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EFFECT OF SELENIUM ON SALT TOLERANCE IN MAIZE PLANTS

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ABSTRACT

Two pot experiments during the seasons of 2017 and 2018 were conducted to investigate the effect of Se as Na_2SeO_4 (2.5 and 5 µM) as foliar applications on growth, photosynthetic pigments, Na/K homeostasis and eventually the yield of maize plants grown under three different levels of salinity (0, 50 and 100 mM NaCl). The results indicated that Se at 2.5 µM recorded the highest significant values in leaves and stem dry weights, total grain yield plant^{-1} and grain filling as indicated by the weight of 100 kernels; As well as, Chl a, Chl b and K concentrations. On contrary, there was a significant decrease in Na concentration and Na/K ratio. Additionally, carotenoids did not reveal any significant changes between Se-treated plants and the untreated ones.
Key words: Zea mays, selenium, salinity, pigments, ionic balance and yield.

INTRODUCTION

Salinity is considered one of the most environmental factors that drastically restrict plant growth and productivity (Dash and Panda, 2001; Schleiff, 2008). It can accelerate senescence, leaf abscission and plant death (Allu *et al.*, 2014; Sade *et al.*, 2017). Additionally, salt stress can negatively affect photosynthesis (Munns and Tester, 2008; Hniličková *et al.*, 2017), water absorption (Munns, 2002), nutrient balance (Munns, 2005) and hormone metabolism (Fahad *et al.*, 2015). It can also disturb the stability of cell membranes, activity of enzymatic systems, and production of reactive oxygen species (ROS) (Pang and Wang, 2008; Jamil *et al.*, 2012).

Maize (Zea mays) represents the third most important cereal crops cultivated worldwide after wheat and rice. It has a high nutritional value for both human and animal and provides suitable raw materials for several industries such as starch, fodder, silage and biofuels (Dhugga, 2007; Ostrander, 2015; Kleinmans *et al.*, 2016). Under saline conditions; maize plants could demonstrate sever damages and significant losses in their growth and yield (Farooq *et al.*, 2015).

Selenium (Se) is an essential trace element with dual effects on the higher plants; At low concentrations, it stimulates plant growth (Turakainen *et al.*, 2004), photosynthesis (Habibi, 2017), antioxidant capacity (Jiang *et al.*, 2017), delay senescence (Xue *et al.*, 2001) and induce tolerance to various abiotic stresses including drought (Germ *et al.*, 2007; Ibrahim and Ibrahim, 2016), salinity (Hawrylak-Nowak, 2009; Jiang *et al.*, 2017; Elkelish *et al.*, 2019), heavy metals (Cartes *et al.*, 2010), UV-irradiation (Valkama *et al.*, 2003), cold (Chu *et al.*, 2010), high temperatures (Djanaguiraman *et al.*, 2010) and oxidative stress (Hasanuzzaman *et al.*, 2010). Adversely, at high concentrations, Se could be toxic because it may be similar and replaced with Sulphur in amino acids and consequently corrupt the three-dimensional structure of proteins and enzymatic functions (Amweg *et al.*, 2003).

Currently, with global climatic changes and scarcity of freshwater particularly in the arid and semi-arid regions like Egypt, increasing the risk of soil salinization has become one of the most challenges that could threaten the existence of mankind by affecting sustainable agriculture and different socio-economic activities. Therefore, this study aimed to know the possible role of foliar application of Se as Na_2SeO_4 (0, 2.5 and 5 µM) on regulating maize salt tolerance by affecting its growth, yield and several biochemical constituents.

MATERIALS AND METHODS

Experiment Layout and growth conditions: Two pot experiments were conducted on 25^{th} and 22^{th} of May 2017 and 2018 respectively in the Experimental Farm, Faculty of Agriculture, Ain shams University, Cairo, Egypt to investigate the effect of foliar applications with distilled water as a control and selenium (Se) as Na_2SeO_4 (2.5 and 5 µM) on maize plants irrigated with three different concentrations of saline water (0, 50 and 100 mM NaCl). The foliar application of Na_2SeO_4 was done twice at 30 and 60 days after sowing; whereas, the irrigation with saline water was started at 36 days after sowing (vegetative growth stage). The experimental design was split plot with Completely Randomized Block Design (CRBD) of main plots. All pots (324) were divided to three equal main groups as replicates. Different saline irrigation treatments were distributed randomly into each replicate as main plots and the foliar treatments as sub-plots. All different treatments of irrigation and foliar applications to each experiment were respectively arranged as follow:

(1)Tap water + distilled water

(2)Tap water + Na_2SeO_4 at 2.5 µM

(3)Tap water + Na_2SeO_4 at 5 µM

(4)Saline water (50 mM NaCl) + distilled water

(5)Saline water (50 mM NaCl) + Na_2SeO_4 at 2.5 µM

(6)Saline water (50 mM NaCl) + Na_2SeO_4 at 5 µM

(7)Saline water (100 mM NaCl) + distilled water

(8)Saline water (100 mM NaCl) + Na_2SeO_4 at 2.5 µM

(9)Saline water (100 mM NaCl) + Na_2SeO_4 at 5 µM

Seeds of maize hybrid triple white (Giza 310) were purchased from The Agriculture Research Center, Giza, Egypt. Five seeds were sown in plastic pots 50 cm length X 30 cm width filled with 27 kg pre-washed sand. After three weeks; pots were thinned to one uniform seedling in size to each pot in order to homogenize the plant material used in the experiments. Applied fertilizers were calculated per pot as recommended by Egyptian Ministry of Agriculture in sandy soil. In the first dose, each pot was provided with 1.6 g calcium triple superphosphate (37.5% P_2O_5), 2.1 g ammonium nitrate (33.5% N) and 1.9 g potassium sulfate (48% K) at two weeks after sowing. In the second and third doses, equal amounts of N and K fertilizers were provided with two weeks intervals at 30 and 45 days after sowing. The other macro and micronutrients, disease and pest control programs were also followed according to the recommendations of Egyptian Ministry of Agriculture.

Studied parameters

Vegetative growth

The leaves, stem and total shoot dry weight of maize plants were determined at 90 days after sowing, the samples were cleaned by washing with tap water then dried in an air-forced ventilated oven at 70 °C until a constant weight.

Biochemical constituents

Leaf pigments

Chlorophyll a, b and carotenoids were extracted in pure acetone and determined as described by Costache *et al.* (2012). The concentrations were calculated using the following equations:

Chlorophyll a = 11.75 A662 – 2.350 A645

Chlorophyll b = 18.61 A645 – 3.960 A662

Carotenoids = 1000 A470 – 2.270 Chl a – 81.4 Chl b/227.

Leaf Mineral Concentration: Dry leaves were grounded and digested using sulphuric acid and hydrogen peroxide. Leaf mineral concentrations of Na and K were determined according to Cottenie *et al.* (1982).

Yield and its components: Ears of maize plants were harvested at 115 days after sowing; the total amount of grains (g. plant^{-1}) and 100 kernel weights were estimated.

Statistics: Data were analyzed using SAS (1988). Means were calculated and Duncan's multiple range test (P≤ 0.05) was used to determine the significant differences between means.

RESULTS AND DISCUSSION

Vegetative growth: Data presented in Table 1 show that increasing the level of salinity negatively affected ($P \leq 0.05$) leaves, stem and total shoot dry weights of maize plants. In this regard, the lowest significant ($P \leq 0.05$) values were observed at high salinity level (100 mM) compared to the moderate one (50 mM) and those that had grown in the absence of applied NaCl. Maize has been known as the most susceptible crop of cereals to salt stress (Katerji *et al.*, 1996) In several previous studies, it was established that all growth parameters including plant length, shoot fresh and dry weights, leaf and internode growth rate of maize plants had been reduced by exposing to a wide array of NaCl salt concentrations (Cramer *et al.*, 1994; Parvaiz, 2014; Soufan and Okla, 2014; Farooq *et al.*, 2015); These effects could be directly attributed to decrease the rate of cell division and elongation (Barakat, 2003; Tabur and Demir, 2010; Valenzuela *et al.*, 2016) through affecting the activities of some transport proteins like H^+-PPase and H^+-ATPase (Shi *et al.*, 2007) or indirectly by affecting multiple vital processes including protein, DNA and RNA synthesis, enzyme function, photosynthesis and respiration (Seckin *et al.*, 2009; Sabbagh *et al.*, 2014; Farooq *et al.*, 2015).

Table (1): Effect of foliar application of Na_2SeO_4 at 0 (distilled water) as a control, 2.5 and 5 µM on some growth parameters of maize plant irrigated with three different concentrations of saline water as NaCl at 90 days after sowing.

	Salinity levels as NaCl			Mean	**Salinity levels as NaCl**			Mean
Na_2SeO_4 (µM)	0 mM	50 mM	100 mM		0 mM	50 mM	100 mM	
	2017				2018			
Leaves dry weight (g. plant^{-1})								
0	58.76 ab	48.11 cde	39.06 f	48.64 B	66.91 ab	58.75 cd	48.72 f	58.13 B
2.5	63.05 a	54.75 bc	44.00 def	53.94 A	71.65 a	62.61 bc	54.70 de	62.99 A
5	61.92 a	50.05 cd	42.66 ef	51.55 AB	69.93 a	60.06 c	51.74 ef	60.57 AB
Mean	61.25 A	50.97 B	41.91 C		69.50 A	60.47 B	51.72 C	
Stem dry weight (g. plant^{-1})								
0	203.97 ab	169.10 c	160.62 c	177.90 B	247.87 b	190.72 cd	158.31 e	198.97 B
2.5	229.68 a	186.86 bc	176.59 bc	197.71 A	276.22 a	211.95 c	171.95 de	220.04 A
5	224.86 a	187.27 bc	170.09 c	194.07 AB	256.61 ab	208.38 c	167.01 e	210.66 AB
Mean	219.50 A	181.07 B	169.10 B		260.23 A	203.68 B	165.75 C	

Cont. Table (1):

Total shoot dry weight (g. plant^{-1})								
0	262.73 bc	217.20 de	199.68 e	226.54 B	314.78 b	249.48 d	207.03 e	257.10 B
2.5	292.73 a	241.61 cd	220.59 de	251.64 A	347.87 a	274.56 c	226.65 e	283.03 A
5	286.78 ab	237.32 cd	212.75 de	245.62 A	326.53 ab	268.43 cd	218.75 e	271.24 A
Mean	280.75 A	232.04 B	211.01 C		329.73 A	264.16 B	217.48 C	
In each variable, data followed by the same letters (small letters for interactions and capital letters for means) are not significantly different using Duncan multiple range test at 5% level.								

Respecting the effect of foliar applications of Se, it can be observed that all investigated growth parameters (leaves, stem and total soot dry weights) was enhanced by both examined foliar treatments of Se at 2.5 or 5 µM compared to the control in the two seasons. In this respect, the highest significant ($P\leq0.05$) increases in shoot dry weight were obtained by the lower concentration of Se at 2.5 µM compared to the other treatments in both seasons. Under salt stress, exogenous applied-Se was showed to stimulate growth of many plant species such as canola (Hashem *et al.*, 2013), tomato (Diao *et al.*, 2014) lettuce (Khalifa *et al.*, 2016), maize (Jiang *et al.*, 2017) and wheat (Elkelish *et al.*, 2019). This positive effect could be due to that applied-Se could be implicated in photosynthesis and regulating of water status and ionic balance of salt-affected plants; Furthermore, it can act as an antioxidant by increasing the activities of both enzymatic and non-enzymatic antioxidant systems leading to reducing NaCl-induced oxidative damages (Jiang *et al.*, 2017; Elkelish *et al.*, 2019).

Regarding the effect of interaction between the different levels of salinity and Se-applications, it can be noticed that the treatment of Se at 2.5 µM under non-saline conditions gave the highest significant ($P \leq 0.05$) results in all studied growth parameters compared to the untreated control in both seasons; whereas, under saline conditions, with exception of leaves dry weight in the second season, the general tendency was that no significant differences were detected between both Se foliar applications and the untreated plants in both seasons.

Photosynthetic pigments: Data in Table 2 show that under saline conditions, photosynthetic pigments including chlorophylls (Chl a and Chl b) and carotenoids were significantly ($P \leq 0.05$) decreased by raising the level of salinity. These effects could be attributed to that salt stress dramatically alters the chloroplast ultrastructure (Zhang *et al.*, 2010) and consequently its pigment complex composition (Parida *et al.*, 2003), it causes a considerable elevating in the concentration of reactive oxygen species (ROS) (Menezes-Benavente *et al.*, 2004; Elkelish *et al.*, 2019) leading to fast degradation to the leaf pigments.

Concerning the effect of Se treatments, it can be observed that both examined concentrations of Se exhibited an improving in the concentrations of chlorophylls (Chl a and Chl b). In this regard, it was found that the treatment of Se at 2.5 µM revealed the highest significant ($P \leq 0.05$) increases in both traits compared to the untreated control in both seasons. On the other hand, no significant differences were observed between all foliar treatments in respect to the concentration of carotenoids.

Improving the concentration of chlorophylls in the Se-treated plants in comparison to the untreated ones had been reported in many previous studies (Moldovan *et al.*, 2009; Saffaryazdi *et al.*, 2012; Ibrahim and Ibrahim, 2016; Elkelish *et al.*, 2019). Selenium at optimal concentration may be involved in enhancing leaf pigments by increasing the capacity of antioxidants and delaying the leaf senescence (Germ *et al.*, 2007; Elkelish *et al.*, 2019). In this context it was found that applied Se increased the activities of several antioxidant enzymes and inhibited the excessive release of ROS (Hartikainen *et al.*, 2000; Ibrahim and Ibrahim, 2016). Conversely, under the circumstances of this study, the non-significant changes in carotenoids between all Se-treated plants and those that untreated indicate that in maize plants, Se may be related to another antioxidant systems or it has not been involved in the pathway of the biosynthesis of carotenoids.

Concerning the effect of interaction, it is obvious that the treatment of Se at 2.5 µM achieved the highest values ($P \leq 0.05$) of Chl a under all levels of salinity in both seasons respectively. On the other hand, all foliar treatments did not affect the concentration of Chl b and carotenoids under the same level of salinity in both seasons.

Table (2): Effect of foliar application of Na_2SeO_4 at 0 (distilled water) as a control, 2.5 and 5 µM on photosynthetic pigments of maize plant irrigated with three different concentrations of saline water as NaCl at 90 days after sowing.

Na2So4 (µM)	**Salinity levels as NaCl**			Mean	**Salinity levels as NaCl**			Mean
	0 mM	50 mM	100 mM		0 mM	50 mM	100 mM	
	2017				2018			
Chl a (mg/g f.wt)								
0	2.49 b	2.19 d	1.90 f	2.19 C	2.54 ab	2.22 c	1.98 d	2.25 B
2.5	2.60 a	2.30 c	2.02 e	2.31 A	2.65 a	2.44 b	2.07 cd	2.39 A
5	2.52 ab	2.25 cd	1.99 e	2.25 B	2.60 ab	2.40 b	2.02 d	2.34 AB
Mean	2.53 A	2.25 B	1.97 C		2.60 A	2.35 B	2.03 C	
Chl b (mg/g f.wt)								
0	1.40 a	1.22 bc	1.19 c	1.27 B	1.48 a	1.25 bcd	1.15 e	1.29 B
2.5	1.47 a	1.29 b	1.25 bc	1.34 A	1.55 a	1.32 b	1.21 cde	1.36 A
5	1.43 a	1.25 bc	1.22 bc	1.30 AB	1.52 a	1.30 bc	1.18 de	1.33 AB
Mean	1.43 A	1.25 B	1.22 B		1.52 A	1.29 B	1.18 C	

Cont. Table (2):

Carotenoids (mg/g-1 f.wt)								
0	0.53 ab	0.46 bc	0.39 c	0.46 A	0.69 ab	0.61 c	0.50 d	0.60 A
2.5	0.56 a	0.50 ab	0.41 c	0.49 A	0.73 a	0.64 bc	0.53 d	0.63 A
5	0.55 ab	0.48 abc	0.40 c	0.48 A	0.71 a	0.62 bc	0.51 d	0.61 A
Mean	0.55 A	0.48 B	0.40 C		0.71 A	0.63 B	0.51 C	
In each variable, data followed by the same letters (small letters for interactions and capital letters for means) are not significantly different using Duncan multiple range test at 5% level.								

Leaf Na, K concentration and Na/K ratio: Data presented in Table 3 show that NaCl stress leading to a significant ($P \leq 0.05$) increase in the concentration of Na in leaves Compared to control plants in both seasons. This accumulation was pronounced and significant ($P \leq 0.05$) between all investigated levels of salinity in the second season. On contrary, there was a significant ($P \leq 0.05$) decrease in the uptake of K in parallel with increasing the level of salinity in both seasons. These responses were directly reflected on Na/K ratio which was increased in the salt stressed plants compared to the unstressed plants in both seasons. It is well documented that Na is the main toxic ion which can interfere with uptake of K and the other nutrients in maize plants (Fortmeier and Schubert, 1995; Sumer, 2004; Eker *et al.*, 2006). These responses could be attributed to the competition between the two elements under salt stress (Azevedo Neto and Tabosa, 2000; Shahzad *et al.*, 2012).

As for the effect of foliar applications, it can be observed that Se-treated plants demonstrated a decrease in Na and increase in K relative to the untreated control in both seasons. In comparison to the untreated control, these findings reached the level of significance particularly by the treatment of Se at 2.5 µM in respect to K in the first season and Na in the second one respectively. A similar trend to Na was observed in regard to Na/K ratio in both seasons. These results could be explained by, that plants treated by Se specifically at the optimum concentration increase the activities of tonoplast H^+ ATPase and Na^+/H^+ anti-port in the roots leading to prevent of Na to reach the upper tissue (Zhang *et al.*, 2006). On the other hand, increasing of K and decreasing of Na/K ratio in Se-treated plants under saline conditions could help in readjustment of osmotic balance and protect the essential processes (Gupta and Gupta, 2017).

Respecting the effect of interaction, it is obvious that generally, the treatment of Se at 2.5 µM achieved the lowest decreases in Na concentration and Na/K ratio; whereas, an opposite trend was observed in respect to K compared to the plants did not receive foliar treatment under all investigated levels of salinity in both seasons.

Table (3): Effect of foliar application of Na_2SeO_4 at 0 (distilled water) as a control, 2.5 and 5 µM on the concentrations of Na, K and Na/K ratio in the leaves of maize plant irrigated with three different concentrations of saline water as NaCl at 90 days after sowing

Na2So4 (µM)	Salinity levels as NaCl			Mean	Salinity levels as NaCl			Mean
	0 mM	50 mM	100 mM		0 mM	50 mM	100 mM	
	2017				2018			
Na%								
0	0.81 bcd	1.03 a	1.08 a	0.97 A	0.92 de	1.02 c	1.22 a	1.05 A
2.5	0.75 d	0.98 abc	1.01 ab	0.91 A	0.87 e	0.93 de	1.12 b	0.97 B
5	0.79 cd	1.00 ab	1.04 a	0.94 A	0.89 e	0.98 cd	1.15 b	1.01 B
Mean	0.78 B	1.00 A	1.04 A		0.89 C	0.98 B	1.16 A	
K%								
0	1.09 bc	0.97 de	0.81 f	0.96 B	1.13 ab	1.04 b	0.82 c	1.00 A
2.5	1.20 a	1.05 cd	0.89 ef	1.04 A	1.22 a	1.12 ab	0.89 c	1.08 A
5	1.15 ab	1.00 cd	0.84 f	1.00 AB	1.17 ab	1.08 ab	0.88 c	1.04 A
Mean	1.15 A	1.00 B	0.85 C		1.18 A	1.08 B	0.86 C	
Na/K ratio								
0	0.74 cd	1.06 ab	1.35 a	1.05 A	0.81 def	0.98 c	1.51 a	1.10 A
2.5	0.63 d	1.06 bc	1.14 ab	0.94 A	0.72 f	0.89 cde	1.26 b	0.96 B
5	0.69 d	1.00 bc	1.24 ab	0.98 A	0.76 ef	0.92 cd	1.31 b	0.99 B
Mean	0.69 C	1.04 B	1.24 A		0.76 C	0.93 B	1.36 A	

In each variable, data followed by the same letters (small letters for interactions and capital letters for means) are not significantly different using Duncan multiple range test at 5% level.

Yield and its components: Data presented in Table 4 show that generally, increasing the level of salinity resulted in significant ($P \leq 0.05$) decreases in ear weight ($g.plant^{-1}$), weight of kernels ($g.ear^{-1}$) and weight of 100 kernels (g). Several previous studies reported that salt stress especially during the reproductive phase causes reduction in the total yield of maize plants by affecting the number or weight of grains (Kaya *et al.*, 2013). These influences could be related to the reduction that occur in photosynthesis and assimilate translocation from sources (leaves) to sinks (grains) leading to abortion or poor grain setting and filling (Lohaus *et al.*, 2000; Schubert, 2011).

Respecting the effect of Se, it can be observed that all yield studied traits were enhanced by both investigated concentrations of of Se at 2.5 or 5 µM compared to the untreated plants. Generally, the highest significant findings were obtained by the treatment of Se at 2.5 µM in both seasons. Improving the quantity and quality of yield by Se as exogenous application either under normal or adverse conditions had been proved in many plant species including canola (Zahedi *et al.*, 2009) potato (Ibrahim and Ibrahim, 2016), wheat (Shahzadi *et al.*, 2017) and faba bean (Desoky *et al.*, 2017). In this study, the positive effect of Se on plant growth (Table 1), photosynthetic pigments (Table 2) and Na/K homeostasis (Table 3) could be reflected on the final yield of grains and its filling in the salt-stressed maize plants compared to the unstressed ones in both seasons.

Concerning the effect of interaction, it can be noticed that the treatment of Se at 2.5 µM gave the highest significant increases in the yield of maize plants under different levels of salinity. These results reflected the crucial role of Se in different vital processes in maize plants under normal or stressful conditions.

Table (4): Effect of foliar application of Na_2SeO_4 at 0 (distilled water) as a control, 2.5 and 5 µM on the yield/plant and its components of maize plants irrigated with three different concentrations of saline water as NaCl at 90 days after sowing.

Na2So 4 (µM)	Salinity levels as NaCl			Mean	Salinity levels as NaCl			Mean
	0 mM	50 mM	100 mM		0 mM	50 mM	100 mM	
	2017				2018			
Ear weight (g. plant^{-1})								
0	405.17 b	370.67 d	335.67 f	370.50 C	413.17 a	369.17 d	328.17 f	370.17 C
2.5	424.33 a	390.67 c	355.00 e	390.00 A	431.38 a	381.17 c	342.17 e	384.91 A
5	415.45 ab	380.21 cd	345.33 ef	380.33 B	425.00 a	376.50 cd	334.50 ef	378.67 B
Mean	414.98 A	380.51 B	345.33 C		423.18 A	375.61 B	334.94 C	
Weight of kernels (g.Ear^{-1})								
0	174.99 bc	162.20 d	136.15 f	157.78 B	186.82 bc	177.60 d	149.81 e	171.41 C
2.5	183.18 a	170.33 cd	144.44 e	165.98 A	197.10 a	186.15 bc	157.08 e	180.11 A
5	179.72 ab	165.41 d	140.42 ef	161.85 AB	191.75 ab	181.59 cd	153.42 e	175.59 AB
Mean	179.30 A	165.98 B	140.34 C		191.89 A	181.78 B	153.44 C	

Cont. Table (4):

Weight of 100-kernals (g)								
0	42.30 ab	36.92 bcd	30.49 d	36.57 A	49.32 abc	43.44 bcd	39.23 d	44.00 A
2.5	46.35 a	39.06 abc	32.43 cd	39.28 A	53.53 a	47.07 abcd	42.65 bcd	47.75 A
5	43.06 ab	37.12 bcd	31.87 cd	37.35 A	51.37 ab	45.61 abcd	40.43 cd	45.80 A
Mean	43.90 A	37.70 B	31.60 C		51.40 A	45.37 B	40.77 B	

In each variable, data followed by the same letters (small letters for interactions and capital letters for means) are not significantly different using Duncan multiple range test at 5% level.

CONCLUSION

The present study indicated that application of Se at low concentration (2.5 µM) enhanced growth, leaf pigments, the balance between Na and K and eventually the yield and its components of maize plants under salt stress conditions. Selenium as foliar applications could be recommended in order to mitigate the adverse effects of salt stress on maize plants.

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تأثير السيلينيوم على تحمل الملوحة فى نباتات الذرة

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المستخلص

نفذت تجربتي أصص موسمي ٢٠١٧ و ٢٠١٨ لاختبار تأثير السيلينيوم كرش ورقي في صورهة (Na_2SeO_4) بتركيز ٢,٥ و ٥ ميكرومولار علي النمو، صبغات البناء الضوئي، والتوازن بين عنصرى Na/K والمحصول لنباتات الذرة تحت ثلاث مستويات من الملوحة (٠، ٥٠ و ١٠٠ مللي مولار NaCl). وقد دلت النتائج على ان معامله ٢,٥ ميكرومولار حققت أعلي قيم معنويه في الوزن الجاف للأوراق والسيقان، كلوروفيل أ و كلوروفيل ب و K، محصول الحبوب الكلي وامتلاء الحبوب من خلال وزن ال١٠٠ حبه. علي العكس من ذلك، كان هناك نقص معنزى في تركيز Na نسبة Na/K. بينما لم تبدى الكاروتينات اي تغييرات معنويه بين النباتات المعاملة بالسيلينيوم وغير المعاملة.

الكلمات الدالة: ذرة، سيلينيوم، ملوحة، الصبغات، نسبة الايونات والمحصول.