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Postharvest performance of cut marigold, rose, and sunflower stems as influenced by homemade and commercial floral preservatives

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Abstract: Effects of homemade or commercial floral preservatives, applied as 48-h grower treatments or continuous retailer/consumer applications, were studied on cut Double Eagle marigold, Red Bentley rose, and Sunbright sunflower. Cut stems of marigold placed in preservative solutions, irrespective of the duration, had a longer vase life than stems in tap water. Continuous use of soda (7 Up) or citric-Kathon and short-term use of citric-Al resulted in the longest extension of vase life. Cut stems of rose had the longest vase life when pulsed with citric-Kathon for 48 h or continuously placed in citric-Al until termination. For sunflower, use of citric-Kathon or citric-Greenshield both as a pulse and as a vase solution extended the vase life similar to commercial preservatives such as Floralife or Chrysal; it was 1.8 days longer than the vase life of stems in tap water. Continuous use of lemon juice plus sugar or citric acid plus sugar reduced the vase life of rose and sunflower stems. The pH of tap water solutions became more acidic when used after 48 h of pulsing with preservative solutions, while greater changes in electrical conductivity were recorded when the preservative solutions containing soda, lemon juice plus sugar, or citric-Al were used until termination. Stems of all species tested kept continuously in soda had the highest dry weight, while citric-Kathon had higher fresh weight at termination, compared to initial fresh weight at harvest, and higher solution uptake. In summary, continuous vase application of citric-Kathon, soda, or citric-Greenshield resulted in the best postharvest performance of marigold and sunflower, and continuous treatment with citric-Al or pulsing with citric-Kathon resulted in the best postharvest performance of cut roses; all of the aforementioned treatments resulted in a vase life similar to those of commercial preservatives. However, mixtures containing lemon juice or citric acid plus sugar had detrimental effects and should not be used for longer periods to handle cut stems of rose or sunflower.

Key words: Aluminum sulfate, citric acid, cut flowers, folk recipes, rose, vase life

1. Introduction

Floral preservatives are a vital component of postharvest handling of cut flowers and are extensively used in floral arrangements to extend longevity and maintain quality (Nowak and Rudnicki, 1990; Çelikel and Reid, 2002; Ahmad et al., 2013). They maintain water uptake by controlling microbial growth and acidifying the solutions (McDaniel, 1996) and provide sugars necessary to carry on metabolic activities after harvest (Dole and Wilkins, 2005). Moreover, they improve flower color development, flower opening, and flower size (Nowak and Rudnicki, 1990).

Different types of floral preservatives, e.g., hydrators, clarifiers, and holding or vase solutions, are produced by several manufacturing companies. Hydrators contain acidifying agents without sugars and are used immediately after harvest, transit, or dry storage to improve water uptake by the stems. Clarifiers contain antimicrobial compounds and are used to maintain water uptake by lowering vascular blockage and controlling microbial growth in the solution. Holding/vase solutions provide food for maintaining metabolic processes and continued flower opening during vase life, because they contain sugars along with acidifiers and biocides.

Sugars are an important component of flower foods because they provide carbohydrates to the cut stems to continue metabolic processes necessary for extension of vase life. However, antimicrobial compounds must be used along with sugars to prevent microbial build-up in the solutions (van Doorn, 1997). Among these biocides, silver compounds such as silver nitrate and silver thiosulfate, chlorine compounds like sodium hypochlorite, sodium dichloroisocyanurate, and several other compounds like cobalt chloride, 8-hydroxyquinoline citrate or sulfate, Physan 20 (Greenshield), or Kathon CG are used to prevent microbial proliferation in vase solutions (Ichimura et al., 2006). Due to environmental hazards associated

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with silver compounds and 8-hydroxyquinoline citrate or sulfate, and the short-term effectiveness of chlorine compounds, Greenshield and Kathon CG can be excellent options for incorporation into floral preservatives. Greenshield (Physan 20) is a quaternary ammonium chloride disinfectant that is stable, safe, and effective in controlling germs in vase solutions, particularly when freshly prepared solutions are used. Kathon CG is another effective, broad-spectrum preservative compound with worldwide registration that can also be used as a biocide in floral preservative solutions. However, limited information is available on the effectiveness of these compounds for extending the vase life of cut flowers.

Among organic acids, citric acid is the most common compound used extensively to lower the pH and control microbial populations in preservative solutions and was effective for cut carnations (*Dianthus caryophyllus* L.) (Kazemi et al., 2012), lisianthus (*Eustoma grandiflorum* Salisb.) (Kiamohammadi and Hashemaabadi, 2011), roses (*Rosa* × *hybrida* L.) (Jowkar et al., 2012), tuberoses (*Polianthes tuberosa* L.) (Jowkar and Salehi, 2006), and sunflower (*Helianthus annuus* L.) (Mensuali-Sodi and Ferrante, 2005). It lowers the pH of cell sap and reduces vascular blockage, thereby improving water uptake and extending longevity. Similarly, citric acid also encourages floral opening and maintains postharvest quality of cut tuberose spikes (Jowkar and Salehi, 2006), and aluminum sulfate is extensively used as a biocide for cut lisianthus (Liao et al., 2001), roses (De Stigter, 1981), and many other cut flower species and stabilizes petal anthocyanin levels to improve the keeping quality and vase life of cut roses (Ichimura et al., 2006).

Several other common products have been used in homemade floral preservatives. Some of these include lemon/lime soda, lemon juice, household bleach, vinegar, aspirin tablets (Greer and Einert, 1994), pennies, or essential oils of several plant species (Fariman and Tehranifar, 2011; Samiee et al., 2013). However, limited information is available on their effectiveness for extending vase life of cut flowers. Commercial preservatives are well researched and effective, but not readily available in many parts of the world. Additionally, several folk recipes are also being used by industry and consumers, but limited scientific information is available about their effects on the longevity and quality of cut stems. Therefore, the present study was conducted to determine the effect of different homemade or commercial floral preservatives on cut roses and 2 popular specialty cut species, marigold and sunflower. The specific objectives of this study were to 1) develop readily available, environmentally safe, and low-cost floral preservatives for growers, florists, and consumers; and 2) evaluate the effects of different ingredients of folk floral preservative recipes being used in the industry. It was hypothesized that the recipes would extend the vase life of tested species, similar to the effects of commercial preservative solutions.

2. Materials and methods

2.1. Plant material

Cut stems of *Tagetes erecta* L. 'Double Eagle' and *Helianthus annuus* L. 'Sunbright' were field-grown in the horticultural field laboratory of North Carolina State University (NCSU) in Raleigh, USA, during 2012 using standard commercial procedures, while those of *Rosa* × *hybrida* L. 'Red Bentley' were received from Esmeralda Farms, Ecuador. All experiments were conducted at the postharvest laboratory of the Department of Horticultural Sciences, NCSU. Marigold and sunflower stems were harvested in the morning before 1000 hours, placed in buckets containing tap water, and transported to the laboratory within 1 h of harvest, while roses were received at the NCSU postharvest laboratory within 3 days of harvest. On arrival, stems were sorted into 17 groups on the basis of stem caliper and bud/flower diameter; for marigold, stage of development (number of open petals) was considered along with stem caliper for sorting stems. Sorting was done into temporary groups of similar diameters and then those flowers were distributed uniformly into groups for treatments. Thus, each treatment would contain the same number of thick stems, intermediate stems, and thin stems. Stems were labeled, recut from the bases to uniform lengths of 45 cm for rose and sunflower and 30 cm for marigold, and placed in respective treatments. After recutting, rose and marigold stems had 3 intact leaves per stem and sunflower had 1 leaf. Solutions used in all experiments were prepared using tap water [pH 6.3, electrical conductivity (EC) 0.34 dS m^{-1}] and stems were placed in solutions after approximately 1 h of solution preparation. For each experiment, fresh solutions were prepared and used. Treatments included 500 mL L^{-1} lemon/lime 7 Up soda (soda); 6 mL L^{-1} lemon juice plus 20 g L^{-1} sugar; 100 mg L^{-1} citric acid plus 20 g L^{-1} sugar plus 200 mg L^{-1} aluminum sulfate (citric-Al); 400 mg L^{-1} citric acid plus 20 g L^{-1} sugar alone, or combined with either 0.5 mL L^{-1} Greenshield (citric-Greenshield) or 0.007 mL L^{-1} Kathon CG (citric-Kathon); 10 mL L^{-1} Floralife Clear Professional Flower Food (Floralife); or 10 mL L^{-1} Chrysal Clear Professional 2 (Chrysal), applied for 48 h (holding solution) or continuously until termination (vase solution). Stems were kept (3 stems per vase) at 21 ± 1 °C with 40%–60% relative humidity (RH) and a 12-h photoperiod provided by cool white fluorescent lamps. The lamps provided a photosynthetic photon flux of around 20 µmol m^{-2} s^{-1}, as measured at bench level with a 1078 QMSW quantum meter (Apogee Instruments, Inc., USA). All experiments were factorial with 5 replicates of 3 stems each and were repeated once for confirmation of results.

2.2. Measurements

Data were collected daily for vase life (duration from placement of stems in vases in the postharvest evaluation room to the time when individual stems terminated), initial and final fresh weight and fresh weight change (of 1 predesignated stem per vase), dry weight (at termination after drying at 70 °C for 72 h), solution uptake (measured in milliliters from all vases when the first stem was terminated in the entire experiment), pH and EC changes in vase solutions (measured at termination of each stem), and termination symptoms. Symptoms for termination were recorded as present or not present and included bent neck, leaf wilting, petal blackening, necrosis, wilting, or stem blackening for marigold (Ahmad et al., 2012); bent neck, failure to open flowers, leaf necrosis, loss of pigment, petal browning/bluing, or wilting for rose (Ahmad et al., 2014); and bent neck, leaf wilting or petal abscission, necrosis, or wilting for sunflower (Jones et al., 1993; Nan, 2007). Cut stems were observed every day during the vase period and a symptom was recorded as present if it occurred on at least 1 petal, leaf, or bud. Each stem was terminated when it had developed 1 or more of the aforementioned symptoms on ≥50% of the flowers, foliage, or stem (Ahmad et al., 2013). Initial solution pH and EC were also recorded.

2.3. Statistical analyses

All experiments were completely randomized designs with factorially arranged treatments and 5 replicate vases of 3 stems each. Data were subjected to analysis of variance (ANOVA) procedures using the general linear model (GLM) procedures of SAS (version 9.3, SAS Institute Inc., USA) and means were separated using Fisher's least significant difference (LSD) at $P \leq 0.05$.

3. Results

3.1. Solution pH and EC

All preservative solutions had an initial pH of 2.8 to 3.2 for all species tested, and relatively small changes in pH (≤0.4 units) were recorded in solutions where stems were kept continuously in the preservatives until termination (Table 1). The stems treated for 48 h had an initial pH of 7.0 for tap water, which became acidic by 0.6–0.9 units at termination and was similar for all species tested and for all treatments. On the other hand, the pH of floral preservative solutions (except soda and lemon juice) used continuously until the senescence of stems became more basic, with the highest increase for Floralife Clear Professional Flower Food, citric-Kathon, and Chrysal Professional 2 (0.4, 0.3, and 0.3 units, respectively). The pH of tap water and citric-Al used continuously until termination did not change during vase period.

Vase solution EC is important for achieving the longest possible vase life of cut flowers. Many cut species perform best when solution EC is moderate, but when salts in the vase solution are too high, it may be detrimental to the vase life of several cut flower species. The EC of all preservative solutions increased during vase period, with greater increases in solutions containing soda, lemon juice plus sugar, or citric-Al used continuously until senescence (Table 1). Stems placed continuously in citric-Al had highest initial and final EC (1.14 and 1.43 dS m^{-1}, respectively). Stems treated with preservatives for 48 h followed by placement in tap water or continuously with citric-Greenshield, citric-Kathon, citric acid plus sugar, Floralife, or Chrysal had similar EC changes.

3.2. Marigold

The longest vase life (15.5–15.7 days) was obtained when stems were placed continuously in vase solutions with soda or citric-Kathon, or pulsed with citric-Al for 48 h, which was >7 days longer than the vase life of stems in tap water (Table 2). Stems treated with any of the homemade or commercial floral preservatives had a longer vase life than untreated stems, irrespective of application duration. Stems placed continuously in soda or citric-Kathon until termination had the highest stem dry weight. Stems in citric-Kathon also had the highest fresh weight change (2.3 g increase in fresh weight compared to initial fresh weight at harvest) during vase period, while those in citric-Al for 48 h and afterwards maintained in tap water, or continuously placed in tap water or lemon juice plus sugar, lost the most weight (4.6, 4.4, and 4.3 g, respectively) until termination as compared to their initial fresh weight at harvest.

Stems placed continuously in citric-Kathon, Floralife, Chrysal, or soda had the highest solution uptakes (106, 103, 100, or 99 mL, respectively; Table 2). Treatment of cut stems of marigold with homemade floral preservatives for 48 h had no effect on dry weight, fresh weight change, solution uptake, or petal blackening. Stems placed continuously in citric-Kathon until termination had no petal blackening. Continuous use of all floral preservatives and pulsing with citric-Greenshield, citric-Al, citric acid plus sugar, or lemon juice plus sugar had no or low percentage of stem blackening. Continuous use of citric-Kathon or commercial preservatives, or pulsing of citric acid plus sugar, lemon juice plus sugar, or citric-Al, had the lowest levels of leaf wilting, which was a major symptom of senescence in stems with other preservatives. Floral preservatives and/or application duration had no effect on petal necrosis or wilting, or bent neck, and averaged 3%, 90%, and 8%, respectively.

3.3. Rose

The stems placed continuously in citric-Al or pulsed with citric-Kathon for 48 h had the longest vase life (13.1 days each), which was 2.8 days longer than stems in tap water (Table 3). Moreover, Floralife, irrespective

Table 1. Effect of homemade or commercial floral preservative solutions (compounds and application duration) on pH and EC changes of Double Eagle African marigold, Red Bentley rose, and Sunbright sunflower. Stems were placed in preservative solutions for 48 h and then moved to tap water, or continuously placed in the solutions until termination. Data represent means of 15 replicate vases of 3 stems each (5 replicate vases for each species).

Preservative solutions		Initial pH	Final pH	pH change[a]	Initial EC (dS m^{-1})	Final EC (dS m^{-1})	EC change[a] (dS m^{-1})
Compounds	Application duration						
Tap water	Until termination	6.3 b[b]	6.3 abc	0.0 cd	0.34 g	0.50 f	0.16 c
7 Up	48 h	7.0 a	6.2 bc	−0.8 fg	0.32 h	0.47 f	0.15 c
Lemon juice + sugar	48 h	7.0 a	6.1 c	−0.9 g	0.32 h	0.44 f	0.12 c
Citric acid + sugar	48 h	7.0 a	6.1 c	−0.9 g	0.32 h	0.44 f	0.12 c
Citric acid + sugar + aluminum sulfate	48 h	7.0 a	6.2 bc	−0.8 fg	0.32 h	0.42 f	0.10 c
Citric acid + sugar + Greenshield	48 h	7.0 a	6.2 bc	−0.8 fg	0.32 h	0.42 f	0.10 c
Citric acid + sugar + Kathon CG	48 h	7.0 a	6.3 abc	−0.7 fg	0.32 h	0.47 f	0.15 c
Floralife Clear Professional Flower Food	48 h	7.0 a	6.4 a	−0.6 f	0.32 h	0.47 f	0.15 c
Chrysal Clear Professional 2	48 h	7.0 a	6.4 a	−0.6 f	0.32 h	0.45 f	0.13 c
7 Up	Until termination	3.2 c	2.8 fg	−0.4 e	0.53 c	1.04 b	0.51 a
Lemon juice + sugar	Until termination	3.1 c	3.0 ef	−0.1 de	0.43 f	0.77 c	0.34 b
Citric acid + sugar	Until termination	3.0 d	3.1 ef	0.1 bcd	0.48 e	0.67 de	0.19 c
Citric acid + sugar + aluminum sulfate	Until termination	2.8 e	2.8 g	0.0 cd	1.14 a	1.43 a	0.29 b
Citric acid + sugar + Greenshield	Until termination	2.9 de	3.1 de	0.2 abc	0.51 d	0.61 e	0.10 c
Citric acid + sugar + Kathon CG	Until termination	2.9 de	3.2 d	0.3 ab	0.52 cd	0.63 e	0.11 c
Floralife Clear Professional Flower Food	Until termination	2.9 de	3.3 d	0.4 a	0.59 b	0.73 cd	0.14 c
Chrysal Clear Professional 2	Until termination	2.8 e	3.1 de	0.3 ab	0.60 b	0.74 cd	0.14 c
Significance[c]							
Overall		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Compound (C)		<0.0001	NS	<0.0001	NS	NS	NS
Duration (D)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[a]: Final value minus initial value.
[b]: Mean separation within columns by Fisher's LSD at P ≤ 0.05.
[c]: P-values were obtained using GLM procedures (SAS version 9.3; SAS Institute Inc.).
[NS]: Nonsignificant at P > 0.05.

of application duration and pulsing with soda, citric-Al, or citric-Greenshield for 48 h, also extended vase life. However, continuous use of lemon juice plus sugar or soda reduced the vase life of cut rose stems to 7.5 and 7.8 days, respectively. Stems placed continuously in soda had the highest dry weight (9.1 g), while those pulsed with citric-Al for 48 h had the lowest stem dry weight (7.0 g). Stems in citric-Kathon continuously lost the least fresh weight during the vase period (8.7 g less fresh weight than initial fresh weight; Table 3). Continuous use of citric-Kathon or citric acid plus sugar until senescence resulted in the highest solution uptake.

Use of citric-Al or citric-Kathon irrespective of application duration and soda, lemon juice, Floralife, or Chrysal for 48 h effectively prevented any bent neck (Table 3). Continuous use of soda, lemon juice plus sugar, or citric acid plus sugar had the lowest levels of leaf necrosis and loss of pigment; however, stems in lemon juice plus sugar, soda, or citric acid plus sugar also had the shortest vase lives. Floral preservatives and/or application duration

Table 2. Effect of homemade or commercial floral preservative solutions (compounds and application duration) on vase life, dry weight, fresh weight change, solution uptake, and termination symptoms (leaf wilting, stem blackening, or petal blackening) of Double Eagle African marigold. Stems were placed in preservative solutions for 48 h and then moved to tap water, or continuously placed in the solutions until termination. Data for dry weight and fresh weight change represent means of 5 stems, data for solution uptake represent means of 5 vases, and all other data represent means of 15 stems with 3 stems per vase.

Preservative solutions		Vase life (d)	Dry weight[a] (g)	Fresh weight change[b] (g)	Solution uptake (mL)	Termination symptoms[c]		
Compounds	Application duration					Leaf wilting (%)	Stem blackening (%)	Petal blackening (%)
Tap water	Until termination	7.9 e[d]	2.0 d	−4.4 c	83 def	67 abcd	33 ab	27 abcde
7 Up	48 h	11.4 d	2.2 cd	−3.8 bc	75 efg	93 ab	53 a	20 bcde
Lemon juice + sugar	48 h	13.7 bcd	2.1 d	−3.2 bc	62 h	47 cde	7 c	27 abcde
Citric acid + sugar	48 h	13.5 bcd	2.1 d	−3.3 bc	71 fgh	33 de	7 c	60 ab
Citric acid + sugar + aluminum sulfate	48 h	15.5 ab	2.1 d	−4.6 c	71 fgh	47 cde	7 c	47 abcd
Citric acid + sugar + Greenshield	48 h	11.8 d	2.3 cd	−3.9 bc	67 gh	87 ab	7 c	27 abcde
Citric acid + sugar + Kathon CG	48 h	12.5 cd	2.3 cd	−2.8 bc	72 fgh	67 abcd	33 ab	33 abcde
Floralife Clear Professional Flower Food	48 h	11.4 d	2.0 d	−3.3 bc	69 gh	73 abc	20 bc	53 abc
Chrysal Clear Professional 2	48 h	11.5 d	2.1 cd	−3.6 bc	74 fgh	87 ab	40 ab	60 ab
7 Up	Until termination	15.7 a	3.3 a	−2.9 bc	99 abc	100 a	0 c	7 de
Lemon juice + sugar	Until termination	12.8 bcd	2.4 bcd	−4.3 c	90 cd	73 abc	0 c	20 bcde
Citric acid + sugar	Until termination	12.7 bcd	2.3 cd	−2.9 bc	92 bcd	73 abc	7 c	7 de
Citric acid + sugar + aluminum sulfate	Until termination	12.9 abcd	2.4 bcd	−3.7 bc	87 de	73 abc	0 c	33 abcde
Citric acid + sugar + Greenshield	Until termination	13.7 abcd	2.6 bc	−3.7 bc	89 cd	60 bcd	0 c	13 cde
Citric acid + sugar + Kathon CG	Until termination	15.5 ab	2.8 ab	2.3 a	106 a	20 e	0 c	0 e
Floralife Clear Professional Flower Food	Until termination	14.7 abc	2.1 cd	−1.2 b	103 ab	47 cde	20 bc	67 a
Chrysal Clear Professional 2	Until termination	14.0 abcd	2.3 cd	−1.9 bc	100 abc	33 de	7 c	67 a
Significance[e]								
Overall		<0.0001	<0.0001	0.0097	<0.0001	0.0029	0.0007	0.0072
Compound (C)		<0.0001	NS	NS	NS	0.0013	<0.0001	NS
Duration (D)		<0.0001	0.0001	NS	<0.0001	<0.0001	<0.0001	0.0191

[a]: Dry weight recorded at termination after drying at 70 °C for 72 h.
[b]: Final fresh weight (recorded at termination) minus initial fresh weight (recorded at harvest).
[c]: Percentage of stems in each treatment exhibiting symptom.
[d]: Mean separation within columns by Fisher's LSD at $P \leq 0.05$.
[e]: P-values were obtained using GLM procedures (SAS version 9.3; SAS Institute Inc.).
[NS]: Nonsignificant at $P > 0.05$.

Table 3. Effect of homemade or commercial floral preservative solutions (compounds and application duration) on vase life, dry weight, fresh weight change, solution uptake, and termination symptoms (bent neck, leaf necrosis, or loss of pigment) of Red Bentley rose. Stems were placed in preservative solutions for 48 h and then moved to tap water, or continuously placed in the solutions until termination. Data for dry weight and fresh weight change represent means of 5 stems, data for solution uptake represent means of 5 vases, and all other data represent means of 15 stems with 3 stems per vase.

Preservative solutions		Vase life (d)	Dry weight[a] (g)	Fresh weight change[b] (g)	Solution uptake (mL)	Termination symptoms[c]		
Compounds	Application duration					Bent neck (%)	Leaf necrosis (%)	Loss of pigment (%)
Tap water	Until termination	10.3 de[d]	7.6 bcde	−12.9 cd	167 ab	13 bc	53 bcd	87 ab
7 Up	48 h	12.7 abc	7.6 bcde	−11.9 abcd	111 cde	0 c	47 cde	100 a
Lemon juice + sugar	48 h	11.8 abcd	8.3 abcd	−14.5 d	93 ef	0 c	87 a	100 a
Citric acid + sugar	48 h	11.5 abcd	7.9 bcde	−13.0 cd	95 def	13 bc	67 abc	87 ab
Citric acid + sugar + aluminum sulfate	48 h	12.1 abc	7.0 e	−13.0 cd	103 cdef	0 c	67 abc	100 a
Citric acid + sugar + Greenshield	48 h	12.7 abc	8.1 abcde	−12.3 bcd	112 cde	7 bc	73 abc	100 a
Citric acid + sugar + Kathon CG	48 h	13.1 a	7.4 cde	−12.9 cd	116 cd	0 c	87 a	100 a
Floralife Clear Professional Flower Food	48 h	12.9 ab	8.3 abcd	−14.7 d	120 c	0 c	67 abc	100 a
Chrysal Clear Professional 2	48 h	11.5 bcd	7.2 de	−12.9 cd	87 f	0 c	80 ab	87 ab
7 Up	Until termination	7.8 fg	9.1 a	−9.4 abc	146 b	27 b	0 f	40 c
Lemon juice + sugar	Until termination	7.5 g	8.4 abc	−10.3 abc	146 b	60 a	0 f	40 c
Citric acid + sugar	Until termination	9.2 ef	8.7 ab	−9.0 ab	170 a	7 bc	0 f	40 c
Citric acid + sugar + aluminum sulfate	Until termination	13.1 a	8.3 abc	−9.6 abc	154 ab	0 c	67 abc	100 a
Citric acid + sugar + Greenshield	Until termination	10.6 de	8.3 abc	−12.4 bcd	159 ab	13 bc	20 ef	73 b
Citric acid + sugar + Kathon CG	Until termination	11.4 cd	8.7 ab	−8.7 a	174 a	0 c	33 de	93 ab
Floralife Clear Professional Flower Food	Until termination	12.4 abc	7.4 cde	−12.5 bcd	157 ab	7 bc	80 ab	100 a
Chrysal Clear Professional 2	Until termination	11.2 cd	8.2 abcd	−10.4 abc	147 b	7 bc	80 ab	100 a
Significance[e]								
Overall		<0.0001	0.0240	0.0208	<0.0001	<0.0001	<0.0001	<0.0001
Compound (C)		0.0032	NS	NS	<0.0001	NS	NS	NS
Duration (D)		<0.0001	0.0066	0.0062	<0.0001	<0.0001	<0.0001	<0.0001

[a]: Dry weight, [b]: final fresh weight, and [c]: percentage of stems exhibiting termination symptoms were recorded as described in Table 2.

[d]: Mean separation within columns by Fisher's LSD at $P \leq 0.05$.

[e]: P-values were obtained using GLM procedures (SAS version 9.3; SAS Institute Inc.).

[NS]: Nonsignificant at $P > 0.05$.

had no effect on petal browning/bluing, wilting, or failure of flowers to open, which averaged 89%, 97%, and 45%, respectively.

3.4. Sunflower

The longest vase life was recorded when stems were placed continuously in commercial preservatives (Chrysal or Floralife) or homemade floral preservatives (citric-Greenshield or citric-Kathon), which was approximately 2 days longer than that of stems in tap water (Table 4). Continuous use of lemon juice plus sugar, citric acid plus sugar, and citric-Al had detrimental effects on cut stems of sunflower and reduced the longevity to 8.9, 9.9, and 10.9 days, respectively, compared to other preservative solutions. However, application of these preservatives for only 48 h had no negative effects on longevity and quality of cut stems. Floral preservatives applied for the short duration of 48 h had no effect on vase life, dry weight, fresh weight change, solution uptake, leaf wilting, or petal necrosis.

Stems placed continuously in soda had the highest dry weight (14.4 g). Stems in soda or citric-Kathon until termination had the highest fresh weight change (21.1 and 16.2 g increase in fresh weight at termination compared to initial fresh weight at harvest, respectively), while stems in lemon juice plus sugar or citric acid plus sugar lost the most fresh weight during the vase period when these mixtures were used until termination (Table 4). Continuous use of citric-Kathon or Floralife had the highest solution uptake.

Continuous use of citric-Al increased leaf wilting of sunflower, which was effectively prevented when stems were treated with Floralife regardless of duration or continuous use of Chrysal, citric-Kathon, citric-Greenshield, or tap water. Moreover, stems pulsed with citric acid plus sugar for 48 h also had no leaf wilting. Use of citric-Al or lemon juice plus sugar until termination had less petal abscission compared to other preservatives. Use of lemon juice, irrespective of application duration, and continuous use of citric acid plus sugar had the lowest levels of petal necrosis (Table 4). Bent neck or petal wilting was not affected by floral preservatives or application duration and averaged 1% and 100%, respectively.

4. Discussion

In these studies, readily available, low-cost, environment friendly, and effective homemade floral preservative solution(s) were tested to maximize postharvest life and quality. It is clear that a complete floral preservative with sugar, acidifier, and an appropriate biocide produced the longest vase life for all 3 species. The treatment combinations with only an acidifier and sugar resulted in a vase life similar to or lower than that obtained with tap water for rose and sunflower. For marigold, the treatments with only sugar and an acidifier lengthened the vase life, but not as much as the treatments that included biocides. Producers of organically grown flowers have long searched for an organically certified floral preservative and some have relied on lemon juice to serve as both the acidifier as well as the biocide (Byczynski, 1997). However, these results show that this strategy is not effective due to microbial contamination. Dense microbial colonies (visual observation) occurred in vase solutions without biocides when used until termination, which may have reduced solution uptake. This shorter vase life may also have resulted in lower leaf necrosis or loss of pigment compared to other preservatives.

This study suggested that the ability of the marigold stems to withstand microbes or the short-term application of these solutions was not enough to allow sufficient microbial growth to block stems, yet allowed uptake of the carbohydrates, thus extending the vase life compared to just water. Several other species such as carnation (van Doorn et al., 1991) and freesia (Woodson, 1987) have been reported to be unaffected by the presence of microorganisms in vase solutions. In such species, vascular blockage may not be the sole reason of senescence, which is a combination of some physical factors (e.g., vascular occlusion due to air embolisms or microbial proliferation) and genetically controlled factors (e.g., loss of membrane permeability) (Woodson, 1991). If solution uptake is not blocked by vascular blockage, genetically controlled loss of membrane integrity may hinder uptake, ultimately leading to senescence.

Commercial floral preservatives have been well researched to provide an appropriate combination of sugar, acidifier, and biocide for extending vase life and, not surprisingly, they were effective in these studies as well. However, in situations where commercial preservatives are not readily available, alternative solutions may be needed. Commercially produced lemon/lime soda, which also contains sugar, acidifier, and biocide, was as equally effective as commercial preservatives for marigolds and sunflowers and when used as a 48-h treatment for roses. The provision of high levels of carbohydrates in soda also resulted in high marigold and sunflower dry weight and a large gain in sunflower fresh weight. Moreover, if organic soda can be used, it might be effective for handling organically produced cut stems. However, cost-effectiveness of soda may be an issue, as the products are generally more expensive than commercial flower foods when used on a large scale (Molenaar and van der Schaaf, 2004).

Interestingly, vase solutions with soda used until termination developed visible microbial colonies in marigold, but did not accelerate the senescence rate. These results might be due to the high levels of carbohydrates available in the soda solutions, which delayed the

Table 4. Effect of homemade or commercial floral preservative solutions (compound and application duration) on vase life, dry weight, fresh weight change, solution uptake, and termination symptoms (leaf wilting, petal abscission, or petal necrosis) of Sunbright sunflower. Stems were placed in preservative solutions for 48 h and then moved to tap water, or continuously placed in the solutions until termination. Data for dry weight and fresh weight change represent means of 5 stems, data for solution uptake represent means of 5 vases, and all other data represent means of 15 stems with 3 stems per vase.

Preservative solutions		Vase life (d)	Dry weight[a] (g)	Fresh weight change[b] (g)	Solution uptake (mL)	Termination symptoms[c]		
Compound	Application duration					Leaf wilting (%)	Petal abscission (%)	Petal necrosis (%)
Tap water	Until termination	11.7 ef[d]	9.2 bcd	−1.2 cd	339 ab	0 f	53 bcd	93 ab
7 Up	48 h	12.7 abcde	10.1 bc	0.9 cd	242 def	40 de	67 abc	73 abcd
Lemon juice + sugar	48 h	11.5 ef	9.1 bcd	−3.3 cde	197 f	13 f	67 abc	47 def
Citric acid + sugar	48 h	12.4 bcde	9.3 bcd	−1.7 cd	215 ef	0 f	100 a	80 abc
Citric acid + sugar + aluminum sulfate	48 h	12.2 cde	9.6 bcd	0.9 cd	251 de	53 cd	47 bcd	67 bcd
Citric acid + sugar + Greenshield	48 h	11.9 def	8.8 bcd	0.3 cd	206 ef	20 ef	53 bcd	80 abc
Citric acid + sugar + Kathon CG	48 h	13.0 abcd	9.6 bcd	1.8 cd	226 ef	13 f	53 bcd	87 abc
Floralife Clear Professional Flower Food	48 h	13.1 abcd	9.0 bcd	2.2 cd	225 ef	0 f	47 bcd	93 ab
Chrysal Clear Professional 2	48 h	13.2 abc	8.1 cd	0.6 cd	200 f	13 f	47 bcd	93 ab
7 Up	Until termination	13.0 abcd	14.4 a	21.1 a	313 bc	73 bc	33 cd	93 ab
Lemon juice + sugar	Until termination	8.9 h	10.2 bc	−12.1 e	282 cd	93 ab	20 d	33 ef
Citric acid + sugar	Until termination	9.9 gh	10.8 b	−6.2 de	326 abc	73 bc	33 cd	27 f
Citric acid + sugar + aluminum sulfate	Until termination	10.9 fg	9.5 bcd	1.7 cd	332 abc	100 a	20 d	60 cde
Citric acid + sugar + Greenshield	Until termination	13.5 ab	11.1 b	12.4 ab	332 abc	0 f	47 bcd	100 a
Citric acid + sugar + Kathon CG	Until termination	13.5 ab	10.3 bc	16.2 a	367 a	0 f	47 bcd	80 abc
Floralife Clear Professional Flower Food	Until termination	13.7 a	7.8 cd	6.0 bc	347 a	0 f	73 ab	80 abc
Chrysal Clear Professional 2	Until termination	13.9 a	7.2 d	3.3 bcd	308 bc	0 f	33 cd	87 abc
Significance[e]								
Overall		<0.0001	0.0007	<0.0001	<0.0001	<0.0001	0.0071	0.0001
Compound (C)		0.0197	NS	NS	<0.0001	<0.0001	NS	0.0205
Duration (D)		<0.0001	0.0338	0.0002	<0.0001	<0.0001	0.0003	0.0121

[a]: Dry weight, [b]: final fresh weight, and [c]: percentage of stems exhibiting termination symptoms were recorded as described in Table 2.
[d]: Mean separation within columns by Fisher's LSD at $P \leq 0.05$.
[e]: P-values were obtained using GLM procedures (version 9.3; SAS Institute Inc.).
[NS]: Nonsignificant at $P > 0.05$.

development of termination symptoms and overcame the negative effects of microbial contamination.

For the remaining treatments, the optimum biocide varied with the flower species. Citric acid and sugar combined with Kathon CG were effective as antimicrobial compounds for sunflowers, when continuously applied for marigolds and when applied for 48 h for roses. Citric acid and sugar combined with aluminum sulfate extended the vase life of marigolds when applied for 48 h and that of cut roses when used continuously. Citric acid and sugar combined with Greenshield were optimum when applied to roses and continuously to sunflowers. Jones and Hill (1993), Kuiper et al. (1995), Elhindi (2012), and Locke (2010) also reported the significance of carbohydrates and germicides for extending postharvest longevity of cut flowers. More specifically, aluminum sulfate has been reported as effective for vase life extension of several cut species, such as lisianthus (Liao et al., 2001) and roses (Ichimura et al., 2006). Addition of Kathon CG or Greenshield effectively controlled bacterial populations in the vase solutions (visual observation).

Compared to short-term application (48 h), continuous use of citric acid and sugar plus Greenshield or Kathon or commercial preservatives resulted in similar or longer vase lives of marigolds and sunflowers. These results depict the necessity of continuous provision of carbohydrates in the vase solutions for continuing metabolic processes for some flower species. Kuiper et al., (1995), Elhindi (2012), and Locke (2010) also reported the significance of carbohydrates for extending postharvest longevity of cut flowers. In addition, the continuous provision of citric acid and sugar plus Greenshield or Kathon or commercial preservatives enhanced water uptake and either reduced fresh weight loss or increased fresh weight gain during the vase period.

On the other hand, for roses, the continuous application of preservatives resulted in a vase life shorter or similar to that in the 48-h treatments. The sugar levels used in the preservatives may have been too high, damaging the flowers when used continuously. Stems placed continuously in solutions with higher sugar levels developed petal necrosis, which may have been the result of toxicity from high sugar concentrations in the vase solution. In particular, lemon/lime soda reduced the vase life of cut rose stems when used until termination, which demonstrated the sensitivity of cut roses to excessive sugar concentrations in vase solutions, resulting in necrosis and early senescence (Markhart and Harper, 1995). However, cut stems placed continuously in lemon/lime soda had the highest dry weight of stems compared to other preservative solutions. Maintenance of low pH in solutions containing soda might have maintained continued metabolic activities and water uptake, resulting in maintaining higher dry matter in the cut stems until termination.

For all 3 species, the continuous provision of sugar and lemon juice or citric acid and sugar resulted in a similar or shorter vase life compared to 48-h applications. The reduction in vase life due to continuous provision of sugar plus lemon juice or citric acid was especially great in roses and sunflowers, resulting in a vase life shorter than that with just tap water. Presence of microbial colonies in vase solutions may have blocked the vascular system, causing reduction in water uptake and rapid water loss and ultimately reducing fresh weight and longevity. As a consequence of reduced water uptake, cut roses exhibited higher rates of bent neck. In addition, continuous application of sugar and lemon juice or citric acid resulted in low percentages of rose leaf necrosis and sunflower petal abscission and necrosis, possibly due to the short vase life, which did not allow enough time for the termination symptoms to develop.

The current study focused on the effect of postharvest treatments on the vase life of cut flowers that were cultivated under the same environmental conditions (per species). Even though the cut flower production conditions were the same in our experiments, the conditions may still have exerted an effect on the obtained data (Fanourakis et al., 2013). A number of factors during production may influence vase life, water uptake, and other measured parameters. For example, cut roses grown at 90% RH have reduced control over water loss; thus, control of bacterial growth in the vase water through the treatments used in this study would be of utmost importance to ensure sufficient water uptake (Fanourakis et al., 2012, 2013). Contrary to this, if the same postharvest treatments were employed for cut flowers with tight control of water loss, their effect would likely be less pronounced.

In conclusion, this study demonstrated the potential impact of homemade or commercial floral preservatives on the postharvest longevity of cut marigold, rose, and sunflower stems. Continuous use of preservative solutions containing citric-Kathon, soda, or citric-Greenshield led to the best overall postharvest performance of cut stems of marigold and sunflower, similar to commercial preservatives. For cut roses, continuous treatment with citric-Al or pulsing with citric-Kathon proved to be the best, and these treatments may be used by industry and consumers as an alternative to commercial preservatives for vase life extension. However, recipes containing lemon juice plus sugar or citric acid plus sugar had detrimental effects on cut stems and should be avoided for handling the tested species.

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