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A Study on the Feasibility of Replacing Silver Nitrate with Natural Compounds in Preservative Solution of *Gerbera jamesonii* Cut Flowers

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Abstract
Gerbera (*Gerbera jamesonii*) from the family of Asteraceae is regarded as one of the best cut flowers in the world. Despite of the publicity of Gerbera's cut flowers, they have a short postharvest life. The objective of the present study was to study the replacement feasibility and the comparison of thymol (isolated from zataria), and essential oils of peppermint and rosemary (200, 400 and 600 mg l^{-1}) with silver nitrate (200 mg l^{-1}) in vase solution of gerbera cut flowers in order to increase vase life and some quality traits. The recorded traits were vase life, carotenoid, solution uptake, relative fresh weight, flower diameter, total dissolved solids and pH. The experiment was laid on a factorial arrangement based on a randomized complete block design with three replications. Means comparison revealed that the highest vase life was related to the treatment of silver nitrate, however, flowers treated with thymol (200 mg l^{-1}) in comparison with other natural treatments, had the highest vase life and did not show significant differences with silver nitrate. The treatment of peppermint essential oil (200 mg l^{-1}) resulted in the highest carotenoid level. The highest relative fresh weight and solution uptake were obtained for the thymol treatment (200 mg l^{-1}). The highest amount of total soluble solids and flower diameter were obtained in the silver nitrate treatment. The lowest pH was obtained from the treatment of 600 mg l^{-1} peppermint essential oil. In total, it can be concluded that thymol and the essential oils of peppermint and rosemary can be used in vase solution of gerbera cut flowers. Further research using other natural compounds is required to find out the appropriate compound and also concentrations in order to help the environment conservation and improve human health in addition to increase the vase life of cut flowers.

Keywords: Gerbera; Natural Compounds; Silver nitrate; Vase life

Introduction

Gerbera (*Gerbera jamesonii*) from the family of Asteraceae is regarded as one of the best cut flowers in the world (Parthasarathy and Nagaraju 1999). Despite of the publicity of Gerbera's cut flowers, they have a short postharvest life mainly caused by wilting (He *et al*. 2006). In spite of their splendid beauty, cut flowers have a limited longevity and quickly undergo senescence process after cutting from the maternal plant. Their longevity is short because newly cut flowers are live samples isolated from maternal plant (Rudnicki *et al.* 1986).

The application of natural compounds like plant essential oils has been recently proposed as a way to control bacterial and fungal infections and to reduce post-harvest losses of horticultural products including fruits, vegetables and flowers (Hassanpour Asil *et al*. 2015). The growing interest in the use of natural compounds instead of chemicals has been fueled by the increasing concern for the healthiness of chemicals and emerging evidence about their adverse impacts on human being and environment. Therefore, it is extensively attempted to identify and discover healthy natural compounds and to apply them in post-harvest technology of horticultural products (Hassanpour Asil *et al.* 2015).

Compounds like hydroxyquinoline sulfate and silver nitrate have been used as antibacterial compounds, but due to their environment polluting feature the use of natural compounds with floral origins and also low-risk chemicals have been recently considered (Madadzadeh *et al*. 2013).

Compounds recently considered for improving the postharvest longevity and quality of cut flowers are plant essential oils. They are natural, safe and dissoluble effective substances of some medicinal herbs. Since they contain phenolic compounds, essential oils have antibacterial features (Bounatirou *et al*. 2007). Examples include thymol, carvacrol and eugenol (Lambert *et al*. 2001; Mihajilov-krstev *et al*. 2009). Essential oils have antimicrobial property reducing the level of bacteria in vase solutions and vessels through which preventing vascular blockage (Solgi *et al*. 2009). Babarabie *et al*. (2015) used thymol and rosemary essential oil in vase solution of *Alstroemeria* cut flowers and reported that the treatments improved vase life and some quality traits of the flowers. In a study on the effect of essential oils of peppermint, thyme and black cumin on vase life of *Alstroemeria* cut flowers, Mousavi Bazaz and Tehranifar (2011) observed positive effect of essential oils on the improvement of vase life.

Khosravi Nahrabadi *et al*. (2015) stated that the essential oils of *Eucalyptus* and *Rosa damascena* enhanced the vase life and physiological traits of gerbera cut flowers. In an investigation into the replacement of essential oils with silver thiosulfate in vase solution of rose cut flowers using rosemary, savory, mint and thymes essential oils, Hoseini Darvishani and Chamani (2013) revealed that all treatments except thymes essential oil reduced vase life of the flowers.

The objective of the present study was to study the replacement feasibility and the comparison of thymol (isolated from zataria) and essential oils of peppermint and rosemary with silver nitrate in vase solution of gerbera cut flowers in order to increase vase life and improve some quality traits.

Materials and Methods

Plant materials, treatments and the experimental site

The study was carried out in Plant Production College of Gorgan University of Agricultural Sciences and Natural Resources in 2014. The flowers were harvested in a greenhouse in Isfahan, Iran, before their commercial maturity, i.e. before the pollination of stamens (Ebrahimzadeh and Seifi 1999). Then, they were immediately transferred to the physiology laboratory of Department of Horticultural Science. The flower stems were re-cut to the length of 30 cm and were soaked into pre-prepared solutions in the refrigerator at 9±2 °C, 60±5% relative humidity, and 400 Candela. The treatments included thymol (isolated from zataria), rosemary and peppermint essential oils with 200, 400 and 600 mg l^{-1} concentrations, and silver nitrate (200 mg l^{-1}). All treatments were applied with 4% sucrose. Distilled water together with 4% sucrose was used as the control. The essential oils were procured from the Tabiat Osare Company in Isfahan, Iran. Their compositions are presented in Tables 1 and 2 according to the analysis of the Essential Oil Preparation Center.

Table 1. The constituents of the peppermint essential oils from Isfahan Nature Extract Company

Compounds	percent
Alpha Pinene	1.72
Beta Pinene	2.44
1,8 cineole	6.82
Limonene	5.91
Alpha terpinene	0.43
Subinene	1.53
Neoiso menthol	1.32
Menthol	20.48
Cis- Dihydro carvone	2.32
Pipertone	1.6
Carvone	13.86
Menthyl acetate	2.12
Beta- Caryophyllene	3.2
Germacrene- D	3.47
Viridiflorol	1.39
Menthone	12.75
Trancs sabinehydrate	2.84
Neodihydro carveol	4.47
Iso- Menthylacetate	0.28
Carvacrol	0.41
Neomenthol	7.63
Para cymene	0.98
Other compounds	2.03

Table 2. The constituents of the rosemary essential oils from Isfahan Nature Extract Company

Compounds	percent
Alpha pinene	29.58
Camphene	6.84
Beta pinene	2.52
Beta myrcene	0.44
Limonene	3.78
1,8 cineol	47.32
Para cymene	1.46
Camphore	3.56
Bornyl acetate	0.17
Alpha terpineole	0.68
Borneole	1.29
Verenone	0.03
Other compounds	2.33

Measured traits

The recorded traits were vase life, carotenoid, solution uptake, relative fresh weight, flower diameter, total dissolved solids and pH.

Vase life of the flowers was measured by the criteria of petal wilting after 50%, neck bending and stem browning (Mutui *et al*. 2001). Arnon's (1967) method was used for measuring carotenoid and carotenoid was determined by spectrophotometer in terms of mg g^{-1} fresh weight after grinding the petals with acetone and completing its volume in this liquid. It is carried out on the 1st, 5th, 9th, 13th and 17th days of the experiment.

Solution uptake from graduated cylinder was determined by Equation (1) on the 1st, 5th, 9th, 13th and 17th days.

Equation (1): $WA=\frac{(S_{t-1})-S_t}{w_{t=0}}$

WA: The amount of absorbed solution

S_t: Solution weight (g) in days zero, 3 and …

S_{t-1}: Solution weight (g) in the previous day

$W_{t=0}$: Stem fresh weight in day zero

The flower fresh weight was measured by a digital scale on the 1st, 5th, 9th, 13th and 17th days using Equation (2).

Equation (2): $\frac{w_t}{w_{t=0}} \times 100$ =relative percentage of fresh weight (RFW)

W_t: Stem fresh weight in the same day and days 3, 6, ...

$W_{t=0}$ = Weight of the stem in day zero

Flower diameter was measured by a digital caliper on the 1st, 5th, 9th, 13th and 17th days. Also, pH meter was used to determine the solution pH at the beginning and end of the experiment.

Statistical Analysis

The experiment was laid as a factorial arrangement based on a randomized complete block design with three replications. Data were statistically analyzed by SAS Software Package, and means were compared by the least significant difference (LSD) test.

Results

Vase life

According to the analysis of variance, effect of the preservative solutions were significant on vase life at the 1% probability level (Table 3). Means comparison revealed that the highest and lowest vase life were related to the treatment of silver nitrate and control, respectively (Figure 1). Among the preservative solution, the maximum vase life was obtained in thymol (200 mg), however, it was not significantly different from the silver nitrate.

Table 3. Analysis of variance of the effect of the preservative solutions on vase life of gerbera cut flower

SOV	df	Vase life
Preservative solutions	10	52.73**
Error	20	9.6
CV (%)	-	23.67

Statistically significant at p≤ 0.05 and p≤ 0.01, respectively

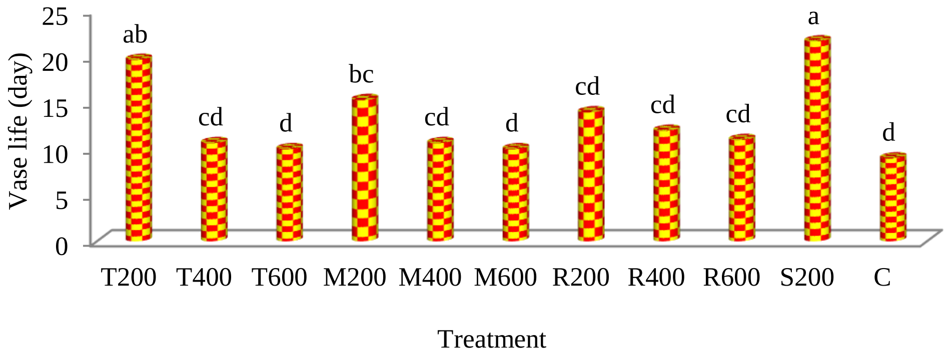

Figure 1. The effect of preservative solution on vase life of gerbera flowers

Carotenoid

Analysis of variance showed that the effect of treatment, time and their interaction were significant for carotenoid at the 1% probability level (Table 4). The interaction between preservatives solution and the post-harvest time, showed that the highest levels of carotenoids was obtained in Rosemary (600 mg l^{-1}) at fifth day (Table 5).

Table 4. Analysis of variance of the effect of preservative solutions and postharvest time on measured characteristics of gerbera cut flowers

SOV	df	Carotenoids	Solution uptake	Relative fresh weight	Flower diameter	Total soluble solids
Preservative solutions (P)	10	0.31**	3.84**	4548**	2971.35**	5.60**
Time (T)	4	6.29**	17.64**	57365.06**	71091.27**	373.04**
P*T	40	0.20**	0.98**	1971.82**	1186.68**	18.61**
Error	110	0.01	0.02	175.69	60.75	0.6
CV (%)	-	15.17	13.35	16.17	9.72	13.19

Statistically significant at p≤ 0.05 and p≤ 0.01, respectively

5. The interaction between preservative solutions and postharvest time for carotenoid content of gerbera cut flowers

Time (day)	T200	T400	T600	M200	M400	M600	R200	R400	R600	S200	C
1	0.29e	0.29d	0.29d	0.29e	0.29d	0.29d	0.29e	0.29e	0.29d	0.29e	0.29d
5	0.58c	1.01a	0.67b	0.41b	0.39c	0.41c	1.74a	1.56a	1.61a	1.45a	0.71a
9	1.30b	0.90b	0.84a	0.83a	0.73a	0.67b	0.83b	0.81b	0.82b	0.7d	0.69b
13	1.41a	0.71c	0.63c	0.56c	0.53b	0.83a	0.79c	0.64c	0.62c	0.79c	0.3c
17	0.62c	0.2e	0.2e	0.42d	0.2e	0.2e	0.56d	0.32d	0.2e	0.85b	0.2e

In each column, means with the similar letters are not significantly different at 5% level of probability using LSD test
T200: Thymol (200 mg l^{-1}) M200: peppermint (200 mg l^{-1}) R200: Rosemary (200 mg l^{-1}) S200:Silver nitrate (200 mg l^{-1})
T400: Thymol (400 mg l^{-1}) M400: peppermint (400 mg l^{-1}) R400: Rosemary (400 mg l^{-1}) C: Control
T600: Thymol (600 mg l^{-1}) M600: peppermint (600 mg l^{-1}) R600: Rosemary (600 mg l^{-1})

Solution uptake

According to the analysis of variance, solution uptake was significantly influenced by the treatment, time and their interaction at the 1% probability level (Table 4). The highest level of solution uptake was obtained in thymol (200 mg l^{-1}) at fifth day (Table 6).

Table 6. The interaction between preservative solutions and postharvest time for solution uptake of gerbera cut flowers

Time (day)	T200	T400	T600	M200	M400	M600	R200	R400	R600	S200	C
1	0.7^{e}	0.7^{b}	0.7^{c}	0.7^{c}	0.7^{c}	0.7^{b}	0.7^{d}	0.7^{c}	0.7^{c}	0.7^{e}	0.7^{c}
5	4.63^{a}	1.19^{a}	1.9^{a}	1.22^{a}	2.75^{a}	2.23^{a}	3.03^{a}	2.28^{a}	3.35^{a}	1.75^{a}	0.75^{b}
9	3.03^{b}	1.14^{a}	0.84^{b}	1.19^{b}	0.91^{b}	0.69^{b}	1.98^{b}	1.57^{b}	1.71^{b}	1.11^{b}	0.82^{a}
13	2.8^{c}	0.3^{c}	0.3^{d}	0.66^{d}	0.3^{d}	0.3^{c}	0.83^{c}	0.4^{d}	0.3^{d}	1.02^{c}	0.3^{d}
17	1.01^{d}	0.2^{d}	0.2^{e}	0.54^{e}	0.2^{e}	0.2^{d}	0.2^{e}	0.2^{e}	0.2^{e}	0.79^{d}	0.2^{e}

In each column, means with the similar letters are not significantly different at 5% level of probability using LSD test

T200: Thymol (200 mg l^{-1}) M200: peppermint (200 mg l^{-1}) R200: Rosemary (200 mg l^{-1}) S200:Silver nitrate (200 mg l^{-1})
T400: Thymol (400 mg l^{-1}) M400: peppermint (400 mg l^{-1}) R400: Rosemary (400 mg l^{-1}) C: Control
T600: Thymol (600 mg l^{-1}) M600: peppermint (600 mg l^{-1}) R600: Rosemary (600 mg l^{-1})

Relative fresh weight

Relative fresh weight was significantly impacted by treatment, time and their interaction at the 1% probability level (Table 4). The highest amount of relative fresh weight was obtained in thymol (200 mg l^{-1}) at the ninth day (Table 7).

Flower diameter

Analysis of variance indicated that the effect of treatment and time and their interaction were significant for flower diameter at the 1% probability level (Table 4). The interaction between preservatives solution and the post-harvest time showed that the highest level of flower diameter was obtained for silver nitrate (200 mg l^{-1}) at the ninth day (Table 8).

Table 7. The interaction between preservative solutions and postharvest time for relative fresh weight of gerbera cut flowers

Time (day)	T200	T400	T600	M200	M400	M600	R200	R400	R600	S200	C
1	100^{d}	100^{c}	100^{c}	100^{c}	100^{c}	100^{c}	100^{c}	100^{c}	100^{c}	100^{e}	100^{c}
5	116.7^{c}	111.43^{a}	118.12^{b}	110.71^{a}	111.78^{b}	109.69^{a}	117.02^{a}	109.58^{b}	114.27^{b}	118.68^{b}	109.13^{b}
9	149.52^{a}	110.07^{b}	137.18^{a}	102.18^{b}	135.86^{a}	105.97^{b}	107.5^{b}	114.75^{a}	148.06^{a}	119.24^{a}	114.79^{a}
13	117.1^{b}	35^{d}	40^{d}	65.36^{d}	40^{d}	40.31^{d}	98.91^{d}	42.9^{d}	50^{d}	118.11^{c}	50.55^{d}
17	99.88^{d}	28^{e}	38^{e}	38.24^{e}	38.3^{e}	38.11^{e}	8.32^{e}	8^{e}	48.3^{e}	110.47^{d}	48^{e}

In each column, means with the similar letters are not significantly different at 5% level of probability using LSD test

T200: Thymol (200 $mg\ l^{-1}$) M200: peppermint (200 $mg\ l^{-1}$) R200: Rosemary (200 $mg\ l^{-1}$) S200:Silver nitrate (200 $mg\ l^{-1}$)

T400: Thymol (400 $mg\ l^{-1}$) M400: peppermint (400 $mg\ l^{-1}$) R400: Rosemary (400 $mg\ l^{-1}$) C: Control

T600: Thymol (600 $mg\ l^{-1}$) M600: peppermint (600 $mg\ l^{-1}$) R600: Rosemary (600 $mg\ l^{-1}$)

Table 8. The interaction between preservative solutions and postharvest time for flower diameter of gerbera cut flowers

Time (day)	T200	T400	T600	M200	M400	M600	R200	R400	R600	S200	C
1	90.36^{c}	111.63^{c}	113.33^{c}	110.7^{c}	114.1^{c}	114.39^{c}	106.72^{c}	119.3^{c}	107.08^{c}	126.69^{c}	113.73^{b}
5	92.7^{b}	113.63^{b}	115.67^{b}	113.43^{b}	116.29^{a}	116.61^{b}	108.48^{b}	122.19^{a}	109.15^{b}	129.45^{a}	115.56^{a}
9	101.52^{b}	116.96^{a}	117.44^{a}	116.34^{a}	115.28^{b}	124.84^{a}	109.54^{a}	121.07^{b}	112.14^{a}	128.71^{a}	111.22^{c}
13	62.17^{d}	80.1^{d}	80.3^{d}	68.75^{d}	78.2^{d}	74.1^{d}	88.48^{d}	38.31^{d}	81^{d}	104.54^{d}	74.2^{d}
17	59.61^{e}	60.3^{e}	61.1^{e}	35.52^{e}	61.3^{e}	48.23^{e}	60.1^{e}	20.11^{e}	65^{e}	99.47^{e}	45.3^{e}

In each column, means with the similar letters are not significantly different at 5% level of probability using LSD test

T200: Thymol (200 $mg\ l^{-1}$) M200: peppermint (200 $mg\ l^{-1}$) R200: Rosemary (200 $mg\ l^{-1}$) S200:Silver nitrate (200 $mg\ l^{-1}$)

T400: Thymol (400 $mg\ l^{-1}$) M400: peppermint (400 $mg\ l^{-1}$) R400: Rosemary (400 $mg\ l^{-1}$) C: Control

T600: Thymol (600 $mg\ l^{-1}$) M600: peppermint (600 $mg\ l^{-1}$) R600: Rosemary (600 $mg\ l^{-1}$)

Total soluble solids

The treatment, time and their interaction were significant for total dissolved solids at the 1% probability level (Table 4). The highest levels of flower diameter was obtained for silver nitrate (200 $mg\ l^{-1}$) at the ninth day (Table 9).

Table 9. The interaction between preservative solutions and postharvest time for total soluble solids of gerbera cut flowers

Time	T200	T400	T600	M200	M400	M600	R200	R400	R600	S200	C
1	4.4^{e}	4.4^{c}	4.4^{c}	4.4^{e}	4.4^{b}	4.4^{c}	4.4^{d}	4.4^{d}	4.4^{c}	4.4^{e}	4.4^{c}
5	6.4^{c}	5.13^{b}	5.6^{b}	5.2^{c}	4.13^{c}	5.8^{b}	6.4^{c}	6^{c}	5.93^{b}	6.53^{d}	5.73^{b}
9	11.33^{a}	8.4^{a}	12.66^{a}	10.73^{a}	10.6^{a}	11.06^{a}	13^{b}	12.73^{a}	12.53^{a}	14.2^{a}	8.06^{a}
13	9.13^{b}	1^{d}	1^{d}	9.6^{b}	0.8^{d}	0.8^{d}	14.4^{a}	9.86^{b}	0.8^{d}	13.73^{b}	0.82^{d}
17	4.93^{d}	0.8^{e}	0.8^{e}	4.53^{d}	0.7^{e}	0.77^{d}	2.93^{e}	0.8^{e}	0.75^{e}	7.73^{c}	0.79^{d}

In each column, means with the similar letters are not significantly different at 5% level of probability using LSD test

T200: Thymol (200 mg l^{-1}) M200: peppermint (200 mg l^{-1}) R200: Rosemary (200 mg l^{-1}) S200:Silver nitrate (200 mg l^{-1})
T400: Thymol (400 mg l^{-1}) M400: peppermint (400 mg l^{-1}) R400: Rosemary (400 mg l^{-1}) C: Control
T600: Thymol (600 mg l^{-1}) M600: peppermint (600 mg l^{-1}) R600: Rosemary (600 mg l^{-1})

The pH

According to analysis of variance, pH was significantly impacted by treatment, time and their interaction at the 1% probability level (Table 10). The interaction between preservatives solution and the post-harvest time showed that the highest levels of pH was obtained for the control treatment at the ninth day (Table 11).

Table 10. Analysis of variance the effect of preservative solutions and postharvest time on pH of the preservative solutions of gerbera cut flowers

SOV	df	pH
Treatment	10	0.95^{**}
Time	1	26.19^{**}
Treatment*Time	10	0.70^{**}
Error	44	0.03
CV (%)		3.44

Statistically significant at p≤ 0.05 and p≤ 0.01, respectively

Table 11. The interaction between preservative solutions and postharvest time for pH of the preservative solutions of gerbera cut flowers

Time (day)	T200	T400	T600	M200	M400	M600	R200	R400	R600	S200	C
1	5.76^{a}	5.76^{a}	5.76^{a}	5.62^{a}	5.62^{a}	5.62^{a}	6.18^{a}	6.18^{a}	6.18^{a}	5.59^{a}	6.3^{a}
22	4.47^{b}	4.69^{b}	4.7^{b}	4.78^{b}	3.71^{b}	4.18^{b}	4.86^{b}	4.01^{b}	3.88^{b}	5.28^{b}	6.13^{b}

In each column, means with the similar letters are not significantly different at 5% level of probability using LSD test
T200: Thymol (200 mg l^{-1}) M200: peppermint (200 mg l^{-1}) R200: Rosemary (200 mg l^{-1}) S200:Silver nitrate (200 mg l^{-1})
T400: Thymol (400 mg l^{-1}) M400: peppermint (400 mg l^{-1}) R400: Rosemary (400 mg l^{-1}) C: Control
T600: Thymol (600 mg l^{-1}) M600: peppermint (600 mg l^{-1}) R600: Rosemary (600 mg l^{-1})

Discussion

It was found that the application of silver nitrate and plant essential oils improved the vase life of gerbera cut flowers. The vascular blockage caused by the growth of bacteria is reportedly one of the major reasons for short vase life of cut flowers

(Ichimura *et al*. 1997). Therefore, the potential of essential oils and silver nitrate in improving the longevity of the flowers can be related to their antimicrobial effects. Hashemabadi (2014) reported longer vase life of carnation cut flowers treated with silver thiosulfate and silver nanoparticles. Also, Kazemi *et al*. (2014) showed that the essential oil of *Zataria multiflora* and rosemary increased the vase life of *Lisianthus* cut flowers which is consistent with the results of the present study.

Paleness is one of the main post-harvest challenges of cut flowers that reduces the quality of the flowers and significantly affects their senescence (Amarjit 2000). Carotenoid and anthocyanin are two major pigments in cut flowers (Amarjit 2000). The change in petal color is mainly associated with vacuole pH (Edrisi 2009). Antibacterial compounds prevent the dissolution of flavonoids and improve flowers' freshness by enhancing water uptake (Hashemabadi and Bagheri 2013). In the present study, the essential oils and silver nitrate retarded the loss of carotenoid in petals to varying degrees. Madadzadeh *et al*. (2013) reported that thymol, carvacrol and nanosilver increased anthocyanin in petals of *Alstroemeria* cut flowers. Also, it was shown that tea essential oil in the vase solution of chrysanthemum increases carotenoid in petals (Hashemabadi and Bagheri 2013) implying the positive effect of some natural substances on the preservation of cut flowers' pigments.

Cut flowers lose their water soon after harvesting and start wilting (Pun *et al*. 2005). Water column incoherence in vessels by air, bacterial infection and low water quality are of the most important factors involved in the post-harvest loss of water uptake by flowering stem (van Doorn and D'hont 1994). Water balance is an important factor in quality and durability of cut flowers (Da Silva 2003) and water deficiency usually results in vascular blockage in the stem (van Doorn 1996). Antibacterial compounds in the vase solution protect vessels and inhibit vascular blockage by preventing microbial activity which, in turn, results in continuous water uptake on the one hand (Anju *et al*. 1999; Kim and Lee 2002; Shanan2012) and higher flower fresh weight and their more freshness on the other hand. It was reported that *Eugenia caryophyllata*'s essential oil and extract can act as an antibacterial compound increasing solution uptake and relative fresh weight of cut gerbera flowers (Ziaei Movahed *et al*. 2010) which is in agreement with our results about the positive impact of plant essential oils on fresh weight and solution uptake.

Flower diameter is a good indicator of flower opening that plays a role in marketing. In relation to flower opening, the growth of petals is the consequence of cell development (Knee 2000) and cell development requires the inflow of water and osmolytes like carbohydrates into petal cells (Evans and Reid 1988). Since the present study indicated that silver nitrate and essential oils, particularly at lower concentrations, increased flower diameter, it can be stated that the applied treatments might have increased sucrose uptake (of vase solution) by plants resulting in higher flower diameter. Consistent with our findings, Mirdehghan *et al*. (2012) showed that the essential oils of savory and thymes increased rose flower diameter although their effects were not as strong as that of silver nitrate. Also, in a study on the use of thymol, menthol and eugenol in the preservation solution of gerbera cut flower, it was revealed that all treatments increased flower diameter but thymol exhibited a better performance (Hashemi and Mirdehghan 2014).

Research shows that total soluble solids decrease as cut flowers age. The loss of total dissolved solids with the senescence is caused by the dissolution and use of internal carbohydrates (Karimi *et al*. 2008). Thus it can be said that carbohydrate requirement of the flowers is partially met by sucrose uptake in some treatments, resulting in increased total dissolved solids. Babarabie *et al*. (2015) reported that rosemary essential oil increased total dissolved solids in *Alstroemeria* cut flowers, which is in agreement with our findings.

Acidic solutions are mobilized in stems more quickly than alkaline or neutral solutions, improving solution uptake by vessels (Edrisi 2009). Since essential oils reduce solution pH, it may be concluded that in addition to their antibacterial features, essential oils are able to reduce water pH by which they are effective on reducing microorganisms. Measuring vase solution pH at the beginning and end of the experiment, Jalili Marandi *et al*. (2011) stated that salicylic acid and essential oils of ajwain and savory reduced vase solution pH of rose cut flowers.

Conclusion

It was found out that silver nitrate was more effective on vase life of the cut flowers than essential oils although other compounds increased vase life of the flowers too and flowers treated with 200 mg l^{-1} thymol had slightly different vase life than those treated with silver nitrate. Also, natural compounds improved the recorded traits, especially at lower concentrations, proving their positive influence. In total, it can be concluded that thymol and the essential oils of peppermint and rosemary can be used in vase solution of gerbera cut flowers. The interaction between preservatives solution and the postharvest time solutions showed that there were significant effects between them. Further research using other natural compounds is required to find out the appropriate concentrations in order to improve environment conservation and human health in addition to increasing vase life of the cut flowers.

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