Original Research Article

Foliar selenium application to improve the tolerance of eggplant grown under salinity stress conditions

Authors' contributions

Both researchers have contributed in all parts of research equally.

ABSTRACT

Sea level rise is one of the most risky climate change impacts under Egyptian conditions to increase the salinity of northern Delta. Increasing the tolerance for salinity in current and future crops is strongly desirable. The current experiment was carried out in the experimental station at Agriculture Research Center, Egypt, during the summer seasons of 2014 and 2015, to evaluate the effect of selenium foliar applications (0, 5, 10, 20, 30 µM Na_2SeO_3) on eggplant grown on a sandy soil and irrigated with different concentrations of saline water (0, 30, 60, 120 mM NaCl). The results showed that the Se supplement with 20 µM showed the best effects on vegetative growth and yield of eggplants under different salinity levels of irrigation water. Increasing salinity resulted in increasing N and P contents in the leaves and fruits of eggplant, but K decreased as a result of some sort of antagonism with Na; in spite of that, N, P and K contents in leaves and fruits increased with increasing Se supplements up to 20 µM to be at higher concentrations then decreased. Regarding K/Na ratio in leaves, the treatment of EC_e 13.5 dS m^{-1} without Se supplements gave the lowest value (0.52); treatment of Se 30 µM under 0 mM NaCl irrigation water gave the highest one (1.71). Also, chlorophyll contents in plant leaves increased with increasing salinity level of irrigation water, but decreased with increasing Se supplements. Regarding the proline contents in fresh leaves, the treatment of EC_e 13.5 dS m^{-1} without Se supplements gave the highest value (51 mg g^{-1}), but the lowest one (30.9 mg g^{-1}) was observed with control treatment.

Keywords: *Sea level rise, Salinity stress, Selenium supplements, Eggplant, proline content.*

1. INTRODUCTION

Egypt is very dependent on natural resources that are vulnerable to climate change. A large portion of the arable land in Nile Delta is particularly exposed to sea level rise. Nicholls et al. [1] estimated a mean value of 1 meter global sea level rise by the year of 2100 which would give rise to a 0.37 meter sea level rise at the Nile delta. This, combined with a non climate induced subsidence of the Nile Delta of 0.38 meters would result in the movement of the shoreline to the current 0.75 meter contour and a 5 percent loss of Egyptian agricultural land by the year of 2060 mainly at the coastal area of Nile Delta. El-Raey et al. [2] suggested land losses of 12 to 15 percent of Egypt's current arable land for a one meter sea level rise. Due to salinization and seawater intrusion, the agricultural activities will be difficult below an elevation of 1 meter.

Salinity is an abiotic stress to limit plant growth [3], and is becoming a serious agricultural problem, especially at arid and semi-arid zones, where 20-30% of the land is seriously damaged by salt [4]. High salt concentrations in the soil drastically reduce the yields of a variety of plants worldwide [5]. However, in Egypt, the saline and drainage water is one of the main waster resources for agriculture, which caused degradation of the soil and adversely affect on plant production [6].

Eggplant (*Solanum melongena* L.) is a traditional vegetable crop in many tropical, subtropical and Mediterranean countries. Eggplant is classified as a salt moderately sensitive vegetable [7]; Bresler et al. [8], on the other hand, classified it as salt sensitive vegetable. This difference in its tolerance classification could be related to differences in used varieties or cultivars and study environmental conditions. Unlukara et al. [9] found a threshold value of salinity lower than 1.5 dS m^{-1} and a slope value of 4.4% on eggplant. Such authors also reported a decrease in plant water consumption due to salinity with a decrease slope of 2.1%.

Proline could accumulate in many plant species under a broad range of stress such as water shortage, salinity, extreme temperatures and high light intensity. Proline is considered to be a compatible solute. It protects folded protein structures against denaturation, stabilizes cell membranes by interacting with phospholipids, functions as a hydroxyl radical scavenger and serves as an energy and nitrogen source. However, the contribution of proline to osmotic adjustment and tolerance of plants exposed to unfavourable environmental conditions is still controversial [10]. The metabolic effects of osmolyte accumulation may, however, be equal or even more important than their role in osmotic adjustment, since stress-regulated changes in proline synthesis and degradation may also affect expression of other genes, ensuring that the genetic response to stress is appropriate to the prevailing environmental stress conditions [11]. Proline could accumulate in leaves and roots to protect against the osmotic pressure under salt stress [12].

Although selenium (Se) is not considered an essential nutrient for plant growth, it is a vital element for human and animal nutrition in trace amounts [13]. However, a diet containing 1 mg Se kg^{-1} dry weight (DW) may lead to chronic Se poisoning in humans and animals, and one-time ingestion of plant material containing 1,000 mg Se kg^{-1} DW can lead to acute Se poisoning and death [14] as it is shown from the conducted experiments (becoming toxic for human and animals fed with these plants) . Selenium is a constituent of seleno-proteins, many of which have important functions, including antioxidant protection, energy metabolism and redox regulation during transcription and gene expression [15]. Selenium supplementation to plants enhance the production and quality of edible plant products, by increasing antioxidant activity of plants, as shown in tea leaves [16], and rice [17]. Foliar application of selenium was shown to be several times more efficient than application in soil fertilizers [18], but strongly dependent on spraying conditions. Also, [19] showed that foliar spray gave a high recovery. However, [20] found foliar application to be less efficient than application to soil at planting.

Thus, the main objective of this study is to evaluate the protective effect by foliar application of selenium supplements (0, 5, 10, 20, 30 µM Na_2SeO_3) on eggplant (vegetative growth, yield, proline and some elements content) grown on a sandy soil and irrigated with different concentrations of saline water (0, 30, 60, 120 mM NaCl).

2. MATERIALS AND METHODS

The current experiment was carried out in the experimental station at the Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center (ARC), Egypt, during the summer seasons of 2014 and 2015. The climatic data at Dokki site during the studied seasons of 2014 and 2015 were shown in Figure 1; these data collected from automated weather station allocated at the site.

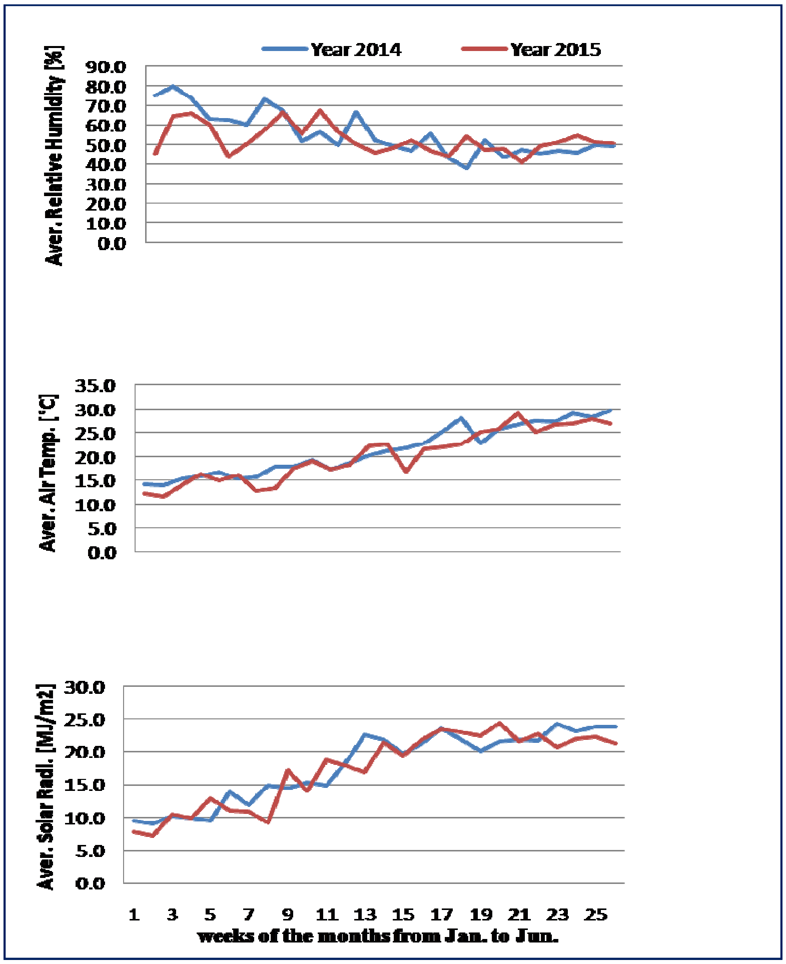

Figure 1. Climatic data at Dokki site during the studied seasons of 2014 and 2015

2.1 Plant materials

Eggplant (*Solanum melongena* L. cv. Baladi) seeds were sown on 20th and 18th January of 2014 and 2015, respectively, in polystyrene trays. After the fifth true leaf stage (26th and 23th February, respectively), the eggplant seedlings were transplanted into bedding system of sandy soil.

2.2 System materials

Open system of sandy soil from Siwa oasis - Matroh governorate, ***Typic Torripsamments***, was used and the physical and chemical characteristics of the soil were listed in Table 1. The system bed performed of bricks on cement base (60cm width x 25cm height x 7.5m length). The final plant spacing was 50cm in the row and 40cm in-between. Black polyethylene (1mm) was used to create the main gully which was filled by the soil. A layer of 2-3cm of gravel takes a place in the bottom of gully bin for leaching the drainage water easily.

No organic matter or manure was applied to the soil to avoid the effect of organic matter on the salinity impacts under the investigated different treatments.

Different salinity irrigation water levels were pumped via submersible pump (110 watt). A plastic tank 120 L (one per each bin system) and submersible pump (one per each tank) were used to pump the nutrient solution and different salinity irrigation water levels via polyethylene pipe (16mm) with 2 liters per hour dripper. The nutrient solution [21] was adjusted by using EC meter to the required level (2.5 dS m^{-1}) in all treatments. The fertigation was programmed to work 2 - 4 times/day and the duration of irrigation time depended upon the season.

Table 1. Some physical and chemical characteristics of the studied soil

Particle size distribution, %		Soluble cations, meq L^{-1}	
Sand	97.5	Ca^{2+}	3.40
Silt	1.50	Mg^{2+}	3.50
Clay	1.00	Na^{+}	1.50
Texture class	Sandy	K^{+}	0.60
$CaCO_3$, %	5.80	Soluble anions, meq L^{-1}	
OM, %	0.05	CO_3^{2-}	0.00
CEC, cmolc kg^{-1}	9.30	HCO_3^{2-}	3.20
pH (1:2.5 soil:water suspension)	8.19	Cl^{-}	4.10
ECe, dS m^{-1}	0.90	SO_4^{2-}	1.70

2.3 Investigated treatments

The application of different treatments, after 2 weeks of transferring the eggplant seedlings, was applied. The study investigated the effects of different selenium (Se) concentrations (0, 5, 10, 20, 30 µM Na_2SeO_3) as foliar application on eggplant cultivated under different saline irrigation water levels (0, 30, 60, 120 mM NaCl) on the studied soil. The EC_w concentrations and Se supplements were applied according to [22, 23, 24, 25].

Eggplants were harvested on 26th and 17th June 2014 and 2015, respectively~~,~~. The collected samples were dried at 70°C in an air forced oven for 48hrs, and then digested by H_2SO_4/H_2O_2 mixture according to the method described by [26] and kept for the elements determination.

2.4 Experiment design

The experimental design was a split plot with 3 replicates. Each experimental plot contained 10 plants. The saline irrigation levels were assigned as main-plots and Se concentrations as sub-plots as Figure 2 illustrates.

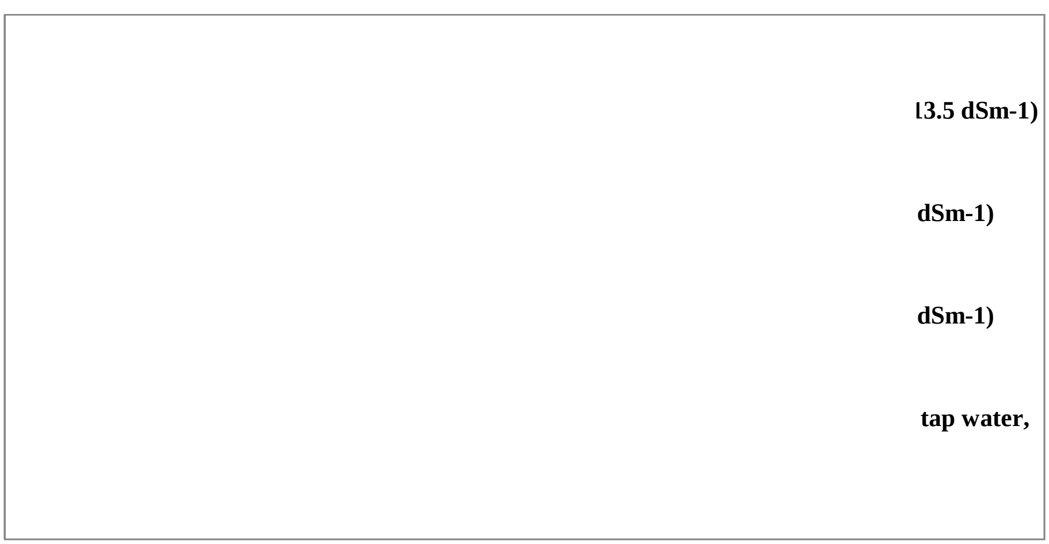

Figure 2. The layout of experimental design

2.5 Measurements

The vegetative and yield characteristics beside the chemical analysis of eggplants were measured as follows:

- Plant height (cm), before starting the flowering stage
- Number of leaves per plant, before starting the flowering stage
- Fresh weight of total fruits per plant (g/plant)
- Number of fruits per plant
- Chlorophyll content in leaves, SPAD:

  Total chlorophyll of the fifth mature leaf from top was measured using Minolta chlorophyll meter Spad-501.
- Proline content in 0.5 g of fresh leaves, at harvest:

Proline content can increase upon exposure of plants to drought, salinity, cold, heavy metals, or certain pathogens. Thus, determination of proline levels is a useful assay to monitor physiological status and to assess stress tolerance of higher plants. Proline content was determined according to the method of [27] modified by [28], and was expressed as mg g^{-1} fresh weight (FW).

- Total N, P, K and Na contents in leaves and fruits, at harvest:

Total nitrogen in plant was determined using Kjeldahl method according to the procedure described by [26]; total phosphorus was determined using spectrophotometer according to [29] and both total potassium and sodium in plant was determined using Flame photometer as described by [30].

Statistical analysis was performed using the analysis of variance adopting a SAS software package [31]. Significance among treatments was evaluated using Duncan's approach ($P \leq 0.05$).

3. RESULTS AND DISCUSSION

3.1 Vegetative growth and yield of eggplants

Data in Table 2 showed that the plant height was different under the studied treatments, with decreasing along increasing irrigation water salinity. However, the plant height increased with increasing Se supplements. Regarding the interaction between irrigation water salinity and Se supplements, the irrigation with tap water and Se 20 µM were found to give the highest plant; the irrigation water with EC_e 13.5 dSm^{-1} and Se 0 µM gave the lowest one. Also, number of leaves per plant went hand by hand with the previous findings on the plant height.

The total fruit fresh weight and the number of fruits per plant (Table 2) were agreed with the findings on the plant height and number of leaves per plant. Generally, the Se supplement with 20 µM showed the best effects on vegetative growth and yield of eggplants under different irrigation water salinity treatments, with higher effect for irrigation with tap water and decreased with increasing salinity in irrigation water. These findings may be due to: (1) Se 20 µM is suitable to counter act salinity problems inside the plant. (2) The vegetative growth and yield of eggplants decreased with increasing salinity in irrigation water. Kabata-Pendias and Pendias [32] mentioned that the mean Se content in clay soils was 0.29 mg kg^{-1} and in coarse mineral soils 0.17 mg kg^{-1}, and in plant Se at 10 ppm DW is considered as phytotoxic. Yassen et al. [25] reported that Se interaction with plants depended on its concentration. At lower rates, Se stimulated growth of ryegrass seedlings, while at high doses it acted as pro-oxidant reducing yields and inducing metabolic disturbances. Terry et al. [13] found that there was a small decrease in shoot accumulation of Se with increasing salt level. Unlukara et al. [9] added that vegetative dry weight of the eggplants decreased with increasing soil salinity and with fruit yield being more sensitive.

Table 2. Effect of irrigation water salinity and selenium supplements on average vegetative growth and yield of eggplants during the two studied seasons

Salinity levels, dS m^{-1} (A)	Selenium concentrations, µM (B)					Mean (A)
	Se 0	Se 5	Se 10	Se 20	Se 30	
			Plant height, cm			
EC_w= 0.75	55.2 g	59.7 d	62.1 c	71.7 a	65.0 b	**62.7 A**
EC_w= 3	52.3 h	57.0 f	61.2 c	64.7 b	61.3 c	**59.3 B**
EC_w= 7	45.3 j	49.7 i	58.0 e	60.3 cd	58.0 e	**54.3 C**
EC_w= 13.5	35.0 l	43.7 k	45.7 j	56.0 g	52.7 h	**46.6 D**
Mean (B)	**47.0 D**	**52.5 C**	**56.7 B**	**63.2 A**	**59.3 B**	
			No. of leaves/plant			
EC_w= 0.75	68.3 i	72.8 h	84.0 f	128 a	113 b	**93.2 A**
EC_w= 3	62.7 k	72.0 h	76.7 g	98.3 d	101 c	**82.1 B**
EC_w= 7	60.3 l	63.7 k	67.7 i	100 c	87.0 e	**75.7 C**
EC_w= 13.5	59.3 l	63.3 k	66.3 j	83.0 f	72.3 h	**68.9 D**
Mean (B)	**62.7 E**	**68.0 D**	**73.7 C**	**102 A**	**93.3 B**	
			Fruit fresh weight, g/plant			
EC_w= 0.75	1149 e	1222 d	1342 c	1686 a	1475 b	**1375 A**
EC_w= 3	748 h	880 g	1019 f	1125 e	1036 f	**962 B**
EC_w= 7	517 k	597 j	675 i	850 g	734 h	**675 C**
EC_w= 13.5	356 m	433 l	513 k	573 jk	544 k	**484 D**
Mean (B)	**693 D**	**783 C**	**887 B**	**1058 A**	**947 B**	
			No. of fruits/plant			
EC_w= 0.75	19.5 d	20.0 d	21.0 c	24.4 a	22.0 b	**21.4 A**
EC_w= 3	14.7 h	15.7 g	17.3 f	18.4 e	17.0 f	**16.6 B**
EC_w= 7	11.7 ij	11.8 i	12.3 i	14.7 h	13.8 h	**12.8 C**
EC_w= 13.5	9.15 k	9.60 k	10.8 j	10.8 j	11.2 j	**10.3 D**
Mean (B)	**13.8 C**	**14.3 C**	**15.3 B**	**17.1 A**	**16.0 B**	

Each value is the mean of 6 replications

This is a factorial experiment from two factors: salinity levels (A), selenium concentrations (B) in a spilt plot design, letters A B C D among the main factors, letters a b c d … among the interaction between the two factors (A×B), and different letters means significant.

3.2 N, P and K contents in leaves and fruits of eggplants

Data in Table 3 showed the effect of irrigation with saline water on N, P and K contents in leaves of eggplants under Se supplements, compared with the control (without any treatments). Increasing salinity resulted in increased N and P contents in the leaves, but decreased K. Almost, N, P and K contents in leaves increased with increasing Se supplements up to 20 µM then decreased with higher concentrations. Regarding the interaction between irrigation water salinity and Se supplements, Se 20 µM with all saline water treatments generally gave the highest value of N, P and K contents in plant leaves; almost all saline water treatments without Se supplement gave the lowest ones.

Table 3. Effect of irrigation water salinity and selenium supplements on average N, P and K contents of eggplant leaves during the two studied seasons

Salinity levels, dS m^{-1} (A)	Selenium concentrations, µM (B)					Mean (A)
	Se 0	Se 5	Se 10	Se 20	Se 30	
			%N			
EC_w= 0.75	2.80 l	3.36 k	3.50 j	4.34 e	3.78 h	**3.56 D**
EC_w= 3	3.78 h	3.76 h	3.64 i	4.48 d	3.99 g	**3.93 C**
EC_w= 7	4.48 d	4.85 c	4.22 f	4.90 c	4.01 g	**4.49 B**
EC_w= 13.5	5.88 a	4.94 c	4.90 c	5.32 b	4.20 f	**5.05 A**
Mean (B)	**4.24 B**	**4.23 B**	**4.07 C**	**4.76 A**	**4.00 C**	
			%P			
EC_w= 0.75	0.61 h	0.62 h	0.65 g	0.70 f	0.65 g	**0.65 C**
EC_w= 3	0.64 g	0.67 f	0.69 f	0.75 e	0.68 f	**0.69 C**
EC_w= 7	0.69 f	0.74 e	0.79 d	0.82 c	0.76 e	**0.76 B**
EC_w= 13.5	0.81 c	0.86 b	0.87 b	0.93 a	0.86 b	**0.87 A**
Mean (B)	**0.69 D**	**0.72 C**	**0.75 B**	**0.80 A**	**0.74 B**	
			%K			
EC_w= 0.75	1.62 e	1.81 c	1.94 b	1.84 c	1.70 d	**1.78 A**
EC_w= 3	1.50 g	1.77 c	1.79 c	1.62 e	1.65 e	**1.67 B**
EC_w= 7	1.26 i	1.57 f	1.58 f	2.20 a	1.58 f	**1.64 B**
EC_w= 13.5	1.09 k	1.16 j	1.23 i	1.40 h	1.53 g	**1.28 C**
Mean (B)	**1.37 D**	**1.58 C**	**1.63 B**	**1.77 A**	**1.62 B**	

Each value is the mean of 6 replications

This is a factorial experiment from two factors: salinity levels (A), selenium concentrations (B) in a spilt plot design, letters A B C D among the main factors, letters a b c d … among the interaction between the two factors (A×B), and different letters means significant.

Regarding the fruits of eggplant, data in Table 4 showed the effect of irrigation water salinity on N, P and K contents under Se supplements which have similar trends with those of plant leaves. Increasing N and P contents in leaves and fruits of eggplant 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 [33]. Also, they reported that Se had a high ability to induce antioxidant and hormon balance in the plant. Yassen et al. [25] found that foliar application of Se on potato plants increased % N, P, K and protein contents in the yield of tubers. Decreasing K content with increasing salinity of irrigation water, on the other hand, may be due to the increase of NaCl concentration; Na^+ content increased in leaves and fruits indicating that the eggplant (which has a glycophytic reaction) could not control uptake of Na^+ [34]. Kong et al. [15] reported that the major influences on Se uptake by plants were soil pH and salinity; Cl^- which inhibit uptake by affecting plant metabolism. In general, increasing N, P and K contents in leaves and fruits of eggplant by increasing foliar Se supplements under irrigation with saline water may be due to the role of Se in increasing antioxidant activity of the plant to face the stress.

Table 4. Effect of irrigation water salinity and selenium supplements on average N, P and K contents of eggplant fruits during the two studied seasons

Salinity levels, dS m^{-1} (A)	Selenium concentrations, µM (B)					Mean (A)
	Se 0	Se 5	Se 10	Se 20	Se 30	
%N						
EC_w= 0.75	2.38 k	2.41 k	2.52 j	2.55 j	2.94 g	**2.56 C**
EC_w= 3	2.40 k	2.57 i	2.68 h	3.10 f	3.02 j	**2.75 C**
EC_w= 7	3.50 d	3.08 f	3.06 f	3.22 e	3.61 c	**3.29 B**
EC_w= 13.5	3.96 a	3.94 b	3.20 e	3.50 d	3.94 b	**3.71 A**
Mean (B)	**3.06 B**	**3.00 C**	**2.87 D**	**3.09 B**	**3.38 A**	
%P						
EC_w= 0.75	0.48 i	0.51 h	0.54 g	0.57 f	0.51 h	**0.52 C**
EC_w= 3	0.55 g	0.60 e	0.62 e	0.68 c	0.65 d	**0.62 C**
EC_w= 7	0.61 e	0.65 d	0.68 c	0.73 b	0.69 c	**0.67 B**
EC_w= 13.5	0.67 c	0.72 b	0.73 b	0.79 a	0.72 b	**0.73 A**
Mean (B)	**0.58 D**	**0.62 C**	**0.64 B**	**0.69 A**	**0.64 B**	
%K						
EC_w= 0.75	1.16 i	1.19 i	1.24 g	1.60 b	1.57 b	**1.35 A**
EC_w= 3	1.11 i	1.14 i	1.23 hi	1.52 c	1.52 c	**1.31 B**
EC_w= 7	1.06 j	1.16 i	1.21 i	1.67 a	1.48 d	**1.32 B**
EC_w= 13.5	0.99 k	1.06 j	1.17 i	1.33 f	1.41 e	**1.19 C**
Mean (B)	**1.08 D**	**1.14 C**	**1.21 B**	**1.53 A**	**1.50 A**	

Each value is the mean of 6 replications

This is a factorial experiment from two factors: salinity levels (A), selenium concentrations (B) in a spilt plot design, letters A B C D among the main factors, letters a b c d … among the interaction between the two factors (A×B), and different letters means significant.

3.3 Some stress markers in leaves of eggplants

Data in Table 5 showed that chlorophyll content in plant leaves increased with increasing salinity of irrigation water, but decreased with increasing Se supplements, significant decrease in the treatment of Se 20 µM being found under irrigating with tap water. Increasing chlorophyll content in plant leaves indicates that plant suffered from saline stress compared to the control (irrigation with tap water). It may be due to a reduction in extension growth under saline stress, increased leaf thickness and its color became darker, which gave high readings with SPAD. Khattab [35] studied the metabolic and oxidative responses associated with exposure of rocket plants (*Eruca sativa* L.) to different levels of Se (0, 5, 10, 100, 1000, 2000 and 3000 µM of sodium selenate) for 10 days. He found that Se up to 10 µM enhanced the growth and levels of chlorophylls, sugar and amino acids. However, high levels of Se (100 µM and up) exert toxic effects. Germ et al. [36] reported that Se protected chloroplasts during stress.

Regarding the proline content in plant fresh leaves, data also showed that proline content increased with increasing salinity of irrigation water (indication of stress), but decreased with increasing Se supplements compared to the control. The treatment of EC_e 13.5 dS m^{-1} without Se supplements gave the highest value of proline content (51 mg g^{-1}), control treatment being the lowest one (30.9 mg g^{-1}). These findings agreed with those obtained by [33] regarding the effect of Se on proline content in cucumber seedlings grown under saline conditions. They explained the accumulation of proline in plant under the stress by increasing biosynthesis or inhibition of proline degradation. Nowak [22] reported that Se enhanced the salt tolerance of cucumber seedlings by protecting the cell membrane against lipid peroxidation. However, he explained the growth-promoting effect of low Se concentrations (5 and 10 µM) under saline conditions due to the antioxidative activity of Se, increase in proline accumulation and/or decrease in content of Cl^- ions in the shoots tissues.

Table 5. Effect of irrigation water salinity and selenium supplements on some stress markers in eggplant leaves during the two studied seasons

Salinity levels, dS m^{-1} (A)	Selenium concentrations, µM (B)					Mean (A)
	Se 0	Se 5	Se 10	Se 20	Se 30	
Chlorophyll content, SPAAD						
EC_w= 0.75	51.3 l	53.5 k	54.2 j	55.2 i	55.1 i	**53.9 C**
EC_w= 3	61.2 d	59.3 f	56.4 i	55.3 i	57.7 h	**58.0 C**
EC_w= 7	62.3 b	60.7 e	60.5 e	57.7 h	58.9 g	**60.0 B**
EC_w= 13.5	65.4 a	62.5 b	60.3 e	59.5 f	61.7 c	**61.9 A**
Mean (B)	**60.1 A**	**59.0 B**	**57.9 B**	**56.9 C**	**58.4 B**	
Proline content, mg g^{-1} FW						
EC_w= 0.75	30.9 n	32.3 m	36.0 l	36.3 k	36.5 j	**34.4 D**
EC_w= 3	45.3 g	42.1 h	40.1 i	45.3 g	45.5 f	**43.7 C**
EC_w= 7	47.7 b	45.7 e	45.4 g	45.7 e	47.4 c	**46.4 B**
EC_w= 13.5	51.0 a	50.9 a	45.9 d	47.4 c	47.8 b	**48.6 A**
Mean (B)	**43.7 B**	**42.8 C**	**41.9 D**	**43.7 B**	**44.3 A**	
K/Na ratio						
EC_w= 0.75	1.41 e	1.47 d	1.54 c	1.65 b	1.71 a	**1.56 A**
EC_w= 3	0.95 i	1.03 h	1.03 h	1.08 g	1.14 f	**1.05 B**
EC_w= 7	0.86 j	0.88 j	0.94 i	0.98 i	0.89 j	**0.91 C**
EC_w= 13.5	0.52 m	0.77 k	0.78 k	0.88 j	0.71 l	**0.73 D**
Mean (B)	**0.94 E**	**1.04 D**	**1.07 C**	**1.15 A**	**1.11 B**	

Each value is the mean of 6 replications

This is a factorial experiment from two factors: salinity levels (A), selenium concentrations (B) in a spilt plot design, letters A B C D among the main factors, letters a b c d … among the interaction between the two factors (A×B), and different letters means significant.

Data in Table 5 showed values of K/Na ratio in leaves of eggplants as an important indicator on salinity stress. K/Na ratio decreased with increasing salinity of irrigation water, but increased generally with increasing Se supplements. Regarding the interaction between irrigation water salinity and Se supplements, the treatment of EC_e 13.5 dS m^{-1} without Se supplements gave the lowest value of K/Na ratio (0.52), the treatment of Se 30 µM under irrigation with tap water being the highest one (1.71). Akinci et al. [34] reported that increasing NaCl in the solution led to a decrease in the K/Na ratio and increased Na in several eggplant varieties.

Germ et al. [36] reported that, in the senescing plants, the addition of Se strengthens the antioxidative capacity by preventing the reduction of tocopherol concentration and by enhancing superoxide dismutase (SOD) activity. Senescence processes are partly delayed due to enhanced antioxidation, which is associated with an increase of glutathione peroxidase (GPx) activity. In ryegrass (*Lolium perenne*) up to Se addition of 1.0 mg kg^{-1}, the decreased lipid peroxidation was connected with Se-induced increase in GPx activity [37]. It was shown that Se has the ability to regulate the water status of plants under conditions of drought [38], and that the protective effect of Se under drought stress conditions was achieved by increasing the water uptake capacity of the root system.

4. CONCLUSION

Under mitigation and adaption strategy of climate change impacts with the expected increase in the salinity of irrigation water especially in the Northern Egypt as a result of sea level rise, the present study recommends the applying selenium as foliar application at the concentration 10 - 20 µM to increase the tolerance of eggplants against salinity of irrigation water and to avoid salinity stress on the yield. These concentrations of Se supplementation present a promising potential for use in conditions of relatively high levels of NaCl in the irrigation water, due to its antioxidative activity. More work is required to investigate the effect of Se on different crops, the real role of it inside the plant in physiological stages and its content; besides studying the impact of sea level rise on the irrigation water and soil salinities.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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