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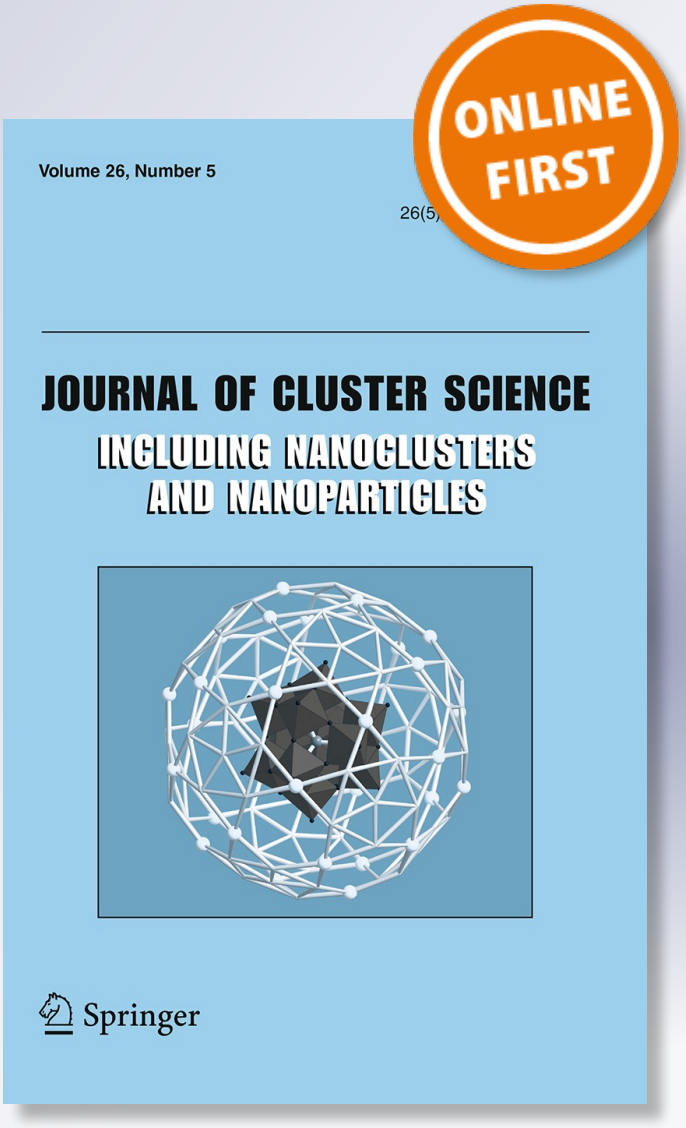
Journal of Cluster Science
Including Nanoclusters and Nanoparticles

ISSN 1040-7278

J Clust Sci
DOI 10.1007/s10876-015-0932-4



Springer

J Clust Sci
DOI 10.1007/s10876-015-0932-4

ORIGINAL PAPER

Effect of Chemical Synthesis Silver Nanoparticles on Germination Indices and Seedlings Growth in Seven Varieties of *Lycopersicon esculentum* Mill (tomato) Plants

Saeed Karami Mehrian[1] · Reza Heidari[1] · Fatemeh Rahmani[1] · Solmaz Najafi[2]

Received: 24 July 2015

Abstract An experiment was conducted to evaluate the effects of synthesis silver nanoparticles (AgNPs), on the seed germination, germination percentage (GP), seedlings vigor index (VI), germination index (GI), tolerance index (TI), root and shoot length (RL and SL) and silver content in seven varieties of *Lycopersicon esculentum* Mill (tomato) plants. AgNPs in 50 nm size in five different concentrations, viz, 0, 25, 50, 75 and 100 mg l^{-1} were synthesized by chemical reduction of metal salt precursor silver nitrate. In the first few days of testing, AgNPs treated seeds sprouted within first 3 days, whereas the control seeds (deionized water) took longer time to sprout, that resulted in the increase in GI, in Early urbanay VF, Super strain B and Primo early varieties. AgNPs caused a significant decreased in GP of Super strain B, and Super stone varieties at 75 and 100 mg l^{-1} concentrations. We detected no significant differences in GP in other varieties. AgNPs application to tomato varieties seeds also caused a drastic decrease in VI, TI, RL and SL in all varieties seedlings. The measurement of Ag content, showed a linear increase with the increase in AgNPs concentrations. Finally, phytotoxicity effect of AgNPs was revealed in seven varieties.

Keywords *Lycopersicon esculentum* Mill · Silver nanoparticles · Germination index · Seedling vigor · Tolerance index

✉ Saeed Karami Mehrian
saeidkaramii@yahoo.com

[1] Department of Biology, Faculty of Science, Urmia University, 51818-57561 Urmia, Iran

[2] Department of Agronomy and Plant Breeding, Faculty of Agriculture, Urmia University, 51818-57561 Urmia, Iran

Published online: 13 October 2015

Introduction

Manufacturers are putting chemical synthesized silver nanoparticles into a growing list of consumer products, despite the fact that little is known about their health or environmental impacts. The widespread use of silver nanoparticles (AgNPs) in the consumer products could be attributed to their potent antimicrobial activity against a wide range of pathogenic microorganisms [1]. These items include clothing, food storage containers, pharmaceuticals, cosmetics, electronics and optical device [2–4]. The main concern is nanoparticles can enter the water system, and could impose potential health and cause negative impact on plants and bacterial colonies in waste water treated plants [5]. AgNPs released into the environment and its interaction with the biotic components of the ecosystem continues to be documented [6]. The silver released from a nanosilver producing washing machine into its effluent caused a significant, dose dependent reduction (60–80 % reduction or abundance) in freshwater bacterial community and plants after exposure to effluent from the washing machine [7]. Nanoparticles show different effects on seed germination of different plants [8]. Toxicity studies of several nano materials such as TiO_2, ZnO, Mg, Al, Pd, Cu, Si, C60 fullerenes, and multiwall carbon nanotubes showed both negative and positive effects on plant growth on certain higher plants [9]. Different sizes of AgNPs were toxic to Arabidopsis thaliana seedlings and they caused stunted growth even at very low concentration [10]. AgNPs decreased the biomass and transpiration rates of *Cucurbita pepo* [11]. The mechanisms involved in AgNP toxicity have not been fully studied. It is still challenging to elucidate whether the toxicity is related to nanoparticles or because of dissolved forms of Ag (Ag^+ ions) and their co-occurrence with AgNPs [12]. The toxic action of metal and metal NPs can potentially involve at least three distinct mechanisms. First, particles may release toxic substances into exposure media, e.g., free Ag^+ ions from silver particles. Second, surface interactions with media may produce toxic substances, e.g., chemical radicals or reactive oxygen species. Third, particle or their surfaces may interact directly with, and disrupt biological targets, e.g., carbon nanotube interaction with membranes or intercalation with DNA [13]. Nanomaterials possess a large specific surface area that can potentially absorb transition metals these absorbed transition metals can catalyze Fenton or Haber–Weiss reactions, to generate hydroxyl radicals that can directly attack DNA [14]. Also cause enzyme inactivation as a result of its interaction with the Sulfhydryl groups of proteins, leading to protein dysfunctioning, and (c) lead to chlorosis, necrosis, stunting, and root-growth inhibition [15–17]. Tomato is one of the most popular vegetables in the world, which has close relation to people's health. No comprehensive research has been conducted on the effects of silver nanoparticles on germination indices and early growth of tomato seedlings. Now this question arises that, why do we use chemical synthetic nanoparticles? It is clear that all AgNPs used in consumer products, are synthesized by different method other than biological synthesis method. So, the need for a risk–benefit analysis for all applications and eventually restrictions of the uses where a clear benefit cannot be demonstrate. And it is important that awareness about benefits and disadvantages of this chemical

synthesized nanomaterial considered and precise information is made available to the general public. The scope of this study was to assess the chemical synthesized silver nanoparticles effects on seed germination, GP, VI, GI, TI, RL, SL and silver content in seven varieties of tomato seeds and seedlings.

Materials and Methods

Chemicals

Silver nitrate ($AgNO_3$, 99.9 %, Merck) and Tri sodium citrate (Merck) were used as received without further purifications. Deionized water was used in all the experiments.

Synthesis of Silver Nanoparticles

AgNPs were prepared by means of the chemical reduction of metal salt precursor silver nitrate (99.9 % $AgNO_3$ Merck). Briefly, solution of silver nitrate ($AgNO_3$) was prepared by dissolving 0.017 g of silver nitrate in 100 ml of distilled water and boiled in ambient atmosphere and 1 % tri sodium citrate solution is prepared by dissolving 1 g of tri sodium citrate into 100 ml of distilled water. 20 ml of silver nitrate solution was kept in hot plate at 90 °C for 5 min and then add 2.5 ml of tri sodium citrate drop by drop once the reduction process begins color change appears and the solution turn into pale yellow [18]. After the changes in color, solution was stirred in magnetic stirrer for 15 min. Five different concentrations, viz, 0, 25, 50, 75 and 100 mg l^{-1} were prepared from stock solution.

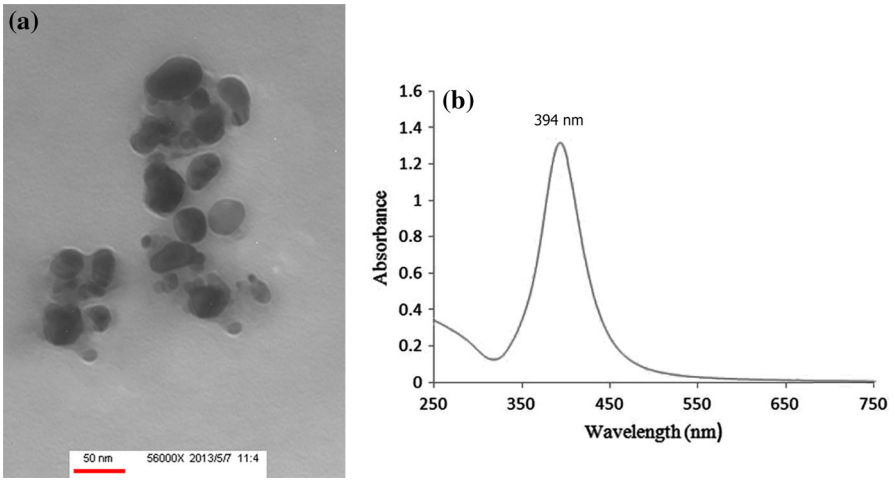


Fig. 1 **a** Transmission-electron micrograph of silver nanoparticles employed in the present study. **b** Formation and the stability of silver nanoparticles in aqueous colloidal solution are confirmed using UV–Vis absorption spectrum of AgNPs

Characterization of Silver Nanoparticles

Formation and the stability of silver nanoparticles in aqueous colloidal solution are confirmed using transmission electron microscopy Carl Zeiss AG—(Zeiss EM 900) and UV–Vis spectral analysis (WPA S2100, UK UV Vis) (Fig. 1a, b).

Germination

Seeds of tomato (*Lycopersicon esculentum* Mill) varieties, Peto early CH, Primo early, Cal.j.n3, Early urbanay VF, King stone, Super stone, Super strain B, were purchased from agricultural biotechnology research institute of Iran, Karaj. Only seeds with germination rate of higher than 90 % were used in further experiments. The seeds were disinfected by treating them with 4 % NaClO solution, followed by rinsing with double-distilled water several times. Total of 105 petri dishes and 5250 seeds were used in this experiment. Seeds were placed in the treatment solution, and petri dishes were shaken for five seconds three times over the course of 1 h to ensure that all the seeds were thoroughly contacted with the solutions. Petri dishes with 100 × 15 mm diameter were floored with whatman no. 1 filter paper. In each Petri dish, 50 seeds were placed and treated with 10 ml of different concentrations of AgNPs, viz, 0, 25, 50, 75 and 100 mg l^{-1}). Petri dishes were placed in 25 ± 2 °C in day time (16 h) and 15–20 °C at night (8 h). The germination was recorded daily and germination percentage was recorded after 6 days treatment. The experiments were conducted with three replications. Germination parameters were calculated using the following equations:

$$\text{Germination Percentage (GP\%)} = (\text{Gf}/\text{n}) \times 100. \quad (1)$$

In which Gf is the total number of germinated seeds at the end of experiment and n is the total number of seed used in the test.

$$\text{Germination Index (GI)} = \sum \text{Gt}/\text{Dt} \quad (2)$$

In which Gt is the number of germinated seeds in t days; Dt is the number of corresponding germination days [19–21].

$$\text{Vigor Index (VI)} = \text{seedling length} \times \text{germination percentage} \quad (3)$$

$$\text{Tolerance Index (TI)} = \text{mean length of longest root in AgNPs solution/length of longest root in control solution} \times 100 \quad (4)$$

Quantification of Silver Nanoparticles in Dry Tissue

Silver content in the leaves of seedlings were assayed, using flame atomic absorption spectroscopy (AAS) method [22]. Leaf tissue samples (1 g) was oven dried at 70 °C to constant weight, followed by acid digestion according to AOAC

Table 1 Germination index of seven varieties of tomato seeds, after 6 days of incubation with increasing concentrations of silver nano-particles

AgNPs mg l^{-1}	Early urbanay VF	Super stone	King stone	Perimo early	Perimo early CH	Super strain B	Cal j.n3
0	9.7 ± 0.8^{c}	6.4 ± 0.4^{a}	9.7 ± 0.84^{a}	3 ± 0.2^{b}	5 ± 0.35^{a}	2.6 ± 0.14^{b}	7.1 ± 0.46^{a}
25	10.9 ± 0.65^{c}	6.6 ± 0.5^{a}	9.1 ± 0.9^{a}	5.2 ± 0.86^{a}	4.6 ± 0.48^{a}	2.7 ± 0.3^{b}	8.2 ± 0.89^{a}
50	13.5 ± 1.13^{b}	6.2 ± 0.34^{a}	9.8 ± 1^{a}	5.1 ± 0.74^{a}	4.8 ± 0.6^{a}	3.2 ± 0.34^{a}	7.6 ± 0.31^{a}
75	$16.9 \pm 0.9^{a,b}$	5.8 ± 0.43^{a}	9.1 ± 0.78^{a}	5.6 ± 0.63^{a}	4.5 ± 0.65^{a}	3.3 ± 0.5^{a}	7.4 ± 0.5^{a}
100	17.4 ± 1.26^{a}	5.8 ± 0.35^{a}	9.5 ± 0.9^{a}	6 ± 0.7^{a}	4.6 ± 0.41^{a}	3.5 ± 0.3^{a}	7.8 ± 0.42^{a}

Within column means followed by the same superscripts are not significantly different at $p < 0.05$

method using HNO_3 and $HClO_4$ (25:10 ml). The clear digested liquid was filtered through a 0.45 μm acid-resistant filter paper and the Ag content in the filtrate was determined using (F-AAS; Perkin-Elmer, Waltham, USA).

Tri Sodium Citrate Toxicity Test

To assess a possible effect of citrate to seeds and seedlings, the citrate toxicity test was conducted in the same concentration as used in silver nanoparticles synthesis.

Statistical Analysis

One way analysis of variance (ANOVA) followed by Tukey HSD tests was employed to examine differences between different treatments at 1 and 5 % probability.

Results and Discussion

Synthesis of Silver Nanoparticles

UV–Vis spectra of nanoparticles shows absorbance peak at 394 nm. This indicates total conversions of silver ions to silver nanoparticles. Also TEM studied confirmed about the shape and size of silver nanoparticles. It was found that the average size of silver nanoparticle was around 50 nm and spherical in shape.

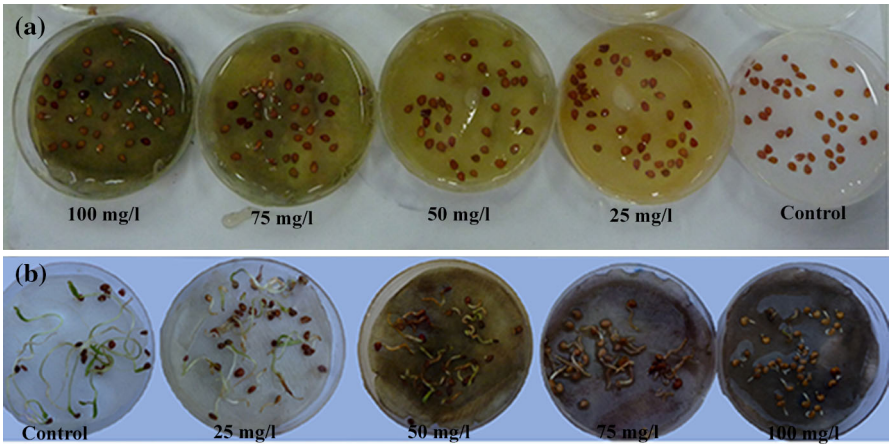


Fig. 2 **a**, **b** AgNPs accelerated seed germination by more water uptake inside seeds. Seedling growth inhibition under different concentration of AgNPs

Tri Sodium Citrate Toxicity Test

Exposed to different citrate concentration showed the similar growth rate as compared to the control (data not shown). It indicates the citrate contained AgNPs has no effect on the plant growth.

GI and GP

We detected a significant increase in the GI in Early urbany VF and Super strain B varieties at 50, 75 and 100 mg l^{-1}, and in Primo early variety at all AgNPs concentrations (Table 1). The control seeds (deionized water) took longer time to sprout, whereas most of treated seeds sprouted within first 3 days (Fig. 2a). It means that the AgNPs accelerated seed germination by more water uptake inside seeds compared to the control. Demonstrated that bimetallic nano zerovalent iron, consisting of elemental iron and silver promote water uptake in seeds [23]. Savithramma et al. (2012) have shown that AgNPs facilitated the penetration of water and nutrients through seed coat and accelerate the seed germination and seedling growth of *Boswellia ovalifoliolata* [24]. Exposure of tomato seeds to carbon nanotubes (CNTs) resulted in enhance seed germination and growth rate due to support water uptake inside seeds [25]. Also reported that AgNPs and osmopriming stimulate seed germination by enhanced supply of soluble carbohydrates to the growing embryo, which was caused by an increase in amylase activities [26]. Exposure to AgNPs significantly decreased GP in Super stone and Super strain B varieties at 75 and 100 mg l^{-1} concentrations. Fluctuate in GP of other varieties based on the exposure concentrations was not significant (Table 2). The decrease in GP can be attributed to the accelerated breakdown of stored food materials in seed and also alterations of selection permeability properties of cell membrane by the application of AgNPs [27]. Reported that AgNPs had an impact on the seed germination of other plants species like zucchini, squash, grass and barley too [11]. Exposure to GA-AgNPs significantly inhibited the germination percentage of *Scirpus cyperinus*, *Juncus effusus* and *Pucciniastrum americanum* plants [28]. AgNP inhibited seed germination in Brassica nigra [29] and Hordeum vulgare, and

Table 2 Germination percentage (%) of seven varieties of tomato seed, after 6 days of incubation with increasing concentrations of silver nano-particles

AgNPs mg l^{-1}	Early urbanay VF	Super stone	King stone	Perimo early	Perimo early CH	Super strain B	Cal j.n3
0	94 ± 9^{a}	100 ± 00^{a}	96 ± 8^{a}	90 ± 10^{a}	86 ± 8^{a}	$76 \pm 13^{a,b}$	82 ± 9^{a}
25	94.6 ± 10^{a}	$93 \pm 10^{a,b}$	86 ± 12^{a}	88 ± 12^{a}	82 ± 9^{a}	$80 \pm 12^{a,b}$	86 ± 8^{a}
50	96 ± 13^{a}	$96 \pm 9^{a,b}$	93 ± 10^{a}	96 ± 00^{a}	92 ± 8^{a}	91 ± 9^{a}	84 ± 9^{a}
75	98 ± 12^{a}	90 ± 8^{b}	92 ± 10^{a}	92 ± 8^{a}	85 ± 10^{a}	72 ± 12^{b}	84 ± 7^{a}
100	97.3 ± 9^{a}	90 ± 9^{b}	90 ± 11^{a}	96 ± 11^{a}	87 ± 11^{a}	74 ± 10^{b}	88 ± 8^{a}

Within column means followed by the same superscripts are not significantly different at $p < 0.05$

Table 3 Vigor index of seven varieties of tomato seeds, after 6 days of incubation with increasing concentrations of silver nano-particles

AgNPs mg l^{-1}	Early urbanay VF	Super stone	King stone	Perimo early	Perimo early CH	Super strain B	Cal j.n3
0	2671 ± 220^{a}	3591 ± 287^{a}	3068 ± 300^{a}	1320 ± 110^{a}	2092 ± 198^{a}	317 ± 41^{a}	2780 ± 187^{a}
25	$1034 \pm 138^{b,c}$	993 ± 102^{b}	$945 \pm 88^{b,c}$	1351 ± 134^{a}	753 ± 76^{b}	295 ± 18^{a}	1126 ± 110^{b}
50	$1053 \pm 160^{b,c}$	778 ± 67^{c}	1189 ± 112^{b}	755 ± 67^{b}	$721 \pm 80^{b,c}$	277 ± 24^{a}	700 ± 78^{c}
75	1084 ± 100^{b}	728 ± 85^{c}	742 ± 60^{c}	848 ± 73^{b}	505 ± 56^{cd}	242 ± 30^{a}	724 ± 56^{c}
100	778 ± 80^{c}	451 ± 34^{d}	659 ± 59^{c}	687 ± 56^{b}	396 ± 24^{d}	125 ± 15^{b}	657 ± 40^{c}

Within column means followed by the same superscripts are not significantly different at $p < 0.05$

reduced shoot length in flax (*Linum usitatissimum*) and barley (*Hordeum vulgare*) [30]. However AgNPs was found to have no significant effect on seed germination in *Cucumis sativus* or *Lactuca sativa* [31], *Vicia faba* [32] and *Bacopa monnieri* (Linn.) [23]. Seed coat thickness and nanoparticles size is other important factor in uptake and penetration of AgNPs solution. Yasur et al. (2013) reported that thicker seed coats of castor, minimize the penetration of AgNPs into the seeds and AgNPs did not cause any toxicity even at higher concentration [12]. Zheng et al. (2005) stated that the considerable effect of nano-sized TiO_2 on spinach germination in tests was probably because of small particle size, which allowed nanoparticles to penetrate the seed during the treatment period, exerting its enhancing functions during growth [33]. It has also been suggested that phytotoxicity is dependent on plant selection, concentration tested; size and exposure condition [11, 34]. We speculate that; fluctuate in germination of tomatoes seeds were due to their differing genetic background, seed coat thickness and sensitivity to AgNPs concentration.

VI and TI

The VI in all varieties and concentrations, strongly decreased compared with the control (Table 3). At highest concentration, the most decrease of VI was observed in super stone (87 %), Peto early CH (81 %), King stone (78 %), Cal j.n3 (76 %), Early urbanay VF (71 %), Primo early (47 %) and Super strain B variety (60 %) compared with the control. Greatest decrease in TI was seen in super stone (90 %), Peto early CH (79 %), King stone (77 %), Cal j.n3 (67 %), Early urbanay VF (83 %), Primo early (60 %) and Super strain B variety (33 %) compared with the control (Table 4). The decrease in TI and VI are due to greater inhibition of seed germination percentage followed by root length and shoot height in response to the composite adverse effects of metal toxicity like AgNPs by oxidative stress. Metal toxicity effect of AgNPs on tomato plants, was investigated previously, which high accumulation of enzymatic and non-enzymatic antioxidant components viz, peroxidase, catalase, superoxide dismutase, malondialdehyde, and free amino acids content under AgNPs was revealed [35]. Yasmeen et al. (2015) reported that AgNPs

Table 4 Tolerance index (%) of seven varieties of tomato seedlings, after 6 days of incubation with increasing concentrations of silver nano-particles

AgNPs mg l^{-1}	Early urbanay VF	Super stone	King stone	Perimo early	Perimo early CH	Super strain B	Cal j.n3
0	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}	100 ± 0.0^{a}
25	17 ± 3^{b}	10 ± 3^{b}	10 ± 1^{c}	39 ± 5^{b}	14 ± 2^{b}	65 ± 7^{b}	18 ± 2^{c}
50	10 ± 0.8^{c}	5 ± 1^{d}	10 ± 1^{c}	33 ± 4^{c}	10 ± 1^{c}	61 ± 6^{b}	24 ± 3^{b}
75	19 ± 3^{b}	6 ± 0.9^{d}	10 ± 1^{c}	22 ± 2^{d}	16 ± 2^{b}	50 ± 6^{c}	25 ± 2^{b}
100	10 ± 2^{c}	8 ± 2^{c}	23 ± 3^{b}	25 ± 4^{d}	17 ± 1^{b}	61 ± 9^{b}	9 ± 0.8^{d}

Within column means followed by the same superscripts are not significantly different at $p < 0.01$

Table 5 Root lengths (mm) of seven varieties of tomato seedlings, after 6 days of incubation with increasing concentrations of silver nano-particles

AgNPs mg l^{-1}	Early urbanay VF	Super stone	King stone	Perimo early	Perimo early CH	Super strain B	Cal j.n3
0	16.8 ± 3^{a}	25.2 ± 4^{a}	21.6 ± 5^{a}	8.55 ± 1.9^{a}	14.6 ± 3^{a}	3 ± 0.4^{a}	21.4 ± 4^{a}
25	$2.9 \pm 0.2^{b,c}$	2.5 ± 0.3^{b}	2.27 ± 0.3^{c}	3.4 ± 0.4^{b}	3 ± 0.2^{b}	2 ± 0.2^{b}	7 ± 0.88^{b}
50	1.81 ± 0.0^{c}	2.1 ± 0.3^{b}	4.93 ± 0.7^{b}	$2.1 \pm 0.23^{c,d}$	2.6 ± 0.33^{b}	1.9 ± 0.1^{b}	6 ± 0.39^{c}
75	1.18 ± 0.2^{c}	1.68 ± 0.1^{b}	2.23 ± 0.3^{c}	1.92 ± 0.4^{d}	2.4 ± 0.24^{b}	1.46 ± 0.12^{c}	5.7 ± 0.3^{c}
100	1.83 ± 0.0^{c}	1.37 ± 0.0^{b}	2.20 ± 0.4^{c}	$2.92 \pm 0.3^{b,c}$	1.6 ± 0.00^{b}	1.95 ± 0.11^{b}	5.4 ± 0.4^{c}

Within column means followed by the same superscripts are not significantly different at $p < 0.01$

Table 6 Shoot lengths (mm) of seven varieties of tomato seedlings, after 6 days of incubation with increasing concentrations of silver nano-particles

AgNPs mg l^{-1}	Early urbanay VF	Super stone	King stone	Perimo early	Perimo early CH	Super strain B	Cal j.n3
0	10.98 ± 1^{a}	14.08 ± 2^{a}	10.3 ± 0.9^{a}	7.97 ± 0.7^{b}	13.49 ± 1.4^{a}	1.5 ± 0.12^{b}	12 ± 0.95^{a}
25	$8.26 \pm 0.6^{b,c}$	7.91 ± 1^{b}	$8.58 \pm 0.9^{a,b}$	13.1 ± 1.8^{a}	8.34 ± 0.92^{b}	1.17 ± 0.1^{a}	8.9 ± 0.8^{b}
50	9.15 ± 0.5^{b}	5.94 ± 0.6^{c}	$7.6 \pm 0.65^{b,c}$	6.21 ± 0.56^{c}	6.17 ± 0.7^{c}	1.5 ± 0.1^{b}	6 ± 0.7^{c}
75	7.22 ± 0.5^{c}	6.36 ± 0.7^{c}	$5.62 \pm 0.6^{c,d}$	8.1 ± 0.9^{b}	4 ± 0.3^{d}	1.41 ± 0.11^{a}	3 ± 0.4^{d}
100	5.2 ± 0.45^{d}	3.42 ± 0.12^{d}	5 ± 0.63^{d}	5.1 ± 0.4^{d}	3.54 ± 0.3^{d}	0.8 ± 0.00^{c}	2 ± 0.23^{d}

Within column means followed by the same superscripts are not significantly different at $p < 0.01$

decreased VI in wheat (*Triticum aestivum*) plants [36]. Drastically, decrease in VI and TI are in conformity with other reports [37, 38]. Haghighi et al. (2012), reported that tomato plants exposed to nano silicon showed significant decrease in VI, also copper and zinc significantly decreased seedling vigor, TI, germination percentage, shoot and root lengths in tomato plants [37]. Marked decrease in the growth parameters such as TI, VI, plant weight, length of shoot and root was seen in hyacinth bean seedlings exposed to heavy metal Cadmium [38].

Effect on Root and Shoot Growth

The root elongation significantly was decreased in all varieties and concentrations compared with the control (Table 5). In relation to shoot length, except in Super strain variety at 25 mg l^{-1} and Primo early variety at 25 and 75 mg l^{-1} concentrations, all other concentrations and varieties showed drastic decrease in shoot length (Table 6). Reported that root and shoot growths are more affected by the Ag treatment than seed germination [34]. AgNPs showed adverse effect on seed germinations, root and shoot growth on *Oryza sativa*, *Vigna radiata* and *Brassica campestris* species when they were soaked and incubated at different concentrations of nanoparticles [39]. AgNPs resulted in reduction in root and shoot growth in wheat (*Triticum aestivum*) seeds [36]. When *Phaselous radiatus*, *Sorghum bicolor* and *Lolium multiflorum* were subjected to silver nanoparticles resulted in reduced root growth, root length and biomass were observed [34, 40]. Seed germination and root elongation are two standard indictors of phytotoxicity suggested by U.S. Environmental Protection Agency. The heavy metal treatments decrease germination capability and seedling growth through inhibition of cell enlargement (Fig. 2b). The decrease in root length was stronger than shoot in all varieties. Roots are the first target exposed to pollutants and show toxic symptoms more strong than shoots [41].

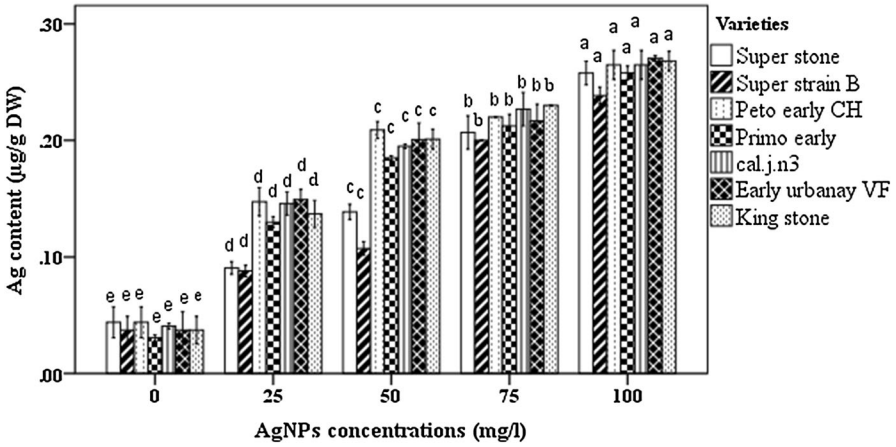


Fig. 3 Linear correlation between Ag content in seedlings and employed AgNPs concentrations in seven varieties of tomato seedlings. *Different letters* are significantly different at $p < 0.01$. Values are presented as the mean ± SE of three independent replications

Also suggested that, Ag content remains associated with roots and translocation from root to shoots is very low [34]. Using AgNPs and root tip cells of onion (*Allium cepa*), researchers demonstrated that AgNPs could disrupt cell division process causing chromatin bridge, stickiness and cell disintegration [42]. This observation suggests toxic effect of AgNPs is firstly due to present of nanoparticles and secondly release of Ag^{+} ions from nanoparticles and generation of free radicals during the AgNPs suspension [43]. Furthermore, AgNPs size, species of plants, exposure time and conditions are effective factors in toxicity of AgNPs.

Atomic Absorption Spectroscopic

Atomic absorption spectroscopic studies showed a linear increase with the induced of AgNPs. Ag content of treated seedlings increased at employed concentrations of AgNPs in uptake range of 0.04–0.3 μg g^{-1} dry weight (Fig. 3). Harris and Bali (2008) reported that the metal uptake was in corresponding with increase in metal concentration and exposure time in *Brassica juncea* and *Medicago sativa* plants [44]. Increasing concentration of AgNPs in media of plants will lead to greater uptake in plants.

Conclusion

Excessive accumulation of AgNPs at high concentrations, exerted a strong stress condition on the growth that its consequences is clearly evident in drastic decrease in the tolerance index, vigor index and seedlings growth inhibition. This study also revealed that nanoparticle had varying effects on germination index by accelerate in germination, by promote water uptake in seeds than VI, tolerance of seedlings, root and shoot growth initiation, depending upon the differing genetic background of tomatoes genotypes, type, size and concentration of nanomaterial.

Acknowledgments Thanks to my parents for all their kindness.

Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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