INTRODUCTION

Tuberose (Polianthes tuberosa L.), a member of the Agavaceae family, is a comorous perennial plant and native to Mexico (De Hertogh and Le Nard 1993). Tuberose flowers have a very pleasant fragrance and are beautiful in bouquets and suitable for interior decoration. Postharvest vase-life of tuberose cut flower is usually 3 days for each floret without using preservatives. Generally less than 50% of buds open after harvest (Reid 1996). There are different flower preservatives that provide water and energy which are required to improve flowers vase-life and to keep their quality over the period of presentation (Salunkhe et al. 1989; Halevy and Kofranek 1997; reviewed in Balas et al. 2006).

Required energy for cell activities is prepared by sugars that oxidize in mitochondria and results in preservation of other organelles’ structure and function (Dilley and Carpenter 1975). Sucrose is the main translocatable sugar in plants (Bieleski 1977). The addition of sugar to vase solution causes flower buds opening in Gladiolus hybrids and Gypsophila spp. (Halevy and Mayak 1981). Ichimura (1998) and Ichimura and Hiraya (1999) reported that continuous sucrose treatment markedly promoted floret opening and extended vase-life in sweet pea (Lathyrus odoratus) cut flowers. It has also been reported that continuous sucrose treatment plus silver thiosulfate complex (STS) pulsing extended mini-gladiolus cut spikes’ vase-life and maintained flower quality (Meir et al. 1995). Liao et al. (2000) indicated that an STS pulse treatment for 2 hrs followed by sucrose treatment in combination with 8-hydroxyquinoline sulfate (8-HQS) preserved rose flowers’ quality and increased their vase-life. Reid (1996) reported a 24 hr pre-treatment with 20% sucrose solution and 250 mg/l 8-hydroxyquinoline citrate (8-HQC) to increase tuberose florets quality and cut flower vase-life.

Microorganisms, which exist in vase water, prevent water absorption by some cut flowers and have negative effect on their vase-life extension. So, sugar should be used with germicides in combination with flower preservative solutions. Citric acid prevents blockage of xylems via pH lowering and reduces bacterial propagation in stem section (Nowak and Rudnicki 1990). 300 mg/l citric acid treatment has been effective on tuberose cut flower vase-life for about 7 days (Jowkar and Salehi 2005).

Studies by Parups and Peterson (1973) showed that both HQC and HQS have anti-bacterial and anti-ethylene effects. Useful germicide properties of 8-HQC have also been proved to maintain the quality and extend the vase-life of some cultivars of rose, scilla and gypsophila (Jones and Hill 1993).

Anti-ethylene compounds such as STS and silver nitrate (AgNO₃) delay flower senescence and prevent their fall (Kofranek 1985; knee 1992). STS has frequently been used as a pulse treatment for flowers preservation (Han 1998) and caused vase-life increase by preventing ethylene effect (Mor et al. 1981). Goszczynska (1989) introduced gibberellic acid (GA₃) at 200 mg/l or 50 mg/l AgNO₃ plus 2% sucrose as the best solutions for the well-maintenance of daffodil Dutch varieties cut flowers. Doss (1986) also indicated the effect of AgNO₃ at 25 mg/l on extending daffodil Dutch varieties cut flowers’ vase-life. A 50 mg/l AgNO₃ solution showed a positive effect on increasing postharvest life of tuberose cut flowers for about 8 days (Saini et al. 1994; Anjum et al. 2001). As there were some different preservative solutions in the literature recommended for tuberose cut flowers, the main purpose of the present study was to find the best one enhancing the vase-life of Iranian cv. ‘Gol Dorosht’, so that the cut flowers could be kept longer under home conditions and for interior decoration.

MATERIALS AND METHODS

Tuberose flowers cv. ‘Gol Dorosht’ were purchased from a tuberose grower of Mahallat city in the west of Iran, where the highest amount of flowers and ornamentals are produced. Stems were cut at 70 cm and trimmed to 60 cm. Required concentrations of preservatives were prepared by dissolving chemicals in 3 kinds of water: Hamedan city tap water, Hamedan cooled boiled water and double distilled water (DDW) which is prepared by twice purification of water through distillation to remove the salts as much as possible. All chemicals were supplied by the Merck Co., Germany. This study was carried out as a factorial experiment.
RESULTS AND DISCUSSION

Different concentrations of 8-HQS had no effect on extending postharvest life of tuberose cut flowers. Although 8-HQS shows micro-biocide effects, in this experiment it did not have any impact on tuberose cut flower vase-life. Ichimura (1998) also confirmed that HQS alone has little effect on extending vase-life and preventing ethylene production in snapdragon (Antirrhimum majus L.) cut flowers.

Citrin acid could maintain tuberose cut flower vase-life a little longer when it was used at 450 mg/l in DDW (Table 1). Although, in general, it had little effect on flower life longevity. Citric acid increases cut flowers life because it inhibits microorganisms’ growth through the reduction of pH in preservative solutions (Alvarez et al. 1994). Jowkar and Salehi (2005) indicated that 450 mg/l citric acid in sterilized DW maintained tuberose ‘GoL Dorosht’ cultivar cut flower longevity for about 9 days, compared with control which was 6.25 days, while in this study even citric acid solution made in DDW had no effect on postharvest life of this cut flower (Table 1). Using sterilized DDW for preparation of preservative solutions plus geographical conditions of area and also flower growth conditions before harvest which potentially could affect vase-life longevity of cut flowers, are probably the reasons of these differences in results, and further studies are needed to clarify this with supporting data.

All concentrations of AgNO3 had a negative effect on tuberose cut flower vase-life as the longest flower life (5 days) was seen in solutions without AgNO3 (Table 1). This result is in agreement with the findings of Alvarez et al. (1994) and Jowkar and Salehi (2005). Jowkar and Salehi (2005) showed that the concentrations of 50 to 150 mg/l AgNO3 caused florets to wilt and top flower spikes to bend. They have also used different concentrations of STS (0.4-1.2 mM) and reported that both semi-opened and opened florets showed wilting and petal tip-burn at the fourth day. These symptoms were observed earlier in the concentration of 1.2 mM.

One of the main factors reducing the vase life of many cut flowers is ethylene, which directly accelerates senescence and results in flower drop (Kofranek 1985; Nowak and Rudnicki 1990). Anti-ethylene compounds, especially STS, can overcome the ethylene effects, and prolong the flower vase life (Kofranek 1985; Nowak and Rudnicki 1990). In the Jowkar and Salehi’s experiment, STS-treated flowers had a short vase life and also showed the symptoms of Ag+ toxicity. Similar results have also been reported by Finger et al. (1999) and Alvarez et al. (1994) in which silver nitrate reduced the vase life of Strelitzia reginae and tuberose cut flowers. According to the above findings and our results, it could be concluded that, tuberose is an ethylene non-sensitive flower and so it is non-climacteric, because otherwise its vase life should be enhanced with the use of STS and/or AgNO3. Similar situations regarding anti-ethylene functions of STS and AgNO3, have been reported in Strelitzia (Finger et al. 1999), Gladialus (Mor et al. 1981) and Sandersonia (Eason and De Vre 1995).

2% sucrose in DDW most extended tuberose cut flower vase-life (15 days) compared with the other treatments (Table 2). Carbohydrates are important resources of energy in plant tissues and these compounds, especially sucrose, have considerable effects on cut flower life (Su et al. 2001; reviewed in Balas et al. 2006; Texeira da Silva 2006). Liao et al. (2000) indicated that pulse sucrose treatment with HQS increased rose cut flowers vase-life. Also, Ichimura and Suto (1999) showed that sucrose reduced sweet pea cut flower sensitivity to ethylene. Reid (1996) also reported that freshly-cut tuberose spikes placed in a preservative vase solution containing 2% sucrose and 8-HQS increased flowers

Fig. 1 (A, B) Broad view of cut flowers in different treatments; (C) Healthy and wilted tuberose flowers in cut flower solution.

Different concentrations of chemicals in preservative solutions were prepared as follows:
1) 8-HQS at 0, 100, 200 and 300 mg/l
2) Citric acid at 0, 150, 300 and 450 mg/l
3) AgNO3 at 0, 50 and 100 mg/l
4) Sucrose at 0, 2, 4 and 8% (w/v)

After the application of preservative solutions, the cut flower vase-life was considered as the time in which a minimum of 4 healthy florets remained on each inflorescence. Flowers were kept in laboratory with maximum and minimum temperature of 25 ± 3 and 21 ± 3°C, respectively (Jowkar and Salehi 2005). In order to keep the flowers similar to the domestic use, the vase solutions were not changed and the stems were not re-cut during the experiment. Data were collected on a daily basis by recording the number of semi-opened, opened and wilted florets and analyzed using MSTAT-C software and the means were compared by Duncan’s Multiple Range Test at P < 0.05 and P < 0.01.

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openings and vase-life over 30%. This combination can thus extend tuberose cut flower vase life in home conditions. Stem re-cutting and changing of the vase solution can increase the effect of this combination.

**REFERENCES**

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Table 1 The effect of different citric acid and AgNO₃ concentrations on the tuberose cut flower vase life (day).

<table>
<thead>
<tr>
<th>Treatment (mg/l)</th>
<th>Vase life (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Citric acid (0)</em></td>
<td>5 a</td>
</tr>
<tr>
<td><em>Citric acid (150)</em></td>
<td>4.6 ab</td>
</tr>
<tr>
<td><em>Citric acid (300)</em></td>
<td>4.4 b</td>
</tr>
<tr>
<td><em>Citric acid (450)</em></td>
<td>5.11 a</td>
</tr>
<tr>
<td><strong>AgNO₃ (0)</strong></td>
<td>5.2 a</td>
</tr>
<tr>
<td><strong>AgNO₃ (50)</strong></td>
<td>3.88 b</td>
</tr>
<tr>
<td><strong>AgNO₃ (100)</strong></td>
<td>4 b</td>
</tr>
</tbody>
</table>

Means with similar letters in each column are not significantly different according to Duncan’s Multiple Range Test (*P* < 0.05, *P* < 0.01**).

Table 2 The effect of different sucrose concentrations prepared in 3 kinds of water on tuberose cut flower vase-life (day)*.

<table>
<thead>
<tr>
<th>Sucrose concentration (%)</th>
<th>Hamedan tap water</th>
<th>Hamedan cool boiled water</th>
<th>Double distilled water</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4.67 cd</td>
<td>4.33 d</td>
<td>6 c</td>
</tr>
<tr>
<td>2</td>
<td>5 cd</td>
<td>4 d</td>
<td>15 a</td>
</tr>
<tr>
<td>4</td>
<td>5 cd</td>
<td>4 d</td>
<td>4.33 d</td>
</tr>
<tr>
<td>8</td>
<td>4 d</td>
<td>4 d</td>
<td>7.66 b</td>
</tr>
</tbody>
</table>

*Means with similar letters in each column are not significantly different according to Duncan’s Multiple Range Test (*P* < 0.01).