International Journal of Horticultural Science and Technology
Vol. 1, No. 1;June 2014, pp 67-77

Effects of Nano-Silver and Sucrose applications on Cut Flower Longevity and Quality of Tuberose (*Polianthus tuberosa*)

Sonia Bahrehmand[1], Jamshid Razmjoo*[2], Homan Farahmand[3]

1.Department of Horticultural Sciences, College of Agriculture, Jiroft Islamic Azad University, Jiroft, Iran

2.Department of Horticultural Sciences, College of Agriculture, Isfahan University of Technology, Isfahan, Iran

3.Department of Horticultural Sciences, College of Agriculture, Shahid Bahonar University, Kerman, Iran

(Received: 22 August 2013, Accepted: 15 March 2014)

Abstract

Tuberose (*Polianthus tuberosa*) is a commercially important cut flower; but its longevity and quality characteristics are compromised by stress during storage and transportation. Thus, it is important to determine the most appropriate preservative solution to best maintained cut flowers. Tests were done to examine the effects on of nano-silver (NS) (0, 15, 30 and 45 mg L^{-1}) and sucrose (0, 4 and 8%) on the quality properties of fresh weight, relative water content, water uptake, total soluble solids, wilting percentage, flower opening and flower longevity. Results showed that averages of evaluations for flower longevity, open flower and stem diameter, fresh weight and relative water content increased under sucrose application and that those for while flower longevity, open flower and stem diameter, water uptake, fresh weight and relative water uptake were increased by NS application. However, applications of 4% sucrose or 45 mg L^{-1} NS treatments enhanced all measured parameters, with only a few exceptions. These parameters were further increased under the treatment of sucrose at 4% combined with 45 mg L^{-1} NS, suggesting that the quality of tuberose cut flowers can be improved by treatment with a combination of sucrose and NS.

Keywords: Cut flowers, flower longevity, postharvest physiology, vase life.

Introduction

Water balance is determined by transpiration and water uptake and is the main factor affecting longevity and quality characteristics of cut flowers (Da Silva, 2003). Occlusion at the end of the basal stem is the primary cause of low water uptake by cut flowers (He *et al*., 2006). This is caused by accumulations of microorganisms, especially bacteria in the vase solution or vessel, air emboli and can cause stem blockage and contribute to physiological wounds (Van Doorn, 1997; Marandi *et al*., 2011). Other study has reported that bacteria in the vase solution induced ethylene production by toxin stress (Zagory and Reid, 1986). Ethylene production causes leaf yellowing, flower drop, irregular opening and premature death (Nowak and Rudnichi, 1990). Therefore, several anti-microbial substances have been tested in pulsing and vase solutions to prevent microbial growth, increase water uptake and increase longevity of cut flowers: these were as follows; silver thiosulphate (Reid *et al*., 1980), silver nitrate (Fujino *et al*., 1983; Butt, 2005), aluminum sulphate (Van Doorn, 1991;

*Corresponding author
Email: krazmjoo@cc.iut.ac.ir

Ichimura and Shimizu-Yumoto, 2007) and 8-hydroxyquinoline sulphate (Ichimura *et al*., 1999). However, these materials usually have large particles and may contribute to environmental pollution (Serek and Reid, 1993). Nano-silver is small in size, has high durability and easy application; it also has no known side effects and tests have determined it as a more effective treatment than other antimicrobial agents so it has recently been used to extend longevity for several species of cut flower (Liu *et al*., 2009; Solgi *et al*., 2009; Lu *et al*., 2010a; Mortazavi *et al.*, 2011; Kazemi and Ameri, 2012).

Sucrose may be consumed by cut flowers as a source of energy and as an osmotic regulator (Bieleski, 1993; Moalem-Beno *et al*., 1997). Cut flowers are prone to a fast drop in levels of sugars and this may contribute to reduced longevity. Therefore, a supplemental dose of sugar applied to cut flowers may serve to extend post-harvest life. However, sucrose dosage needs to be made appropriately in order to provide an effective balance between sugar-water concentration in the cellular tissue of cut flowers for each treatment, species or even for a specific cultivar within a species (Lu *et al*., 2010b). Furthermore, sucrose in the vase solution may promote microbial growth and that would inhibit water uptake by presence of dissolved sugars that cause blockage in xylem vessels (Van Doorn, 1997; Ranwala and Miller, 2009). Recent studies have tested nano-silver in combination with sucrose to increase the vase life of cut flowers (Mortazavi *et al*., 2011; Moradi *et al*., 2012).

Tuberose (*Polianthus tuberosa*) is a popular cut flower used in arrangements and its individual florets provide fragrance to a bouquet. However, fewer than 50% of buds normally open after harvest and florets and buds may fail to open or even fall from the spike after a few days in a vase (Khondakar and Maxundar, 1985; Reid, 1996). Jowkar and Salehi (2005) used tap water and different concentrations of sucrose, silver thiosulphate, silver nitrate and citric acid and reported that silver thiosulphate caused severe burning of the florets and silver nitrate caused florets to wilt and ends of flower spikes to bend; results showed the best evaluation for flower longevity under citric acid treatment and the second best for that of tap water. Hutchinson *et al*. (2003) showed that application of silver thiosulphate and accel (a liquid concentrate containing 20 g a.i BAL-1 and 2.0 g a.i GAL-1) increased flower longevity and floret opening of cut tuberose flowers indirectly, while application by sucrose pulsing increased flower longevity and floret opening through enhanced substrate utilization and better mobilization along the spike. Naidu and Reid (1989) showed that a holding solution containing sugar (1.5%) or pre-treatment with sucrose (20%) for 15-20 h improved vase life of tuberose cut flowers before and after storage.

The literature cited above reported that, flowers of this species were susceptible to reduced longevity from the affects of solution agents and stress during storage and transportation, thus it is important that flowers be placed in the most effective vase preservative solution.

Little information is available on the effects of nano-silver treatment, alone or in combination with sucrose, on vase life of tuberose cut flowers. Recent research (Asgari *et al.*, 2013) has reported that application of nano-silver had no effect on quality and vase life of tuberose cut flowers, but that application of sucrose (1%) increased evaluations for these traits. Tests reported in this study were done to determine the effects of sucrose and nano-silver applications on vase life and some quality parameters of cut tuberose flowers.

Materials and methods

Plant material and preparation

Plants were grown in a greenhouse under natural light in Mahalat, Iran, in 2011. At the bud stage (two opened florets), flowers

were cut with sharp sterilized secateurs and all other unwanted materials were removed. Each flower was cut to the length of 25 cm. Cut flowers were immediately put into buckets partially filled with tap water and covered with a plastic film to prevent moisture loss during transportation to the laboratory. In the laboratory, cut flowers were cleaned and samples with uniform flowers with three uppermost leaflets were selected for tests. Flower stems were recut under deionized water to about 20 cm length in order to eliminate the possibility of air blockage in the stem. Tests were arranged as a two way factorial (3×4) in a randomized complete design with three replicates. Tests were done on treatments of four concentrations (0, 15, 30 or 45 mg L^{-1}) of nano-silver (Nanocid) obtained from Nano Pars Company, Tehran, Iran and three concentrations (0, 4 or 8%) of sucrose and treatment under deionized water was used as the control. Six flowers were put in respective solutions for 6h. After treatment, assigned samples of flower stems were immediately transferred into containers filled with deionized water. All experiments were conducted in a phytotron at the temperature of 18°C, light intensity of 12-14 micro mol m^{-2} s^{-1} and relative humidity of 65% with a daily light period of 12 h under ventilation. The flowers were observed daily until complete senescence of petals had occurred.

Flower longevity

Flower longevity was calculated as the number of days after harvest (day 0) until flowers showed signs of bent neck and observation of advanced fading on petals.

Water uptake

Water uptake was determined by subtracting the mean volume of water evaporation from empty bottles from that of water reduction in bottles containing flowers, expressed as mL g^{-1} FW.

Fresh weight and flower diameter

Fresh weight was measured for each treatment at the end of the experiment (just before the onset of wilting).

Measurements were taken for diameter of opened and closed flowers and stem by a digital caliper gauge.

Relative water content

Relative water content (RWC) was measured according to evaluations of fresh weight (FW), turgid weight (TD) and dry weight (DW). To obtain evaluations for turgid weight, samples were floated in distilled water for 6 h inside a closed container and weighed, after gently wiping water away from plant tissue with tissue paper. Samples were put in an oven for 24 h at 750 to obtain dry weight (DW). Evaluation of relative water content was expressed by RWC (%) = [(FW-DW)/ (TW-DW)] × 100.

Opening of flowers and wilting percentage

Visual rating for opening of flowers was determined on the basis of 0-100%, with 0= no opened flower. The same method was used to estimate wilting percentage.

Soluble solids content

The extract of recuts of terminal segments of cut flowers was used to determine soluble solids of the stem. Two to three droplets of extract were spread on the glass plate of a digital refractometer (ATAGO, Model DR-A1, Japan) and Brix degree was recorded for soluble solid content.

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using SAS statistical software (SAS, Institute Inc., 2009). Means were compared by the least significant difference (LSD) test at the level of 0.05 percent probability.

Results

Relative water content of stem was increased under sucrose application but the

difference for results between concentrations of 4% and 8% was determined as not significant (Table 1). Nano-silver application also increased RWC in cut tuberose and RWC increased under increased concentration of NS (Table 1). However, interaction between sucrose and nano-silver concentration and treatment with 4% sucrose and 30 or 45 mg L^{-1} nano-silver was determined as the highest evaluation for RWC, while the control (0% sucrose and 0 mg L^{-1} NS) had the lowest (Table 2).

On average, treatment of cut tuberose flower with sucrose caused a reduction in water uptake (Table 1), however application of 4% sucrose applied alone, increased water uptake (Table 2). Nano-silver treatment increased water uptake of cut tuberose (Table 1). However, the increase was treatment-dose-specific and the treatment of 4% sucrose and 15 mg L^{-1} nano-silver had the lowest evaluation whereas treatment with 0% sucrose and 45 mg L^{-1} nano-silver had the highest evaluation for water uptake (Table 2).

Evaluations for fresh weight increased under application of sucrose or nano-silver (Table 1). In addition, the highest evaluation was recorded from the treatment of 45 mg L^{-1}nano-silver with 4% sucrose, while the control treatment (0 mg L^{-1} nano-silver and 0% sucrose) had the lowest evaluation for fresh weight (Table 2).

Total soluble solid (TSS) was not affected by sucrose application; but TSS was reduced under increasing nano-silver concentration (Table 1). Applications of 4% or 8% sucrose without nano-silver had higher evaluations for TSS while application of 45 mg L^{-1} nano-silver produced the lowest TSS in cut tuberose (Table 2).

On average, percentages for flower wilting percentage were not affected by sucrose concentration while nano-silver application decreased wilting percentage according to increasing concentration (Table 1). However, application of 4% sucrose alone caused a reduction in wilting percentage (Table 2). Higher evaluations for wilting percentage were recorded with 0 and 8% sucrose and 0 mg L^{-1} nano-silver (55%), while application of 0% sucrose with 45 mg L^{-1} nano-silver had the lowest evaluation fir wilting percentage (33.3) (Table 2).

Table 1. **Effects of sucrose and nano-silver on fresh weight (FW), relative water content (RWC), water uptake, total soluble solid and wilting of cut tuberose flowers**

RC	FW (g)	RWC (%)	Water uptake (ml g^{-1})	Total soluble solid (%)	Wilting (%)
0	166.2 b†	72.0 b	47.9 a	1.5 a	43.6 a
4	177.8 a	75.2 a	44.2 b	1.6 a	41.5 a
8	177.1 a	75.4 a	45.1 b	1.7 a	43.2 a
Nano-silver concentration (mg L^{-1})					
0	164.7 c	63.4 c	42.7 c	2.2 a	51.5 a
15	171.7 b	74.6 b	45.8 b	1.7 b	44.4 b
30	175.2 ab	77.4 ab	44.5 bc	1.3 c	39.8 c
45	183.2 a	80.1 a	49.8 a	1.4 c	35.4 d

† In each column for each treatment, means followed by the same letters are not significantly different according to LSD test at 0.05 level.

Table 2. **Interaction between sucrose and nano-silver levels on fresh weight (FW), relative water content (RWC), water uptake, total soluble solid and wilting of cut tuberose flowers**

Sucrose concentration (%)	Nano-silver concentration (mg L^{-1})	FW (g)	RWC (%)	Water uptake (ml g^{-1})	Total soluble solid (%)	Wilting (%)
0	0	145.5 d†	61.6 b	40.5 e	2.1 ab	55.5 a
0	15	180.8 abc	77.5 ab	51.8 ab	1.9 abc	46.7 b
0	30	156.6 bcd	71.0 ab	44.6 cde	1.3 de	38.9 cde
0	45	179.8 abc	77.9 ab	54.7 a	1.0 e	33.3 de
4	0	180.0 abc	63.9 ab	43.6 cde	2.2 a	43.9 bc
4	15	153.3 cd	68.7 ab	38.9 e	1.5 cd	42.3 bc
4	30	187.2 ab	82.3 a	47.5 bc	1.2 de	41.7 bcd
4	45	190.6 a	81.9 a	46.7 bcd	1.6 bcd	37.8 cde
8	0	166.5 a-d	64.6 ab	40.0 cde	2.2 a	55.0 a
8	15	181.1 abc	77.6 ab	46.8 cd	1.6 bcd	43.9 bc
8	30	181.1 abc	78.8 ab	41.4 de	1.4 de	38.9 cde
8	45	179.1 abc	80.3 ab	47.8 bc	1.7 bcd	35.0 de

† In each column, means followed by the same letters are not significantly different according to LSD test at 0.05 levels.

On average (main effect), flower opening was not affected by sucrose treatment (Table 3), but application of sucrose alone, 8% sucrose increased flower opening by about 20% compared with the control (Table 4). Application of 30 mg L^{-1} nano-silver increased flower opening while application of 15 and 45 mg L^{-1} decreased flower opening (Table 3). Application of 8% sucrose with 0 mg L^{-1} nano-silver or 4% sucrose with 30 mg L^{-1} NS had the highest evaluation for flower opening whereas, application of 8% sucrose with 45 mg L^{-1} nano-silver had the lowest evaluation for percentage of flower opening (Table 4).

On average, sucrose application had no effect on closed flower diameter (Table 3), but application of sucrose alone caused a reduction in diameter of closed flower (Table 4). Nano-silver treatment reduced this trait (Table 3). Control had the highest evaluation whereas 0% sucrose with 45 mg L^{-1} NS had the lowest for closed flower diameter (Table 4).

With increasing sucrose concentration, opened flower diameter also showed an increase while the effect of nano-silver was dependent on concentration and that of 15 mg L^{-1} and 45 mg L^{-1} increased evaluations for this trait (Table 3). Application of 4% sucrose with 15 mg L^{-1} nano-silver and application of 0% sucrose with 30 mg L^{-1} nano-silver produced the highest and lowest evaluations fir closed flower diameter, respectively (Table 4).

Sucrose and nano-silver treatments increased stem diameter (Table 3). The highest evaluation for stem diameter was recorded from the treatment of 8% sucrose with 15 mg L^{-1} nano-silver or 4% sucrose with 30 mg L^{-1} nano-silver while the lowest evaluation for stem diameter was obtained under the combination of 4% sucrose with 15 mg L^{-1} nano-silver (Table 4).

Sucrose or nano-silver treatments increased longevity in cut tuberose flower (Table 3). When application of sucrose alone, 4% increased while 8% slightly reduced flower longevity (Table 4). Treatment of NS applied alone, increased

NS concentration and increased flower longevity (Table 4). In addition, treatment of 4% sucrose with 45 mg L^{-1} nano-silver had the longest, and 8% sucrose applied with 0 mg L^{-1} NS produced the lowest evaluation for flower longevity (Table 4).

Table 3. Effects of sucrose and nano-silver on vase life, flower opening, open flower, closed flower and stem diameters of cut tuberose flowers

Sucrose concentration (%)	Vase life (day)	Flower opening (%)	Closed flower diameter (cm)	Open flower diameter (cm)	Stem diameter (cm)
0	7.6 b†	51.8 a	0.73 a	1.85 b	0.72 b
4	9.3 a	48.0 a	0.71 a	1.89 ab	0.76 a
8	8.9 a	51.2 a	0.70 a	1.94 a	0.76 a
Nano-silver concentration (mg L^{-1})					
0	6.7 d	50.9 ab	0.75 a	1.85 bc	0.70 b
15	8.1 c	48.3 b	0.72 ab	1.96 a	0.74 b
30	9.1 b	54.4 a	0.67 b	1.83 c	0.78 a
45	10.5 a	47.8 b	0.72 ab	1.92 ab	0.76 a

† In each column for each treatment, means followed by the same letters are not significantly different according to LSD test at 0.05 levels.

Table 4. Interactions between sucrose and nano-silver levels on vase life, flower opening, open flower, closed flower and stem diameters of cut tuberose flowers

Sucrose concentration (%)	Nano-silver concentration (mg L^{-1})	Vase life (day)	Flower opening (%)	Closed flower diameter (cm)	Open flower diameter (cm)	Stem diameter (cm)
0	0	6.5 fg†	49.4 bc	0.94 a	1.86 bcd	0.69 c
0	15	6.5 fg	46.6 cde	0.67 b-e	1.86 bcd	0.72 c
0	30	7.5 f	53.3 abc	0.70 b-e	1.78 d	0.75 abc
0	45	10.0 bc	57.8 ab	0.61 e	1.87 bcd	0.74 abc
4	0	7.6 ef	43.7 de	0.65 cde	1.84 cd	0.71 c
4	15	8.6 bcd	45.0 cde	0.72 b-e	2.04 a	0.67 c
4	30	9.3 cd	58.9 a	0.69 b-e	1.80 d	0.83 a
4	45	11.4 a	44.4 cde	0.77 bc	1.86 bcd	0.82 ab
8	0	6.1 g	59.4 a	0.64 de	1.85 cd	0.71 c
8	15	9.0 cd	53.3 abc	0.75 bcd	1.98 abc	0.83 a
8	30	10.3 b	51.1 ad	0.63 de	1.90 a-d	0.77 abc
8	45	10.2 b	41.1 e	0.78 b	2.03 ab	0.73 bc

† Means followed by the same letters are not significantly different according to LSD test at 0.05 levels.

Discussion

RWC

The results showed that sucrose or nano-silver application improved RWC in cut tuberose flowers, but the effects were dependent on treatment and concentration and application of 4% sucrose with 30 mg L^{-1} NS was determined as the most

effective. In contrast with our results, Mortazavi *et al*. (2011) reported that sucrose application had no significant effect on RWC of cut rose (cv. 'Royal') and tests reported in Asgari *et al*. (2013) showed that application of nano-silver had no effect while sucrose or sucrose application with NS increased RWC in cut tuberose flowers. In line with our results, Kiamohammadi *et al*., (2011) in *Lisianthus* and, Mortazavi *et al.*, (2010) in cut rose (cv. 'Varlon') reported that sucrose treatment increased RWC. These contrasting results could be due to difference in terms of sucrose concentration, temperature, species and cultivar. In contrast, Mortazavi *et al*,. (2011) reported that nano-silver had no significant effect on RWC in cut rose 'Royal'. Increased in RWC by NS application was likely caused by an increase in water uptake as indicated in Table 1 and a reduction of transpiration and inhibition of microbial growth at the end of stem as concluded by Lu *et al.*,. (2010b).

Water uptake

Findings of these tests indicated that NS application increased water uptake and that the treatment of 45 mg L^{-1} NS was the most effective concentration, but application of sucrose alone reduced water uptake in cut tuberose flowers. Ichimura and Shimizu-Yumo (2007) reported that treating cut rose flower with 2% sucrose increased water uptake. Kazemi and Ameri (2012) also showed that water uptake by gerbera cut flower was increased by application of higher sucrose concentration. It has been reported that water uptake by cut flowers was affected by sucrose concentration (Butt, 2005). Similar results to those of this study were reported in Lu *et al*. (2010b) in cut rose flower cv. 'Movie Star' and Kazemi and Ameri (2012) in cut gerbera; such that application of nano-silver increased water uptake. Increased in water uptake could be attributed to inhibition of microbial growth in vase solution by NS as reported by Lu *et al*. (2010b).

Fresh weight

In our study, fresh weight of cut tuberose flowers was increased by sucrose or NS application, but the highest increase was recorded under treatment of 4% sucrose applied with 45 mg L^{-1} NS. In agreement with results of these tests, Ichimura and Shimizu-Yumo (2007) reported that application of 2% sucrose increased fresh weight of cut rose. Lu *et al*. (2010a) reported that application of nano-silver increased fresh weight of cut rose (cv. 'Movie') Star. Lu *et al*. (2010a) reported that when 10 mg L-nano-silver was applied with 5% sucrose alleviated the fresh weight of cut flower rose cv. 'Movie' Star more than treatments of either sucrose or nano-silver. This increase in evaluations for fresh weight was possibly caused by the increased energy supply from sucrose and the regulation of water by NS (Lu *et al.*, 2010a; Lu *et al*., 2010b).

TSS

Application of 4% or 8% sucrose increased the TSS of cut tuberose flowers while NS application reduced evaluations for this trait. In contrast, Moradi *et al*. (2012) reported that application of 4 mg L^{-1} nano-silver with 3% sucrose resulted in the highest amount of TSS in cut carnation 'Cream Viana'.

Wilting percentage

Wilting percentage was reduced by application of 4% sucrose, but it increased less than 8%, while NS application reduced wilting percentage. In contrast, Elgimabi and Ahmed (2009) reported that applications of 1% to 3% sucrose reduced wilting percentage of cut rose flower. With a few exceptions, RWC and water uptake increased with allocation of sucrose treatments, thus decreased wilting percentage could be at least partially due to an increase of water uptake and RWC as indicated in Table 1.

Flower opening and closing

The highest evaluation for flowering opening was obtained under 8% and the

lowest under the combined application of 8% sucrose and 45 mg L^{-1} NS. The highest and lowest evaluations for closed flower diameter were recorded for the control and 45 mg L^{-1} NS respectively, and the highest and lowest evaluations for open flower diameter were detected under the treatment of the combination of 4% sucrose with 15 mg L^{-1} NS and 30 mg L^{-1} NS, respectively. Doi and Reid (1995) showed that application of 20 g mL^{-1} sucrose increased flower opening of cut flower hybrid Limonium. Mortazavi *et al*. (2010) reported that application of nano-silver or sucrose increased flower opening of cut rose flower, but that the combination of sucrose (4%) and nano-silver (5 mg L^{-1}) was more effective.

In contrast to the results of these tests, those reported in Liao et al. (2000) applied 80 g L^{-1} sucrose and Ichimura and Shimizu-Yumo (2007) applied 2% sucrose and reported that sucrose increased flower diameter of cut rose. These contrasting results could be attributed to differences concentration of sucrose and species (Butt, 2005).

Stem diameter

Application of both sucrose and NS increased stem diameter. In agreement with findings of this study Ansari *et al*. (2011) reported that treatment 5 mg L^{-1} nano-silver plus 4% sucrose increased evaluations for stem diameter of cut flower gerbera. Stem diameter is one the most important indexes for measuring quality of cut flower and is an evaluation used to determine its marketability (Ansari *et al*. 2011).

Flower longevity

Both sucrose and NS application increased cut tuberose flowers longevity, however, the highest evaluation for flower longevity was recorded from the treatment of 4% sucrose applied with 45 mg L^{-1} NS. Doi and Reid (1995) in flower hybrid Limonium, Butt (2005) in cut rose flower rose, Mortazavi *et al*., (2011) in cut flower rose cv. 'Royal' and Kazemi and Ameri (2012) in tests on gerbera cut flower reported that sucrose application increased vase life of cut flowers. Results of these tests are in general agreement with the results reported in other studies. Also Lu *et al*. (2010a) in rose cut flower cv. 'Movie Star', Basiri *et al*., (2011) in carnation, Mortazavi *et al*. (2011) in cut flower rose cv. 'Royal' and Kazemi and Amiri (2012) in gerbera also reported that nano-silver application increased vase life. In addition, and in line with results of these tests, Basiri *et al*., (2011) in carnation, Mortazavi *et al*. (2011) in rose cut flower rose cv. 'Royal', Moradi *et al*. (2012) in Dianthus cv. 'Cream Viana' reported that application of the combination of sucrose and NS further prolonged the vase life of these flowers compared with that of the control. Many flowers are harvested before they are fully developed in order to minimize mechanical damage that may occur during processing and handling and a long postharvest longevity in the cut flowers. In addition, they undergo physiological changes that may lead to early senescence. Therefore, development of these cut flowers and maintenance of their metabolic activities require adequate availability of sugars. Furthermore, ethylene production is one of the main adverse effects in cut flowers (Nowak and Rudnicki, 1990). In addition, accumulation of microorganisms especially bacteria in the vase solution or vessel, air emboli and physiological wounds from healing caused by stem blockage leads to reduced vase life of cut flowers (Van Doorn 1997; Marandi *et al*. 2011). Continuing transpiration by leaves and other parts could be another reason for reduced longevity among cut flowers. Consequently, depletion of soluble carbohydrates, negative water balance and presence of ethylene are the main causes of shortened vase life in cut flowers. In this research, sucrose treatment alone increased flower longevity for about 1 d and some of the related quality traits of cut tuberose flowers; this can be attributed to availability of sucrose that serve to suppresses ethylene

biosynthesis and that supplies substrates for respiration and structural materials (Halevy and Mayak 1979); induces stomata closure; reduces transpiration and water loss, (Chen *et al*., 2001); suppresses respiration in plant tissues (Ichimura *et al*., 2000) and reduces wilting (Borocho *et al*., 1976).

Also determined in this experiment was that the treatment of NS (45 mg L^{-1}) alone served to maintain vase life and related quality traits of cut tuberose flowers for 3.5 d. This result was most likely caused by the fact that NS has the following effects; reduces transpiration in association with reduced stomata aperture (stomata closure), increases hydraulic conductance, inhibits bacterial growth in the vase solution and at the cut stem end (Liu *et al* 2009; Lu *et al*. 2010a); prevents ethylene-mediated processes, such as flower senescence and abscission (Ichimura *et al*. 2008). These effects of NS are due to its particle size, with higher surface to volume ratio (Raffi *et al*., 2008) that maintains a more favorable water balance in cut flower tissues.

The results of this experiment demonstrated that combined treatment of NS (45 mg L^{-1}) and sucrose (4%) improved vase life for about 5 d and affected related parameters of cut tuberose flowers more than did applications of sucrose or NS alone and these results are probably caused by the role of NS as an antibacterial agent and the effect of sucrose that extends flower longevity and related quality traits. Nanotechnology is a promising technology in the field related to generating new applications in agriculture. However, only a few nano products are currently are available for use in agriculture; the most prominent of which is nano-silver. Nano-silver particles are usually smaller than 100 nm and contain 20-15, 000 silver atoms. Nano-scale silver has demonstrated some very unusual and interesting physical, chemical and biological properties (Moaddab *et al*., 2011). One of its unique properties is that of antimicrobial activity. NS particles have a high surface area to volume ratio and thus, provide good contact with microorganisms; as such they are highly effective germicides (Rai *et al*., 2009). These particles are able to attach to cell a membrane and penetrate bacteria; this disrupts respiration and cell division and leads to cell death. Quality and longevity of cut flowers is determined by water balance and water imbalance occurs when a stem end becomes blocked by vascular occlusion, that serves to inhibit water supply to the cut flowers (Van Doorn, 1997). Vascular blockage was reportedly caused by living bacteria and products of their decay (van Doorn, 1997). In addition, such microorganisms may secret enzymes, toxic compounds and ethylene that serve to accelerate senesce (Williamson *et al*., 2002). Extended vase life and increasing the quality of cut tuberose in these tests be explained by unique physical, chemical and biological properties of NS that have the affect of inhibiting bacterial growth.

In conclusion, sucrose (4%) or NS (45 mg L^{-1} NS) treatments extended flower longevity and improved most of the related parameters of cut tuberose flowers. However, these traits were further improved when 4% sucrose was combined with 45 mg L^{-1} NS. These results suggest that flower longevity of cut tuberose flowers could be extended by combined treatment with sucrose and NS.

REFERENCES

1.Ansari, S., E. Hadavi, M. Salehi, P. Moradi. 2011. Application of Microorganisms Compared with Nanoparticles of Silver, Humic and Gibberellic acid on Vase Life of Cut Gerbera Goodtiming. J. Orna. Hort. Plants1: 27-33.

2.Asgari, M., M.H. Azimi, Z.Hamzehi, S. Mortezavi, F. Khodabandelu. 2013. Effect of Nano-Silver and Sucrose on Vase Life of Tuberose (*Polianthus tuberosa* cv. Peril) Cut Flowers. Int. J. Agron. Plant Product. 4:680-687.

3.Basiri, Y., H. Zarei, K. Mashayekhi. 2011. Effect of Nano-Silver Treatments on Vase Life of Cut Flowers of Carnation. J. Adv. Lab. Res. Bio. 1:49-54.

4.Bieleski, R.L. 1993. Fructan Hydrolysis Drives Petal Expansion in the Ephemeral Daylily Flower. Plant Physiol. 103:213-219.

5.Borocho, A., S. Mayak, A. H. Halvey. 1976. Combined Effects of Absciscic Acid and Sucrose on Growth and Senescence of Rose Flowers. Physiol. Plant. 36:221-224.

6.Butt, S. J. 2005. Extending the Vase Life of Rose (Rosa Hybrid) with Different Preservatives. Int. J. Agr. Biol. 7:97-99.

7.Chen, W. S, L. J., Liao, C. Y. Chen, K. U. Huang. 2001. Gibberlic Acid and Sucrose Affect Vase Life in *Oncidium* spp. Acta. Bot. Gallica. 148:177-181.

8.Da Silva, J. A. T. 2003. The Cut Flower: Postharvest Considerations. Online J. Biol. Sci. 3: 406-442.

9.Doi, M, and M. Reid. 1995. Sucrose Improves the Post-Harvest Life of Cut Flowers of Hybrid Limonium. HortScience 30:1058-1060.

10.Elgimabi, M, and O. K. Ahmed. 2009. Effect of Bactericides and Sucrose Pulsing on Vase Life Cut Rose Flowers (Rosa hybrid). Bot. Res. Int. 2:164-168.

11.Fujino, D. W., M. S. Reid, and H. C. Kohl. 1983. The Water Relations of Maid Hair Fronds Treated with Silver Nitrate. Scientia Hort. 19:349-355.

12.Halevy,A. H, and S. Mayak. 1976. Senescence and Postharvest Physiology of Cut Flowers. Part 1. Hort. Rev. 1:204-236.

13.He, S., D. C. Joyce, D. E. Irving, and J. D. Faragher. 2006. Stem End Blockage in Cut Grevillea 'Crimson-Yul-Lo' Inflorescence. Postharvest Biol. Technol. 41:78-84.

14.Hutchinson, M.J., D.K. Chebet, and V.E. Emonger. 2003. Effect of Accel, Sicrose and Silver Thiosulphate on the Water Relation and Post-Harvest Physiology of Cut Tuberose Flowers. Afric. Crop Sci. J. 4:279-287.

15.Ichimura, K., K. Kojima, and R. Goto. 1999. Effects of Temperature, 8-Hydroxyquinoline Sulphate and Sucrose on the Vase Life of Cut Rose Flowers. Postharvest Biol. Technol. 15:33-40.

16.Ichimura,K., K. Kohata, and R. Goto. 2000. Soluble Carbohydrates in Delphinium and their Influence in Sepal Abscission in Cut Flowers. Physiol. Plant. 108, 307-313.

17.Ichimura, K, and H. Shimizu-Yumoto. 2007. Extension of the Vase Life of Cut Rose by Treatment with Sucrose Before and During Simulates Transport. Bull. Natl. Inst. Flor. Sci. 7, 17-27.

18.Ichimura, K., S. Yoshioka, and H. Yumoto-Shimizu. 2008. Effects of Silver Thiosulphate complex (STS), Sucrose and Combined Pulse Treatments on the Vase Life of Cut Snapdragon Flowers. Environ. Control Biol. 46:155-162.

19.Jowkar, M. M, and H. Salehi. 2005. Effects of Different Preservative Solutions on the Vase Life of Cut Tuberose Flowers at Usual Home Conditions. Acta Hort. 629:411-416.

20.Kazemi, M, and A. Ameri. 2012. Postharvest Life of Cut Gerbera Flowers as Affected by Nano-Silver and Acetylsalicylic Acid. Asian J. Biochem. 7:106-111.

21.Khondakar, S.R, and K. Maxundar. 1985. Studies on Prolonging the Vase Life of Tuberose Cut Flowers. South Ind. Hort. 33:145-147.

22.Kiamohammadi, M., A. Golchin, and D. Hashemabadi. 2011. Effects of Different Floral Preservation Solutions on Keeping Quality of Cut Lisianthus. J. Orna. Hort. Plants 1:115-122.

23.Liao, L.J., Y.H. Lin, K.L. Huang, W.S. Chen, and Y.M. Cheng. 2000. Postharvest Life of Cut Rose Flowers as Affected by Silver Thiosulfate and Sucrose. Bot. Bull. Acad. Sin. 41:299-303.

24.Liu, J.P., S.H. He, Z.Q. Zhang, J.P. Cao, P.T.L.V., S.D. He, G.P. Cheng, and D.C. Joyce. 2009. Nano-silver Pulse Treatments Inhibit Stem-End Bacteria on Cut Gerbera cv. Roikou Flowers. Postharvest Biol. Technol. 54:59-62.

25.Lu, P., S. He, H. Li, J. Cao, and H. Xu. 2010a. Effects of Nano-Silver Treatment on Vase Life of Cut Flower Rose cv. Movie Star Flowers. J. Food. Agr. Environ. 8:1118-1122.

26.Lu, P., J. Cao, S. He, J. Liu, H. Li, G. Cheng, Y. Ding, and D. C. Joyce. 2010b. Nano-silver Pulse Treatments Improve Water Relations of Cut Rose cv. Movie Star Flowers. Postharvest Biol. Technol. 57:196-202.

27.Marandi, R., A. Hassani, A. Abdollahian, and S. Hanafi. 2011. Improvement of the Vase Life of Cut Gladiolus Flowers by Essential Oil, Salicylic Acid and Silver Thiosulfate. J. Med. Plant Res. 5:5039-5043.

28.Moaddab, S., H. Ahari., D. Shahbazzadeh., A. A. Motallebi, and A. A. Anvar. 2011. Toxicity

Study of Nanosilver (Nanocid) on Osteoblast Cancer Cell Line. Int. Nano Lett. 1:11-16.

29.Moalem-Beno, D., G. Tamari, Y. Leitner-Dagon, A. Borochov, and D. Weiss. 1997. Sugar-dependent Gibberellins-Induced Synthesis Gene Expression in *Petunia Corollas*. Plant Physiol. 113:419-424.

30.Moradi, P., H. Afshari, and A. G. Ebadi. 2012. The Effect of Benzyl Adenine, Nano Silver, 8-Hydroxylquinolin Sulfate, and Sucrose on Longevity Improvement and Some other Quality Characteristics of Dianthus cv. Cream Viana Cut Flower. Ind. J. Sci. Technol. 5:2459-2463.

31.Mortazavi, S.N., H. Rabi Angourani, and M.Khodadadi. 2010. Effect of Sucrose and Calcium Chloride on the Quality and Longevity of Cut Flower Rose cv. Varlon. Seed Plant Prod. J. 26:559-563.

32.Mortazavi, S.N., M. Mohebbi, and Y. Sharafi. 2011. Effects of Nanosilver and Sucrose on Vase Life of Cut Rose Flower (Rosa hybrid cv. Royal). J. Med. Plants Res. 5:6455-6459.

33.Naidu, S.N, and M.S. Reid. 1989. Postharvest handling of tuberose (*Polianthes tuberosa* L.). Acta Hort. (ISHS). 261:313-317.

34.Nowak, J, and R.M. Rundicki. 1990. Postharvest Handling and Storage of Cut Flowers, Florist Green and Pot Plants. Timber Press Inc., Portand, Oregon, USA. Pp 2109.

35.Raffi, M., F. Hussian, Y. M. Bhatti, J. I. Akhter, A. Hameed, and M. M. Hasan. 2008. Antibacterial Characterization of Silver Nanoparticles against *E. coli* ATCC-15224. J. Mater. Sci. Technol. 24:192-196.

36.Rai, M., A. Yadav, and A, Gade. 2009. Silver Nanoparticle as a New Generation of Antimicrobials. Biotechnol. Adv. 27:76-93.

37.Ranwala, A.P, and W. B. Miller. 2009. Comparison of the Dynamics of Non-Structural Carbohydrate Pools in Cut Tulip Stems Supplied with Sucrose or Trehalose. Postharvest Biol. Technol. 52:91-96.

38.Reid, M.S., J.L. Paull, A.K. Frahoomand, A.M. Kofranek, and G.L. Staby. 1980. Pulse treatments with the Silver Thiosulphate Complex Extend the Vase Life of Cut Carnation. J. Amer. Soc. Hort. Sci. 105:25-27.

39.Reid, M., 1996. Postharvest Handling Recommendations of Cut Tuberose. Perishable Hand. Newsletter 88:21-22.

40.SAS, Inst. Inc. 2009. SAS/S. Ver. 902. User s Guide, Second Ed. Cary, NC, USA.

41.Serek, M., M.S. Reid. 1993.Anti-ethylene Treatments for Potted Flower Plants-Relative Efficacy of Inhibitors of Ethylene Action and Biosynthesis. HortScience 28:1180-1181.

42.Solgi, M., M. Kafi, T. S. Taghavi, and R. Naderi. 2009. Essential Oils and Silver Nanoparticles (SNP) as Noval Agents to Extend Vase-Life of Gerbera (*Gerbera Jamesonii* cv. Dune) Flowers. Postharvest Biol. Technol. 55:155-158.

43.Van Doorn, W.G., G. Groenewegn, P. A. Van de Pol, and C.E.M. Berkholst. 1991. Effect of Carbohydrate and Water Status on Flower Opening of Cut Madelon Rose. Posharvest Biol. Technol. 1:47-57.

44.Van Doorn, W.G. 1997. Water Relation of Cut Flowers. Hort. Rev. 18:1-85.

45.Williamson, V., J. Faragher., S. Parsons, and P. Franz. 2002. Inhibiting the Postharvest Wounding Response in Wildflowers. Publ. No. 02/114. Rural Indust. Res. & Dev. Corp., Canberra.

46.Zagory, D., and M. S. Reid. 1986. Role of Vase Solution Microorganisms in the Life of Cut Flowers. J. Amer. Soc. Hort. Sci. 111:154-158.