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ORIGINAL ARTICLE

# Evaluation of several holding solutions for prolonging vase-life and keeping quality of cut sweet pea flowers (*Lathyrus odoratus* L.)

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**KEYWORDS**

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**Abstract** Cut spikes of sweet pea (*Lathyrus odoratus* L.) were kept in 2% sucrose, 200 ppm 8-hydroxyquinoline sulfate (8-HQS), pulsing treatment with 200 ppm 8-HQS in combination with 2% sucrose for 12 h, pulsing the spikes with 0.2 mM silver thiosulfate (STS) for 1 h and pulsing with 0.2 mM STS for 1 h followed by 2% sucrose solution. Therefore, this study aimed to see their effects on keeping quality and vase-life of the cut flowers. A control (deionized water) and a standard preservative were also included in the experiment. The results showed that all treatments had improved the keeping quality and vase-life of the cut flowers comparing to control ones. Among all these treatments, the 8-HQS combined with 2% sucrose showed the best water uptake, water balance, percentage of maximum increase in fresh weight of the cut flower stems and vase-life which was extended up to 17 days. Moreover, this keeping solution retarded the chlorophyll as well as carbohydrate degradation. However, anthocyanin concentrations were increased by treatments with sucrose alone or STS followed by sucrose during the postharvest life. It has been concluded that 200 ppm 8-HQS combined with 2% sucrose solution has the potential to be used as a commercial

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cut flower preservative solution to delay flower senescence, enhance post harvest quality and prolong the vase-life of sweet pea cut flowers.



## 1. Introduction

Sweet peas are one of the world's favorite garden flowers, available in a wide range of colors, and having exceptional fragrance. However, because of their short vase-life and handling and transportation difficulties, there is presently only a very small commercial production of these flowers. Postharvest problems include delicacy of opened florets, early floret senescence, the flower of sweet pea being highly ethylene sensitive, and the longevity of the cut flower being very short (Mor et al., 1984; Waltering and van Doorn, 1988; Ohkawa et al., 1991).

Keeping quality is an important parameter for the evaluation of cut flower quality, for both domestic and export markets. One of the greatest problems in postharvest flower physiology is the blockage of vascular system, due to air or bacterial growth, which reduces water uptake and this blocks xylem vessels leading to water stress (Van Meetern et al., 2001) that was expressed in the form of early wilting of flowers (Henriette and Clerkx, 2001), as a result of premature loss of cell turgidity and might appear when water uptake and transpiration are out of balance during a lasting period of time. Adding chemical preservatives to the holding solution is recommended to prolong the vase-life of the cut flowers. All holding solutions must contain essentially two components, sugar and germicides. The germicide 8-hydroxyquinoline sulfate (8-HQS) is one of the very important preservatives used in floral industry (Nowak and Rudnicki, 1990), it acts as an antimicrobial agent (Ketsa et al., 1995) and increasing water by reducing "physiological" stem blockage in sterile tissues uptake (Reddy et al., 1996). However, this treatment was more effective when sucrose was added to 8-HQS (Ichimura et al., 1999). Sucrose has been found to be the most commonly used sugar in prolonging vase-life of cut flowers. The exogenous application of sucrose supplies the cut flowers with much needed substrates for respiration, and enables cut flowers harvested at the bud stage to open, which otherwise could not occur naturally (Pun and Ichimura, 2003), and it acts as osmotically active molecule, thereby leading to the promotion of subsequent water relations (Ichimura and Hismatsu, 1999). Thus, in 200 ppm 8-HQS + 2% sucrose invaded due to sugar contents taking a significant amount of water and this has also been counted toward water uptake. This preservative solution might be good vase solutions of the present study, which suggest that this is suitable in these conditions.

Therefore, in the present study besides hydroxyquinoline sulfate (8-HQS), a silver thiosulfate (STS) was used to investigate their effects on keeping quality and vase-life of sweet pea cut flowers. It acts as an ethylene antagonist, reduce ethylene production and respiration (Veen 1979), and extend flower longevity (Reid et al., 1980). In this connection, Sexton et al. (1995) and Ichimura and Hiraya (1999) indicated that a pulse treatment of sucrose and/or silver thiosulfate (STS) was effective in maintaining the vase-life of cut sweet pea flowers. Also, the interactive effects of the combined application of sugars and antimicrobial agents increased vase-life by up to 22%, and improved spikes quality of the two gladiolus cultivars (Al-Humaid, 2004).

The main objective of the present study was to find out best solutions for enhancing the vase-life of sweet pea cut flowers so that the flowers can be kept for longer period for interior decoration.

## 2. Material and methods

### 2.1. Plant materials and treatments

Sweet peas *Lathyrus odoratus* L. cultivar Diana (Unwins Seeds, Histon, UK) were grown under standard greenhouse conditions (22 °C day, 15 °C night). There are no grade standards for sweet peas, but quality flowers have long, straight stems, at least five buds on each spike and the flowers were cut from the plant on October 21, 2009. The harvested flowers were brought to the laboratory of Plant Production Department, College of Food and Agricultural Sciences, King Saud University, Saudi Arabia. As soon as the spikes had been cut, they were recut 1 cm from the basal under water to avoid air embolism. Each treatment consisted of 10 replicates (bottles), and each bottle contained one cut flower stem (one spike). Treatment effects were evaluated by keeping the samples in the laboratory at a temperature of 22 ± 2 °C, 10 μmol $m^{-2}$ $s^{-1}$ irradiance, using cool-white fluorescence lamps for a 12-h photoperiod and relative humidity of 60 ± 10%. The day of harvest was designated as day zero.

To examine the effects of the vase solution components on the keeping quality of sweet pea cut flowers, five different preservative solutions (treatments) were used as follows: (1) 2% sucrose, (2) 200 ppm 8-hydroxyquinoline sulfate (8-HQS), (3) pulsing the spikes with 200 ppm 8-HQS in combination with 2% sucrose for 12 h, (4) pulsing the spikes with 0.2 mM silver thiosulfate (STS) for 1 h, (5) pulsing the spikes with 0.2 mM STS for 1 h followed by 2% sucrose solution, (6) or deionized water (DI) used as a control. The STS was prepared as described by Gorin et al. (1985). The preparation of the STS solution proceeds as follows:

1. Dissolve 0.079 g $AgNO_3$ in 500 ml of deionized water.
2. Dissolve 0.462 g $Na_2S_2O_3 \cdot 5H_2O$ in 500 ml of deionized water.
3. Pour $AgNO_3$ solution into $Na_2S_2O_3 \cdot 5H_2O$ solution while stirring. The concentration of silver is 0.463 mM.

Data were recorded on vase-life (days), total water uptake and balance (ml/flower/day) by the spikes, percentage of maximum increase of fresh weight (%), leaf chlorophyll content (mg $g^{-1}$ dry weight), carbohydrate content (mg $g^{-1}$ dry weight) of petals and stems and anthocyanin concentrations (mg $g^{-1}$ fresh weight) for petals of sweet pea cut flowers.

### 2.2. Vase-life

Sweet peas are harvested when the last bud on the stem is about half open, in the "bud-stage" flowers are harvested

when the petals on the first bud are colored and near full size, but have not yet opened. Flowers are harvested by holding the stem between the thumb and forefinger near the base (supporting the vine with two fingers behind and one in front) and then pulling the flower backward and upward from the axil of the leaf. The vase-life of sweet pea flowers was considered terminated when the last open floret wilted and lost decorative value (Ichimura and Hiraya, 1999).

### 2.3. Water relations

#### 2.3.1. Vase solution uptake (VSU) rate

Weights of vases containing vase solution without the cut flowers were recorded daily during the vase-life evaluation period. Average daily VSU rate was calculated by the formula: VSU [g $g^{-1}$ initial fresh weight (IFW)] = ($St^{-1}$−St)/IFW of the stem, where St is weight of vase solution (g) at $t$ = day 1, 2, 3, etc., and $St^{-1}$ is the weight of vase solution (g) on the previous day (Damunupola, 2009).

#### 2.3.2. Water balance (ml/flower/day)

The following components of water balance of each cut flower stem (a spike) can be distinguished: water uptake, transport, water loss, and the capacity of flower tissue to retain its water (Halevy and Mayak, 1981).

### 2.4. Maximum increase of fresh weight (%)

Fresh weights of cut sweet pea flowers were measured daily during vase-life. The original fresh weight was measured immediately after cutting flowers and before the immersing in keeping solutions. The flowers were weighted every day until the end of the vase-life. The fresh weight of each cut flower was expressed relatively to their initial weights to represent the % of weight loss for each cut flower stem (He et al., 2006).

### 2.5. Chlorophyll determination

Chlorophyll content of sweet pea leaves was extracted by acetone from samples of cut leaf segments (0.59) taken on day 0 (at the beginning of experiment), day 3 and on the day when the vase-life of the control flowers was terminated (day 7). The samples were taken from the leaves in the upper part of the flowering stems. The samples were collected separately from each replicate and the average of the three replicates was calculated. Extraction in acetone was repeated until all pigments were extracted. The absorbance of the extracts was determined by a spectrophotometer (type GBC, UV/VIS 916, Australia). The chlorophyll content was determined according to Moran and Porath (1980) and calculated from a previously plotted standard curves and expressed in mg $g^{-1}$ on dry weight (DW) basis. The equations for the determination of the concentrations of chl. a and chl. b are:

chl a $11.24\,A_{661.6} - 2.04\,A_{644.8}$

chl b $20.13\,A_{664.8} - 4.19\,A_{661.6}$

Since $A$ is absorbance.

### 2.6. Changes in sugar content

The changing sugar content of sweet pea flowers during vase-life were determined on the stems and petals held in DI and in a commercial preservative. Samples were taken on day 1, 3 and 5 and separated by a high performance liquid chromatography (HPLC) fitted with differential refractometer to detect fructose, glucose and sucrose in a different sample. Stems and petals were extracted in 2 or 5 ml 80% ethanol depending on the weight of the sample, by shaking for 3 h. One millilliter of the extract was then evaporated to dryness in a water bath, redissolved in 1 ml DI, and used directly for HPLC analysis of sugars. Sugars were separated on two 10 cm long Aminex Fast Carbohydrate Columns connected in series, and concentrations determined by refractive index of the eluent peaks and comparison with peak area of an inositol internal standard (Moon-Soo et al., 2001).

### 2.7. Determination of anthocyanin concentrations

The third floret from the bottom of each spike was excised 4 days after harvest and the petals (200 mg) were diced, the pieces were immersed in 5 ml of 1% HCl in methanol at 4 °C in the dark for overnight. Supernatants were then decanted and washed twice with 2.5 ml of acidified methanol. All supernatants were combined to 10 ml and the absorbance of the combined solution was measured by spectrophotometer at 530 nm (Ichimura and Hiraya, 1999).

### 2.8. Statistical analysis

The results were interpreted according to Steel and Torrie (1980) and the differences between the means of the treatments were considered significant when they were equal or more than the least significant difference (L.S.D.) at the 5% level.

## 3. Results and discussion

### 3.1. Vase-life

Results of (Table 1) showed that the vase-life of sweet pea cut flowers was significantly extended as a result of using of 8-HQS, as compared to the control. The vase-life was longer in 8-HQS at 200 ppm which resulted in 14 days in comparison with 7 days of the control ones. Although, sucrose resulted in the lowest vase-life comparing to 8-HQS treatment, the longest vase-life was attained when sucrose was applied at 2% w/v, where it gave 11.35 days in comparison with 7 days of the control ones. However, the two compounds used significantly extended the vase-life of sweet pea cut flowers compared to control. These results may be due to the role of 8-HQS as antimicrobial agent and hence, it might reduce stem plugging. This explains the short vase-life of untreated control and long vase-life when 8-HQS was applied. Sugars alone, however, tend to promote microbial growth. Hence, the combination of sugars and biocides might have extended the vase-life of cut flowers (Halevy and Mayak, 1981). Otherwise, adding sucrose to 8-HQS treatment gave longer vase-life than the 8-HQS treatment alone. The best treatment was 200 ppm 8-HQS + 2% sucrose, which prolong the vase-life up to 17 days comparing to 7 days for the control ones. It may be concluded that the best combination of chemicals in the holding solution should be 200 ppm 8-HQS + 2% sucrose as this treatment recorded the maximum useful vase-life.

Regarding the effects of the STS treatment on vase-life of cut sweet pea flowers, the data indicated that STS has been

**Table 1** Effect of the different preservative solutions on vase-life, water uptake and percentage of maximum increase in fresh weight of sweet pea cut flowers.

| Treatments | Vase-life (days) | Water uptake (ml/flower/day) | Maximum increase in fresh weight (%) |
|---|---|---|---|
| Distilled water (control) | 7 | 2.95 | 29.25 |
| 2% sucrose | 11.35 | 3.27 | 31.74 |
| 200 ppm 8-HQS | 14.33 | 5.65 | 39.38 |
| 8-HQS + sucrose | 17 | 7.08 | 55.25 |
| 0.2 mM STS | 14 | 3.58 | 34.93 |
| STS + sucrose | 15 | 5.73 | 43.52 |
| L.S.D. 5% | 2.31 | 2.05 | 2.42 |

shown to be very effective in extending the vase-life of sweet pea. This is in agreement with findings obtained on sweet pea (Mor et al., 1984; Ishihara et al., 1991; Sexton et al., 1995). However, combined treatment with STS and sucrose may be preferable for improving the vase-life of cut sweet pea flowers (Table 1). But, no marked difference in the vase-life between STS and STS followed by sucrose was found, although the latter showed a slightly greater positive effect than the former. Awad et al. (1986) also attributed the beneficial effect of STS in the vase-water to the production of $Ag^{+}$ ions, which might inhibit the rise of ethylene precursor, thereby enhancing the longevity of cut flowers. In this study, in cut sweet pea flowers, 8-HQS extended the vase-life of florets more than STS (Table 1). This indicates that 8-HQS is more effective than STS in increasing vase-life. This was similar to the result obtained for *Dendrobium* flowers (Ketsa and Boonrote, 1990). The superiority of HQS over STS may have been due to the relative immobility of STS in the stem (Veen and Van de Geijin, 1978).

Concerning the role of sucrose whether with 8-HQS or STS, the previous results show that adding sucrose extended the vase-life and improved the quality of sweet pea cut flowers. Adding a carbohydrate source such sucrose to the holding solution resulted in an extension of vase-life if growth of microorganisms was controlled, and the increased flower longevity in the acidic solutions was due to the inhibition of vascular blockage and increased water absorption (Marousky, 1972). Dissolved sugars in cells of petals are osmotically active substances that are drawn into the corolla-cells making the cells turgid with hydrolyzed sugars ready for respiration (Ichimura and Hismatsu, 1999). Similar findings were obtained by Ichimura (1998), Beura et al. (2001), Dineshbabu et al. (2002) and Moneruzzaman et al. (2010).

### 3.2. Water relations

#### 3.2.1. Water uptake (ml/flower/day)

Data recorded in Table 1 indicated that HQS + sucrose solution was more effective in maintaining water uptake and prolonging vase-life than when either HQS, STS was used alone or STS followed by sucrose. The maximum quantity of holding solution was absorbed (Table 1) in the treatment 200 ppm 8-HQS + 2% sucrose, which was (7.08 ml) in comparison to (2.95 ml) for control. This suggests that the synergistic effect of HQS + sucrose on increasing vase-life was the result of a suppression of microbial growth (Ketsa et al., 1995), resulting in increased water uptake. The water uptake via the cut flowers placed in a keeping solution resulted in better water balance and flower freshness (Reddy et al., 1996) and reduced early wilting, and thus the vase-life of the cut flowers was enhanced. As a consequence, the present investigation revealed that the best holding solution for cut sweet pea would be a combination of both 8-HQS and sucrose would result in better water balance. This might be due to the fact that the 8-HQS present in the holding solution acted as a biocide inhibiting microbial population that might have resulted in blockage of the vascular tissues. The blockage of the base of stem due to bacterial plugging results in a decrease of water uptake by stem. A very high level of turgidity is necessary for continuation of normal metabolic activities in the cut flowers. Sucrose helps to maintain water balance and also delays turgidity loss as the flower senescence (Sven and Jose, 2004). The translocated sugars are accumulated in the flower and increase osmotic concentration and improving their ability to absorb water and maintain their turgidity (Halevy et al., 1978). This was in conformity with the findings of Rogers (1973). This is in agreement with the observation of rose cut flowers, where total water uptake and vase-life had increased as well as inhibited flower senescence and bent neck in when using 8-HQS + sucrose in comparison to control (Kim and Lee, 2002; Elgimabi and Ahmed, 2009). Moreover, Beura et al. (2001) showed that the combination treatment of 8-HQS and sucrose improved the postharvest quality of Gladiolus spikes. In *Dendrobium hybrid* flowers, holding solutions containing 8-HQS + sucrose extended the vase-life and improved flower quality, water consumption, fresh weight and flower freshness (Dineshbabu et al., 2002).

#### 3.2.2. Water balance (ml/flower/day)

Flower turgidity is the result of the balance between the rate of water uptake and water loss, and gains in fresh weight can occur only when the rate of water uptake is greater than transpiration. However, the cut flower of sweet pea that absorbs more water is not always the flower that reaches the highest level of turgidity, this also depends upon how well the flower is able to retain the water it absorbs. In addition, the determination of water balance herein gave a clear view to what happened indigenously inflorescence throughout vase-life. The overall water balance in this experiment followed the same trend, but data illustrated in Fig. 1 reveal that sweet pea flowers which were treated with combination of both 8-HQS and sucrose showed better water balance than those with other treatments. Results of the present study may be explained on the basis that 8-HQS plays an important role in improving the water balance of sweet pea cut flowers by preventing the growth of microorganism in xylem and thus maintained water uptake by flower stems (Kwon and Kim 2000). However, the results show that

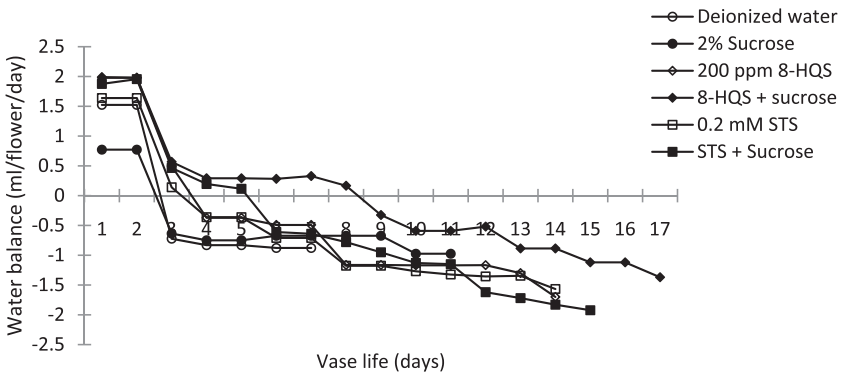


**Figure 1** Water balance (ml/flower/day) of sweet pea cut flowers as affected by different holding solutions during vase-life.

8-HQS has a positive effect on increasing the water balance of cut sweet pea flowers, especially when combined with other sucrose. Thus, if bacterial growth could be eliminated, sucrose (2%) would result in better water balance of the cut sweet pea flowers. Sucrose plays an important role in improving the water balance of cut flowers by affecting the osmotic potential of the cut flowers and the water holding capacity of the tissues allowing less water to be transpired (Halevy et al., 1978). Moreover, sucrose is widely used in floral preservatives, which acts as a food source or respiratory substrate and delays the degradation of proteins and improves the water balance of cut flowers (Moon-Soo et al., 2001). In agreement with these results were those obtained by Fahmy (2005), Elgimabi and Ahmed (2009).

### 3.3. Maximum increase of fresh weight (%)

With respect to holding solution effect on maximum increase of fresh weight of sweet peas cut flowers, data presented in Table 1 show that a higher fresh weight was maintained in florets from spikes placed in 200 ppm 8-HQS + 2% sucrose than those of control. Relevant values for the maximum increase in fresh weight percentage were 55.25%. However, the lowest values of this parameter accompanied the control, which was 29.25% during vase-life. The application of HQS increased the vase-life as well as fresh weight (% of initial) of cut flowers, where 8-HQS treatment prevented the growth of microorganism in xylem and thus maintained water uptake by flower stems. The major effect of sucrose on sweet pea flowers is probably due to the increase in osmotic concentration of the flowers and by this, to improve water uptake, but sucrose may also affect the nutrition or energy supply of the flowers. Sucrose may have, also, a beneficial effect on maintaining higher fresh weights in cut flowering stems by inducing stomatal closure in the leaves and thus, reducing water loss (Marousky, 1972). Furthermore, pulsing sweet pea flowers in 8-HQS solution at 200 ppm in vases resulted in higher longevity period, which might indicate that each of 8-HQS and sucrose played a critical role in promoting water absorption and metabolic processes within flower. Moreover, the hydraulic conductance of cut rose stem segments from the control treatment decreased rapidly after harvest, but those for the HQS + sucrose and HQS treatment were maintained near their initial level (Kim and Lee, 2002).

### 3.4. Chlorophyll content

Data recorded in Table 2 indicate that a pulse treatment with sucrose + 8-HQS was most effective in retarding chlorophyll degradation compared to control. The concentration of chlorophyll a was higher than chlorophyll b at any point of time throughout the vase-life. When cut sweet pea flowers were treated with 200 ppm 8-HQS, chlorophyll content on the 1st day was 0.679, 0.335 mg $g^{-1}$ weight for chl. a and chl. b, respectively. However, sucrose at 2% was added, chlorophyll content increased. Thus, at the end of the experiment the accumulated chl. a and chl. b, were 1.769, 0.395 mg $l^{-1}$, respectively. Ewa et al. (2004) showed that a standard preservative solution containing 2% sucrose and 200 mg $dm^{-3}$ citrate or sulfate of hydroxyquinoline (8-HQC or 8-HQS) is often used to prolong the vase-life of *Zantedeschia aethiopica* and *Z. elliottiana* of cut flowers. It has antibacterial properties and pro-

**Table 2** Effect of the different preservative solutions on chlorophyll content (mg $g^{-1}$ dry weight) of leaves of sweet pea cut flowers.

| Days of determination of chl. a and chl. b | | | | | | |
|---|---|---|---|---|---|---|
| Treatments | 1st day | | 3rd day | | 5th day | |
| | Chl. a | Chl. b | Chl. a | Chl. b | Chl. a | Chl. b |
| Distilled water (control) | 0.725 | 0.385 | 0.941 | 0.406 | 0.596 | 0.070 |
| 2% sucrose | 0.734 | 0.412 | 1.423 | 0.743 | 0.687 | 0.186 |
| 200 ppm 8-HQS | 0.679 | 0.335 | 1.765 | 0.599 | 1.892 | 0.404 |
| 8-HQS + sucrose | 0.732 | 0.412 | 1.942 | 1.163 | 1.769 | 0.395 |
| 0.2 mM STS | 0.654 | 0.325 | 1.683 | 0.531 | 1.734 | 0.387 |
| STS + sucrose | 0.685 | 0.396 | 1.872 | 1.054 | 1.567 | 0.352 |
| L.S.D. 5% | 0.063 | 0.056 | 0.087 | 0.092 | 1.011 | 0.032 |

vides respirational substrate (Halevy and Mayak, 1981). Sugar treatment also hastened senescence of leaf discs in the model plant *Nicotiana tabacum* and sugar levels were higher in tobacco leaves that were about to senesce as compared to younger leaves (Masclaux et al., 2000). Skutnik et al. (2001) showed that a sugar-containing preservative dramatically reduces vase-life and decreases chlorophyll content in the *Z. aethiopica* leaves.

### 3.5. Changes in sugar content

The data (Tables 3 and 4) show that fructose, glucose and sucrose were the main soluble carbohydrates in petals and stems of sweet pea cut flowers. Fructose was the major component in petals as well as in stems, and generally it was higher in petals than in stems. Sucrose contents in petals and stems were lower than glucose. The carbohydrate content significantly increased

**Table 3** Effect of the different preservative solutions on carbohydrate content (in $mg^{-1}$ dry weight) for petals of sweet pea cut flowers.

| Days of determination of carbohydrate content | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatments | 1st day | | | 3rd day | | | 5th day | | |
| | Fructose | Glucose | Sucrose | Fructose | Glucose | Sucrose | Fructose | Glucose | Sucrose |
| Distilled water (control) | 0.91 | 0.30 | 0.08 | 0.13 | 0.03 | 0.02 | 0.65 | 0.14 | 0.29 |
| 2% sucrose | 1.35 | 1.97 | 0.43 | 2.99 | 1.95 | 1.22 | 0.37 | 0.88 | 0.11 |
| 200 ppm 8-HQS | 2.87 | 1.97 | 1.00 | 2.06 | 2.99 | 0.08 | 1.93 | 1.24 | 0.15 |
| 8-HQS + sucrose | 4.18 | 3.55 | 1.23 | 5.97 | 4.34 | 1.99 | 2.87 | 1.63 | 1.01 |
| 0.2 mM STS | 2.43 | 1.82 | 0.89 | 2.03 | 2.56 | 0.05 | 1.85 | 1.12 | 0.08 |
| STS + sucrose | 3.65 | 2.85 | 1.07 | 2.99 | 3.74 | 1.53 | 2.41 | 1.15 | 0.75 |
| L.S.D. 5% | 1.79 | 1.34 | 0.97 | 1.89 | 1.12 | 0.86 | 0.78 | 0.62 | 0.36 |

**Table 4** Effect of the different preservative solutions on carbohydrate content (in $mg^{-1}$ dry weight) for stems of sweet pea cut flowers.

| Days of determination of carbohydrate content | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatments | 1st day | | | 3rd day | | | 5th day | | |
| | Fructose | Glucose | Sucrose | Fructose | Glucose | Sucrose | Fructose | Glucose | Sucrose |
| Distilled water (control) | 0.91 | 0.30 | 0.08 | 0.70 | 0.60 | 0.11 | 0.62 | 0.43 | 0.19 |
| 2% sucrose | 1.17 | 1.08 | 0.32 | 2.32 | 2.00 | 1.23 | 0.89 | 0.47 | 0.09 |
| 200 ppm 8-HQS | 1.95 | 1.00 | 0.16 | 2.43 | 2.00 | 1.45 | 0.87 | 1.08 | 0.69 |
| 8-HQS + sucrose | 2.21 | 1.30 | 1.07 | 3.53 | 2.11 | 1.97 | 1.51 | 0.40 | 0.84 |
| 0.2 mM STS | 1.82 | 0.89 | 0.11 | 2.31 | 1.78 | 1.32 | 0.63 | 1.01 | 0.52 |
| STS + sucrose | 2.03 | 1.12 | 1.02 | 3.11 | 1.92 | 1.82 | 1.24 | 0.29 | 0.65 |
| L.S.D. 5% | 1.03 | 0.89 | 0.72 | 1.02 | 0.78 | 0.56 | 0.58 | 0.42 | 0.34 |

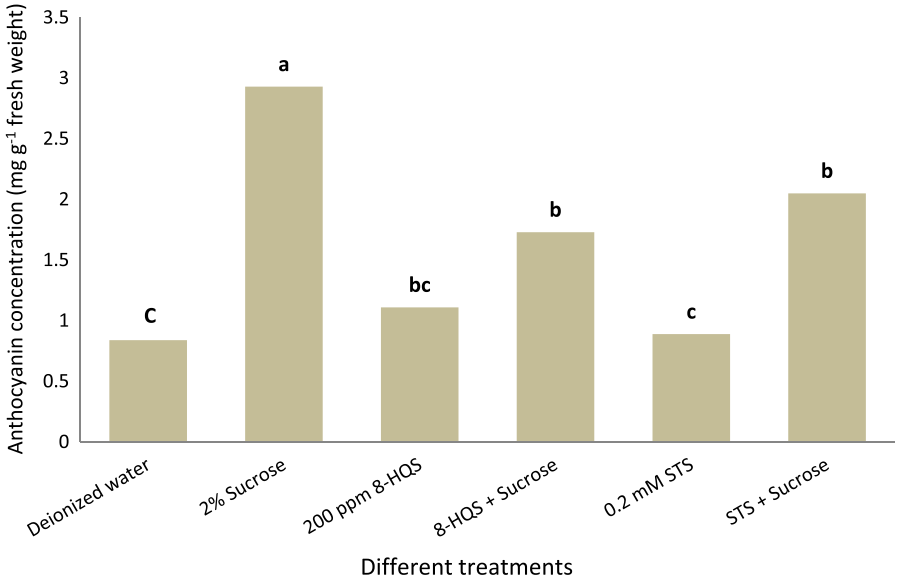


**Figure 2** Effect of the different preservative solutions on Anthocyanin concentrations (mg $g^{-1}$ fresh weight) of petals of sweet pea cut flowers.

as a result of using 200 ppm 8-HQS + 2% sucrose till the 3rd day, and then sharply decreased on the 5th day at which the vase-life of control was terminated. The concentrations of fructose, glucose and sucrose in sweet pea petals were 0.65, 0.14 and 0.29 mg $g^{-1}$ dry weight in controls at the end of the experiments (Table 3). At the same time, values of those sugars in petals of cut flowers placed in 200 ppm 8-HQS, 200 ppm 8-HQS + 2% sucrose or in 2% sucrose alone were 1.93, 1.24 and 0.15 mg $g^{-1}$, respectively (Table 3). While, stem contents of the previous sugars increased at the beginning of the experiment, they decreased toward the end of the experiment compared to control (Table 4). It is well known that sugar supply, increases the longevity of many cut flowers, since they act as a source of nutrition for tissues approaching carbohydrate starvation (Halevy and Mayak, 1981). The results showed that sucrose + 8-HQS reduced chlorophyll content degradation (Table 2) and preserved carbohydrates content (Tables 3 and 4). This might be inhibiting ethylene action and as a result, the vase-life could be increased. This was attributed to the inhibition of ethylene action by 8-HQS (Bartoli et al., 1997; WeiMing et al., 1997). This is in agreement with earlier reports of Hussein (1994), Ichimura et al. (1999), Knee (2002) and Elgimabi and Ahmed (2009). They indicated that glucose, fructose and sucrose in petals of rose cut flowers were increased by the 8-HQS + sucrose treatment compared with control.

### 3.6. Anthocyanin concentrations

Anthocyanin concentrations of sweet pea florets treated with sucrose alone were the greatest, followed by the STS/sucrose treatment, the STS treatment alone had an insignificant increase in anthocyanin concentration compared to the control (Fig. 2). Anthocyanins were also very high in ephemeral flowers and they may be linked to senescence processes, orchid flowers during senescence change from white to pink or blue (Chadwick et al., 1980). In petunias the flower longevity was inversely correlated to anthocyanins content (Ferrante et al., 2006). Tsukaya et al. (1991) and Moalem-Beno et al. (1997) reported with petunia that gene expression of chalcone synthase, a key enzyme of anthocyanin biosynthesis, is induced by sucrose. Thus, stimulation of anthocyanin production of cut sweet pea by sucrose may involve anthocyanin biosynthetic gene expressions. Furthermore, a supply of sugars is required for the glycosylation of anthocyanins (Ichimura and Hiraya, 1999). Anthocyanin concentrations in florets supplied with sucrose alone was greater than spikes treated with STS followed by sucrose (Table 1). In general, water uptake of cut flowers decreases with time (van Doorn, 1997). Since sucrose was applied to spike after a 1 h-treatment of STS, flowers treated with sucrose alone may have taken up more sucrose. Therefore, differences of anthocyanin concentration between treatments could be attributed to a different amount of sucrose taken up by spikes. This is in agreement with the findings obtained on sweet pea (Ichimura and Hiraya, 1999). Similarly, the availability of carbohydrate may be important for the synthesis of the lignin that is the likely reason that pedicels of sugar-treated flowers are stronger, and for the anthocyanins that are the basis for color in these flowers. In addition, sucrose promotes pigmentation of petal colors in some cut flowers such as *Eustoma* (Ichimura and Korenaga, 1998) and sweet pea (Ichimura and Hiraya, 1999) whereas, STS accelerates fading of petal colors of cut sweet pea flowers (Watanabe et al., 1999).

## 4. Conclusion

From the results of the present study, it can be concluded that 200 ppm 8-HQS + 2% sucrose treatment has improved sweet pea cut flower quality by increasing the vase-life, water uptake, water balance and percentage of maximum increase in fresh weight. Also, this preservative solution reduced chlorophyll degradation and preserved carbohydrates content during the postharvest life. However, anthocyanin concentrations of petals were increased by treatments with sucrose alone or STS followed by sucrose. Therefore, 200 ppm 8-HQS + 2% sucrose solution has a potential to be used as a commercial cut flower preservative solution for prolonging the vase-life and post harvest quality of sweet pea cut flowers.

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