Journal of Ornamental Plants
www.jornamental.iaurasht.ac.ir
ISSN (Print): 2251-6433 ISSN (Online): 2251-6441
Research Paper
Volume 11, Number 4: 281-295, December, 2021
DOR: https://dorl.net/dor/20.1001.1.22516433.2021.11.4.4.7

Biochemical and Physiological Responses of Tuberose (*Polianthes tuberosa* L.) Cut Flower to Silver Nanoparticles Treatment

Keramatallah Mohammadi[1], Saeid Chavoshi[2*], Hossein Ali Asadi-Gharneh[3], Masoud Gomarian[2] and Behzad Edrisi[1,4]

[1] Department of Horticultural Sciences, Arak Branch, Islamic Azad University, Arak, Iran

[2] Department of Agronomy and Plant Breeding, Arak Branch, Islamic Azad University, Arak, Iran

3 Department of Horticulture, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran

4 Ornamental Plants Research Center, Horticultural Sciences Research Institute, Agricultural Research, Education and Extension Organization (AREEO), Mahallat, Iran

Received: 01 August 2021 Accepted: 25 December 2021

*Corresponding author's email: s-chavoshi@iau-arak.ac.ir

Abstract

Tuberose is a valuable ornamental plant with a high economic value, which is among the five leading cut flowers of the world. The major obstacle hindering the development of cut flower exports, especially tuberoses, is their short postharvest vase life caused by the disruption of the plant's water relations due to growth and an increase in vase solution microbial load. The quality and longevity of flowers are highly dependent on their stem stability and antioxidant systems. This research investigated the effect of Nano-silver (NS) applied to the cut flowers of tuberoses cv. 'Dezfuli' in 24 h pulse treatments in a randomized complete design. The cut flowers were treated with NS at four rates (0 as control, 10, 20, and 30 mg/L) along with 3% sucrose. Then, the treated flowers were fully immersed in deionized water. The results showed that the application of NS treatment positively increased the activity of antioxidant enzymes and improved postharvest conditions in *Polianthes tuberosa* L. (cut tuberose flower). Moreover, NS reduced the accumulation of malondialdehyde (MDA) in flower stems and also had a positive effect on the rate of chlorophyll increase compared to the control. NS extended the postharvest vase life of the treated flowers versus the control and increased solution uptake and fresh weight of the cut flowers. In this experiment, the 10 mg/L rate of NS exhibited the best results.

Keywords: Antioxidant, Nano-silver, *Polianthes tuberosa*, Postharvest, Sucrose, Vase life.

INTRODUCTION

The tuberose (*Polianthes tuberosa* L.) is a perennial plant from the family Agavaceae, which is native to Mexico and grows in hot and semi-hot regions of the world. This flower species is mainly grown in Mahalat and Dezful in Iran. The tuberose is a valuable ornamental and aromatic plant among cut flowers (Nalousi *et al*., 2019). The Iranian cut tuberose is among the main commercial flowers in Iran, which has been interested in other countries due to their pleasant scent and beautiful florets (Feng *et al*., 2000; Hung and Kao, 2005; Kumar *et al*., 2010; Naidu and Reid, 1989; Waithaka *et al*., 2001).

The main issues in the production of cut tuberoses are their short postharvest vase life, the lack of their floret blooming, neck bending, the loss of the visual quality of the flowers, and consequently, their high wastage. Flowers display symptoms of withering immediately after harvest. The florets bloom on a pairwise basis starting from the bottom, but about 50% of the florets do not usually bloom and shed. The mean vase life of cut tuberoses varies from 5 to 10 days (Naidu and Reid, 1989; Waithaka *et al*., 2001). Petal senescence in flowers was accompanied by the continuous and rapid production of free oxygen radicals (Baker *et al*., 1977).

Ichimura (1998) reported that carbohydrates could reduce ethylene sensitivity in cut flowers, thereby extending their vase lives (Ichimura, 1998; Yamada *et al*., 2007). Nanotechnology is an ongoing revolution that will influence whole the world. Given the extensive and applied effects of this technology on advancing scientific goals, researchers in different fields will have no chance for growth if they do not tend to get involved in nanotechnology in the coming decades (Sastry *et al*., 2010). The application of nanotechnology in crop production allows optimal release and increase in nutrient uptake efficiency, which will have economic and environmental benefits (Liu and Lal, 2015). These nanoparticles have, however, potentially adverse effects on plants (Boonyanitlpony *et al*., 2011). Silver nanoparticle (NS) is an antimicrobial factor in plants (Naing and Kim, 2020) so that nanoparticle absorption by the leaves from the surrounding atmosphere has been proven and it has been revealed that the structure of the hairs and stomata was influenced by these nanoparticles (da Silva *et al*., 2006). In general, nanoparticles, especially (NS), are strong antibacterial compounds that influence most bacteria. They have antifungal activities, too (Roy *et al*., 2013). The use of various compounds, such as chemicals, preservatives, and antimicrobials, prolongs and improves the quality and postharvest life of cut flowers (Madadzadeh *et al*., 2014).

In addition, NS is an important treatment to extend postharvest longevity in the cut flower industry and is well known for its positive and effective impacts in preservative solutions (Li *et al*., 2017; Naing *et al*., 2017; Zhao *et al*., 2018). Research has documented that the application of NS + sucrose to cut gerbera flowers resulted in more extension of the postharvest longevity than the application of other growth regulators, e.g., 8-hydroxyquinoline. The vase of the gerbera flowers was almost doubled in the treatments of 1 or 2 mg/L NS (Solgi *et al*., 2009). According to research, sucrose can delay the aging process and maintain membrane health. Moreover, it can prevent the production of ethylene in flowers and reduce ethylene sensitivity (Halevy and Mayak, 1979). In another study, silver nanoparticles (SNP) increased the vase life of *Alstroemeria* cut flowers (Madadzadeh *et al*., 2014). Also, the treatment with (NS) either in pulsed in standard vase solution or a combination of both increased the vase lives of cut roses, carnations, and gerberas (Liu *et al*., 2009b). The present research aimed to study the effect of (NS) treatment at different rates on vase life, apparent quality, and physiological traits of cut tuberose flowers.

MATERIALS AND METHODS

Plant materials

The cut tuberose flower cv. 'Dezfuli' were commercially harvested. 'Dezfuli' was procured from Dezful County, which were delivered in suitable 25-spray packages at the Sepahan Flowers

and Ornamental Plants Market. They were then, transferred to the horticulture laboratory of Islamic Azad University in Isfahan (Khorasgan). The cut flowers were first sorted. After they were uniformed by height, they were re-cut under running water to adjust branch height at 60 cm.

Treatments and storage conditions

To prepare the (NS) treatments, the target quantities of the compound were weighed with a digital scale, solved, and adjusted to the target volume in 500-mL Erlenmeyer. Then, the cut tuberose 'Dezfuli' flowers were treated in three concentrations of (NS) (10, 20, and 30 mg/L), as well as a control (distilled water), for 24 hours, and after the pulse treatment, they were kept in deionized distilled water until the end of the experiment. The environmental conditions of their storage were 22 ± 2 °C with a 12/12 hr. day/night photoperiod and a 1400-lux illuminance provided by white fluorescent lamps. The relative humidity was 70 %.

Enzyme assay

Preparation of enzymatic extract

The extraction buffer consisted of 0.1 M (100 mM) sodium phosphate buffer with a pH level of 7.5, 1 mM AS, and 0.5 mM Na_2-EDTA. One gram of fresh texture along with 4 cc of extraction buffer was ground on ice in a mortar. Next, it was centrifuged at 4°C for 30 minutes at 13,000 rpm. After that, the supernatant was collected, distributed in Eppendorf tubes, and then kept at -20 °C.

Polyphenol oxidase (PPO) enzyme activity assay

The reaction mixture consisted of 2.5 ml of 0.2 M phosphate buffer with a pH level of 7.6 + 200 µl of 0.02 M pyrogallol. After adding 100 µl of the enzymatic extract to the reaction mixture, changes in the absorption of samples were measured at 430 nm/min at 4°C, and finally, the activity of the enzyme polyphenol oxidase (PPO) was calculated and reported based on changes in the absorption of samples per gram of fresh texture ($\Delta A.min^{-1}\ g^{-1}$ FW). (Abeles and Biles, 1991).

Malondialdehyde assay method

The amount of malondialdehyde (MDA), as an index for membrane lipid peroxidation, was measured by Heath and Packer's (1969) method. To this end, 0.2 g of fresh leaf texture was weighed and ground in a porcelain mortar containing 5 ml of 0.1% trichloroacetic acid (TCA). The resulting extract was centrifuged at 10,000 rpm for five minutes. Four ml of a 20 % chloroacetic acid solution containing 0.5 % thiobarbituric acid (TBA) was added to 1 ml of the supernatant resulting from centrifugation. The resulting solution was heated in a hot water bath (bain-marie) at 95°C for 30 minutes. Then, the samples were immediately cooled in ice and the solution was centrifuged again at 10,000 rpm for 10 minutes. The absorption intensity of this solution was read at a wavelength of 532 nm using a spectrophotometer. The substance considered to get absorbed at this wavelength is a red MDA-TBA complex. The absorption of the other non-specific pigments was determined at a wavelength of 600 nm and subtracted from this value. To calculate the concentration of malondialdehyde, the extinction coefficient (155 $mM^{-1}\ cm^{-1}$) and the following equation were used (Heath and Packer, 1969).

$$MDA\ (\mu mol\ g^{-1}\ FW) = [A532\text{-}A600/155] \times 1000$$

Measurement of relative fresh weight of the flowers

The relative fresh weights of the flowers were measured during the assessment period for which a cut flower was weighed to record its fresh weight. Then, the following formula was used

to determine the relative fresh weight (Setyadjit *et al*., 2004).

$$\text{Relative fresh weight}=\frac{W_t}{W_t=0}\times 100$$

In which W_t represents stem weight (g) on days 0, 3, and 6 and W_t=0 represents the weight of the same flower on day 0. The relative fresh weight of each treatment on day 1 (FW_1) was considered as the base fresh weight and the variations on the next days were measured in relation to this base value.

Rate of solution uptake

To measure this trait, after the flowers in the vase solution were placed in a graded cylinder, the container was sealed to prevent solution evaporation so that the solution decline could be interpreted as its uptake by the flowers. The following equation was applied to estimate the rate of solution uptake (Hettarachchi and Balas, 2005):

$$\text{Solution uptake (ml day}^{-1}\text{ stem}^{-1}) = \frac{V_{t-1}-V_t}{\text{stem}}$$

In which V_{t-1} represents the solution volume on the measurement days and V_1 represents the solution volume on the previous day (Hettarachchi and Balas, 2005).

Flower dry weight and petals fresh weight

The dry weight of the treated flowers was measured after oven-drying at 70 °C for 24 h. Petals fresh weight was masured from total petals of a single floret during vase period.

Measurement of leaf chlorophyll content

To measure the chlorophyll content of the leaves, 0.3 g pieces of the leaves were taken, and after tearing them into further pieces, they were homogenized using 80% acetone in a porcelain mortar (addition of a small amount of sodium carbonate, while grinding, prevents the relative release of magnesium present in the structure of chlorophylls). Then, they were filtered using a Whatman filter paper. The extract was diluted using 80 % acetone to the extent needed. To calculate the chlorophyll content, the solution absorption was measured at 645 and 663 nm. Finally, the chlorophyll content was calculated using the following formula and then reported in mg g^{-1} of fresh weight (Arnon, 1949).

Total chl. = 20.2 A645 + 8.02 A663

Phenolic compounds assay

For the phenol compounds, 0.3 g of the tissue pieces were placed in 80 % ethanol at 80 °C for 20 minutes. Then, the volume of the solutions was equalized and centrifuged at 12000 rpm for 15 minutes. The supernatant was used to measure dissolved phenol content (Goldwasser *et al*., 1999).

To measure dissolved phenol compounds, 1 mL of the extract + 1 mL of 50 % Folin + 2 mL of saturated sodium carbonate (21 %) was kept still for 10 minutes. Then, it was centrifuged at 12000 rpm for 15 minutes and the absorbance of the samples was read with a Shimidazu-carry 50 spectrophotometer. Tannic acid was used as the standard for the measurement of phenol content. Therefore, 10 mg of tannic acid was dissolved in 10 mL of 50% methanol (or 80% ethanol) and was used as standard stock. The standard curve was employed to determine the concentration of dissolved and wall-attached phenol compounds. Finally, the dissolved phenol was recorded and reported in mg g^{-1} F.W.

Measurement of dissolved sugars

Sugars were measured by Kochert's (1978) procedure for which 0.2 g of plant fresh weight was homogenized and then, it was heated with 10 mL of 80 % ethanol (Merk) in a hot bath for 15 minutes. The contents of the tubes were infiltrated through filter paper. Next, 0.5 ml of the solution supernatant was taken for the shoot. After the volume of all samples was adjusted to 2 mL by adding distilled water in test tubes, they were added with 1 mL of 5 % phenol and 5 mL of thick sulfuric acid. The samples were kept at laboratory temperature for 30 minutes. Then, they were read at 485 nm with a spectrophotometer. Fructose was used as the standard material. The sample values were calculated by the standard curve in mg g^{-1} DW.

Vase life

The postharvest life of the cut flowers was calculated upon the emergence of symptoms such as petal wilting, bending neck of flowers, color change, or petal fall from the day of harvest to the end of marketability. In addition, the vase life of the leaves was determined based on the wrinkling of more than 50 % of the leaves on the branch. Chlorosis and necrosis are among the parameters determining the vase life of foliage (Knee, 2000).

Data Analysis

The experiment was conducted in a completely randomized design with three replications. The obtained data were performed by analysis of variance using SAS software package, the means were compared by Duncan's test at the 5 % level, and the graphs were drawn in MS-Excel.

RESULTS

Phenol content

Analysis of variance showed that NS treatment and time and their interaction significantly affected total phenol content (Table 1). Based on the results, phenol content was similar among all treatments on day 0 whereas the highest phenol content on day 3 was observed in the plants treated with 10 mg/L NS and those treated with 30 mg/L NS (Fig. 1).

Dissolves sugar content of petals

Data analysis revealed that soluble sugar content of petals was significantly influenced by NS treatment and time and their interaction (Table 1). Treatments induced changes in dissolved sugar content. It was found that NS increased the dissolved sugar content of petals on day 3, but the increase was not statistically significant. On day 6, the dissolved sugar content was, however, significantly higher in the SNP-treated samples than in the control (Fig. 2).

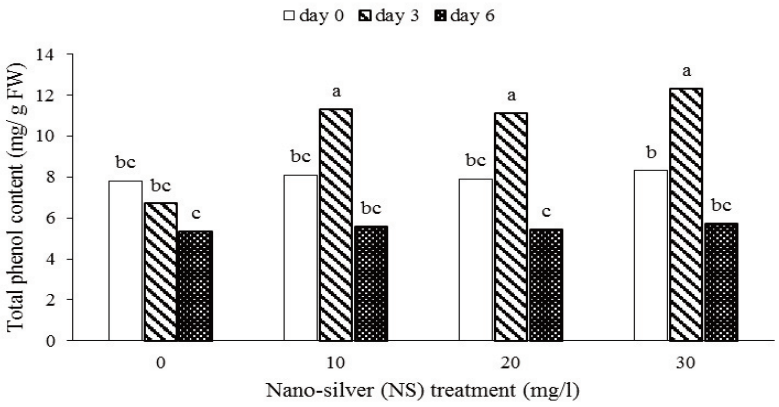

Fig. 1. Mean total phenol in different treatments of cut tuberoses on different days (different letters showed significant differences at the P<0.05 level).

Table 1. The results of the ANOVA for the effect of time and silver nanoparticles on phenol, sugar, fresh and dry weight and RFW.

S.o.V	df	MS				
		Total phenol	Petal dissolved sugars	Petals fresh weight	Flower dry weight	Relative fresh weight
Time	2	70.26 **	529.9**	0.77ns	1336**	589.0**
Treatment	3	7.84 **	211.5**	0.25 ns	47.00 ns	626.9**
Time × treatment	6	5.48 **	49.17**	0.12 ns	8.75 ns	249.3**
Error	24	0.88	3.23	0.30	102.3	26.22
CV (%)		11.78	6.34	8.99	7.60	5.43

** and ns: significant at P < 0.01 and insignificant, respectively.

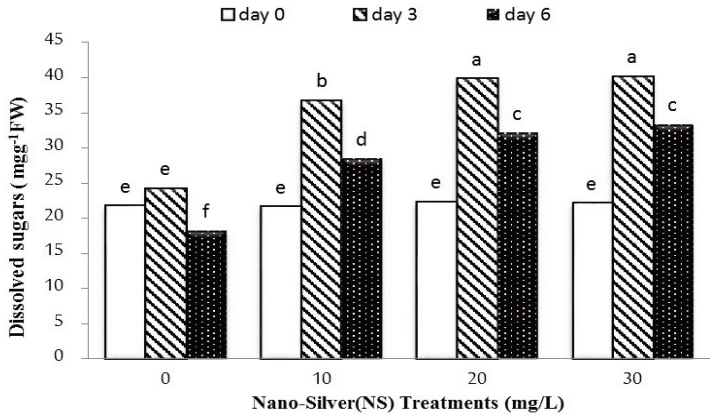

Fig. 2. Mean dissolved sugars of petals in different treatments of cut tuberoses on different days (different letters showed significant differences at the P<0.05 level).

Relative fresh weight

Analysis of variance showed that NS treatment and time and their interaction significantly affected Relative fresh weight (Table 1).It was revealed that relative fresh weight descended over time, but the intensity of its decrease was significantly lower in the NS-treated samples than in the control. NS was effective in reducing the rate of relative fresh weight loss until day 6, but then, it started to lose its effectiveness. The lowest decline in relative fresh weight was observed in the NS-treated plants than in the control (Fig. 3).

Fresh weight of petals

Data analysis suggested that the fresh weight of petals was not significantly affected by different levels of NS during vase period (Table 1).

Flower dry weight

Analysis of variance showed that time on the vase solution significantly affected the dry weight of flower (Table 1). Results showed that the dry weight of cut flower decreased significantly during vase period and reached 86% of the control value at 6 days after initial time (Fig. 4).

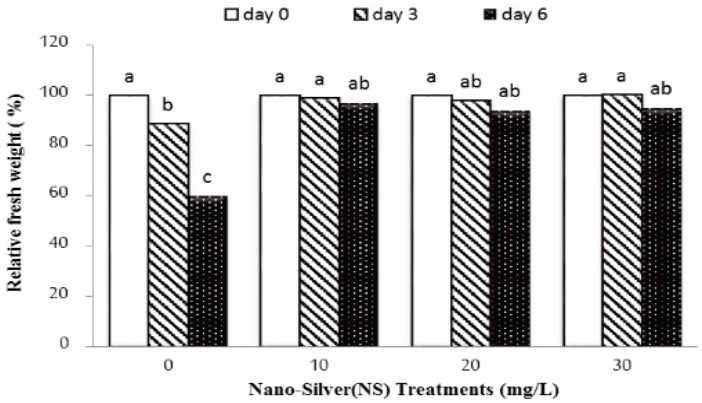

Fig. 3. Mean relative fresh weight in different treatments of cut tuberoses on different days (different letters showed significant differences at the P<0.05 level).a

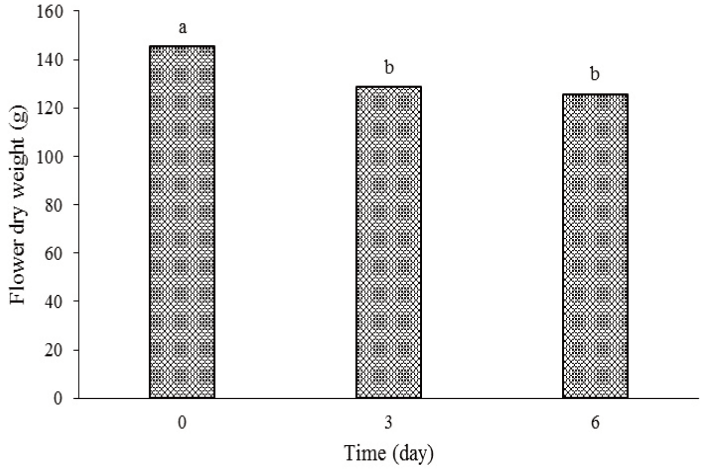

Fig. 4. Change in flower dry weight of cut tuberose during vase period (different letters showed significant differences at the P<0.05 level).

Solution uptake

Data analysis revealed that solution uptake was significantly influenced by NS treatment and time and their interaction (Table 2). Based on the results, solution uptake was increased in all treatments significantly on day 3 versus the control. However, it was decreased in all treatments on day 6. Solution uptake was the highest in the treatments of 10 and 30 mg/L (Fig. 5).

Table 2. The results of the ANOVA for the effects of time and silver nanoparticle treatment on PPO, MDA, solution uptake, chlorophyll and petal sugars.

S.o.V	df	MS				
		Polyphenoloxidase (PPO)	Malondialdehyde (MDA)	Solutionuptake	Total chlorophyll	Petal dissolved sugars
Time	2	2.42**	2818**	7783**	8.02**	529.9**
Treatment	3	0.36**	55.83**	2264**	3.45*	211.5**
Time × treatment	6	0.12*	25.12*	43.49*	0.35^{ns}	49.17**
Error	24	0.05	8.79	16.49	1.06	3.23
CV (%)		15.82	5.65	7.28	10.12	6.34

*, ** and ^{ns}: significant at P<0.05, P<0.01 and insignificant, respectively.

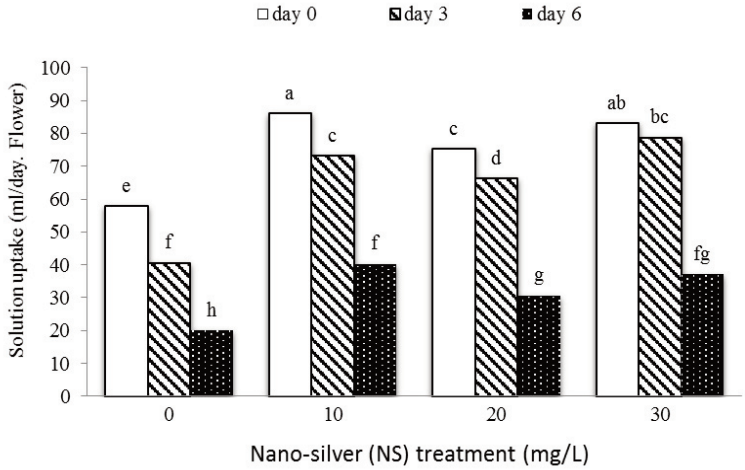

Fig. 5. Mean values of solution uptake in different treatments of cut tuberoses on different days (different letters showed significant differences at the P<0.05 level).

Polyphenol oxidase (PPO) enzyme

Analysis of variance showed that NS treatment and time and their intraction significantly affected activity of polyphenol oxidase enzyme (Table 2). The results of polyphenol oxidase (PPO) enzyme activity demonstrated that on day 3, using treatments with different NS concentrations resulted in a change in PPO activity in different treatments. However, these differences were significant. On day 6, the highest PPO activity was observed in NS 10 and NS 30 treatments, which was significantly higher than the control (Fig. 6).

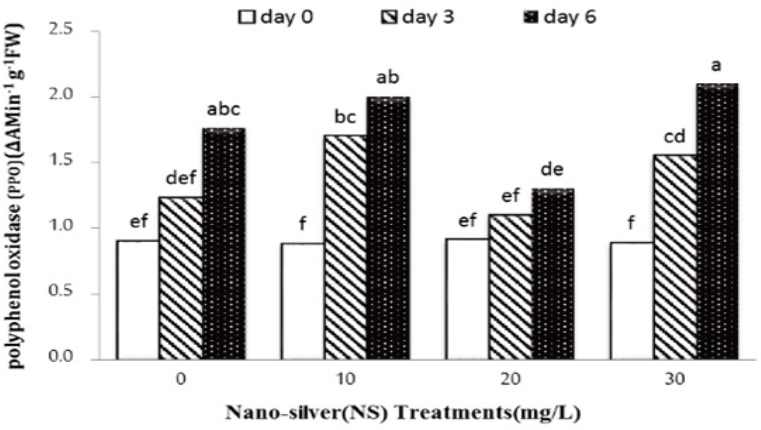

Fig. 6. The mean values of polyphenol oxidase (PPO) enzyme activity in different treatments of cut flowers of *Polianthes tuberosa* L. 'Dezfuli' on different days (Different letters show significant differences at P<0.05).

Malondialdehyde (MDA) production

Data analysis revealed that MDA content was significantly influenced by NS treatment and time and their interaction (Table 2). The results showed that the values of MDA in all treated flowers decreased on day 3 and then increased on day 6. NS treatments induced a change in MDA production activity and resulted in a significant difference compared to the control. The results revealed that MDA content increased during storage. MDA is measured as a suitable indicator for membrane lipid peroxidation (Fig. 7).

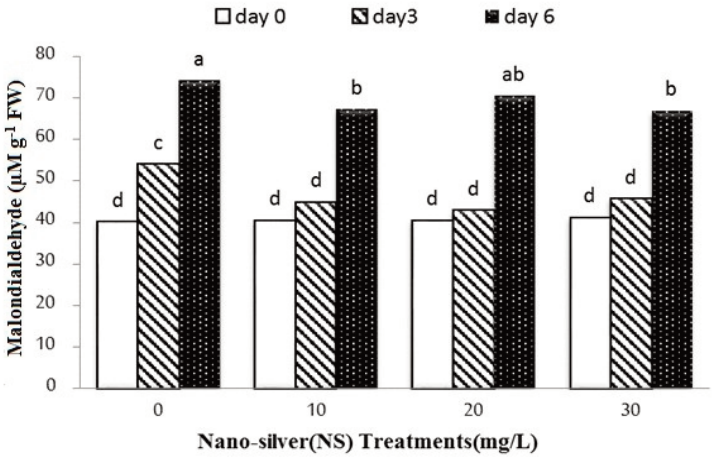

Fig. 7. The mean values of MDA in different treatments of cut flowers of *Polianthes tuberosa* L. 'Dezful' on different days (Different letters show significant differences at P<0.05).

Chlorophyll content

Analysis of variance showed that NS treatment and time significantly affected the chlorophyll content of cut flowers (Table 2). Fig. 8 illustrates that the elevation of NS levels exhibited significant effects on the chlorophyll content. However, cut flowers treated by 10 mg/l NS had a significantly higher chlorophyll content as compared with control (Fig. 8). Furthermore, the level of total chlorophyll declined significantly during vase period and reached 85% of the control value at 6 days after initial time (Fig. 8).

Vase life

Data analysis revealed that vase life of cut flower was significantly influenced by NS treatment and time and their interaction (Table 3). The effects of NS treatments were investigated on the longevity of *Polianthes tuberosa* L. cut flowers. The research showed that the use of NS treatments significantly increased the postharvest life of cut flowers of *Polianthes tuberosa* L. compared to the control. The highest increase in postharvest life in flower branches was in the NS treatment of 10 mg/L (Fig. 9).

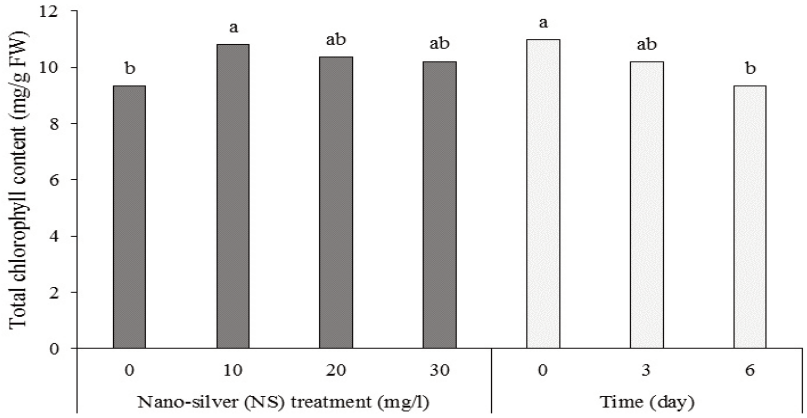

Fig. 8. The mean values of total chlorophyll in different treatments of cut flowers of *Polianthes tuberosa* L. 'Dezfuli' on different days (For each factor, different letters show significant differences at P<0.05).

Table 3. The results of the ANOVA for the effect of time and silver nanoparticles on vase life.

S.o.V	df	MS
Treatment	3	35.00**
Error	8	2.50
CV (%)		15.06

**: significant at P<0.01.

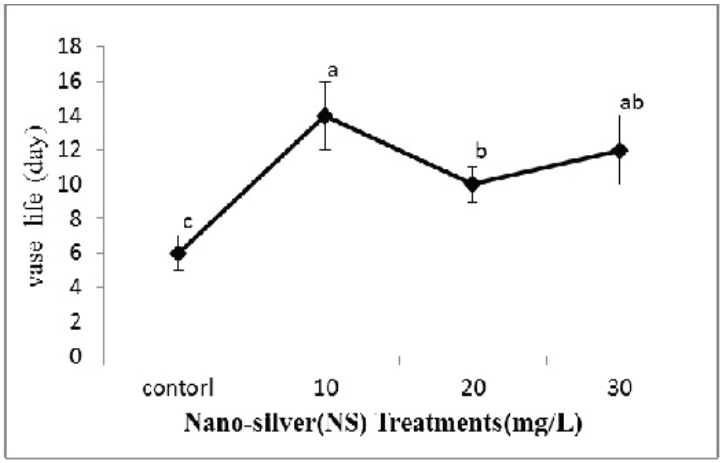

Fig. 9. The mean values of vase life in different treatments of cut flowers of *Polianthes tuberosa* L. 'Dezfuli' on different days (Different letters show significant differences at P<0.05).

DISCUSSION

Over time, the lipid peroxidation of the membrane increased, and the membrane stability decreased. The intensity of membrane stability reduction in the control treatment was significantly higher than that in the other treatments. The reduction in the membrane stability is the irreversible and final phase of senescence and is associated with membrane lipid peroxidation. Lipid peroxidation of the membrane is directly related to the senescence (aging) process. Reactive oxygen species in plant tissues can initiate the senescence process. The pulse treatment of flowers with salicylic acid was related to lower membrane stabilization activity and lower lipoxygenase (membrane oxidation enzyme) activity, reduced oxidative stress, and delayed senescence processes of cut rose flowers. (Gerailoo *et al*., 2011). Priyadarshini *et al*. (2012) reported that NS particles decreased H_2O_2 production and increased the efficiency of redox reactions. They also reported that higher concentrations of NS enhanced the activity of H_2O_2-metabolizing enzymes. Enhanced SOD activity of leaves under NS treatments may be interpreted as a direct response to augmented O^{-2} formation since SOD is an enzyme that catalyzes the conversion of the O^{-2} to O_2 and H_2O_2 (Hafis *et al*., 2011).

Polyphenol oxidase has been shown to oxidize phenolic compounds, causing post-harvest products to turn brown (Sikora and Świeca, 2018). Therefore, a delay in senescence has been observed (Soleimani Aghdam *et al*., 2015). Antioxidant enzymes are one of the most effective systems that protect plants from threats like pathogens and dehydration to prevent cellular senescence and death (Hoque *et al*., 2016; Hossain *et al*., 2015).

Decreased chlorophyll during postharvest is a sign of senescence (aging) in cut flowers. The NS treatment of roses increased the amount of chlorophyll (Elgimabi and Ahmed, 2009). The results of the present study showed that the treatments that had the highest increase caused an increase in postharvest life and quality of cut flowers of *Polianthes tuberosa* L. compared to the control.

The application of NS at different concentrations resulted in a change in polyphenol oxidase activity in different treatments. The highest polyphenol oxidase activity was observed in the treatment of 10 mg/L NS and 30 mg/L NS. Polyphenol oxidase increases in response to biotic and abiotic stresses. The enzyme polyphenol oxidase has been shown to oxidize phenolic compounds, causing products to turn brown after harvest. Therefore, the accumulation of total phenol and flavonoids in the two varieties of *Gerbera jameosonii* may reduce polyphenol oxidase activity (Sikora and Świeca, 2018).

Hatami and Ghorbanpour reported that the MDA content decreased significantly with the increase of NS concentration up to 60 mg L^{-1} in both Foxi and Flowerfairy cultivars of *Pelargonium zonale*. Maximum decline of 17.34 % and 19.97 % in MDA content was recorded at 60 mg L^{-1} NS treatment as compared to the control for, respectively and then a rapid increase followed at 80 mg L^{-1} (Hatami and Ghorbanpour 2014).

Based on the comparison of the means for the effect of NS treatment on solution uptake, different concentrations of NS had a positive effect on solution uptake and increased it in most days (Fig. 5). This implies a direct and linear relationship with vase life. In this experiment, NS also increased water uptake and retarded flower wilting, which is consistent with Ichimura *et al*. (2008) who stated that NS extended the vase life and quality of cut *Narcissus tazzeta* 'Chinensis' by improving water relations. NS at different rates improved the vase life and solution uptake versus the control significantly. It also brought about a significant difference in relative fresh weight (Fig. 3). Our findings are consistent with Liu *et al*. (2009a) who applied NS to cut gerberas and reported that the lowest rate of NS, i.e., 4 mg/L, postponed the reduction of relative fresh weight. The results are also in agreement with Lu *et al*. (2010).

In Zhao *et al*. (2018) study, the microstructures of *Paeonia lactiflora* stem-ends were observed, and 8 days after NS treatment, some microbes could be observed in vessels of control, whereas NS-treated *P. lactiflora* inhibited microbial growth. Meantime, Ag^{+} distribution releasing from NS treatment was detected, and the results showed that Ag^{+} could not be detected in control, while Ag^{+} mostly remained within the bottom stem of NS-treated cut *P. lactiflora* flowers, followed by leaf, top stem, and petal during the vase period (Zhao *et al*., 2018) The results showed that sucrose was positively effective in the retention of relative fresh weight, resulting in a significant difference versus the control. We also observed that sucrose positively influenced the blooming of the studied flowers. This corroborates the results of other researchers as to the positive effect of sucrose and nanoparticles on the postharvest quality of cut flowers (Madadzadeh *et al*., 2014).

Rabiza-Świder *et al*. (2020) reported that NS prevented tylose formation of cut snapdragon flowers, but not the blockages caused by bacteria. Cut flowers treated with 1 mg L^{-1} NS with 2 % sucrose had a longer vase life than those held in water or in NS alone, and improved flower opening, coloration and higher relative water content of flowers in the lower (older) part of the spike. Carbohydrate accumulated in flowers in the NS solution. NS limited increased electric conductivity, and with sucrose decreased the pH of cell sap. NS also limited the increase in the malondialdehyde content, especially in the upper (younger) part of spikes where also the hydrogen peroxide content was much lower than in flowers from the lower spike parts. The activities of antioxidative enzymes were higher in the NS-treated flowers, especially when the NS solution was supplemented with sucrose, and the nuclei and epidermis degradation was delayed (Rabiza-Świder *et al*., 2020).

Ichimura (1998) reports the carbohydrates may reduce the ethylene sensitivity of cut flowers, thereby increasing their vase life (Yamada *et al*., 2007). Its role as antibacterial and ethylene inhibitors has also been documented (Naing and Kim, 2020). The application of sucrose to cut roses increased the fresh weight of the flowers (Fig. 4), which agrees with Ichimura and Goto (2002) who reported that cut *Narcissus tazzeta* 'Chinensis' had higher carbohydrate content in winter than other seasons. So, sucrose may not influence cut *Narcissus tazzeta* significantly due

to the different concentrations of carbohydrates in their stem, leaf, and flower tissues versus petals, which is inconsistent with our findings. Sucrose may increase the effect of cytokinins in delaying senescence, thereby reducing the effect of ethylene in stimulating aging (Mayak *et al*., 1978) and may do it by changing the ethylene sensitivity of the tissue. Another effect of sugars is their involvement in the osmotic regulation of flowers, which postpones senescence (Aarts, 1957; Naing and Kim, 2020).

CONCLUSION

The post-harvest life of the cut tuberose flowers was influenced by the NS treatments, so that the flowers lived longer with these treatments. The longest postharvest life was related to the flowers treated with 10 mg/L NS. The results of the present study indicate that applying nano-silver is an effective treatment in prolonging the life of *Polianthes tuberosa* L. cut flowers. According to the results, it seems that nano-silver reduces the accumulation of free radicals by stimulating the antioxidant system, thereby reducing chlorophyll degradation, membrane peroxidation, delaying the senescence (aging) process, and increasing the longevity of flowers. Studies have revealed that pretreatment with NS in different concentrations has prolonged the vase life and the quality of flowers, maintained the balance of water relations, reduced occlusion, and thus delayed aging. According to the results of the experiment, applying NS particles as a pretreatment of cut flowers of *Polianthes tuberosa* L. increases their durability and quality. The application of NS significantly contributed to retaining the plant's water balance and increasing the stem's water potential as revealed by the means of the data. The application of NS and sucrose increased water uptake, flower fresh and dry weight, and the retention of water relations. Sucrose acted as an alternative to carbohydrates and increased sugar compounds. Owing to the continuity of these factors, the postharvest vase life of cut tuberoses was increased versus the control significantly.

ACKNOWLEDGMENT

Thanks to all the loved ones who helped the snake in this research.

Literature Cited

Aarts, J.F.T. 1957. Over de houdbaarheid van snijbloemen. Meded de Landbouw hogeschool te Wageninge, 57: 1-62.

Abeles, F.B. and Biles, C.L. 1991. Characterization of peroxidase in lignifying peach fruit endocarp. Plant Physiology, 95: 269-273.

Arnon, D.I. 1949. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. Plant Physiology, 24: 1-15.

Baker, J.E., Lalang, C.Y., Lieberman, M. and Hardonberg, R. 1977. Delay of senescence in carnation by a rhizobitoxine analog and sodium benzoate. Horticultural Science, 12: 28–39.

Boonyanitlpony, P., Kumar, P., Kositsup, B. and Baruah, S. 2011. Effect of zinc oxide nanoparticles on roots of rice (*Oryza sativa* L.). World Journal of Environmental Biosciences, 27: 172-176.

da Silva, L.C., Oliva, M.A., Azevedo, A.A. and De Araujo, J.M. 2006. Responses of restinga plant species to pollution from an iron pelletization factory. Water, Air, and Soil Pollution, 175(1): 241-256.

Elgimabi, M.N. and Ahmed, O.K. 2009. Effects of bactericides and sucrose-pulsing on vase life of rose cut flowers (*Rosa hybrida*). Botany Research International, 2 (3): 164-168.

Feng, Q.L., Wu, J., Chen, G.Q., Cui, F.Z., Kim. T.N. and Kim, J.O. 2000. A mechanistic study of the antibacterial effect of silver ions on *Escherichia coli* and *Staphylococcus aureus*. Journal of Biomedical Materials Research, 52: 662-668.

Gerailoo, S. and Ghasemnezhad, M. 2011. Effect of salicylic acid on antioxidant enzyme activity and petal senescence in 'Yellow Island' cut rose flowers. Journal of Fruit and Ornamental Plant Research, 19: 183-193.

Goldwasser, Y., Herschhorn, J., Plakhine, D., Klefeld, Y. and Rubin, B. 1999. Biochemical factors involved in vetch resistance to *Orobanche aegyptiaca*. Physiological and Molecular Plant Pathology, 54: 87-96.

Hafis, C., Romero-Puertas, M.C. and Sandalio, L.M. 2011. Antioxidative response of *Hordeum maritimum* L. to potassium deficiency. Acta Physiologiae Plantarum, 33: 193–202.

Halevy, A.H. and Mayak, S. 1979. Senescence and postharvest physiology of cut flowers. Part 1. Horticultural Reviews, 1: 204-236.

Hatami, M. and Ghorbanpour, M. 2014. Defense enzyme activities and biochemical variations of *Pelargonium zonale* in response to nanosilver application and dark storage. Turkish Journal of Biology, 38: 130-139.

Heath, R. and Packer, L. 1969. Photoperoxidation in isolated chloroplast, kinetics and stoichiometry of fatty acid peroxidation. Archives of Biochemmistry, 125: 189-198.

Hettarachchi, M.P. and Balas, J. 2005. Postharvest handling of cut kniphofia (*Kniohofia uvaris* oken 'Flamenco') flowers. Acta Horticulturae, 669: 359-365.

Hoque, T.S., Hossain, M.A., Mostofa, M.G., Burritt, D.J., Fujita, M. and Tran, L.S.P. 2016. Methylglyoxal: An emerging signaling molecule in plant abiotic stress responses and tolerance. Frontiers in Plant Science, 7 (Article 1341): 1-11.

Hossain, M.A., Bhattacharjee, S., Armin, S.M., Qian, P., Xin, W., Li, H.Y., Burritt, D.J., Fujita, M. and Tran, L.S.P. 2015. Hydrogen peroxide priming modulates abiotic oxidative stress tolerance: Insights from ROS detoxification and scavenging. Frontiers in Plant Science, 6: 420. https://doi.org/10.3389/fpls.2015.00420

Hung, K.T. and Kao, C.H. 2005. Nitric oxide counteracts the senescence of rice leaves induced by hydrogen peroxide. Botanical Bulletin- Academia Sinica Taipei, 46: 21–28.

Ichimura, K. 1998. Improvement of postharvest life in several cut flowers by the addition of sucrose. Japan Agriculture Reserch Quartery, 32: 275-280.

Ichimura, K. and Goto, R. 2002. Effect of gibberellin A3 on leaf yellowing and vase life of cut *Narcissus tazzeta* var Chinensis flowers. Journal of Japanese Society of Horticulturae, 69 (4): 423–427.

Ichimura, K., Yoshioka, S. and Yumoto-Shimizu, H. 2008. Effects of silver thiosulfate complex (STS), sucrose and combined pulse treatments on the vase life of cut snapdragon flowers. Environmental Control in Biology, 46: 155-162.

Knee, M. 2000. Selection of biocides for use in floral preservatives. Postharvest Biology and Technology, 18: 227–234.

Kochert, G. 1978. Carbohydrate determination by the phenol sulfuric acid method, in Helebust. *In*: Handbook physiological methods. (Ed. Craig, J. S.) 96-97. Cambridge University Press, Cambridge.

Kumar, N., Pal, M., Singh, A., Sairam, R.K. and Srivastava, G.C. 2010. Exogenous proline alleviates oxidative stress and increase vase life in rose. Scientia Horticulturae, 127: 79-85.

Li, H.B., Li, H.M., Liu, J., Luo, Z., Joyce, D.C. and He, S. 2017. Nano-silver treatments reduced bacterial colonization and biofilm formation at the stem-ends of cut gladiolus 'Eerde' spikes. Postharvest Biology and Technology, 123: 102–111. Https: //doi.org/10.1016/j. postharvbio.2016.08.014.

Liu, R. and Lal, R. 2015. Potentials of engineered nanoparticles as fertilizers for increasing agronomic productions. Science of the Total Environment, 514: 131–139.

Liu, J., He, S., Zhang, Z., Cao, J., Lv, P., He, S., Chenge, G. and Joyce, D.C. 2009a. Nano-silver

pulse treatments inhibit stem-end bacteria on cut gerbera cv. Ruikou flowers. Postharvest Biology and Technology, 54: 59-62.

Liu, J., Zhang, Z., He, S., Cao, J., Lv, P. and Joyce, D.C. 2009b. Effects of postharvest nano-silver treatments on cut flowers. International Society for Horticultural Science (ISHS) Postharvest Quality of Ornamentals conference, Odense, Denmark, August 11–14th.

Lu, P., Cao, J., He, Sh., Liu, J., Li, H., Chenga, G., Dinga, Y. and Joycec, D.C. 2010. Nano-silver pulse treatments improve water relations of cut rose cv. Movie Star flowers. Postharvest Biology and Technology, 57: 196–202.

Madadzadeh, N., Hassanpour Asil, M. and Roein, Z. 2014. Effect of essential oils and silver nanoparticles (SNP) on vase life of *Alstroemeria* cut flowers (cv. Sukari). Iranian Journal of Horticultural Science, 45: 65-78. (In Persian)

Mayak, S., Kofranek, A.M. and Tirosh, T. 1978. The effect of inorganic salts on geophytes plants. Acta Horticulturae, 325: 131–137.

Naidu, S.N. and Reid, M.S. 1989. Postharvest handling of tuberose (*Polianthes tuberosa* L.). Acta Horticulturae, 261: 313–318.

Naing, A.H. and Kim, C.K. 2020. Application of nano-silver particles to control the postharvest biology of cut flowers: A review. Scientia Horticulturae, 270: 109463. https://doi.org/10.1016/j.scienta.2020.109463

Naing, A.H., Win, N.M., Han, J.S., Lim, K.B. and Kim, C.K., 2017. Role of nano-silver and the bacterial strain *Enterobacter cloacae* in increasing vase life of cut carnation 'Omea'. Frontiers in Plant Science, 8: 1590. https://doi.org/10.3389/fpls. 2017.01590.

Nalousi, M., Hatamzadeh, A., Azadi, P., Mohsenpour, M. and mizadeh, L.H. 2019. A procedure for indirect shoot organogenesis of *Polianthes tuberosa* L. and analysis of genetic stability using ISSR markers in regenerated plants. Scientia Horticulturae, 244: 315-321.

Priyadarshini, S., Deepesh, B., Zaidi, M.G.H., Pardha Saradhi, P., Khanna, P.K. and Arora, S. 2012. Silver nanoparticle-mediated enhancement in growth and antioxidant status of *Brassica juncea*. Applied Biochemistry and Biotechnology, 167: 2225–2233.

Rabiza-Świder, J., Skutnik, E., Jędrzejuk, A. and Rochala Wojciechowska, J. 2020. Nanosilver and sucrose delay the senescence of cut snapdragon flowers. Postharvest Biology and Technology, 165: 111165. https://doi.org/10.1016/ j.postharvbio.2020.111165

Roy, S., Barua, N., Buragohain, A.K. and Ahmed, G.A. 2013. Study of ZnO nanoparticles: Antibacterial property and light depolarization property using light scattering tool. Journal of Quantitative Spectroscopy and Radiative Transfer, 118: 8-13.

Sastry, R., Rao, N. and Richard, C. 2010. Can nanotechnology provide the innovations for a second green revolution in India agriculture? Biological Trace Element Research, 13: 639-648.

Setyadjit, S., Joyce, D.C., Irving, D.E. and Simons, D.H. 2004. Effects of 6-benzylaminopurine treatment on the longevity of harvested grevillea 'Sylvia' inflorescences. Journal of Plant Growth Regulation, 43: 9-14.

Sikora, M. and Świeca, M. 2018. Effect of ascorbic acid postharvest treatment on enzymatic browning, phenolics and antioxidant capacity of stored mung bean sprouts. Food Chemistry, 239: 1160–1166.

Soleimani Aghdam, M., Naderi, R., Sarcheshmeh, M.A.A. and Babalar, M. 2015. Amelioration of postharvest chilling injury in anthurium cut flowers by γ-aminobutyricacid (GABA) treatments. Postharvest Biology and Technology, 110: 70–76.

Solgi, M., Kafi, M., Taghavi, T.S. and Naderi, R. 2009. Essential oils and silver nanoparticles (SNP) as novel agents to extend vase life of gerbera (*Gerbera jamesonii* cv. 'Dune') flowers. Postharvest Biology and Technology, 53: 155–158.

Waithaka, K., Reid, M.S. and Dodge, L.L. 2001. Cold storage and power keeping quality of cut

tuberose (*Polianthes tuberosa* L.). Journal of Horticultural Science and Biotechnology, 76 (3): 271-275.

Yamada, K., Ito, M., Oyama, T. and Nakada, M. 2007. Analysis of sucrose metabolism during petal growth of cut roses. Postharvest Biology and Technology, 43: 175-177.

Zhao, D., Cheng, M., Tang, W., Liu, D., Zhou, S., Meng, J. and Tao, J. 2018. Nano-silver modifies the vase life of cut herbaceous peony (*Paeonia lactiflora* Pall.) flowers. Protoplasma, 1: 1–13.

How to cite this article:
Mohammadi, K., Chavoshi, S., Asadi-Gharneh, H., Gomarian, M. and Edrisi, B. 2021. Biochemical and physiological responses of tuberose (*Polianthes tuberosa* L.) cut flower to silver nanoparticles treatment *Journal of Ornamental Plants,* 11(4), 281-295.
URL: http://jornamental.iaurasht.ac.ir/article_687652_da4eedf295be2e23f1eb04d6da5ad4b7.pdf