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Scientific Research

Investigating the effect of selenium nanoparticles on the quality and shelf life of cherry tomato (*Solanum lycopersicum* L. cv Roma)

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ABSTRACT

Nowadays, the demand for healthy and quality products has increased among consumers, and the use of selenium nanoparticles has beneficial effects in delaying aging and maintaining the quality of horticultural products due to its antioxidant properties. This research was carried out with the aim of investigating the effect of selenium nanoparticles on the quality and shelf life of cherry tomato fruit in a factorial experiment in the form of a completely random statistical design with three replications. First, cherry tomato seeds were cultivated in pots containing perlite and vermiculite (1-2) after disinfection. Then, the seedlings were sprayed with selenium nanoparticles (2, 4, 6 and 8 mg l^{-1}) at flower formation 3 times with an interval 10 days. After harvesting, the containers containing 5 fruits were placed in a refrigerator with a temperature of 4±1°C and a humidity of 85-90%. Sampling and evaluation of traits were done on the day of the experiment, 7, 14 and 21 days after harvesting. The results showed that the highest percentage of fruit relative fresh weight and cell membrane stability index, amount of soluble solids and titratable acidity, total carotenoid and chlorophyll content, amount of vitamin C and total antioxidant activity in the treatment of selenium nanoparticles was 4 mg l^{-1} and the highest amount pH and total phenol were obtained in the treatment of selenium nanoparticles of 2 mg l^{-1}. Also, the maximum and minimum storage life of fruits were observed with 29.5 and 18.3 days respectively in the treatment of selenium nanoparticles 4 mg l^{-1} and 8 mg l^{-1}. According to the results obtained from this research, the use of selenium nanoparticles with concentrations of 2 mg l^{-1} is an effective treatment for maintaining the quality and shelf life of Roma cherry tomatoes.

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1-Introduction

Tomato (*Lycopersicon esculentum*) is a plant that belongs to the Solanaceae family and is native to Central and South America. It is one of the most valuable sources of minerals. Cherry tomatoes are particularly rich in vitamins C, A, K and antioxidant compounds such as lycopene [1]. This product is also consumed fresh or processed due to its appealing appearance, and it plays a crucial role in the human diet due to its nutritional and medicinal benefits [2]. The consumption of tomatoes and their derivatives has been shown to reduce the risk of developing gastrointestinal, cardiovascular diseases, osteoporosis, and prostate cancer [3]. Tomatoes are a climacteric fruit, and due to their ability to produce significant amounts of ethylene, resulting in a limited storage period. A substantial portion of this produce is lost after harvest due to inadequate preservation methods [4].

Today, researchers are exploring innovative techniques to enhance plant performance. Nanoparticles, due to their unique physical properties, can significantly improve plant metabolism. By penetrating the leaves and cells, these particles facilitate the transfer of chemical substances to the DNA and plant cells, resulting in morphological and physiological changes in the plants. The effects of nanoparticles on plants are influenced by their composition, concentration, size, and physical and chemical properties, as well as the specific plant species involved [5]. Selenium (Se) is a micronutrient known for its antioxidant, anti-cancer, and antiviral properties, and it is recognized as an essential element for human and animal health [6]. While selenium can be toxic to plants at high concentrations, it offers beneficial effects at lower levels and is considered a non-essential element for plant growth. Nevertheless, it plays a crucial role in promoting growth, enhancing the enzymatic antioxidant system, and improving plant tolerance to environmental stresses [7]. Selenium mitigates the levels of reactive oxygen species by converting superoxide anions into hydrogen peroxide or through the action of antioxidant enzymes such as glutathione peroxidase and glutathione S-transferase [8].

In a study, Aftab et al. (2023) reported that the application of selenium to strawberry plants (*Fragaria* × *ananassa* Duch) reduced weight loss and fruit decay percentages compared to the control, while simultaneously increasing fruit moisture content, peroxidase and catalase enzyme activity, phenol content, total antioxidant activity (DPPH), and shelf life [9]. In tomato (*Lycopersicum esculentum* L, cv. Foria.), the application of selenium also enhanced relative water content, chlorophyll and carotenoid levels, peroxidase and catalase enzyme activity, root volume, and the number of leaves, while reducing the cell membrane stability index [10]. Mohebbi et al. (2019) investigated the effects of crown spraying with sodium selenate on maintaining the quality of Starking Delicious apple fruits during storage. The results indicated that treating the fruits with different levels of selenium significantly reduced ethylene production and helped maintain flesh firmness, pH, titratable acidity, total soluble solids, vitamin C, and anthocyanin content compared to the control fruits [11].

Given the nutritional value and economic significance of tomatoes, the need to reduce high post-harvest losses, and the beneficial role of selenium in enhancing the post-harvest quality of horticultural products, this research was conducted. Previous studies have explored the impact of selenium on increasing the yield and quality of other fruit crops. However, no research has been conducted on the effects of selenium on preserving the quality and shelf life of Roma cherry tomatoes. Therefore, this study aimed to investigate the effect of selenium nanoparticles on the quality and shelf life of cherry tomato (*Solanum lycopersicum* L., cv Roma).

2- Materials and Methods

2.1. Sample Preparation

Initially, seeds of the cherry tomato variety Roma were sown in pots containing perlite and vermiculite after sterilization. During the flowering stage, the seedlings were sprayed with selenium nanoparticles (2.5, 5, 7.5, and 10 mg l^{-1}) in three instances at 10-day intervals. After harvesting, the fruits were sorted by size and uniformity, with soft, damaged, and non-uniform fruits being discarded. Then, healthy, similarly

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sized, and colored fruits were selected and placed in containers containing five fruits each, stored in a refrigerator at a temperature of ±4 degrees Celsius and 85 to 90 percent humidity. Sampling and evaluation of the traits were conducted on the day the experiment started, as well as 7, 14, and 21 days after harvest.

2.2. Relative Fresh Weight of Fruits

The fresh weight of the fruits was measured using a digital scale with a precision of 0.01 grams. The relative fresh weight was calculated using equation (1) and expressed as a percentage [12].

(1) Equation

Relative Fresh Weight (%) = (Target Day Fresh Weight / Fresh Weight on Day 0) × 100

2.3. Weight Loss of Fruits

To evaluate the percentage of weight loss of the fruits, the weight of the samples was measured before and after storage using the following equation (2) [13].

(2) Equation

Weight Loss(%) = [(Initial Fresh Weight − Secondary Fresh Weight) / Initial Fresh Weight] × 100

2.4. Cell Membrane Stability Index

Initially, one gram of the fruits were placed in falcon tubes containing distilled water and stored in a water bath at 30 degrees Celsius for 60 minutes. After removing the samples from the water bath, the EC_1 (1:1) was read using an EC meter (Model 7310, Mehama Ozma). The Falcon tubes were then placedin an autoclave at 120 degrees Celsius with 2.1 atm pressure for 20 minutes and then cooled. The EC_2 (1:3) was read, and the cell membrane stability index was calculated using equation (3) and expressed as a percentage [14].

(3) Equation

Cell Membrane Stability = {1 − (EC1 / EC2)} × 100

2.5. Soluble Solids Content

The percentage of soluble solids content in the fruits was measured using a digital refractometer (RA-620/RA-600, KEM, Kyoto, Japan) [15].

2.6. Titration Acidity

The acidity percentage in the fruits was measured using a titration method with 0.1N sodium hydroxide and calculated as the percentage of citric acid [3].

2.7. pH

The pH of the fruit juice was measured using a pH meter (METROHM-632, Brinkmann, Geneva, Switzerland) [15].

2.8. Carotenoid Content

To extract the extract from the cherry tomatoes, one gram of fruit was ground with 5 mL of 80% ethyl acetate and then stored at 4 degrees Celsius for 24 hours. The absorbance of the extract was measured using a spectrophotometer (Visible UV, Spectro Flex 6600) at wavelengths of 480 and 510 nm. The carotenoid content was calculated using equation (4) and expressed as mg g^{-1} of fresh weight [4].

Car (mg/g FW)= 7.6(A480) - 1.49(A510) × V/1000 × W (4) Equation

2.9. Total Chlorophyll Content

To measure the total chlorophyll content of the fruits, the absorbance of the samples at wavelengths of 645 and 663 nm was measured using a spectrophotometer. The total chlorophyll content was calculated using equation (5) and expressed as mg g^{-1} of fresh weight [4].

Chlo total (mg/g FW)= 20.2(A645) + 8.02(A663) × V/1000 × W (5) Equation

2.10. Vitamin C Content

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To measure the vitamin C content of the fruits, a two-stage oxidation-reduction titration method was used, and the results were expressed as mg (ascorbic acid) 100 g^{-1} of fresh weight [16].

2.11. Total Phenol Content

To measure the total phenol content of the fruits, a Folin-Ciocalteu reagent was used, and the absorbance of the samples at a wavelength of 765 nm was measured using a spectrophotometer. The results were then expressed as mg (gallic acid) g^{-1}[12].

2.12. Antioxidant Capacity

To evaluate the total antioxidant capacity of the extracts (DPPH), 5 mL of the extracted samples were mixed with 1 mL of a methanolic solution of 1 mM DPPH and stored in the dark at room temperature for 30 minutes. The absorbance of the samples was measured at a wavelength of 517 nm using a spectrophotometer, and the antioxidant activity was calculated as a percentage using equation (6) [17]

$$\text{DPPH radical-scavenging activity \%} = [(A_{control} - A_{sample}) / A_{control})] \times 100 \quad \text{(6) Equation}$$

2.13. Storage Life

The cherry tomatoes were stored in the refrigerator at a temperature of 4±1 degrees Celsius and a relative humidity of 85 to 90%. The storage life of the fruits after harvest was determined based on signs such as senescence, mold, softening, and breakage, and was expressed in days [2].

2.14. Statistical Analysis

This experiment was conducted as a factorial in a completely randomized design with 3 replicates and 5 fruits per replicate, resulting in a total of 75 cherry tomatoes. The data was analyzed using SPSS software and the means of the data were compared using a Duncan's multiple range test at a significance levels of 1 and 5 %.

3-Results and Discussion

The variance analysis of the data showed that the effect of selenium nanoparticles as a treatment on the relative fresh weight, weight loss of the fruits, soluble solids content, titratable acidity, carotenoid content, total phenol content, antioxidant capacity, and storage life of cherry tomato fruits was significant at the 1% level, and the cell membrane stability index, pH, total chlorophyll content, and vitamin C content at the 5% level. The effect of time was significant at the 1% level for the relative fresh weight, cell membrane stability index, and carotenoid content of the cherry tomato fruits, and at the 5% level for weight loss, soluble solids content, titratable acidity, pH, total chlorophyll content, total phenol content, and antioxidant capacity. The interaction between selenium nanoparticles and time was also significant at the 1% level for relative fresh weight, weight loss, cell membrane stability index, soluble solids content, titratable acidity, carotenoid content, and total phenol content, and at the 5% level for pH, total chlorophyll content, and vitamin C content (Table 1).

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Table 1. Analysis of variance of selenium nanoparticles on quality and shelf life of *Solanum lycopersicum* L., cv Roma

Source of variation	DF	Mean square											
		Relative fresh weight	Weight loss	Cell membrane stability index	Soluble solid	Titratable acidity	pH	Carotenoid	Total chlorophyll	Vitamin C	Phenol	Total antioxidant	Shelf life
Treatment	4	137.2** 7	47.126*	132.51*	8.6** 5	174**	10.7* 1	9.45**	1.47*	8.17*	63.3** 3	11.42**	57.63**
Time	3	246.1** 1	89.328*	178.15*	15.1* 3	4.02*	34.2* 6	14.75**	3.15*	13.1* 2	97.2* 2	18.16*	---
Treatment×Time	12	25.73**	13.14**	23.16**	4.6** 4	0.82**	5.09*	6.12**	0.79*	4.86*	38.6** 5	4.37**	---
Error	40	0.81	0.137	0.785	0.041	0.008	0.07 2	0.081	0.012	0.089	0.775	0.075	0.042
CV (%)	---	11.19	10.25	9.42	10.37	9.58	10.4 3	10.74	11.08	10.21	11.56	9.46	10.32

* and ** are significant at the 5% and 1% levels, Respectively

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3.1. Relative Fresh Weight of Fruit

The results indicated that during the storage period, a decrease in the relative fresh weight of the fruits was observed in all treatments. After 21 days of harvest, the highest relative fresh weight was recorded in the treatment with 4 mg l^{-1} selenium nanoparticles with 72.46% and the lowest was noted in the treatment with 8 mg l^{-1} selenium nanoparticles, at 49.92% (Table 2). The decline in relative fresh weight during storage may be attributed to increased transpiration and evaporation from the fruit's surface [18]. The foliar application of selenium positively influences chlorophyll synthesis, carbon fixation, stimulation of cell division in meristematic cells, and the synthesis and hydrolysis of starch, all of which significantly contribute to fruit weight [19]. Consistent with the findings of this experiment, similar enhancements in fruit weight have been reported by Wang et al. (2018) in blueberry (*Vaccinium spp*) using selenium application [20].

Table 2. Effect of selenium nanoparticles on physicochemical traits of *Solanum lycopersicum* L., cv Roma

Days	Treatment (mg l^{-1})	Relative fresh weight (%)	Weight loss (%)	Cell membrane stability index (%)	TA (mg 100 ml^{-1})	TSS (°Brix)	pH
1	Control	100^{a}	0.00^{a}	100.00^{a}	0.52^{cd}	5.42^{c}	5.49^{b}
	selenium nanoparticles 2	100^{a}	0.00^{a}	100.00^{a}	0.56^{b}	5.71^{b}	5.69^{a}
	selenium nanoparticles 4	100^{a}	0.00^{a}	100.00^{a}	0.59^{a}	5.87^{a}	5.61^{a}
	selenium nanoparticles 6	100^{a}	0.00^{a}	100.00^{a}	0.51^{d}	5.26^{d}	5.38^{c}
	selenium nanoparticles 8	100^{a}	0.00^{a}	100.00^{a}	0.48^{e}	5.07^{de}	5.31^{d}
7	Control	80.36^{e}	9.67^{d}	86.16^{c}	0.48^{e}	5.13^{e}	5.07^{e}
	selenium nanoparticles 2	86.31^{c}	6.12^{c}	92.45^{b}	0.51^{d}	5.37^{d}	5.38^{c}
	selenium nanoparticles 4	88.47^{b}	5.31^{b}	90.37^{b}	0.54^{c}	5.51^{c}	5.35^{c}
	selenium nanoparticles 6	75.25^{fg}	12.45^{f}	80.25^{d}	0.45^{f}	4.82^{f}	4.84^{fg}
	selenium nanoparticles 8	70.16^{h}	15.79^{g}	76.59^{e}	0.38^{g}	4.64^{g}	4.57^{gh}
14	Control	73.19^{g}	14.83^{g}	74.32^{ef}	0.32^{h}	4.32^{h}	4.51^{gh}
	selenium nanoparticles 2	77.62^{f}	9.31^{d}	80.67^{d}	0.39^{g}	4.64^{fg}	4.86^{f}
	selenium nanoparticles 4	83.27^{d}	11.06^{e}	81.59^{d}	0.42^{fg}	4.61^{g}	4.67^{fg}
	selenium nanoparticles6	66.45^{i}	18.82^{i}	69.83^{f}	0.26^{i}	4.08^{ij}	3.92^{j}
	selenium nanoparticles 8	63.38^{ij}	19.94^{ij}	62.43^{g}	0.20^{k}	3.76^{k}	3.61^{j}
21	Control	57.38^{j}	17.35^{h}	68.57^{f}	0.21^{k}	3.86^{jk}	4.13^{i}
	selenium nanoparticles 2	65.15^{i}	15.41^{gh}	73.32^{ef}	0.26^{j}	4.03^{j}	4.65^{fg}
	selenium nanoparticles 4	72.46^{h}	13.26^{ef}	76.41^{e}	0.32^{h}	4.25^{i}	4.42^{h}
	selenium nanoparticles 6	54.74^{k}	21.97^{j}	62.51^{g}	0.17^{l}	3.59^{l}	3.79^{j}
	selenium nanoparticles 8	49.92^{l}	24.82^{k}	57.68^{h}	0.11^{m}	3.10^{m}	3.35^{k}

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Values marked by different letters are significantly different (P< 0.05).

3.2. Fruit Weight Loss

Comparative analysis of the mean data results revealed that the highest weight loss of the fruit, observed after 21 days of harvest was observed in the treatment with 8 mg l^{-1} selenium nanoparticles, with 24.82%, and the lowest was recorded in the treatment with 4 mg l^{-1} selenium nanoparticles, with 13.26% (Table 2). The findings indicate that the increase in weight loss percentage of the fruits can be attributed to water loss resulting from respiration and transpiration processes during the storage period. The reduced percentage of weight loss at lower concentrations of selenium nanoparticles may be related to their antioxidant properties and the role of selenium in delaying aging by decreasing ethylene production. In contrast, the increased weight loss at higher concentrations of selenium is likely due to enhanced water loss and elevated respiration rates [21]. Additionally, in guava fruit (*Psidium guajava* L), the application of selenium has also been shown to delay weight loss after harvesting [22].

3.3. Cell Membrane Stability Index

The experimental data presented in Table 2 indicate that the percentage of the cell membrane stability index decreased during the storage period in all treatments. After 21 days of harvest, the highest and lowest cell membrane stability indices were recorded in the treatments with 4 mg l^{-1} and 8 mg l^{-1} selenium nanoparticles, respectively, with values of 76.41% and 57.78%. The cell membrane is composed of phospholipids, and since fatty acids and lipids are highly sensitive to oxygen, their reaction with oxygen can lead to membrane degradation. Consequently, the application of selenium enhances the activity of antioxidant enzymes, facilitating the detoxification of active oxygen and reducing lipid peroxidation, thereby preserving the cell membrane stability index throughout the storage period [23]. Additionally, selenium improves membrane stability by promoting potassium uptake in plant cells [18]. The results of this experiment are consistent with those of Mozafarian et al. (2016) and Razi et al. (2020) on two tomato cultivars (*Lycopersicum esculentum* L. cv. Foria and *Solanum lycopersicum* L. cv. Login 935) [10, 24].

3.4. Soluble Solids Content

According to the results obtained from the comparison of mean data during the storage period, the content of soluble solids decreased, with the highest level recorded at 4.25° Brix in the treatment with 4 mg l^{-1} selenium nanoparticles and the lowest at 3.1° Brix in the treatment with 8 mg l^{-1} selenium nanoparticles after 21 days of harvest (Table 2). During this period, increased respiration leads to the consumption of respiratory substrates, such as carbohydrates, resulting in a decrease in soluble solids content [4]. Selenium positively influences the production of photosynthetic pigments, thereby enhancing the intensity of photosynthesis and increasing soluble sugar levels. Conversely, selenium also plays a significant role in reducing the respiration rate, which helps to prevent the consumption of soluble sugars and increases the soluble solids content [25]. In one study, the foliar application of selenium on Fakhri grape (*Vitis vinifera* cv. Fakhri) resulted in an increase in soluble solids content [26]. Furthermore, Yuan et al. (2021) reported an increase in soluble solids in pear (*Pyrus Ussuriensis*) with selenium application [27].

3.5. Titration Acidity

The analysis of the data (Table 2) showed that titratable acidity decreased during the storage period. The highest titratable acidity recorded was 0.32% in the treatment with 4 mg l^{-1} selenium nanoparticles, while the lowest was 0.11% in the treatment with 8 mg l^{-1} selenium nanoparticles after 21 days of harvest. Organic acids significantly influence the taste of fruits, and their levels tend to decline during storage as they serve as respiratory substrates [28]. The observed increase in acidity with the application of selenium nanoparticles is attributed to the role of selenium in reducing the intensity of respiration

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in the fruits [11], This finding is consistent with the research conducted by of Elham and colleagues (2013) on Navel orange fruit [29].

3.6. pH

The results of the comparison of mean data indicate that the pH of the fruits decreased during the storage period. The highest pH of 4.65 was observed in the treatment with 2 mg l^{-1} selenium nanoparticles, while the lowest pH of 3.35 was recorded in the treatment with 8 mg l^{-1} selenium nanoparticles after 21 days of harvest (Table 2). In this study, the increase in pH at lower selenium concentrations may be related to respiration and the consumption of organic acids in the fruits. This finding aligns with the research conducted by Mohabbi et al. (2019) on the impact of sodium selenate foliar application on Starking Delicious apple fruit [11].

3.7. Carotenoids

As illustrated in Figure 1, the carotenoid content of the fruits decreased over the storage period. The highest carotenoid content recorded was 3.86 mg per gram of fresh weight in the treatment with 4 mg l^{-1} selenium nanoparticles, while the lowest was 1.90 mg in the treatment with 8 mg l^{-1} selenium nanoparticles, measured after 21 days of harvest. The reduction in carotenoids, which serve as non-enzymatic antioxidants, suggests their degradation under conditions of high oxidative stress [14]. Mozafari et al. (2020) linked the increase in carotenoid content to selenium's influence on mineral elements in plants. Since the primary components of photosynthetic pigments possess nitrogenous structures, selenium enhances nitrogen levels, thereby promoting the production of photosynthetic pigments and carotenoids [26]. The results of this experiment indicate that the foliar application of selenium significantly increased the carotenoid content in carrots [31].

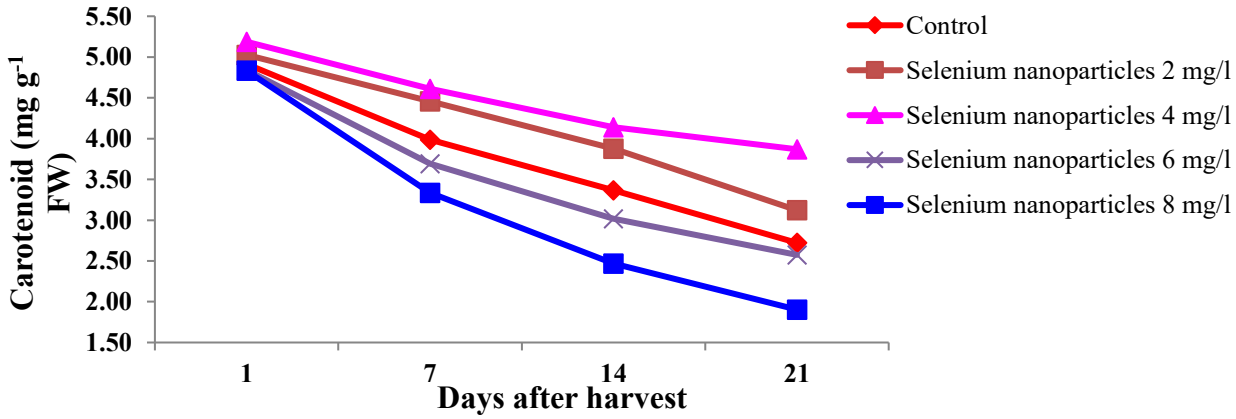

Fig 1 Effect of selenium nanoparticles on carotenoid content of *Solanum lycopersicum* L., cv Roma

3.8. Total Chlorophyll

The changes in total chlorophyll content, as shown in Figure 1, indicate that the total chlorophyll content of the fruits decreased during the storage period across all treatments. The treatment with 4 mg l^{-1} selenium nanoparticles exhibited the highest total chlorophyll content at 0.54 mg g^{-1} of fresh weight, while the treatment with 8 mg l^{-1} selenium nanoparticles demonstrated the lowest total chlorophyll content at 0.21 mg g^{-1} of fresh weight on day 21 after harvest. The reduction in chlorophyll levels during the storage period can be attributed to three factors: a decrease in pH, oxidative stress, and the activity of the enzyme chlorophyllase, all of which occur more rapidly due to respiration and the aging process [30]. The total chlorophyll content in fruits treated with lower concentrations of selenium nanoparticles increased, likely due to the protective effect of selenium on chloroplast enzymes and the enhanced absorption of

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magnesium and iron, which ultimately promotes the biosynthesis of photosynthetic pigments [18]. Conversely, higher concentrations of selenium can inhibit the enzymes responsible for chlorophyll biosynthesis, adversely affecting chlorophyll content [25]. An increase in photosynthetic pigments due to selenium has also been reported in blueberry fruit (*Vaccinium spp*.) [20].

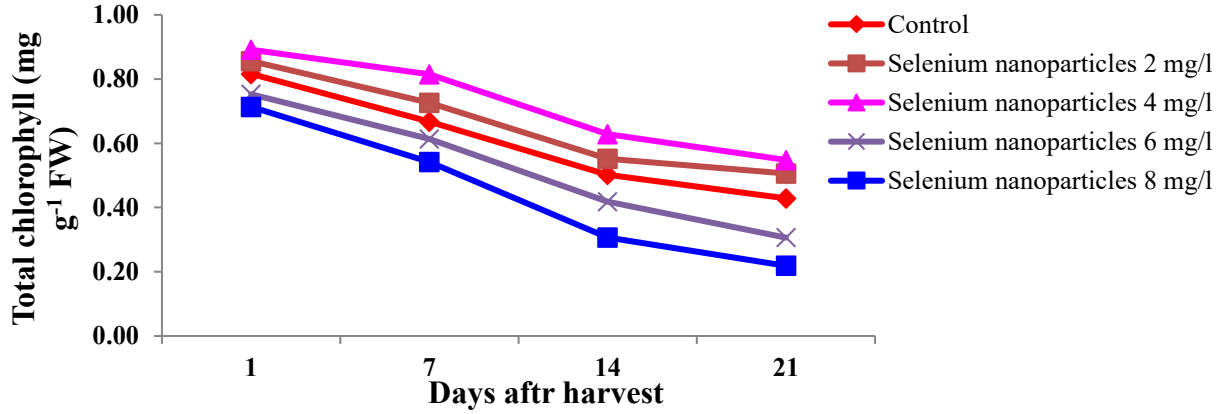

Fig 2 Effect of selenium nanoparticles on total chlorophyll content of *Solanum lycopersicum* L., cv Roma

3.9. Vitamin C

The results indicated that treatments with 4 mg l^{-1} selenium nanoparticles (5.11 mg $100g^{-1}$) and 8 mg l^{-1} selenium nanoparticles (3.61 mg $100g^{-1}$) had the highest and lowest amounts of vitamin C, respectively, after 21 days of storage (Figure 3). In this study, the vitamin C content decreased during the storage period because it is significantly affected by the water loss from the fruit and exhibits a positive correlation with fruit weight loss [32]. After harvest, the vitamin C content is hydrolyzed by the enzyme ascorbic acid oxidase, leading to a decrease; furthermore, ascorbic acid serves as a cofactor for ACC oxidase in ethylene production, resulting in a reduction of its levels over time during storage [12]. Selenium, due to its antioxidant properties and its ability to activate mechanisms that reduce oxidative activity, helps preserve antioxidant compounds such as vitamin C throughout the storage period [11]. Zhou et al. (2018) attributed the increased vitamin C levels in tomatoes to selenium's effect on reduced glutathione, which plays a role in the vitamin C synthesis cycle [25]. Additionally, Lu et al. (2022) reported an increase in vitamin C levels in strawberries (Strawberry cv. Sweet Charlie) with the application of selenium [32].

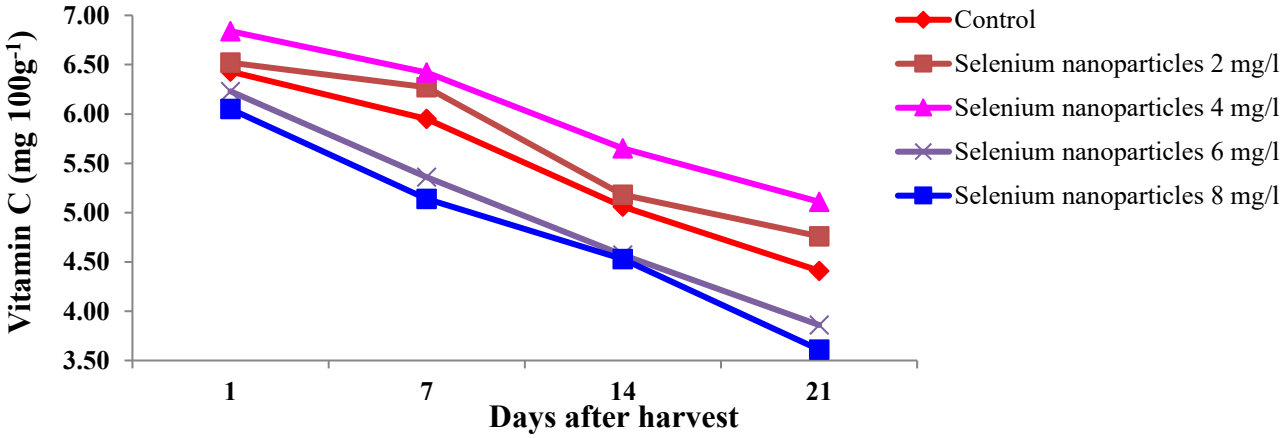

Fig 3 Effect of selenium nanoparticles on vitamin C of *Solanum lycopersicum* L., cv Roma

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3.10. Phenols

According to the results of the mean comparison, the treatment with 2 mg l-1 selenium nanoparticles demonstrated the highest total phenol content at 22.71 mg g-1 of dry weight, while the treatment with 8 mg l-1 selenium nanoparticles exhibited the lowest content at 11.46 mg g-1 of dry weight after 21 days of harvesting (Figure 4). The degradation of cellular structures due to fruit aging has led to a decrease in phenol content during the storage period [33]. Additionally, phenols serve as substrates for the enzyme polyphenol oxidase, resulting in a reduction of their levels post-harvest [34]. The increase in phenol content in fruits may be linked to the role of selenium in enhancing phenylalanine ammonia-lyase, a key enzyme in the synthesis of phenolic compounds [35]. Research conducted by Gros et al. (2021) reported the impact of selenium on phenolic compounds in apples (*Malus domestica*) [36].

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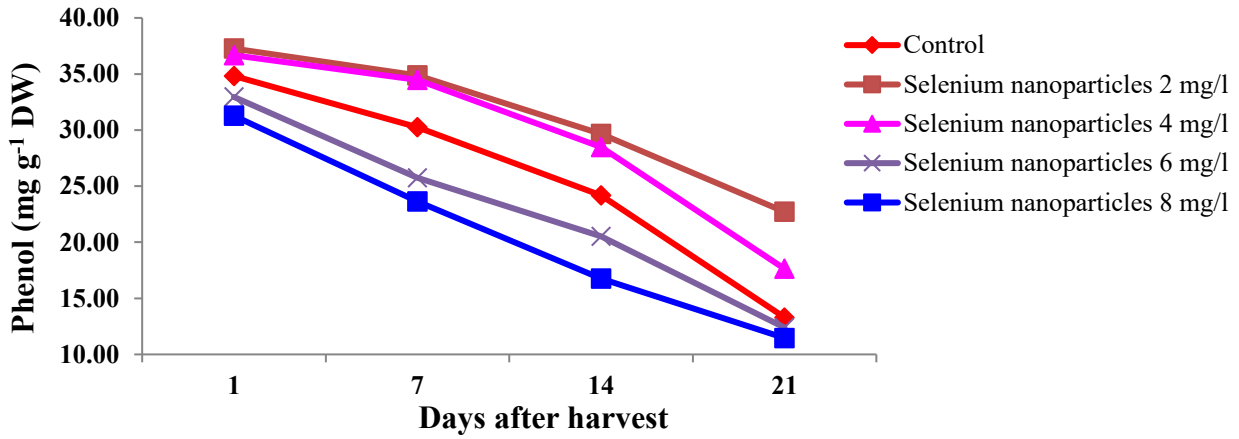

Fig 4 Effect of selenium nanoparticles on phenol content of *Solanum lycopersicum* L., cv Roma

3.11. Total Antioxidant Activity

Figure 5 demonstrates that total antioxidant activity decreased after harvesting. The treatment with 4 mg l^{-1} selenium nanoparticles exhibited the highest antioxidant capacity at 4.19%, while the treatment with 8 mg l^{-1} selenium nanoparticles showed the lowest capacity at 3.08%. Both enzymatic and non-enzymatic activities contribute to the degradation of cell membranes, the generation of reactive oxygen species, and the involvement of these compounds in cellular metabolism. Consequently, this leads to a decrease in total antioxidant activity in the fruit during the storage period [37]. Furthermore, selenium is a crucial component of the enzyme glutathione peroxidase; low concentrations of selenium significantly influence the metabolism of plant cells. By enhancing the activity of antioxidant enzymes and compounds such as ascorbate peroxidase, glutathione peroxidase, glutathione, ascorbate, and proline, selenium can effectively reduce hydrogen peroxide levels in plants [38]. The results of this experiment regarding the effect of selenium on increasing antioxidant activity align with studies on apple fruit (*Malus domestica*) [3].

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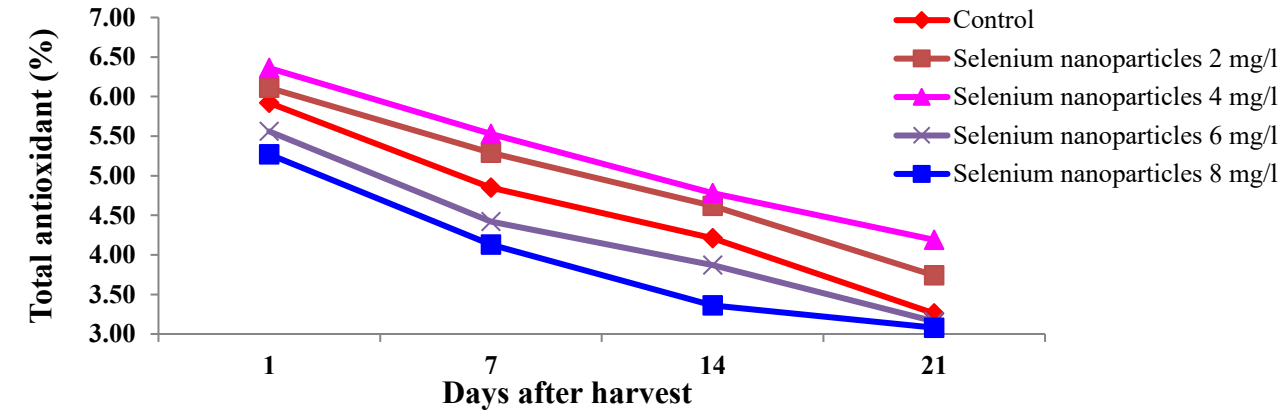

Fig 5 Effect of selenium nanoparticles on total antioxidant of *Solanum lycopersicum* L., cv Roma

3.12. Shelf Life

The results indicated that the longest shelf life (29.5 days) was observed in the treatment with 4 mg l^{-1} selenium nanoparticles, while the shortest shelf life (18.3 days) was noted in the treatment with 8 mg l^{-1} selenium nanoparticles (Figure 6). Research conducted by Zhou et al. (2017) on tomato plants demonstrated that selenium inhibits the biosynthetic genes responsible for ethylene production, thereby reducing both ethylene production and respiration rate by increasing antioxidant capacity, which ultimately prolongs the shelf life of the fruit. This finding aligns the results of this study [25]. Furthermore, Eslam et al. (2018) reported an increased shelf life in cherry tomatoes (*Solanum lycopersicum* cv. Unicorn) with the application of selenium [40].

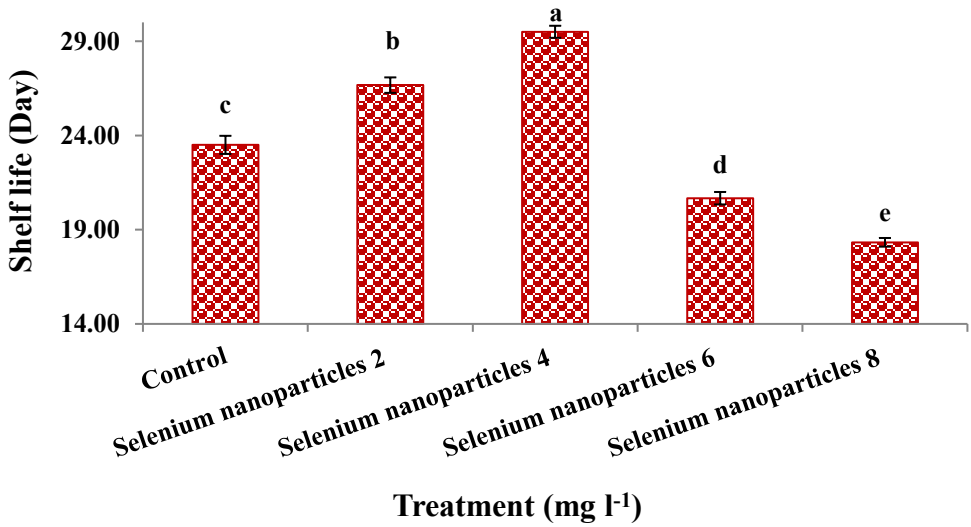

Fig 6 Effect of selenium nanoparticles on shelf life of *Solanum lycopersicum* L., cv Roma

4-Conclusion

Preserving the nutritional value, color, aroma, flavor, and other factors that influence the economic value and shelf life of this valuable product is crucial. This can be achieved using natural compounds that promote consumer health and environmental safety, such as selenium, a rare and essential element for human health that can be obtained through a balanced diet. In this study, selenium nanoparticles were utilized to enhance the quality and shelf life of tomatoes.

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The results indicated that treatment with 4 mg l^{-1} selenium nanoparticles resulted in the highest percentages of relative fresh weight of the fruit, cell membrane stability index, total soluble solids, titratable acidity, carotenoid and total chlorophyll content, Vitamin C levels, antioxidant capacity, and shelf life. Furthermore, the highest pH and total phenol content were observed in the treatment with 2 mg l^{-1} selenium nanoparticles. Overall, the application of selenium nanoparticles at concentrations of 2 and 4 mg l^{-1} can significantly contribute to preserving the quality and shelf life of cherry tomatoes (*Solanum lycopersicum* L. cv Roma) for fresh consumption and processing.

5-Refrenses

[1] Otroshi, M., Karimi, R. 2014. Effect of concentration of plant growth regulators on in vitro micropropagation of cherry tomato. Soil and plant interaction, 5(19): 127-133.

[2] Imani, A., Danaee, E. 2023. The effect of Aloe vera gel and Chitosan as an oral coating on the quality properties and shelf life of Tomato (*Solanum lycopersicum*) during storage. Journal of Food Biosciences and Technology, 13(3): 19-26.

[3] Ganjloo, A., Zandi, M., Bimakr, M., Monajem, S. 2020. Ripening stages control of Cherry Tomato coated with Aloe Vera gel using artificial vision system. Journal of food science and technology, 17 (105): 135-149.

[4] Gelyani, S., Danaee, E. 2025. The Effect of starch coating and hot water treatment on the quality and shelf life of Tomatoes (*Solanum lycopersicum*). Journal of Innovation in Food Science and Technology, 16 (4): 89-102.

[5] Shah Valibar, A., Ismailzadeh Bahabadi, P., Yusufzai, F. 2016. The effect of nanoparticles on the growth and metabolism of plants. The first international conference on new findings in biotechnology.

[6] Murphy, L.A., Reeves, P.G., Jones, S.S. 2014. Selenium and quality characteristics expressed in wheat breeding lines. Food Systemic Journal, 32: 52-63.

[7] Nawaz, F., Ashraf, M.Y., Ahmad, R., Waraich, E.A., Shabbir, R.N. 2014. Selenium (Se) regulates seedling growth in wheat under drought stress. Advances in Chemistry, (3): 1-7.

[8] Feng, R., Wei, C., Tu, S. 2013. The roles of selenium in protecting plants against abiotic stresses. Environmental and Experimental Botany, 87: 58-68.

[9] Aftab, A., Ali, M., Yousaf, Z., Binjawhar, D. N., Hyder, S., Aftab, Z.-e.-H., Maqbool, Z., Shahzadi, Z., Eldin, S. M., Iqbal, R., Ali, I. 2023. Shelf-life extension of *Fragaria* × *ananassa* Duch. Using selenium nanoparticles synthesized from Cassia fistula Linn. Leaves. Food Science & Nutrition, 11: 3464–3484.

[10] Mozafariyan, M., Pessarakli, M., Saghafi, K. 2017. Effects of selenium on some morphological and physiological traits of tomatoplants grown under hydroponic condition. Journal of Plant Nutrition, 40(2): 139-144.

[11] Mohebbi, S., Babalar, M., Zamani, Z., Askari Sarcheshmeh, M. A. 2019. Influence of canopy spraying with sodium selenate on selenium biofortification and fruit quality maintenance of 'Starking Delicious' apple during storage. Iranian Journal of Horticultural Science, 50(3): 501-514.

[12] Soroori, S., Danaee, E., Hemmati, K., Ladan Moghadam, A.R. 2021. The metabolic response and enzymatic activity of *Calendula officinalis* L. to foliar application of spermidine, citric acid and proline under drought stress and in a post-harvest condition. Journal of Agriculture Science and Technology, 23 (6): 1339-1353.

[13] Shorakaie, H., Mirzaalian Dastjerdi, A., Ghasemi, M., Rastegar, S. 2024. Investigating the effects of UV-C and ultrasonic treatments on the shelf life of Langra mango fruits. Journal of food science and technology, 147(21): 16-33.

[14] Danaee, Abdossi, V. 2016. Evaluation of the effect of plant growth substances on longevity of gerbera cut flowers cv. Sorbet. Iranian Journal of Plant Physiology, 7 (1): 1943- 1947.

[15] Danaee, E., Abdossi, V. 2019. Phytochemical and Morphophysiological Responses in Basil (*Ocimum basilicum* L.) Plant to Application of Polyamines. Journal of Medicinal Plants, 18 (69): 125-133.

[DOI: 10.22034/FSCT.22.162.122]

[16] Babashpour-Asl, M., Piryaei, M. 2022. Antioxidant Activities and Several Bioactive Substances of Different Extracts of *Vitis vinifera* L. Journal of Food Biosciences and Technology, 12(2): 49-60.

[17] Soroori, S. and E, Danaee. 2023. Effect of Foliar Application of Citric Acid on Morpho-Physiological and Phytochemical Traits of *Calendula Officinalis* L. Under Drought Stress. International Journal of Horticultural Science and Technology, 10(4): 364-371

[18] Rastegari, H., Tehranifar, A., Nemati, S.H., Vazifehshenas, M.R. 2014. Effect of pre harvest application of salicylic Acid on post-harvest characteristics of pomegranate fruit and storage in cold Store. Journal of Horticultural Science, 28(3): 360-368.

[19] Safaryazdi, A., Lahoti, M., Ganjali, A. 2012. Effect of different concentrations of selenium on plant physiological characteristics of spinach *Spinacia oleraceae*. Journal of Horticultural Science, 26(3): 292-300.

[20] Wang, Y.N., Yi, C., Wang, Y.X., Wang, X. 2018. Effects of selenium fertilizer on fruit quality and plant resistance of Blueberry. IOP Conference Series Earth and Environmental Science, 199(3): 032071.

[21] Pezzarossa, B., Rosellini, I., Borghesi, E., Tonutti, P. 2014. Effects of Se-enrichment on yield, fruit composition and ripening of tomato (*Solanum lycopersicum*) plants grown in hydroponics. Scientia Horticulturae, 165: 106–110.

[22] Choudhary, P., Jain, V. 2018. Effect of post-harvest treatments of selenium on physico-chemical quality in guava (*Psidium guajava* L.). Horticulture International Journal, 2(2): 41-44.

[23] Bybordi, A. 2016. Effect of Zeolite, Selenium and Silicon on yield, yield components and some physiological traits of Canola under salt stress conditions. Iranian Journal of Field Crops Research, 14(1): 154-170.

[24] Rady, M., Belal, H., Gadallah, F., Semida, W. 2020. Selenium application in two methods promotes drought tolerance in *Solanum lycopersicum* plant by inducing the antioxidant defense system. Scientia Horticulture, 266(6): 109290.

[25] Zhu, Z., Chen, Y., Shi, G., Zhang, X. 2017. Selenium delays tomato fruit ripening by inhibiting ethylene biosynthesis and enhancing the antioxidant defense system. Food Chemistry, 219: 179-184.

[26] Mozaffari, M., Razavi, F., Rabiei, V., Kheiry, A., Hassani, A. 2020. Effect of preharvest spraying of selenium on qualitative and biochemical characteristics of Grape cv. Fakhri (*Vitis vinifera* cv. Fakhri). Journal of Horticultural Science, 34(1): 61-74.

[27] Yuan, C., Bu, H., Zhao, J., Liu, J., Yuan, H., Wang, A. 2021. Selenium increases fruit quality by reducing ethylene production and the stone cell content in Pear (*Pyrus Ussuriensis*), Agricultural and Food Sciences, 1-17.

[28] Esmaeili, N., Naghshband, R., Zare Nahandi, F. 2019. Evaluation of the effect of harvest time and fruit cold storage period on some of qualitative characteristics of Cornelian cherry fruit. Food Research Journal, 29(3): 69-84.

[29] Elham, Z., Motty, A.E., Orabi, S.A. 2013. The beneficial effects of using zinc, yeast and selenium on yield, fruit quality and antioxidant defense systems in navel orange trees grown under newly reclaimed sandy soil. Journal of Applied Sciences Research, 9(10): 6487-6497.

[30] Fakorizadeh, S., daneshvar, M., Zare-Bavani M. 2024. Postharvest application of chitosan and putrescine on maintaining the quality and extend shelf-life of cucumber (*Cucumis sativus* L.). Journal of food science and technology, 20 (144): 112-130.

[31] Oliveira, V.C., Faquin., Guimarães, K., Andrade, F. 2018. Agronomic biofortification of carrot with selenium. Ciência e Agrotecnologia, Lavras, 42(2): 138-147.

[32] Lu, N., Wu, L., Zhang, X., Zhang, Y., Shan, C. 2022. Selenium improves the content of vitamin C in the fruit of strawberry by regulating the enzymes responsible for vitamin C metabolism. Plant Soil Environ, 68(4): 205-211.

[33] Rostamzadeh, B., Ramin, A.A., Amini, F., Pirmoradian, M. 2015. Effect of chitosan coating on increasing postharvest life and maintaining apple fruit quality Cv "Soltani". Journal of Crop Production and Processing, 5 (17): 263-272.

[DOI: 10.22034/FSCT.22.162.122]

[34] Zarbakhsh, S., Rastegar, S. 2017. The effect of salicylic acid and gum arabic on some quantitative and qualitative characteristics of *Ziziphus mauritina* Lam during storage. Journal of Food Technology and Nutrition, 14(2): 87-98.

[35] Hosseinzadeh Rostam Kalaei, M., Abdossi, V., Danaee, E. 2022. Evaluation of foliar application of selenium and flowering stages on selected properties of Iranian Borage as a medicinal plan. Scientific Reports, 12: 1-10.

[36] Groth, S., Budke, C., Weber, T., Neugart, S., Brockmann, S., Holz, M., Sawadski, BC., Daum, D., Rohn, S. 2021. Relationship between phenolic compounds, antioxidant properties, and the allergenic protein Mal d 1 in different Selenium-biofortified apple cultivars (*Malus domestica*). Molecules, 26(9): 2647.

[37] Zeraatgar, H., Davarynejad, G.H., Moradinezhad, F., Abedi, B. 2018. Investigation of changes in total phenolic compounds and antioxidant activity of fresh fruit jujube under storage conditions. The first national conference on new opportunities for production and employment in the agricultural sector in the east of the country.

[38] Chomchan, R., Siripongvutikorn, S., Puttarak, P. 2017. Selenium bio-fortification: an alternative to improve phytochemicals and bioactivities of plant foods. Functional Foods in Health and Disease, 7(4): 263-279.

[39] Wang, X., Chang, F., Dong, Q., Jia, P., Luan, H., Wang, X., Zhang, J., Yuan, X., Zhang, X., Yang, S., Qi, G., Guo, S. 2023. Selenium application during fruit development can effectively inhibit browning of fresh-cut apples by enhancing antioxidant capacity and suppressing polyphenol oxidase activity. Journal of Plant Physiology, 287: 154050.

[40] Islam, M.Z., Mele, M.A., Baek, J.P., Kang, H.M. 2018. Iron, odine and Selenium effects on quality, shelf life and microbial activity of Cherry Tomatoes. Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 46(2): 388–392.

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مقاله علمی_پژوهشی

بررسی اثر نانوذرات سلنیوم بر کیفیت و ماندگاری میوه گوجه‌فرنگی گیلاسی (*Solanum lycopersicum* L. cv Roma)

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چکیده

امروزه تقاضا برای محصولات سالم و با کیفیت در میان مصرف کنندگان افزایش پیدا کرده است و استفاده از نانوذرات سلنیوم به دلیل خواص آنتی‌اکسیدانی، اثرات سودمندی در به تاخیر انداختن پیری و حفظ کیفیت محصولات باغبانی دارد. این پژوهش با هدف بررسی اثر نانوذرات سلنیوم بر کیفیت و عمر انباری میوه گوجه فرنگی گیلاسی بصورت فاکتوریل در قالب طرح آماری کاملاً تصادفی با سه تکرار اجرا شد. ابتدا بذرهای گوجه‌فرنگی گیلاسی رقم Roma پس از ضدعفونی در گلدان حاوی پرلایت و ورمی‌کولایت (۲-۱) کشت گردید. سپس نشاها در مرحله تشکیل گل توسط نانوذرات سلنیوم (۲، ٤، ٦ و ۸ میلی‌گرم در لیتر) در ۳ مرتبه و به فاصله ۱۰ روز محلول‌پاشی شدند. پس از برداشت، ظروف حاوی ۵ میوه در یخچال با دمای ۱±٤ درجه سانتی‌گراد و رطوبت ۸۵ تا ۹۰ درصد، قرارداده شدند. نمونه‌برداری و ارزیابی صفات هم در روز شروع آزمایش، ۷، ١٤ و ۲۱ روز پس از برداشت انجام شد. نتایج نشان داد که بیشترین درصد وزن تر نسبی میوه و شاخص ثبات غشاء سلول، میزان مواد جامد محلول و اسیدیته قابل تیتراسیون، محتوای کارتنوئید و کلروفیل کل، میزان ویتامین ث و فعالیت آنتی‌اکسیدان کل در تیمار نانوذرات سلنیوم ٤ میلی‌گرم در لیتر بود و بیشترین میزان pH و فنل کل در تیمار نانوذرات سلنیوم ۲ میلی‌گرم در لیتر بدست آمد. همچنین بیشترین و کمترین عمر انبارمانی میوه‌ها به ترتیب با ۲۹/۵ و ۱۸/۳ روز در تیمار نانوذرات سلنیوم ٤ میلی‌گرم در لیتر و ۸ میلی‌گرم در لیتر مشاهده شد. با توجه به نتایج بدست آمده از این پژوهش کاربرد نانوذرات سلنیوم با غلظت‌های ۲ و ٤ میلی‌گرم در لیتر تیمار موثری در جهت حفظ کیفیت و ماندگاری گوجه‌فرنگی گیلاسی رقم Roma می‌باشد.