INTRODUCTION
Gerbera (Gerbera jamesonii) (Asteraceae) 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). 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 major factors which determine quality and longevity of cut flowers (Lu 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 (Van Doorn, 1997).

Some organic acids such as salicylic acid (SA), malic acid, citric acid and ascorbic acid have important role on extending the postharvest longevity of cut flowers (Jin et al., 2006). 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). Salicylic acid is a natural phenolic compound and regulates growth of some plants. Salicylic acid, as a key molecule has an important role in plant responses to various environmental stresses such (Jamshidi et al., 2012). Salicylic acid delays the process of senescence in flowers. Ascorbic acid (vitamin C) plays an important role in plant growth and development especially in electron transport system (El-Kobisy et al., 2005). 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). Some studies were done related to the effect of ascorbic acid on vase life of several cut flowers (Abdulrahman et al., 2012; Islam et al., 2013; Banaee et al., 2013). Salicylic acid 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). Citric acid like other organic acids can influence on the vase life of cut flowers. 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). 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 purpose of this study was to evaluate the effect of different concentrations of salicylic acid, citric acid and ascorbic acid on vase life and some other traits of cut gerbera (Gerbera jamesonii) flowers.

MATERIALS AND METHODS
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.

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 µmol m⁻²s⁻¹ light intensity.
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).

Fresh weight was measured with a digital balance (Sartorius TE 1502S). The first measurement was done just after the pulse treatment and the last measurement was recorded at the last day of vase life. Then, the last weight was subtracted from the first one; their difference represents fresh weight loss.

In the end of flower vase life, flowers of each treatment were weighed, and then were dried to constant weight in an oven for 24 h at 72°C. Dry matter percentage of cut flowers was calculated as per the following equation: DM (%) = Dry weight/fresh weight × 100.

The final day °Brix was measured at the last day of vase life using handheld refractometer (Atago N-1α model).

Flower diameter was measured with a digital caliper (Guanglu) as the following expressions: (the biggest diameter of the flower + the perpendicular diameter to it ÷ 2) every other day, they were signed as D1, D3,…, DL for every flower. D represents “diameter” and the number shows the day, L represents the last day of vase life. Then according to this formula (D1/D1+D3/D3+…+DL/DL-2= X). Flower diameter decreasing index was calculated. After that, X was divided by the number of ratios; the average is flower diameter decreasing index. The first measurement was done exactly after the pulse treatment and the last one was done at the last day of vase life.

The 0.5 g frozen petals were macerated in a mortar with a pestle in 1 ml of 85% methanol (85% methanol + 15% acetic acid) and were kept in a refrigerator for 24 h. After this time, the macerate was centrifuged at 10 000 × g, at the temperature of 4°C for 10 min and the supernatant was used to determine its β− Carotene content. To determine β−Carotene content of petals, the supernatant was filtered and 50 µl of it was injected to the HPLC, model: Waters 1525 with column of C18, 250 mm in length and 4.6 nm in particles diameter.

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 colonies counting were replicated three times.

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**

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. The longest vase life (11.31 days) was obtained with 100 mg l-1 citric acid (Table-1). 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 1). Longevity in control cut flowers was 5.80 days. Correlations between the results showed that the vase life with loss of fresh weight (r=0.622≤0.01), dry matter percentage (r=0.531≤0.05), brix degree (r=0.703≤0.01), flower diameter (r=0.409≤0.05), petal carotenoid (r=0.593≤0.01) and vase solution bacterial colonies (r=0.630≤0.01) had significant positive correlation (Table-2). Other correlations have been shown in Table-2.

The results showed that the cut flower’s fresh weight was affected markedly by treatments as compared to the control (p≤0.01). Mean comparisons showed that 100 mg l-1 citric acid had the highest fresh weight (9.80 g) between other treatments (Table-1). Additionally, 200 mg l-1 citric acid with 9.03 g fresh weight inhibited fresh weight loss more than the other treatment and control (5.13 g) (Table-1). It must have been due to changes in solution uptake in cut gerbera flowers. Minimum increasing the fresh weight (5.03) was obtained in 50 mg l-1 ascorbic acid. This amount is less than that of control, even (Table-1).

ANOVA showed that the effect of different treatments on dry matter was significant at 1% level of probability. Results of mean comparison (Table-1) revealed that the maximum dry matter percentage with 20.95% and minimum dry matter percentage with 15.81% were related to treatment of 200 mg l-1 citric acid and control, respectively. Moreover, 100 mg l-1 salicylic acid with 19.37% and 200 mg l-1 ascorbic acid with 18.09% had the high dry matter.

The results showed that salicylic acid, citric acid and ascorbic acid increased final day °Brix significantly (p≤0.01). Mean comparison of the data showed that the 200 and 100 mg l-1 citric acid were the best treatments which increased final day °Brix up to 2.02 and 1.99%, respectively (Table-1). The lowest brix degree (1.37%) was obtained in the control cut flowers.

Data analysis showed that the effect of different concentrations of salicylic acid, citric acid and ascorbic acid were no significant on flower diameter increasing index. Mean comparisons of the effect of salicylic acid, citric acid and ascorbic acid on the flower diameter revealed that the maximum flower diameter increasing index (1.03) rather than the control (0.97) was obtained in cut flowers treated with 100 mg l-1 citric acid (Table-1).

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. 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-1). Based on our findings, significant difference was no seen among various concentrations of salicylic acid, citric acid and ascorbic acid on total carotenoid content of cut
gerbera petals. Mean comparison among different concentrations of salicylic acid, citric acid and ascorbic acid indicates that there is no noticeable difference between treatments (Table-1).

**DISCUSSIONS**

Some studies showed the positive effect of salicylic acid, citric acid and ascorbic acid on post-harvest life 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 SA was significantly higher than that of the control treatments. This finding suggests the potential for the use of SA as substitutes for chemicals commonly used in preservative solution for gerbera cut flowers (Jamshidi *et al.*, 2012). SA significantly increased vase life, dry weight and flower diameter of cut gerbera flowers (Jamshidi *et al.*, 2012). SA effects on solution uptake. Positive effect of citric acid on vase life of some cut flowers has been shown (Eidyan, 2010; Darandeh and Hadavi, 2012). Study of Darandeh and Hadavi (2012) on the effect of pre-harvest foliar application of citric acid on vase life of *Lilium* showed that 0.15% citric acid increased vase life from 11.8 in control treatment to 14 days. More solution uptake of cut flowers held in citric acid suggesting a possible decrease in xylem blockage due to reduced microbial growth. Positive effect of citric acid may be attributed to its antimicrobial activity. 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).

Positive effect of ascorbic acid on post-harvest longevity of several cut flowers has been shown (Abdulrahman *et al.*, 2012; Abri *et al.*, 2013; Banaee *et al.*, 2013). Study of Abdulrahman *et al.* (2012) on the effect of ascorbic acid on vase life of *Antirrhinum majus* L. showed that ascorbic acid increased vase life. Nahed *et al.* (2011) revealed that the best results for flowering parameters of gladiolus plants were obtained by application of ascorbic acid. Study of Abri *et al.* (2013) on cut rose flowers revealed that 4 mM ascorbic acid had the maximum vase life 8 days as compared to the days in the control. Vase life of cut rose and cut *Alpinia purpurata* flowers treated with ascorbic acid was significantly longer than that of control flowers (Jin *et al.*, 2006; Ieamtim *et al.*, 2008). Some studies did not shown the positive effect of ascorbic acid on increasing the vase life of cut flowers (Islam *et al.*, 2013). Positive effect of ascorbic acid may be attributed to its antimicrobial activity that reduce bacterial population and resulted in increase the vessels conductivity and water uptake. In many cut flowers, suppression of microbial growth in the vase solution results in delayed wilting (van Doorn, 1997). Our study showed that vase life of cut gerbera flowers increased when we use suitable concentrations of salicylic acid, citric acid and ascorbic acid.

**Table-1. 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**.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Vase life (day)</th>
<th>Dry matter percentage (g)</th>
<th>Flower opening index</th>
<th>°Brix</th>
<th>Loss of fresh weight (g)</th>
<th>Petal carotenoids (µg F.W.)</th>
<th>Bacterial population vase solution (Log10 CFU ml⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA1</td>
<td>8.48b</td>
<td>15.99ef</td>
<td>0.996a</td>
<td>1.386f</td>
<td>5.03d</td>
<td>4.71a</td>
<td>180ab</td>
</tr>
<tr>
<td>AA2</td>
<td>8.54b</td>
<td>16.51def</td>
<td>0.993a</td>
<td>1.680cd</td>
<td>6.71cd</td>
<td>4.72a</td>
<td>180ab</td>
</tr>
<tr>
<td>AA4</td>
<td>9.89ab</td>
<td>18.09bcde</td>
<td>0.993a</td>
<td>1.693c</td>
<td>7.39bc</td>
<td>4.75a</td>
<td>99.6cd</td>
</tr>
<tr>
<td>CA1</td>
<td>9.32b</td>
<td>17.99bcdef</td>
<td>0.966a</td>
<td>1.483ef</td>
<td>7.30bc</td>
<td>4.75a</td>
<td>173ab</td>
</tr>
<tr>
<td>CA2</td>
<td>11.31a</td>
<td>20.95a</td>
<td>1.036a</td>
<td>1.990a</td>
<td>9.80a</td>
<td>4.79a</td>
<td>66.33d</td>
</tr>
<tr>
<td>CA4</td>
<td>10.09ab</td>
<td>19.00abc</td>
<td>1.013a</td>
<td>2.023a</td>
<td>9.03ab</td>
<td>4.84a</td>
<td>70.33d</td>
</tr>
<tr>
<td>SA1</td>
<td>8.97b</td>
<td>17.04cdef</td>
<td>0.993a</td>
<td>1.576de</td>
<td>7.18bc</td>
<td>4.74a</td>
<td>155bc</td>
</tr>
<tr>
<td>SA2</td>
<td>11.21a</td>
<td>19.37ab</td>
<td>1.016a</td>
<td>1.853b</td>
<td>8.95ab</td>
<td>4.85a</td>
<td>67.33d</td>
</tr>
<tr>
<td>SA4</td>
<td>9.92ab</td>
<td>18.75abcd</td>
<td>1.003a</td>
<td>1.840b</td>
<td>7.51bc</td>
<td>4.82a</td>
<td>80.00d</td>
</tr>
<tr>
<td>Control</td>
<td>5.80c</td>
<td>15.81f</td>
<td>0.973a</td>
<td>1.376f</td>
<td>5.13d</td>
<td>4.08b</td>
<td>220a</td>
</tr>
</tbody>
</table>

*Values in each row that are followed by the same letter are not significantly different by LSD test.
Table-2. Correlations between measured traits.

<table>
<thead>
<tr>
<th></th>
<th>Vase life</th>
<th>Dry matter percent</th>
<th>Flower opening index</th>
<th>°Brix</th>
<th>Fresh weight</th>
<th>Petal carotenoids</th>
<th>Bacterial population vase solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vase life</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry matter percent</td>
<td>0.531**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flower opening index</td>
<td>0.409*</td>
<td>0.365*</td>
<td>1</td>
<td>0.409*</td>
<td>0.365*</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>°Brix</td>
<td>0.703**</td>
<td>0.723**</td>
<td>0.365*</td>
<td>1</td>
<td>0.365*</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Fresh weight</td>
<td>0.622**</td>
<td>0.705**</td>
<td>0.159</td>
<td>0.787**</td>
<td>0.159</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Petal carotenoids</td>
<td>0.593**</td>
<td>0.373*</td>
<td>0.292</td>
<td>0.452**</td>
<td>0.432*</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Bacterial population</td>
<td>0.630**</td>
<td>-0.597**</td>
<td>-0.159</td>
<td>-0.751**</td>
<td>-0.618**</td>
<td>-0.395*</td>
<td>1</td>
</tr>
</tbody>
</table>

* And **: Significant at α = 5% and 1%, respectively

CONCLUSIONS

The present study showed that vase life of cut gerbera flowers increased when we use suitable concentrations of salicylic acid, citric acid and ascorbic acid. Some organic acids enhance the post-harvest longevity of cut flowers. Vase life of cut gerbera flowers is relatively short. The maximum vase life of cut flowers was observed in flowers treated with 100 mg l⁻¹ of citric acid.

REFERENCES


Eidyane B. 2010. Effect of iron and citric acid foliar applications in combination with nitrogen fertigation on tuberose (Polinthes tuberosa L.), Horticulture. Karaj, Islamic Azad University, Karaj Branch 75.


Regulation of ascorbate peroxidase at the transcript level is involved in tolerance to postharvest water deficit stress in the cut rose Samantha. J. Postharvest Biol. Tech. 40: 236-243.


