Journal of Ornamental Plants
Available online on: www.jornamental.iaurasht.ac.ir
ISSN (Print): 2251-6433 ISSN (Online): 2251-6441

Effect of Salicylic Acid, Citric Acid and Ascorbic Acid on Post-harvest Quality and Vase Life of Gerbera (*Gerbera jamesonii*) Cut Flowers

Mona Mehdikhah [1], Rasoul Onsinejad [2], Mohammad Nabi Ilkaee [3] and Behzad Kaviani [2*]
[1] Former M.Sc. Student, Department of Horticulture, Rasht Branch, Islamic Azad University, Rasht, Iran
[2] Department of Horticulture, Rasht Branch, Islamic Azad University, Rasht, Iran
[3] Department of Agronomy and Plant Breeding, Karaj Branch, Islamic Azad University, Karaj, Iran

Received: 18 January 2016 Accepted: 27 May 2016
*Corresponding author's email: b.kaviani@yahoo.com

Abstract

Cut gerbera (*Gerbera jamesonii*) flowers are sensitive to microbial contamination and have short vase life. The effect of salicylic acid, citric acid and ascorbic acid (50, 100 and 200 mg l^{-1}) was evaluated on vase life of gerbera flowers. Changes in vase life, water absorption, and bacterial population in stem and vase solution, also biochemical characteristics such as protein concentration, lipid peroxidation level and enzymes activity such as superoxide dismutase and peroxidase were measured and compared with the control. Results showed that the maximum vase life (11.31 and 11.21 days) was achieved in 100 mg l^{-1} of both citric acid and salicylic acid, respectively. The vase life of control cut flowers was 5.80 days. Most solution uptake (0.907 ml g^{-1} F.W) was obtained in 100 mg l^{-1} of citric acid, too. The least bacterial colonies in stem end (151.00) and vase solution (66.33) was obtained in 100 mg l^{-1} citric acid. Differences between the content of bacterial colonies in vase solution containing 200 mg l^{-1} citric acid and 100 and 200 mg l^{-1} salicylic acid was not significant with 100 mg l^{-1} citric acid. The lowest content (46.04 and 46.21 nmol g^{-1} F.W.) of lipid peroxidation or MDA content was obtained from cut flowers treated with 200 mg l^{-1} of citric acid and 100 mg l^{-1} salicylic acid, respectively. Maximum activity of the peroxidase (0.063 mmol g^{-1} F.W.) and superoxide dismutase (40.80 nmol g^{-1} F.W.) enzymes was observed in 200 mg l^{-1} of citric acid.

Keywords: Asteraceae, Longevity, Organic acids, Ornamental plants, Plant growth regulators, Vase solution.

INTRODUCTION

Gerbera (*Gerbera jamesonii*) is one of the most important cut flower of the Asteraceae family. This species is a perennial tropical plant, which is well known for its rich flower colors and shapes and is one of the ten most popular cut flowers in the world. Gerbera has short vase life and is sensitive to microbial contamination at the stem end and in the preservative solution (Balestra *et al.*, 2005; Liu *et al.*, 2009). The vase life of flowers has a critical importance in determining the value of the crop. Senescence is one step of the normal developmental cycle of plants and effects on the cell, tissue, and organ or organization level (Mansouri, 2012). Senescence is an oxidative process involving a general degradation of the cellular structures (Mansouri, 2012). Recently, it has been found that salicylic acid delayed rose and Gladiolus flower senescence (Ezhilmathi *et al.,* 2007; Alaey *et al.,* 2011). Microbial contamination causes stem end blockage, imbalance between water uptake and water loss and finally wilting and shortening vase life (Balestra *et al.*, 2005). Water balance is one of the main factors which determine quality and longevity of cut flowers (Lü *et al.*, 2010). Reduced water uptake caused by xylem blockage and enhanced transpiration are the major reasons for wilting (van Doorn, 1997). Stem end blockage in cut flowers is classified as microbial contamination due to living bacteria and their wasted products, physical wound because of air emboli and physiological injury (Safa *et al*., 2015).

Some organic acids such as salicylic acid, malic acid, citric acid and ascorbic acid have important role on extending the postharvest longevity of cut flowers. Organic acids are source of both carbon and energy for cells and are used in the respiratory cycle and some other biochemical pathway (da Silva, 2003; Darandeh and Hadavi, 2012). Ascorbic acid (vitamin C) plays an important role in plant growth and development especially in electron transport system (El-Kobisy *et al.,* 2005). This compound also links developmental senescence and programmed cell death through a complex signal transduction network (Barth *et al.,* 2006). Ascorbic acid has been associated with some biological activities in plants such as in enzyme co-factor, antioxidant and electron transporter at the plasma membrane or in the chloroplast (Conklin, 2001). A high level of endogenous ascorbic acid is necessary to maintain the antioxidant system that protect plants from oxidative damage (Cheruth, 2009). Some studies were done related to the effect of ascorbic acid on vase life of several cut flowers (Islam *et al.*, 2013; Banaee *et al*., 2013; Abri *et al.*, 2013). Salicylic acid (SA) is a plant signal molecule that plays a key role in plant growth, development, and defense responses (Ding *et al.*, 2002). Also, a potential of salicylic acid in response to stresses and gene expression during senescence has been shown (Morris *et al.*, 2000; Buchanan-Wollaston *et al*., 2003). This compound also acts as a plant growth regulator and plays an important role in plant growth and impacts on many physiological processes in plants with low concentration (Alaey *et al*., 2011). It acts as antioxidant, resistance to diseases, heat generation, flowering and other physiological and morphological processes. Nowadays, its role on extending the vase life of cut flowers has been identified. Citric acid like other organic acids can influence on the vase life of cut flowers. Citric acid reduces bacterial population in vase solution and increases the water conductance in xylem of cut flowers (van Doorn, 1997). Citric acid is one of the mobile forms of iron in plants, thus it plays an important role in iron transport (Hell and Stephan, 2003; Darandeh and Hadavi, 2012). Citric acid acts by reducing the pH of water and the proliferation of bacteria, which block the xylem vessels in the cut region (Nowak and Rudnicki, 1990). The positive effect of citric acid on postharvest longevity of some cut flowers like Lilium and tuberose was reported (Eidyan, 2010; Darandeh and Hadavi, 2012). The aim of this work was to study the effect of different concentrations of salicylic acid, citric acid and ascorbic acid on vase life, post-harvest quality and some other traits of cut gerbera (*Gerbera jamesonii*) flowers.

MATERIALS AND METHODS

Plant material

Cut gerbera (*Gerbera jamesonii* cv. 'Balance') flowers were obtained from plants grown

in the Plant and Flower Center in Esfahan city, Iran. They were immediately stood in buckets and transported to the postharvest laboratory. Buckets containing the flower stems were covered with a plastic film shroud to minimize moisture loss during transportation. At the laboratory, stems were re-cut under 4°C deionized water to ~50 cm length to remove air emboli. The flowers were selected for uniformity of size, color and freedom from any defects.

Experimental design and treatments

The experimental design was a randomized completely blocks design (RCBD) with 10 treatments. Treatments were the concentrations of 50, 100 and 200 mg l^{-1} of salicylic acid, citric acid and ascorbic acid along with the control. Experiment was done with 3 replications, 30 plots and 250 flower bunches. In each plot, two cut gerbera flowers were placed into 1000 ml vase filled with 250 ml of preservative solutions including the aforementioned matters. Then, these cut gerbera stems were placed into 1000 ml pots filled with 500 ml of preservative solutions supplemented with 3% sucrose. Distilled water was used as the control. The outer surface of vases was covered with sheets of paper. The flowers were kept in a vase life (controlled environment) room under the following conditions: 20 ± 2°C, relative humidity of 60-70%, 15-20 $\mu molm^{-2}s^{-1}$ light intensity (cool white florescent tubes) and a daily light period of 12 h.

Measurement of traits

Vase life

Vase life of the cut stems was assessed daily; throughout the vase life evaluation. The end of vase life is defined taking into consideration the visible wilting and stem bending more than 90° (He *et al*., 2006).

Solution uptake (water absorption)

In order to determine the evaporation of vase solutions, 4 dishes with 500 ml distilled water had been placed between the dishes containing cut flowers. These dishes content were weighted at the last day of each plot's vase life, solution uptake was determined for each plot as the following expressions: (500 - the reduced content of solution in the dishes at the last day of vase life + the surface evaporation of the last day = Y). Then, Y was divided by the first day flower fresh weight of each plot and multiplied by 100: (Y/the first day fresh weight); this data is solution uptake per plot (ml g^{-1} F.W).

Vase solution bacterial colonies

For determination of the number of bacteria colonies in vase solutions, 24 h after pulse treatment, 2 ml of vase solution was sampled from each vase and then diluted with 2 ml of 0.9% sterile normal saline. Liquid extract (0.1 ml) was spread on the nutrient agar plates and bacterial colonies were enumerated after incubation for 24 h at 37°C (Liu *et al.*, 2009; Lu *et al*., 2010). All bacteria colonies counting were replicated three times.

Stem end bacterial colonies

For determinations of bacterial concentration in stems after pulsing, 2-cm length (approximately 0.5 g) segments were cut from the stem ends. Explants were washed three times with sterile distilled water to reduce surface microbial loads. The explants were then ground and diluted with 0.9% sterile saline. Aliquots (0.1 mL) of extract were spread on nutrient agar plates, and bacterial colonies were enumerated after incubation for 24 h at 37°C. All bacteria counts were conducted on triplicate sub-samples (Balestra *et al.*, 2005).

Petal protein

At the 5th day of vase life, one cut flower of each plot was removed and dried in an oven for 24 h. Total protein content of petals was measured based on Bradford method (Bradford, 1976).

Lipid peroxidation (MDA content)

Lipid peroxidation was assessed using the Bates et al. (1973) method. Petal samples (0.25 g) were homogenized in 1 mL of 0.1% trichloroacetic acid (TCA). The homogenate was centrifuged at 14000 g for 15 min, and then 500 µL of supernatant was added to 500 µL of 0.5% thiobarbituric acid (TBA) in 20% TCA. The mixture was heated at 95°C for 30 min and then cooled in an ice bath. After centrifugation at 10000 g for 10 min, the absorbance of the supernatant was calculated at 532 nm. The MDA content was measured when the extinction coefficient of the sample was 155 mM cm^{-1}.

Peroxidase enzyme (POD)

Each extract used for measuring POD activity was prepared by freezing 0.5 g of petal tissue in liquid nitrogen and then grinding the tissue in 10 ml of extraction buffer [50 mM phosphate buffer, pH 7 containing 0.5 mM EDTA and 2% PVPP (w/v)]. The resulting homogenate was centrifuged for 20 min at 15000 g, and the supernatant was used to determine enzymatic activity. POD activity was assayed by spectrophotometric measurement of guaiacol formation in 1 mL of a reaction mixture consisting of 450 µL of 25 mM guaiacol, 450 µL of 225 mM H2O2 and 100 µL of crude enzyme. The activity is expressed as mM per mg of fresh weight.

Super oxide dismutase enzyme (SOD)

A cut flower was removed from vase solution at the 5th day and measurement of SOD was done using spectrophotometry by Giannopolitis and Ries (1997) method from petal tissue.

Statistical analysis

Data were subjected to analysis of variance in SAS statistical software and means were compared by the least significant difference (LSD) test at the 0.05 and 0.01 of probability level.

RESULTS

In our study, different doses of salicylic acid, citric acid and ascorbic acid were used as the main sources of variation. Based on our results, salicylic acid, citric acid and ascorbic acid could extend the vase life of cut gerbera (*Gerbera jamesonii* cv. 'Balance') flowers. The results are summarized in Tables 1 and 2. Our data revealed that there are differences in the effect of the different concentrations of salicylic acid, citric acid and ascorbic acid.

Vase life

Based on our results, significant differences were found among different concentrations of salicylic acid, citric acid and ascorbic acid ($P<0.01$) in extending the vase life of cut gerbera flowers (Table 1). The longest vase life (11.31 days) was obtained with 100 mg l^{-1} citric acid (Table 2). The 100 mg l^{-1} of salicylic acid increased the vase life to 11.21 days that was good treatment after 100 mg l^{-1} citric acid (Table 2). Longevity in control cut flowers was 5.80 days. Correlations between the results showed that the vase life with water absorption ($r=0.600<0.01$), vase solution bacterial colonies ($r=-0.630<0.01$) and stem end bacterial colonies ($r=-0.724<0.01$) had significant positive correlation (Table 3). Other correlations between all traits have been shown in Table 3.

Solution uptake (water absorption)

Analysis of variance (ANOVA) showed that the most effective treatment on vase solution uptake was 100 mg l^{-1} citric acid ($P<0.05$) (Table 1). Salicylic acid and ascorbic acid had the less

efficiency than citric acid (Table 2). Mean comparisons showed that citric acid (100 mg l^{-1}) with 0.907 ml g^{-1} F.W had the most significant effect (Table 2). Least solution uptake (0.415 ml g^{-1} F.W) was calculated in control treatment.

Bacterial population of vase solution

According to our results, significant differences were found among various concentrations of salicylic acid, citric acid and ascorbic acid ($P<0.01$) on bacterial contamination of cut gerbera flowers (Table 1). Mean comparison among different concentrations of treatments indicates the priority of 100 mg l^{-1} citric acid (with 66 colonies) and 100 mg l^{-1} salicylic acid (with 67 colonies) rather than the other treatments and control (with 220 colonies) (Table 2).

Bacterial population of stem end

Salicylic acid, citric acid and ascorbic acid had significant effect on bacterial populations in the stem end of cut gerbera flowers ($P<0.01$) (Table 1). The lowest bacterial colonies (151.00) and the highest bacterial colonies (431.00) were obtained in the stems treated with 100 mg l^{-1} citric acid and the control, respectively (Table 2). The content of bacterial colonies (415.00) in stem end treated with 100 mg l^{-1} ascorbic acid was high, too. The presence of salicylic acid, citric acid and ascorbic acid in preservative solution had a significant effect on bacterial concentrations in the stem ends of cut gerbera.

Petal protein content

According to the findings, significant difference was found among various concentrations of salicylic acid, citric acid and ascorbic acid ($P<0.05$) on total protein content of cut gerbera petals (Table 1). Mean comparison among different concentrations of salicylic acid, citric acid and ascorbic acid indicates the priority of 100 mg l^{-1} salicylic acid (23.28% petal protein) and 200 mg l^{-1} citric acid (22.62% petal protein) as compared to the control and 200 mg l^{-1} salicylic acid (18.43% petal protein) (Table 2).

Lipid peroxidation (MDA content)

Data analysis of variance showed that the effect of different treatments on MDA content was significant ($P<0.01$) (Table 1). Information obtained of mean comparison revealed that all treatments caused to decrease of MDA accumulation than that of the control (Table 2). The highest (67.05 nmol g^{-1} F.W.) and the lowest (46.04 nmol g^{-1} F.W.) content of MDA were obtained from control cut flowers and cut flowers treated with 200 mg l^{-1} of citric acid. The content of MDA in cut flowers treated with 100 mg l^{-1} of salicylic acid (46.21 nmol g^{-1} F.W.) and 50 mg l^{-1} of ascorbic acid (49.50 nmol g^{-1} F.W.) was low (Table 2).

Peroxidase enzyme (POD)

Activity of the POD enzyme changed as salicylic acid, citric acid and ascorbic acid concentrations altered. Maximum activity of the POD enzyme (0.063 mmol g^{-1} F.W.) was observed in 200 mg l^{-1} of citric acid (Table 2). Activity of this enzyme in 100 mg l^{-1} of salicylic acid was good and greater than the activity of the other treatments and control (0.030 mmol g^{-1} F.W.) (Table 2). The effect of salicylic acid, citric acid and ascorbic acid on POD activity was significant ($P<0.01$) (Table 1).

Superoxide dismutase enzyme (SOD)

The effect of salicylic acid, citric acid and ascorbic acid on SOD activity was significant ($P<0.05$) (Table 1). Activity of the SOD enzyme changed as salicylic acid, citric acid and ascorbic acid concentrations altered. Maximum activity of the SOD enzyme (40.80 nmol g^{-1} F.W.) was ob-

Table 1. Analysis of variance of the effect of different concentrations of salicylic acid, citric acid and ascorbic acid on various traits in cut gerbera *(Gerbera jamesonii)* flowers*

S.o.V	df	Vase life	Water absorption	Petal protein content	MDA	SOD	POD	Bacterial population of stem end	Bacterial population of vase solution
Treatments	9	7.52**	8.75*	9.73*	139**	35.87*	0.00041**	23612**	10241**
Error	20	0.987	3.35	3.36	36.68	15.05	0.00006	2523	1468
CV (%)		10.61	28.61	8.9	11.23	11.13	16.71	17.59	29.62

* and **: Significant at α ≤ 5% and 1%, respectively.

Table 2. Mean comparison of the effect of different concentrations of salicylic acid (SA), citric acid (CA) and ascorbic acid (AA) on various traits in cut gerbera *(Gerbera jamesonii)* flowers*

Treatments	Vase life (day)	Water absorption (ml g^{-1} F.W)	Petal protein content (%)	MDA (nmol g^{-1} F.W.)	SOD (mmol g^{-1} F.W.)	POD (µmol g^{-1} F.W.)	Bacterial population of stem end (colonies)	Bacterial population of vase solution (colonies)
AA_1	8.48_{b}	0.434^{d}	21.35^{abc}	49.50^{cd}	36.18^{abc}	0.053^{ab}	293.00^{bc}	180.00^{ab}
AA_2	8.54_{b}	0.473^{cd}	19.39^{bc}	58.15^{abc}	32.10^{bc}	0.036^{d}	415.00^{a}	180.00^{ab}
AA_3	9.89_{ab}	0.679^{abcd}	22.33^{ab}	50.75^{bcd}	36.30^{abc}	0.056^{ab}	290.00^{bc}	99.60^{cd}
CA_1	9.32_{b}	0.613^{abcd}	21.35^{abc}	48.94^{cd}	37.79^{abc}	0.050^{bc}	243.00^{bcd}	173.00^{ab}
CA_2	11.31_{a}	0.907^{a}	19.39^{bc}	57.16^{abc}	31.50^{c}	0.036^{d}	151.00^{e}	66.33^{d}
CA_3	10.09_{ab}	0.766^{abc}	22.62^{a}	46.04^{d}	40.80^{a}	0.063^{a}	228.00^{cde}	70.33^{d}
SA_1	8.97_{b}	0.539^{bcd}	19.39^{bc}	54.64^{bcd}	31.50^{c}	0.040^{cd}	323.00^{b}	155.00^{bc}
SA_2	11.21_{a}	0.805^{ab}	23.28^{a}	46.21^{d}	38.34^{ab}	0.060^{ab}	195.00^{de}	67.33^{d}
SA_3	9.92_{ab}	0.763^{abc}	18.43^{c}	67.05^{a}	31.42^{c}	0.0300^{d}	284.00^{bc}	80.00^{d}
Control	5.80c	0.415^{d}	18.43^{c}	60.43^{ab}	32.44^{bc}	0.036^{d}	431.00^{a}	220.00^{a}

*Values in each row that are followed by the same letter are not significantly different by LSD test. Numbers (1, 2 and 3) after AA, CA and SA: concentrations of 50, 100 and 200 mg l^{-1}, respectively.

Table 3. Correlations between measured traits

	Vase life	Water absorption	Petal protein content	MDA	SOD	POD	Bacterial population of stem end	Bacterial population of vase solution
Vase life	1							
Water absorption	0.600**	1						
Petal protein content	0.323	0.099	1					
MDA	-0.266	-0.1	-0.490*	1				
SOD	0.029	0.078	0.558**	-0.354	1			
POD	0.257	0.162	0.751**	-0.703**	0.659**	1		
Bacterial population of stem end	-0.630**	-0.641**	-0.255	0.195	-0.248	-0.305	1	
Bacterial population of vase solution	-0.724**	-0.454*	-0.381*	0.266	-0.143	-0.324	0.563**	1

* and **: Significant at α < 5% and 1%, respectively

served in 200 mg l^{-1} of citric acid (Table 2). Activity of this enzyme in 100 mg l^{-1} of salicylic acid (38.34 nmol g^{-1} F.W.) was also greater than the activity of the other treatments and control (31.42 nmol g^{-1} F.W.) (Table 2). Differences between these two treatments were not significant. Minimum activity of the SOD enzyme (31.40 nmol g^{-1} F.W.) was observed in 200 mg l^{-1} of salicylic acid (Table 2).

DISCUSSION

Current study demonstrated that medium concentrations of both of citric acid and salicylic acid can increase vase life of cut gerbera flowers. The extended vase life in these concentrations is associated with increased fresh weight and water absorption. Mansouri (2012) showed that low concentration of salicylic acid can increase vase life of chrysanthemum flower. Also, Kazemi *et al.* (2011) found an increase in vase life of cut carnation flowers treated with 1.5 mM salicylic acid for 10 days. Some investigations showed the positive effect of salicylic acid, citric acid and ascorbic acid on post-harvest quality of several cut flowers (de Capdeville *et al*., 2003; Kazemi *et al.*, 2012). Jamshidi *et al.* (2012) revealed that a flower's vase life of cut gerbera when held in a solution containing 1 mM salicylic acid was significantly higher than that of the control treatment. This finding suggests a potential for application of salicylic acid as substitutes for chemicals commonly used in preservative solution for gerbera cut flowers (Jamshidi *et al*., 2012). Salicylic acid increased vase life, dry weight and flower diameter of cut gerbera flowers (Jamshidi *et al*., 2012). There was a reduction in fresh weight of gerbera flowers during its vase life. The reduction in fresh weight could be due to decreased water uptake or increase in water loss, and increase in respiration rate (Mansouri, 2012). Our work showed that the loss of fresh weight in cut gerbera flowers treated with 100 mg l^{-1} citric acid and salicylic acid was lower than that of the flowers treated with other concentrations and control. Abri *et al.* (2013) showed that for the maximum vase life, cut roses 'Royal Class' should be pulsed in the solution of 4 mM salicylic acid for 18 h. Ieamtim *et al*. (2008) showed that vase life of Alpinia purpurata flowers treated with ascorbic acid was significantly longer than that of control flowers. These researchers revealed that salicylic acid increased the vase life of flowers by reducing respiration rate and ethylene production. Jin *et al*. (2006) demonstrated that salicylic acid improved flower tolerance to water deficit stress and increased vase life of cut rose flowers. Study of de Capdeville *et al.* (2003) on cut rose flowers treated with citric acid and salicylic acid showed that vase life was considerably reduced. Probably the pulsing time with salicylic acid was too long. In our study, medium concentration of citric acid and salicylic acid was suitable for prolonging the vase life of cut gerbera flowers. Therefore, it is important to assist

the best time and concentrations of these acids.

Effect of citric acid on prolonging the vase life of some cut flowers has been shown (Eidyan, 2010; Darandeh and Hadavi, 2012). Darandeh and Hadavi (2012) investigation on the effect of pre-harvest foliar application of citric acid on vase life of lily revealed that citric acid increased vase life of cut flowers. More solution uptake of cut flowers held in citric acid suggesting a decrease in xylem blockage due to reduced microbial growth (He *et al.*, 2006). Low water uptake by cut flowers is often due to occlusions located mainly in the basal stem end (He *et al*., 2006) and microorganisms and their decay products are a common cause of stem end blockage (van Doorn, 1997; Williamson *et al*., 2002). Citric acid is considered to maintain the water balance and to reduce bacterial proliferation in the vase solution, thus avoiding the obstruction of the xylem vessels (de Capdeville *et al.*, 2003).

Proper effect of ascorbic acid on post-harvest longevity of some cut flowers has been shown (Abdulrahman *et al.*, 2012; Banaee *et al*., 2013). Study of Abdulrahman *et al*. (2012) on vase life of *Antirrhinum majus* L. revealed that ascorbic acid increased vase life. Vase life of cut rose and cut Alpinia purpurata flowers treated with ascorbic acid was significantly longer than that of control (Jin *et al*., 2006; Ieamtim *et al.*, 2008). Several studies did not shown the positive effect of ascorbic acid on increasing the vase life of cut flowers (Islam *et al*., 2013). Ascorbic acid has an antimicrobial activity that reduce bacterial population and resulted in increase the vessels conductivity and water uptake (de Capdeville *et al.*, 2003; Kazemi *et al*., 2012). Our study showed that vase life of cut gerbera flowers increased when we use suitable concentrations of salicylic acid, citric acid and ascorbic acid. Treatment of cut rose flower by salicylic acid increased vase life of flowers (Zamani *et al.,* 2011; Alaey *et al.,* 2011).

Our study showed that protein concentration in all cut flowers treated with salicylic acid, citric acid and ascorbic acid was higher than that of control. This finding is agreement with study of Abri *et al.* (2013) on cut rose flowers. An event during senescence in plants is protein degradation. Protein degradation during petal senescence has been shown in some plants (Sugawara *et al.*, 2002; Wagstaff *et al*., 2002; Pak and van Doorn, 2005; Sood *et al.*, 2006; Azeez *et al.,* 2007).

Alteration in antioxidants activity such as POD and SOD during post-harvest life of cut flowers have been shown (Giannopolitis and Ries 1997). Some studies have demonstrated that vase life of flowers is modulated by antioxidants (Chakrabarty *et al.,* 2009). Study of Abri *et al.* (2013) on rose cut flowers showed that SOD and POD activity declined during flower vase life. Activity of POD increased during flower senescence of Phalaenopsis (Tewari *et al.*, 2009). POD enzymatic activity increases gradually as floral senescence progresses (Gerailoo and Ghasemnezhad, 2011). An increase in the POD activity of petals might strengthen vascular cells, which remain functional during the late stage of senescence (Panavas and Rubinstein, 1998). Previous studies and our study showed that POD is involved in senescence, because it catalyzes the degradation of H_2O_2. The POD enzyme uses H_2O_2 as a substrate for several reactions. Lower POD activity in flowers treated with salicylic acid compared to the control could be due to a lower oxidative stress in the flowers (Abri *et al.*, 2013).

Literature Cited

Abdulrahman, Y.A., Ali, S.F. and Faizi, H.S. 2012. Effect of sucrose and ascorbic acid concentrations on vase life of snapdragon (*Antirrhinum majus* L.) cut flowers. International Journal of Pure Applied Science and Technology, 13 (2): 32-41.

Abri, F., Ghasemnezhad, M., Hasansajedi, R. and Bakhshi, D. 2013. Effect of ascorbic acid on vase life and petal senescence in cut rose flowers (*Rosa hybrida* cv. 'Royal Class'). American-Eurasian Journal of Agriculture and Environmental Science, 13 (1): 38-43.

Alaey, M., Babalar, M., Naderi, R. and Kafi, M. 2011. Effect of pre- and postharvest salicylic acid treatment on physio-chemical attributes in relation to vase life of rose cut flowers. Postharvest

Biology and Technology, 61: 91-94.
Azeez, A., Sane, A.P., Bhatnagar, D. and Nath, P. 2007. Enhanced expression of serine proteases during floral senescence in *Gladiolus*. Journal of Phytochemistry, 68: 1352-1357.
Balestra, G.M., Agostini, R., Bellincontro, A., Mencarelli, F. and Varvaro, L. 2005. Bacterial populations related to gerbera (*Gerbera jamesonii* L.) stem break. Phytopathology of Mediterranean, 44: 291-299.
Banaee, S., Hadavi, E. and Moradi, P. 2013. Effect of ascorbic acid, 8-hydroxyquinoline sulfate and sucrose on the longevity and anthocyanin content of cut *Gerbera* flowers. Current Agricultural Research Journal, 1 (1): 29-33.
Barth, C., De Tullio, M. and Conklin, P.L. 2006. The role of ascorbic acid in the control of flowering time and the onset of senescence. Oxford Journals, 57: 1657-1665.
Bates, L.S., Waldren, R.P. and Teare, I.D. 1973. Rapid determination of free proline for water stress studies. Plant Soil, 39: 205-207.
Bradford, M.M. 1976. A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Journal of Analytical Biochemistry, 72: 248-254.
Buchanan-Wollaston, V., Earl, S., Harrison, E., Mathas, E., Navab-pour, S., Page, T. and Pink, D. 2003. The molecular analysis of plant senescence—a genomics approach. Plant Biotechnology Journal, 1: 3–22.
Chakrabarty, D., Kumar Verma, A. and Kumar Datta, S. 2009. Oxidative stress and antioxidant activity as the basis of senescence in *Hemerocalli*s (day lily) flowers. Journal of Horticulture and Forestry, 1: 113-119.
Cheruth, A.J. 2009. Changes in non-enzymatic anti oxidation and ajmalicine production in *Catharanthus roseus* with different soil salinity regimes. Botany Research International, 2 (1): 1-6.
Conklin, P. 2001. Recent advances in the role of biosynthesis of ascorbic acid in plant cell environment. Journal of Plant, Cell and Environment, 24: 383-394.
Darandeh, N. and Hadavi, E. 2012. Effect of pre-harvest foliar application of citric acid and malic acid on chlorophyll content and post-harvest vase life of *Lilium* cv. Brunello. Frontiers in Plant Science, 2: 1-3.
da Silva, J.A.T. 2003. The cut flower: postharvest considerations. Online Journal of Biological Science, 3: 406-442.
de Capdeville, G., Maffia, L.A., Finger, F.L. and Batista, U.G. 2003. Gray mold severity and vase life of rose buds after pulsing with citric acid, salicylic acid, calcium sulfate, sucrose and silver thiosulfate. Fitopatology Brasileae, 28 (4): 380-385.
Ding, C.K., Wang, C.Y. and Gross, K.C. 2002. Jasmonate and salicylate induce the expression of pathogenesis-related-protein genes and increase resistance to chilling injury in tomato fruit. Planta, 214: 895–901.
Eidyan, B. 2010. Effect of iron and citric acid foliar applications in combination with nitrogen fertigation on tuberose (*Polianthes tuberosa* L.). Horticulture. Karaj, Islamic Azad University, Karaj Branch 75.
El-Kobisy, D.S., Kady, K.A., Hedani, R.A. and Agamy, R.A. 2005. Response of pea plant (*Pisum sativum*) to treatment with ascorbic acid. Egyptian Journal of Applied Science, 20: 36-50.
Ezhilmathi, K., Singh, V.P., Arora, A. and Sairam, R.K. 2007. Effect of 5-sulfosalicylic acid on antioxidant activity in relation to vase life of *Gladiolus* cut flowers. Plant Growth Regulation, 51: 99–108.
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 (1): 183-193.
Giannopolitis, C. and Ries, S. 1997. Superoxid dismutase. I: Occurence in higher plant. Plant Physiology,

59: 309–314.
He, S., Joyce, D.C., Irving, D.E. and Faragher, J.D. 2006. Stem end blockage in cut *Grevillea* 'Crimson Yul-lo' in inflorescences. Postharvest Biology and Technology, 41: 78-84.
Hell, R. and Stephan, U.W. 2003. Iron uptake, trafficking and homeostasis in plants. Planta, 216: 541–551.
Ieamtim, P., Buanong, M. and Kanlayanarat, S. 2008. Role of ascorbic acid on vase life of red ginger (*Alpinia purpurata* (Vieill.) K. Schum). Journal of Acta Horticulture, 804: 287-290.
Islam, M., Mehraj, H., Roni, M., Mahasen, M. and Uddin, A.J. 2013. Influence of sucrose and ascorbic acid on vase life of red ginger (*Alpinia purpurata* Vieill.). Bangladesh Research Publication Journal, 8 (1): 104-106.
Jamshidi, M., Hadavi, E. and Naderi, R. 2012. Effects of salicylic acid and malic acid on vase life and bacterial and yeast populations of preservative solution in cut *Gerbera* flowers. International Journal of AgriScience, 2 (8): 671-674.
Jin, J., Ningwei, S.H., Nan, M., Jinhe, B. and Junping, C. 2006. Regulation of ascorbate peroxidase at the transcript level is involved in tolerance to postharvest water deficit stress in the cut rose Samantha. Journal of Postharvest Biology and Technology, 40: 236-243.
Kazemi, M., Hadavi, E. and Hekmati, J. 2011. Role of salicylic acid in decreases of membrane senescence in cut carnation flowers. American Journal of Plant Physiology, 1–7.
Kazemi, M., Hadavi, E. and Hekmati, J. 2012. Effect of salicylic acid, malic acid, citric acid and sucrose on antioxidant activity, membrane stability and ACC-oxidase activity in relation to vase life of carnation cut flowers. Journal of Plant Science, 7 (2): 78-84.
Kazemi, M., Hadavi, E. and Moradi, P. 2013. The effect of malic acid on the bacteria populations of cut flowers of carnations vase solution. World Applied Science Journal, 10 (7): 737-740.
Liu, J.P., He, S.G., Zhang, Z.Q., Cao, J.P., Lv, P.T., He, S.D., Cheng, G.P. and Joyce, D.C. 2009. Nano-silver pulse treatments inhibit stem-end bacteria on cut gerbera cv. Ruikou flowers. Postharvest Biology and Technology, 54: 59-62.
Lü, P., Cao, J., He, S., Liu, J., Li, H., Cheng, G., Ding, Y. and Joyce, D.C. 2010. Nano-silver pulse treatments improve water relations of cut rose cv. Movie Star flowers. Postharvest Biology and Technology, 57: 196-202.
Mansouri, H. 2012. Salicylic acid and sodium nitroprusside improve postharvest life of chrysanthemums. Scientia Horticulturae, 145: 29–33
Morris, K.A.H., Mackerness, S., Page, T., John, C.F., Murphy, A.M., Carr, J.P. and Buchanan-Wollaston, V. 2000. Salicylic acid has a role in regulating gene expression during leaf senescence. Plant Journal, 23: 677–685.
Nowak, J. and Rudnicki, R.M. 1990. Postharvest handling and storage of cut flowers florist, greens and potted plants. Timber Press. 210 p.
Safa, Z., Hashemabadi, D., Kaviani, B., Nikchi, N. and Zarchini, M., 2015. Studies on quality and vase life of cut *Gerbera jamesonii* cv. 'Balance' flowers by silver nanoparticles and chlorophenol. Journal of Environmental Biology, 36 (2): 425-431.
Pak, C. and Van Doorn, W.G. 2005. Delay of Iris flower senescence by protease inhibitors. Journal of New Phytologist, 165: 473-480.
Panavas, T. and Rubinstein, B. 1998. Oxidative events during programmed cell death of daylily (*Hemeocallis hybrid*) petals. Plant Science, 133: 125-138.
Sood, S.H., Vyas, D. and Nagar, P.K. 2006. Physiological and biochemical studies during flower development in two rose species. Journal of Scientia Horticulturae, 108: 390-396.
Sugawara, H., Shibuya, K., Yoshioka, T., Hashiba, T. and Satoh, S. 2002. Is a cysteine proteinase inhibitor involved in the regulation of petal wilting in senescing carnation (*Dianthus caryophyllus* L.) flowers? Oxford Journals, 53: 407-413.
Tewari, R.K., Kumar, T., Kim, S., Hahn, E.J. and Paek, K.Y. 2009. Nitric oxide retards xanthine

oxidase-mediated superoxide anion generation in *Phalaenopsis* flower: an implication of NO in the senescence and oxidative stress regulation. Journal of Plant Cell Report, 28: 267-279.
van Doorn, W.G. 1997. Water relations of cut flowers. Horticulture Review, 18: 1-85.
Wagstaff, C., Leverentz, M.K., Grifths, G., Thomas, B., Chanasut, U., Stead, A.D. and Rogers, H.J. 2002. Cysteine protease gene expression and proteolytic activity during senescence of *Alestromeria* petals. Journal of Experimental Botany, 53: 133-240.
Williamson, V.G., Faragher, J.D., Parsons, S. and Franz, P. 2002. Inhibiting the postharvest wound response in wildflowers. Rural Industries Research and Development Corporation (RIRDC), Publication No. 02/114.
Zamani, S., Kazemi, M. and Aran, M. 2011. Postharvest life of cut rose flowers as affected by salicylic acid and glutamin. World Applied Science Journal, 12 (9): 1621–1624.

How to cite this article:
Mehdikhah, M., Onsinejad, R., Ilkaee, M. and Kaviani, B. 2016. Effect of salicylic acid, citric acid and ascorbic acid on post-harvest quality and vase life of Gerbera (*Gerbera jamesonii*) cut flowers. *Journal of Ornamental Plants, 6(3): 181-191*.
URL: **http://jornamental.iaurasht.ac.ir/article_524827_756e8d2e9b967e544394ba431f3c5868.pdf**