increased by 33.25 %.

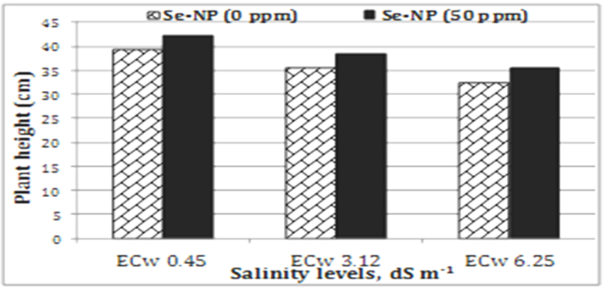

Fig. 1. Interaction between salinity levels and selenium nanoparticle (Se-NPs) spraying on plant height of coriander plants.

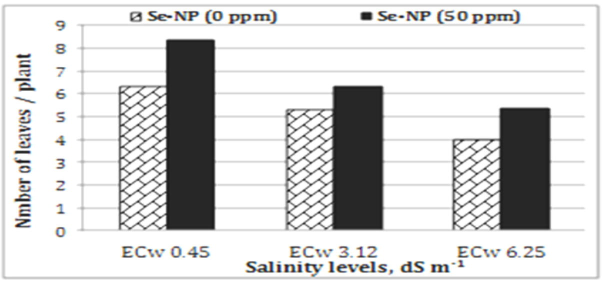

Fig. 2. Interaction between salinity levels and selenium nanoparticle (Se-NPs) spraying on number of leaves/plant of coriander plants.

The effectiveness of (Se-NP1) treatment was clear in leaves fresh and dry weight of coriander plants under non-saline and saline conditions compared to (Se-NP0) treatment (Table 3 and Figs. 3 & 4). The (Se-NP1) treatment showed non-significant increase in leaves fresh and dry weight compared to (Se-NP0) grown under all salinity levels. Nano-Se spraying was beneficial for salt-exposed plants only when Se was applied at low concentration, since under irrigation with salinity water with application of (Se-NP1), all vegetative growth parameters increased compared to untreated plants.

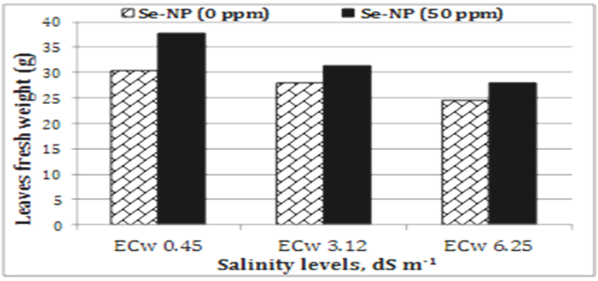

Fig. 3. Interaction between salinity levels and selenium nanoparticle (Se-NPs) spraying on leaves fresh weight of coriander plants.

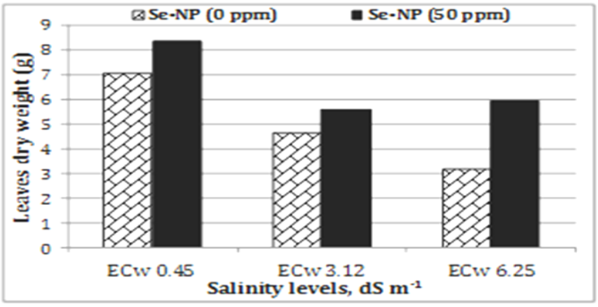

Fig. 4. Interaction between salinity levels and selenium nanoparticle (Se-NPs) spraying on leaves dry weight of coriander plants.

The exogenous application of selenium nanoparticle has been shown to alleviate the negative effects and decrease the deleterious effect of increase salinity in various plant species. This is due to the positive role of Se in several physiological and biochemical mechanisms (Djanaguiraman *et al.*, 2005). It can protect the plant cell from oxidative damage by regulating the antioxidant defense system in the chloroplasts, which was associated with the improvement of the photochemical efficiency of PSII, help maintain plant water homeostasis under osmotic stress, inhibited lipid peroxidation process thus protecting the cell membrane and enhancing their stability, reduce in content of CLions in shoot issues and improved accumulation of free proline (Hawrylak-Nowak, 2009; Hasanuzzaman *et al.*, 2013; Diao *et al.*, 2014 and Jiang *et al.*, 2017).

Total chlorophyll content (SPAD reading) in leaves of coriander plants showed also a similar trend that (Se-NP1) treatment under salinity stress improved that all previous parameter compared to (Se-NP0) (Table 3). Under saline conditions (6.25 dS m^{-1}), the amount of total chlorophyll (6.66) was obtained by foliar application of (Se-NP1) compared to distilled water added to the spray as a control 0 ppm (Se-NP0) (5.86), by increasing of 13.65%. On the other hand, the lowest amount of all vegetative growth characteristics such as plant height, number of leaves per plant as well as leaves fresh and dry weight and total chlorophyll content of coriander plants were recorded by (Se-NP0) under all salinity levels. Generally, (Se-NP1) treatment showed the best effectiveness in mitigating salinity effect on those previous parameters of coriander plants compared to (Se-NP0) treatment. Foliar spray with low concentration of Se can help maintains the integrity of cell membranes in chloroplasts in leaf tissue exposed to salinity, enhanced photosynthesis, stimulated antioxidative system and thus increases the accumulation of photosynthetic pigments in leaves (Diao *et al.*, 2014 and Boghdady *et al.*, 2017).

Data in Table 4 showed the effect of irrigation with saline water on N concentration in leaves of coriander under the exogenous application of selenium nanoparticle, compared with the control (without any treatments) during the studied season. Nitrogen concentration in leaves recorded non-significant increase with (Se-NP1) application under all salinity levels compared to (Se-NP0) without selenium nanoparticle foliar application. Regarding the interaction between irrigation water salinity and Se-NPs application, (Se-NP1) application with all saline water treatments generally gave the highest value of N concentration in plant leaves compared to (Se-NP0). Increasing salinity from 0.45, 3.12 to 6.25 dS m^{-1} treatments with the application of (Se-NP1) resulted in significant increase N concentration in coriander leaves by 88.49, 185.71 and 204.00 %, respectively. These results are agreement with Abd El-Nasser *et al.*, (2010) who reported that Se had a high ability to induce antioxidant and hormone balance in the plant. Yassen *et al.*, (2011) found that foliar application of Se on potato plants increased nitrogen, phosphorous, potassium concentrations and protein contents in the yield of tubers.

The obtained results in Fig. 5 showed that N uptake by coriander grown in sandy soil were significantly affected by water salinity. Uptake of N was reduced by increasing salinity irrigation water (Fig. 5). The maximum N uptake value by leaves (15.78 g/plant) was found in sandy soil under 0.45 dS m^{-1} level and the lower was observed at the highest water salinity level 6.25 dS m^{-1}. This is because higher salinity can cause nutrient imbalances and may affect protein synthesis (Abou El-Nour, 2005). On the other hands, foliar application of (Se-NP1) increased non-significant nitrogen (N) uptake.

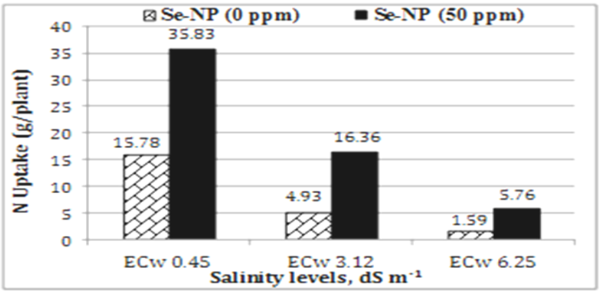

Fig. 5. Interaction between salinity levels and selenium nanoparticle (Se-NPs) spraying on N uptake of coriander plants.

The results presented in Table 4 and Figs. 6 & 7 showed that among the different treatments, interaction between irrigation with all salinity water levels and Se-NPs application resulted in non-significant effect in K^+ and Na^+ concentrations coriander leaves ($P < 0.05$). Under irrigation with non-saline and saline water without Se-NPs application, potassium concentration reduced in leaves, whereas Na^+ content increased (Table 4 and Figs. 6 & 7). On the other hand, under saline and non-saline conditions by application of Se-NP1, potassium concentration was increased in leaves, whereas sodium concentration decreased compared to (Se-NP0) (Table 4 and Figs. 6 & 7). These results indicate that there was a competition between sodium and potassium regarding their uptake. Addition of Se-NP1 significantly decreased sodium concentration in leaves of coriander plants (Table 4 and Fig. 7). Presence of this element (Se-NPs) in saline conditions mitigates the negative impacts of sodium on potassium uptake. The noticeable reduction in sodium accumulation can represent a mechanism that Se increases the binding of sodium to the cell wall to avoid sodium toxicity in the cytoplasm (Hawrylak-Nowak, 2009 and Chaoqiang *et al.*, 2017).

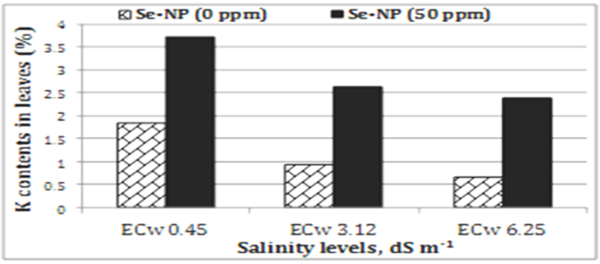

Fig. 6. Interaction between salinity levels and selenium nanoparticle (Se-NPs) spraying on K% in leaves of coriander plants.

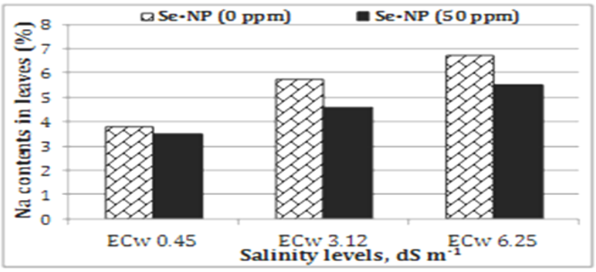

Fig. 7. Interaction between salinity levels and selenium nanoparticle (Se-NPs) spraying on Na% in leaves of coriander plants.

Data in Table 4 and Fig. 8 & 9 showed values of Na/K ratio and K/Na ratio in leaves of coriander as an important indicator on salt stress. Values of Na/K ratio increased as the salinity level increased without addition of selenium nanoparticle (Se-NP0), but decreased with (Se-NP1) under all salinity levels (Table 4 and Fig. 8). The (Se-NP1) treatment showed non-significant decrease in Na/K ratio compared to (Se-NP0) grown under the highest salinity level S2 (6.25 dS m^{-1}), as It decreased by 35.35%.

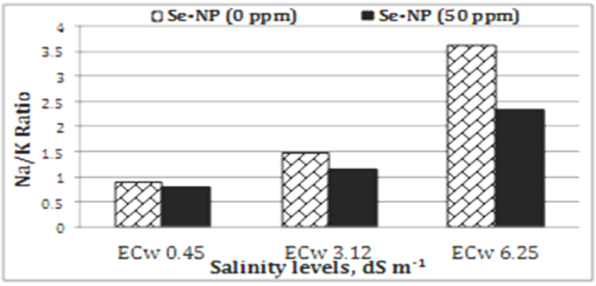

Fig. 8. Interaction between salinity levels and selenium nanoparticle (Se-NPs) spraying on Na/K ratio in leaves of coriander plants.

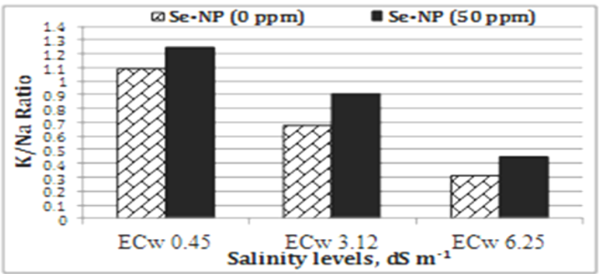

Fig. 9. Interaction between salinity levels and selenium nanoparticle (Se-NPs) on K/Na ratio in leaves of coriander plants.

On the contrary, K/Na ratio decreased with increasing salinity of irrigation water without addition of Nano-selenium but increased generally with application of (Se-NP1) under all salinity levels (Table 4 and Fig. 9). Regarding the interaction between irrigation water salinity and Se-NP1 treatment, the treatment of EC_w 6.25 dS m^{-1} without selenium nanoparticle (Se-NP0) gave the lowest value of K/Na ratio (0.31), the treatment of (Se-NP1) under irrigation with tap water being the highest one (1.25). The increase in K/Na ratio with 6.25 dS m^{-1} treatment under (Se-NP1) foliar application was insignificant compared to (Se-NP0) with 45.16 % reduction (Fig. 9). These results are agreement with Akinci *et al.,* (2004) who found that reduce in the K/Na ratio and increased sodium in several eggplant varieties with increasing NaCl in the solution. The reduced Na/K ratio observed in selenium nanoparticle application may be due to Se adapted photosynthesis and metabolism occurred in leaf tissues altered source/sink relationships and root system, thereby decreasing Na/K ratio, regulating uptake and redistribution of important essential elements which in turn relieves salinity signs. Lower accumulation of sodium in leaves rather than improved potassium accumulation is the main mechanism contributing to higher salt tolerance in the coriander plants tested (Hawrylak-Nowak, 2009).

Figure 10 show that salinity stress caused non-significant decreased K uptake by leaves of coriander. Saqib *et al.,* (2004) found that excessive sodium content in root growth environment, in saline conditions lead to reduction of K uptake due to the antagonism of sodium and potassium at sorption sites in the roots. On the other hand, Se increases in K uptake under salt stress. Under saline conditions, Se mitigates the adverse impact of sodium on potassium uptake. These results are agreement with (Astaneh *et al.*, 2018).

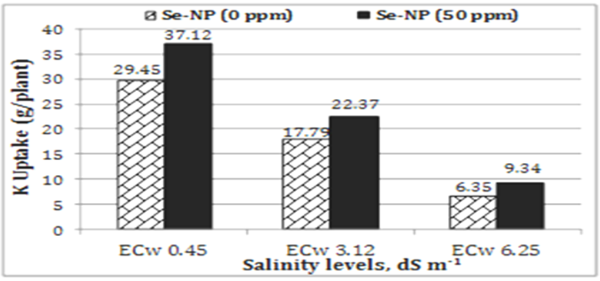

Fig. 10. Interaction between salinity levels and selenium nanoparticle (Se-NPs) spraying on K uptake of coriander plants.

Generally, selenium nanoparticle application by foliar spraying resulted in higher contents of dry matter, N and K in the coriander plants under saline stress which has a positive impact on the permeability and activity the cellular membrane, redistribution of some essential elements and it regulated uptake. These results are consistent with the work of (Hawrylak-Nowak, 2008; Feng *et al.,* 2013; Abul-Soud and Abd-Elrahman 2016; Castillo-Godina *et al.,* 2016 and Shalaby *et al.*, 2017).

CONCLUSION

It could be concluded that, enhancement in coriander growth, total chlorophyll content and mineral concentrations of plants exposed to salt conditions under the influence spraying of Nano-Se may be due to reduce Na concentrations in leaves and consequently reduce the Na/K ratio, osmotic adjustment, ion balance and antioxidant enzymes activities. Therefore, spraying with selenium nanoparticle can reduce the saline effects caused by irrigation with seawater and have a positive effect on coriander plant, which leads to the possibility of planting coriander under the dilute concentrations of seawater.

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مساهمة النانوسيلينيوم في تخفيف الاثار السلبية للملوحة علي نبات الكزبرة

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النانوتكنولوجي هو أحد المجالات العلمية التي تفتح افاق كبيرة للتطبيق في مختلف المجالات ، وخاصة التكنولوجيا الحيوية الزراعية. السلينيوم (Se) هوعنصر نادر ضروري للإنسان والحيوان ، ويبدو أنه عنصر مفيد للعديد من النباتات. هناك العديد من الأدلة تظهر أن التركيزات المنخفضة من السيلينيوم (Se) قد تزيد من تحمل النباتات للاجهادات البيئية. لهذا الغرض ، أجريت تجربة أصص في المزرعة التجريبية لكلية الزراعة ، جامعة المنصورة ، محافظة الدقهلية ، مصر ، خلال فصل الربيع عام 2016 ، لدراسة التخفيف المحتمل للأثار السلبية للري بالمياه المالحه عن طريق الرش الورقي بالسيلينيوم في شكل جسيمات نانوية للسيلينيوم (Se-NPs) بتركيزين (صفر و 50 جزء في المليون) على نبات الكزبرة المزروع في تربة رملية والتي تروي بتركيزات مختلفة من المياه المالحةS1 (3.12 ديسيمنز متر$^{-1}$)، S2 (6.25 ديسيمنز متر$^{-1}$)، وماء الصنبور ككنترول S0 (0.45 ديسيمنز متر$^{-1}$) وقد أجريت هذه الدراسة التجريبية باستخدام تصميم قطع منشقة مرة واحدة في ثلاثة مكررات. أظهرت الملوحة الآثار السلبية على صفات نمو النبات المختلفة ، محتوى الكلوروفيل الكلي. لوحظ أن الرش بالنانو سيلينيوم (Se-NP1) بتركيز 50 جزء في المليون أظهر أفضل الآثار على النمو الخضري ومحتوي الكلوروفيل الكلي في نباتات الكزبرة تحت مستويات الملوحة المختلفة لمياه الري. أدت زيادة الملوحة إلى نقص محتوي النيتروجين والبوتاسيوم في أوراق نباتات الكزبرة ، ولكن زاد محتوي الصوديوم بسبب التنافس بينه وبين البوتاسيوم؛ وعلى الرغم من ذلك ، فقد ازداد محتوي أوراق نباتات الكزبرة من النيتروجين والبوتاسيوم مع الرش بالجسيمات النانوية للسيلينيوم (Se-NP1) بمعدل 50 جزء في المليون لتكون هي التركيزات الأعلى مقارنة بمحتواها في النباتات المعاملة بالرش بالماء المقطر ككنترول صفر جزء في المليون سيلينيوم (Se-NP0). ارتفعت قيم نسبة Na / K في أوراق الكزبرة مع زيادة مستويات الملوحة بينما انخفضت نسبة K / Na. على العكس من ذلك، انخفضت قيم نسبة Na / Kمع الرش بالجسيمات النانوية للسيلينيوم (Se-NP1) بمعدل 50 جزءًا في المليون ، ولكن نسبة K / Na زادت مع نفس معدل الرش بالجسيمات النانوية للسيلينيوم (Se-NP1) تحت جميع مستويات الملوحة. وخلصت الدراسة إلى أن الرش الورقي للجسيمات النانوية للسيلينيوم يمكن أن يخفف من أضرار الإجهاد الملحي على نباتات الكزبرة كما أنه يؤدي الي زيادة في تركيزات البوتاسيوم وانخفاض في تركيزات Na تحت الإجهاد الملحي.