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Effect of Silver Nanoparticles on Salt Tolerancy of Tomato Transplants (*Solanum lycopersicom,* Mill.)

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Abstract

A pot experiment was conducted at the Vegetable Experimental Farm, Faculty of Agriculture, Assiut University, Assiut, during the summer seasons of 2014 and 2015 to study the effect of Silver Nanoparticles (SNP) on salt tolerance in tomato. The experimental soil type was clay. Split plot arrangement in Randomized Complete Blocks Design (RCBD) with four replicates was used. The salt solution (sodium chloride) concentrations [(0 %(control plots were irrigated with deionized water), 30, 60, 90, 120 mM/L)] were distributed in main plots, while the Silver Nanoparticles concentrations [(0 %(control plots were soaked in distilled water), 10, 20, 40 ppm)] were arranged in sub plots. The obtained results indicated that soaking tomato transplants in Silver nanoparticles for 24 hours had no significant effect on increasing tomato tolerance to sodium chloride salt within the used levels. This was reflected in negative effects on fruit number per plant, fruit diameter, average fruit weight, number of branches per plant and plant height. The control treatment (soaked in distilled water) of SNP was consistently superior for all studied traits. SNP treatments reduced the fruit number per plant, fruit diameter, average fruit weight, number of branches per plant and plant height.

Keywords: *Tomato, Salt applications, Silver Nanoparticles.*

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Introduction

Nanotechnology has many positive effects applications in chemical, manufacturing, medical and agricultural sector (Manchikanti and Bandopadhyay, 2010). Nanomaterials show unique features because of their very small size (Haghighi *et al*., 2012). They can change physic–chemical characteristics due to their great surface area than their bulk materials. Because of these larger surface areas, their solubility and surface reactivity are enhanced (Ruffini and Cremonini. 2009). Manufacturing the preparation ways of nanomaterials can change their characteristics, for example, the addition of nanoparticles in liquid changes their chemical, physiological and transport characteristics compared to their base fluids such as enhancement of thermal conductivity (Ashok and Raykar, 2008). AgNPs have been implicated in agriculture for improving crops. There are many reports indicating that appropriate concentrations of AgNPs play an important role in plant growth (Kaveh *et al*., 2013; Salama, 2012; Sharma *et al*., 2012; Vannini *et al*., 2013) and improving photosynthetic quantum efficiency and chlorophyll content (Hatami and Ghorbanpour, 2013; Sharma *et al*., 2012). AgNPs are also used as antimicrobial agents to manage plant diseases (Lamsal *et al*., 2011).

Nowadays, salinity considered one of the most important environmental problems that cause a significant reduction in growth. No available information about the useful effects of SNP application to reduce salt stress damages in Tomato. Although potential of AgNPs in improving salinity resistance has been reported in several plant species (Ekhtiyari *et al.,* 2011; Ekhtiyari and Moraghebi, 2011), its role in alleviation of salinity effect and related mechanisms is still unknown. The application of nanosilver during germination process may enhance germination traits, plant growth and resistance to salinity conditions in basil seedlings (Darvishzadeh *et al*., 2015). Therefore, the main objective of this work was to study the effect of Silver Nanoparticles on salt tolerance in tomato (*Solanum lycopersicom*).

Materials and Methods

A pot experiment was carried out at the Vegetable Experimental Farm, Faculty of Agriculture, Assiut University, Assiut, during the summer seasons of 2014 and 2015 to study the effect of Silver Nanoparticles (SNP) on salt tolerance in tomato transplants. The pot was 25 cm diameter filled with 6 kg of the clay soil from the farm. The physical and chemical properties of the soil are presented in Table 1a and NaCl concentrations used are presented in Table 1b. Split plot arrangement in Randomized Complete Blocks Design (RCBD) with four replicates was used. The experiment included five salinity levels of irrigation water (0, 30, 60, 90, 120 mM/L of sodium chloride, NaCl) which were distributed in the main plots, while the Silver Nanoparticles concentrations (0, 10, 20, 40 ppm) were arranged in the sub plots. Deionized water was used to prepare the salt solution. The tomato cultivar used in this investigation was Nirouz (TH99806) F_1 hybrid. The seeds of tomato were planted in the nursery on 5^{th} of February and the transplanting was done on 18th of March in both seasons. The transplants were soaked in a solution of silver nanoparticles (SNP) levels for 24 hours before transplanting. The Silver Nanoparticle solutions were obtained from the Chemistry Department, Faculty of Science, Azhar University, Assiut branch, Assiut. All other cultural practices were carried out as recommended for tomato production and the soil moisture was maintained at the pot capacity. After irrigation with the five salinity levels all the guarded plants were used from each sub-plot to measure the number of survived plants after 1 and 4 weeks, number of fruits per plants, fruit diameter, average fruit weight, number of branches per plant and plant height (cm).

Table 1a. Physical and chemical characteristics of the soil used in the pot experiment.

Characteristic	Values	Characteristic	Valuse
pH(1:1)	8.01	Caly %	48.95
EC1:1 dSm^{-1}	1.07	Silt %	29.37
ECe dSm^{-1}	1.65	Sand %	21.68
Soluble Cations,(meq/kg soil)		Soil texture	Clay
Ca^{2+}	9.5	Bulk density, (g/cm^3)	1.12
Mg^{2+}	3.0	Field capacity, (F.C)%	43.02
Na^{+}	6.5	Wilting Point (W.P)%	22.33
K^{+}	1.0	W.Saturation %	65.01
Soluble Anions,(meq/100 g soil)			
Cl^{-}	4.0		
$HCO_3^{-}+CO_3^{2-}$	7.0		
SO_4^{2-}	9.0		
Total nitrogen (ppm)	8.0		
Available Phosphorus (ppm)	11.2		
Available Potassium (ppm)	300		

Table 1b. Salt concentration in the irrigation water and in the soil at the end of the experiment.

Treatments	**NaCl concentrations as**			**ECe* dSm^{-1} at the soil**	**Salinity level**
	ECw dSm^{-1}	**m Mole**	**ppm**		
Control	**0**	—	—	**1.65**	**Normal**
1	**2.742**	**30**	1755	**5.19**	**Saline**
2	**5.484**	**60**	3510	**9.28**	**Moderately saline**
3	**8.226**	**90**	5265	**13.38**	**Highly saline**
4	**10.969**	**120**	7020	**17.49**	**V. Highly saline**

*ECe = Electrical conductivity in the soil part extract.

All collected data were statistically analyzed according to the analysis of variance (ANOVA) procedure using the MSTAT-C Statistical Software Package (Michigan State University, Freed *et al*., 1991). Differences between means were compared by the least significant test LSD test at 5% level of probability (Gomez and Gomez, 1984), only when a significant "F" test was obtained.

Results and Discussion

1- The survived plants after one week of the irrigation with saline water:

The illustrated data in Table 2 show that Silver Nanoparticles significantly affected the survived plants after one week irrigated with saline water in the two growing seasons. The highest mean values of the survived plants were obtained from 20 ppm SNP and control treatments, while, the differences between (20 ppm SNP and control) and 10 ppm treatments were not significant in both seasons. However, the 40 ppm SNP reduced the number of plant survival significantly. Here too, the effect of salt concentrations and the interaction did not show significance in both seasons.

2- The survived plants after one month of the irrigation with saline water:

Data presented in Table 3 declare that salt concentrations had a significant effect on the survived plants after one month in both seasons. The data indicate that by increasing the salt level, more plants died in both seasons. Also, the data show that the SNP had a significant effect in this respect in both seasons. Moreover, control, 10 and 20 ppm SNP had more survived plants than 40 ppm SNP concentration in both seasons. Also, the data emphasize that the interaction had a highly significant effect on this trait in the two growing seasons. The data reveal that the best interactions were between 10 ppm SNP and 30mM\L salt in both seasons. Also, the interaction between 10 ppm SNP and 60mM\L salt kept more than 50% of plants in both seasons.

3- Number of fruits per plant:

Illustrated data in Table 4 show that the studied variables and their interaction had a highly significant effect on the number of fruits per plant in both seasons. Only the control treatments of salt and Silver nanoparticles gave the highest mean values of fruit number per plant in both seasons. Also, the interaction between 10 ppm SNP and 30 mM\L salt produced the largest number of fruits per plant in both seasons. The SNP treatments did not increase the fruit number per plant compared with control in both seasons.

4-Average fruit diameter (cm):

Presented data (Table 5) reveal that the studied variables and their interaction had a highly significant effect on the average of fruit diameter in both seasons. Control treatments of salt and Silver rnanoparticles gave the highest mean values of fruit diameter in both seasons. Among the remaining treatments, the highest fruit diameter was obtained from the interaction between 10 ppm SNP with 30mM\L salt in both seasons. The SNP treatments on average did not increase the fruit diameter compared with control treatment in both seasons.

5- Average fruit weight (g):

Data exhibited in Table 6 reveal that the studied variables and their interaction gave a highly significant effect on the average fruit diameter in both seasons. Also, the data indicate that control treatments of salt and SNP gave the highest average fruit weight in both seasons while silver nanoparticles failed in increasing the average fruit weight compared to the control treatment in both seasons. Here too, the interaction between 10 ppm SNP and 30mM\L NaCl salt gave the highest average fruit weight relative to others except the control in both seasons.

6- Number of branches per plant:

Data presented in Table 7 declare that salt, Silver nanoparticles and the interaction had a significant effect on number of branches per plant in both seasons. The greatest mean values of branches number per plant were obtained from the control treatment of both salt and SNP in both seasons. Among the different interaction 10 and 20 ppm SNP with 60mM\L salt gave the largest number of branches per plant in the first season only (4.00).But, in the second season, the interaction between 10 ppm SNP and 30 mM\L salt gave the greatest number of branches per plant (5.00) in the second season only.

7- Plan height (cm):

Data illustrated in Table 8 reveal that the studied variables and their interaction show a highly significant effect on the plant height in both seasons. Meanwhile, the control treatments of salt and silver nanoparticles gave the tallest plants compared with the other studied treatments.

Discussion

The authors are unaware of previous study using SNP in tomato transplants under NaCl salt stress. Overall, results revealed that Silver nanoparticles did not appear to enhance tomato tolerance in this regard. There was a sever reduction in all measured variables at higher concentration of salinity and SNP .The reductions seemed to be due to high salinity firstly and getting worse with application of SNP. SNP reduced the fruit number per plant, fruit diameter, average fruit weight, number of branches per plant and plant height. Within the range of SNP concentrations used, it is not recommended to use SNP applications for tomato plants. The SNP treatments may cause toxicity to the plants. Song *et al*. (2013) reported that in greenhouse experiments, mature tomato plants showed evidence of phytotoxicity due to AgNPs by exhibiting low chlorophyll contents, higher SOD, and less fruit production. Nevertheless, Darvishzadeh *et al*., (2015) found that the application of nano-silver particles at the concentration of 40 mg.kg-1 led to the increases in germination percentage and improved the resistance to salinity conditions in basil.

In conclusion, Silver nanoparticles 10, 20 and 40 ppm used in this study did not positively affect enhance tolerate to salt stress. These conflicted results of different researchers suggest that plant species and environmental conditions may be counted in the effect of SNP here.

Table 2. Effect of sodium chloride salt (NaCl) and Silver nanoparticles (SNP) on the percentage of the survived plants one week after transplanting of tomato.

Nano(B) / Salt (A)	2014					2015				
	Control	10 ppm	20 ppm	40 ppm	Mean	Control	10 ppm	20 ppm	40 ppm	Mean
control	100	100	100	100	**100**	100	100	100	100	**100**
30mM\L	100	100	100	100	**100**	100	100	100	100	**100**
60mM\L	100	100	100	87.5	**96.88**	100	100	100	87.5	**96.88**
90mM\L	100	100	100	87.5	**96.88**	100	100	100	87.5	**96.88**
120mM\L	100	87.5	100	75	**90.63**	100	87.5	100	75	**90.63**
Mean	**100**	**97.5**	**100**	**90**	**96.88**	**100**	**97.5**	**100**	**90**	**96.88**
L.S.D.0.05 of A	N.S					N.S				
L.S.D.0.05 of B	7.02					7.02				
L.S.D.0.05 of AB	N.S					N.S				

Table 3. Effect of sodium chloride salt (NaCl) and Silver nanoparticles (SNP) on the percentage of the survived plants four weeks after transplanting of tomato.

Nano(B) / Salt (A)	2014					2015				
	Control	10 ppm	20 ppm	40 ppm	Mean	Control	10 ppm	20 ppm	40 ppm	Mean
control	100	100	100	100	**100**	100	100	100	100	**100**
30mM\L	100	81.25	75	75	**82.81**	100	81.25	80	68.75	**82.5**
60mM\L	100	68.75	50	0	**54.69**	90	66.25	56.25	20	**58.13**
90mM\L	50	6.25	0	0	**14.06**	62.5	0	0	0	**15.63**
120mM\L	0	0	0	0	**0**	0	0	0	0	**0**
Mean	**70**	**51.25**	**45**	**35**	**49.06**	**70.5**	**49.5**	**47.25**	**37.75**	**51.25**
L.S.D.0.05 of A	12.18					6.00				
L.S.D.0.05 of B	4.83					5.00				
L.S.D.0.05 of AB	10.81					11.19				

Table 4. Effect of sodium chloride salt (NaCl) and Silver nanoparticles (SNP) on average number of fruits per tomato plant.

Nano(B) / Salt(A)	2014					2015				
	Control	10 ppm	20 ppm	40 ppm	Mean	Control	10 ppm	20 ppm	40 ppm	Mean
Control	24	23	22.5	21.5	**22.75**	27.5	25	22.5	21.5	**24.13**
30mM\L	23	23	22	22	**22.50**	22.5	22	21.5	21	**21.75**
60mM\L	21	0	0	0	**5.25**	22	0	0	0	**5.50**
90mM\L	21	0	0	0	**5.25**	21	0	0	0	**5.25**
120mM\L	0	0	0	0	**0**	0	0	0	0	**0.00**
Mean	**17.8**	**9.20**	**8.90**	**8.70**	**11.15**	**18.6**	**9.40**	**8.80**	**8.50**	**11.33**
L.S.D.0.05 of A	1.11					1.13				
L.S.D.0.05 of B	0.29					0.30				
L.S.D.0.05 of AB	0.64					0.67				

Table 5. Effect of sodium chloride salt (NaCl) and Silver nanoparticles (SNP) on the average fruit diameter (cm) of tomato.

Salt(A) \ Nano(B)	2014					2015				
	Control	10 ppm	20 ppm	40 ppm	Mean	Control	10 ppm	20 ppm	40 ppm	Mean
control	2.80	2.28	2.28	2.00	**2.34**	3.28	2.60	2.53	2.08	**2.62**
30mM\L	2.70	2.44	2.28	1.93	**2.34**	2.43	2.43	2.33	2.20	**2.34**
60mM\L	2.13	0	0	0	**0.53**	2.58	0	0	0	**0.64**
90mM\L	1.60	0	0	0	**0.40**	1.5	0	0	0	**0.38**
120mM\L	0	0	0	0	**0**	0	0	0	0	**0**
Mean	**1.85**	**0.94**	**0.91**	**0.79**	**1.12**	**1.96**	**1.01**	**0.97**	**0.86**	**1.20**
L.S.D.0.05 of A	**0.12**					**0.08**				
L.S.D.0.05 of B	**0.03**					**0.02**				
L.S.D.0.05 of AB	**0.06**					**0.04**				

Table 6. Effect of sodium chloride salt (NaCl) and Silver nanoparticles (SNP) on the average tomato fruit weight (g).

Salt(A) \ Nano(B)	2014					2015				
	Control	10 ppm	20 ppm	40 ppm	Mean	Control	10 ppm	20 ppm	40 ppm	Mean
control	24.50	22.00	18.38	16.00	**20.22**	22.50	22.25	19.75	18.00	**20.63**
30mM\L	20.75	19.53	17.00	14.88	**18.04**	20.75	18.50	17.13	12.50	**17.22**
60mM\L	13	0	0	0	**3.25**	10.5	0	0	0	**2.63**
90mM\L	7	0	0	0	**1.75**	6	0	0	0	**1.50**
120mM\L	0	0	0	0	**0**	0	0	0	0	**0**
Mean	**13.05**	**8.31**	**7.08**	**6.18**	**8.65**	**11.95**	**8.15**	**7.38**	**6.10**	**8.39**
L.S.D.0.05 of A	**1.01**					**0.63**				
L.S.D.0.05 of B	**0.17**					**0.09**				
L.S.D.0.05 of AB	**0.38**					**0.20**				

Table 7. Effect of sodium chloride salt (NaCl) and Silver nanoparticles (SNP) on number of branches per plant of tomato.

Salt(A) \ Nano(B)	2014					2015				
	Control	10 ppm	20 ppm	40 ppm	Mean	Control	10 ppm	20 ppm	40 ppm	Mean
control	5.75	4.25	3.75	3.50	**4.31**	6.75	5.00	4.75	4.50	**5.25**
30mM\L	3.75	3.75	3.00	3.00	**3.38**	5.25	5.00	4.50	3.00	**4.44**
60mM\L	4.00	4.00	4.00	0	**3**	4.00	4.00	4.00	0	**3.00**
90mM\L	4.00	0	0	0	**1**	4.00	0	0	0	**1.00**
120mM\L	0	0	0	0	**0**	0	0	0	0	**0**
Mean	**3.50**	**2.40**	**2.15**	**1.30**	**2.34**	**4.00**	**2.80**	**2.65**	**1.50**	**2.74**
L.S.D.0.05 of A	**0.19**					**0.15**				
L.S.D.0.05 of B	**0.06**					**0.04**				
L.S.D.0.05 of AB	**0.13**					**0.09**				

Table 8. Effect of sodium chloride salt (NaCl) and Silver nanoparticles (SNP) on plant height (cm) of tomato plants.

Nano(B) / Salt(A)	2014					2015				
	Con-trol	10 ppm	20 ppm	40 ppm	Mean	Con-trol	10 ppm	20 ppm	40 ppm	Mean
control	37.00	34.75	33.75	32.50	**34.5**	38.00	35.25	33.50	30.25	**34.25**
30mM\L	34.75	34.25	32.25	26.25	**31.88**	33.00	30.25	30.00	22.75	**29**
60mM\L	30.00	29.50	28.50	0	**22**	33.25	28.50	28.00	0	**22.44**
90mM\L	18	0	0	0	**4.5**	18	0	0	0	**4.5**
120mM\L	0	0	0	0	**0**	0	0	0	0	**0**
Mean	**23.95**	**19.70**	**18.90**	**11.75**	**18.58**	**24.45**	**18.80**	**18.30**	**10.60**	**18.04**
L.S.D.0.05 of A		**1.64**				**0.98**				
L.S.D.0.05 of B		**0.34**				**0.22**				
L.S.D.0.05 of AB		**0.77**				**0.50**				

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تأثير جزيئات الفضة النانومترية على تحمل الملحية فى شتلات الطماطم

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الملخص

تم إجراء تجربة أصص فى مزرعة الخضر البحثية بكلية الزراعة – جامعة أسيوط خلال موسمى صيف ٢٠١٤ و ٢٠١٥ لدراسة تأثير جزيئات الفضة النانومترية على تحمل الملحية فى الطماطم . والتربة المستخدمة كانت طينية. تم استخدام تصميم قطاعات كاملة العشوائية بترتيب الوحدات المنشقة مرة واحدة لاربع مكررات. وكان تركيز محلول الملح (كلوريد الصوديوم) صفر و ٣٠ و٦٠ و٩٠ و١٢٠ ملليمول / لتر موجودة فى القطع الرئيسية بينما تركيزات جزيئات الفضة النانومترية صفر و ١٠ و ٢٠ و ٤٠ جزء فى المليون كانت موجودة فى القطع الشقية. وأظهرت النتائج أن جزيئات الفضة النانومترية لم تظهر إختلافات معنوية وأن هذه التركيزات من جزيئات الفضة النانومترية لم تساعد نباتات الطماطم على تحمل الملحية وكانت معاملة الكنترول (النقع في ماء مقطر) هي الأفضل لكل الصفات المدروسة.