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Postharvest water quality affects vase life of cut *Dendranthema*, *Dianthus*, *Helianthus*, and *Zinnia*

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ABSTRACT

Water quality can have a significant impact on the vase life of cut flowers. The effects of vase solution pH and electrical conductivity (EC) on the vase life and postharvest characteristics of *Dendranthema* L. 'Naru Lavender', *Dianthus* L. 'Burgundy Sangria', *Helianthus* L. 'Sunbright', and *Zinnia* L. 'Benary's Giant Scarlet' were investigated. Vase life of *Dendranthema* increased to 14.6 d in acidic solutions from 6.1 d for distilled water. Solution uptake of cut *Dendranthema* was also greater in acidic solutions (94 mL) compared to distilled water (76 mL). There was no significant difference in vase life of *Dendranthema* when solution EC ranged from 0.50 dS m^{-1} (21.7 d) to 4.00 dS m^{-1} (19.3 d) of NaCl; however, all solutions with NaCl resulted in a longer vase life than distilled water. For *Dianthus* the use of buffers to alter pH reduced vase life from 24.4 d for the non-buffered control to 19.9 d for the citrate buffered solutions, but no effect of actual pH was noted. Additionally, increasing the EC from 0.00 to 4.00 dS m^{-1} decreased vase life by 10 d. Cut *Zinnia* stems were not influenced by solution pH, but as EC increased from 0.00 to 4.00 dS m^{-1} vase life decreased from 10.6 to 6.8 d. *Helianthus* vase life was not affected by EC, but decreasing pH increased vase life by 1.1 d when stems were held in acidic solutions compared to basic solutions. The use of commercial holding solution reduced the negative effects of high EC on salt-sensitive *Dendranthema*, *Dianthus*, and *Zinnia* and increased solution uptake. For *Dendranthema* vase life was 24.6 d when held in preservative at an EC of 2.50 dS m^{-1}, while it was reduced to 17.4 d without preservative at the same EC. For *Helianthus*, solutions with preservative had a solution uptake 10 mL greater than solutions without preservative. In general, stems with longer vase lives also had a high incidence of necrotic leaves and petals, petal wilt and bent neck. In conclusion, each species had unique reactions to the vase solution treatments, but the general effects were consistent: high solution pH or EC or the use of buffers either had no effect or reduced vase life and the use of floral preservatives increased vase life.

1. Introduction

Water quality can have a significant impact on the vase life of cut flowers. Cut flowers are usually placed in tap water, which depending on its source, can contain various chemical compounds, organic matter, and microorganisms and can vary in pH. Previous studies have found the positive effects of low solution pH on species such as *Rosa* L. (Regan and Dole, 2010; Conrado et al., 1980; Durkin, 1979) and *Helianthus* (Stevens et al., 1993). Regan and Dole (2010) found that optimal vase life for cut *Rosa* 'Freedom,' 'Charlotte,' and 'Classy' resulted from a low pH of 3.1 to 4.0. Low pH slows bacterial growth, improves stem water uptake, and increases fresh weight (Conrado et al., 1980; Durkin, 1979).

Another important factor affecting water quality is electrical conductivity (EC). Measurements of EC estimate the amount of total dissolved salts/solids (TDS), or the total amount of dissolved ions (salinity) in the water. Many studies have focused on the effects of EC associated with crop production; however, little information is available on postharvest EC problems with cut flowers. Frequently, flower producers, wholesalers, retailers, and consumers use highly mineralized water for holding cut flowers (Waters, 1966). Hard water containing calcium and magnesium is less harmful to vase life than softer water that contains a higher concentration of sodium; a low EC reduces interference with water uptake (Gast, 2000). The effects that EC has on vase life of flowers, including stems and leaves, depends on the concentration and species. Regan and Dole (2010) found that optimal vase life for cut *Rosa* 'Freedom,' 'Charlotte,' and 'Classy' resulted from an EC of 1.0 to 1.3 dS m^{-1}. The objectives of these studies were to investigate the effects of two water quality components, pH and EC, on the vase life and various postharvest characteristics of *Dendranthema* 'Naru Lavender', *Dianthus* 'Burgundy Sangria', *Helianthus* 'Sunbright', and *Zinnia* 'Benary's Giant Scarlet'.

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2. Materials and methods

2.1. pH

Cut stems of *Dendranthema* and *Dianthus* were received from commercial flower producers (Bogota, Colombia, South America) and cut *Helianthus* and *Zinnia* stems were harvested from field beds planted on 8 May 2009 in Raleigh, NC in 1.2 m × 30.5 m, loamy clay soil beds. Upon arrival or after harvest the stems were re-cut and placed into tap water for hydration. Stems were sorted into thirteen groups of 15 stems, according to either stem caliper (*Helianthus*), flower size (*Zinnia*), openness (*Dianthus*, *Helianthus*), or number of florets per stem (*Dendranthema*). Stems were cut to 45 cm, labeled, and placed into treatments. Stems were held in distilled water amended with one of the following buffers: (1) sodium citrate 2-hydrate (citrate) at 0.377 g L^{-1}, (2) bis–tris propane (bis–tris) at 0.361 g L^{-1}, and (3) sodium phosphate (phosphate) at 0.367 g L^{-1}. Each buffer solution was amended as needed to produce an acidic, neutral or basic pH. The acidic solutions were created by adding 3.3, 3.0, 2.7, or 0.6 mL L^{-1} of 1 M hydrochloric acid (HCl) to citrate, phosphate, and bis–tris buffered solutions or distilled water, respectively, to create a target pH of 3.2. Neutral solutions were created by adding 0.3, 1.7, 1.7, or 0.3 mL L^{-1} of HCl to citrate, phosphate, and bis–tris buffered solutions or distilled water, respectively, to create a target pH of 6.5. The basic solutions were created by adding 0, 0.2, 1.0, or 0.5 mL L^{-1} of 0.3 M sodium hydroxide (NaOH) to citrate, phosphate, and bis–tris buffered solutions or distilled water, respectively, to create a target pH of 8.2. A distilled water (pH 5.3, 0.00 dS m^{-1}) control was also included. Each treatment had five replications (vases) of three stems per vase for a total of 15 stems per treatment. Vases were arranged in a completely randomized design and placed in a postharvest environment at 21 ± 2 °C at 40–60% RH under approximately 20 mol m^{-2} s^{-1} light for 12 h d^{-1}. Data collected included vase life and reasons for termination (all stems); initial fresh weight, termination fresh and dry weight (one stem per vase); and final solution pH and EC (when last stem is terminated in each vase). Water uptake was recorded for each vase when the first stem in the entire study was terminated. Reasons for termination included petal blueing, darkening, drop, fading, necrosis, rolling, or wilting, botrytis, bent neck, necrotic leaves, or necrotic stem were recorded as either present or not present.

2.2. Electrical conductivity

Cut stems of *Dendranthema*, *Dianthus*, *Helianthus*, and *Zinnia* stems were handled as indicated above prior to being placed in solutions of varying EC. Sodium chloride (NaCl) was added to distilled water to create an EC of 0 (0 g L^{-1}), 0.25 (0.119 g L^{-1}), 0.50 (0.265 g L^{-1}), 0.75 (0.369 g L^{-1}), 1.00 (0.497 g L^{-1}), 2.00 (1.033 g L^{-1}), 2.50 (1.294 g L^{-1}), 3.00 (1.601 g L^{-1}), or 4.00 (2.163 g L^{-1}) dS m^{-1}. NaCl was also added to distilled water plus a holding preservative at 10 mL L^{-1} (pH 3.7, EC 0.40 dS m^{-1}, Floralife Professional, Floralife, Walterboro, SC) to create an EC of 0.41 (0 g L^{-1}) 0.50 (0.064 g L^{-1}), 0.75 (0.186 g L^{-1}), 1.00 (0.318 g L^{-1}), 2.00 (0.850 g L^{-1}), 2.50 (1.176 g L^{-1}), 3.00 (1.459 g L^{-1}), or 4.00 (2.082 g L^{-1}) dS m^{-1}. An EC treatment of 0.25 dS m^{-1} was not included due to the initial EC of the holding solution being 0.41 dS m^{-1}. Each treatment had five replications (vases) of three stems per vase for a total of 15 stems per treatment. Postharvest environment and data collected were the same as indicated above.

2.3. Statistical analysis

Data were analyzed using Analysis of Variance (ANOVA) procedures using the General Linear Models (GLM) procedure using vase as the experimental unit and means were separated using Tukey's Multiple Comparison procedure at $P \leq 0.05$. All statistical analysis was performed using SAS (Version 9.3, SAS Inst., Inc., Cary, NC). Trend analysis procedure was also conducted on the EC treatment data and binomial data (reasons for termination) were analyzed using the GLIMMIX procedure, a generalized linear mixed model (GLMM). Where appropriate, relationships between parameters were fitted to non-linear regression models using Microsoft Excel (Microsoft Co., Redmond, WA).

3. Results

3.1. Dendranthema pH

Solution pH and buffer interacted such that an acidic solution buffered with phosphate resulted in the longest vase life of 18.2 d, while an acidic solution buffered with citrate had a vase life of 11.1 d (Table 1). The lowest vase life, 6.1 d, resulted from non-buffered solutions with neutral or basic pH and the distilled water control. Solution uptake was greatest in the non-buffered acidic treatment at 103 mL per stem and lowest in the non-buffered basic solution at 67 mL. Solutions buffered with phosphate had a greater decrease in fresh weight of 14.8 g as compared to bis–tris and citrate with a loss of 11.6 and 10.6 g, respectively. Non-buffered solutions had a 12.7 g decrease in fresh weight. Bent neck was observed on 53% of stems in the acidic solution buffered with bis–tris and the basic solution buffered with phosphate. Necrotic petals were observed on 100% of stems in the phosphate buffered neutral solution, while no stems had necrotic petals in the non-buffered neutral solutions. Incidence of necrotic stem was highest in bis–tris or phosphate buffered acidic solutions at 60% and 53%, respectively. The only treatment to have 100% incidence of necrotic leaves was an acidic pH buffered with phosphate (Table 1).

3.2. Dianthus pH

The distilled water treatment resulted in the longest vase life of 25.9 d compared to the citrate buffered neutral solution with the shortest vase life of 16.7 d (Table 2). Solution uptake was greatest in the distilled water control and acidic solutions of 48 and 47 mL per stem, respectively, while neutral and basic solutions were 44 mL. Acidic solutions resulted in less of a reduction in fresh weight of 1.42 g, as compared to the average of the other pH solutions of 3.02 g. The incidence of necrotic petals ranged from 80% for the phosphate buffered acidic solution to 13% for the phosphate buffered neutral solution (Table 2). The non-buffered solutions had the lowest incidence of petal wilt of 70%, whereas bis–tris had the highest of 92% (data not presented). Citrate and phosphate were intermediate for petal wilt at 83% and 79%, respectively.

3.3. Helianthus pH

Solution pH had a statistically significant (0.0089) effect on vase life of *Helianthus* with the unaltered control and acidic solutions had the longest vase lives of 11.3 d, while neutral lasted 10.7 d, and basic solutions had the shortest vase life of 10.2 d; however, these differences are not great enough for practical significance. The interaction between buffer and pH had significant effects on the change in pH and EC of the solutions (Table 3), but not on vase life. The non-buffered acidic treatment increased in pH the most by 2.50 pH units and the non-buffered basic solution decreased the least by 1.82 pH units. The solution EC increased the most in both the bis–tris basic and phosphate neutral treatments (0.11 dS m^{-1}) and least in the distilled water control (0.01 dS m^{-1}). Neutral solutions showed less incidence of petal drop at 18% as compared to the distilled water control at 47%; acidic and basic solutions were intermediate at 37% and 40% (data not presented). Stems in bis–tris and