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# VASE WATER EFFECTS ON POSTHARVEST LONGEVITY AND WATER RELATIONS OF *Gladiolus grandiflorus* 'WHITE PROSPERITY'

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Water from different sources was compared in regard to optimizing the postharvest performance of cut gladiolus flowers. Tap water from different flower markets was compared with distilled, deionized, canal, and carbonated water to find the best water type to be used by the industry in regards to postharvest longevity and water relations of cut gladiolus. Carbonated water proved to be the best water for handling cut gladiolus as it not only extended longevity, but also maintained relative fresh weight, and continued water uptake by the cut stems. Deionized water and distilled water were better than tap water from different regional flower markets. The canal water and tap water from Pattoki were the worst water types due to their higher heavy metals and salt levels; therefore, the growers and florists should avoid using these water types for handling their cut flowers. In summary, cut gladiolus should be placed in carbonated water for its effective control on bacterial proliferation and lower pH. Additionally, tap water should be analyzed before using for cut flower handling.
**Keywords:** Gladiolus, relative fresh weight, sword lily, vase life, vase solution uptake, water sources.

## INTRODUCTION

*Gladiolus grandiflorus*, a member of family Iridaceae, is one of the four most popular cut flowers in the world (Bai *et al.,* 2009; Memon *et al*., 2012, 2013). In Pakistan, it is most popular bulbous cut flower which has high demand due to its easy short-duration production, gorgeous spikes of several different colors, and high returns on investment. While its cultivation has increased in the country during last decade, its postharvest handling protocols have not been standardized, which may cause shorter vase life. Due to this reason, despite quality production, a higher percentage of cut gladiolus stems have shorter postharvest longevity, which can be attributed to several factors, e.g., improper handling, non-availability of standard preservatives, geotropism, use of good quality water to hydrate the stems etc.
The longevity of cut flowers is greatly affected by vase water composition and is one of the major challenges for florists today (Ahmad *et al*., 2013a). Water quality is also an important concern for consumers (Marandi *et al*., 2011). Use of tap water for handling cut flowers is not recommended, because of variable salt composition, which causes variations in the keeping quality of cut flowers (van Meeteren *et al.,* 2000). Therefore, deionized water should be used for cut flowers during postharvest handling (Halevy and Mayak, 1979). It has also been reported that deionized water itself is not standardized due to its different properties. For example, use of DI water from two different sources resulted in significantly different changes in fresh weight during vase life (van Meeteren *et al.,* 2000). For research, the scientists suggest using distilled water as a common control vase solution (Reid and Kofranek, 1980). However, the use of different water sources in published reports suggests that there is no recommended standard vase water for postharvest research (van Meeteren and van Gelder, 1999). However, it is difficult to use deionized or distilled water in the cut flower industry, which necessitates using available tap water. Therefore, the tap water should be analyzed before use, because it can vary greatly in the physico-chemical properties, which can affect postharvest longevity and water relations of the cut flowers.
Addition of 10 mM KCl to the vase solution improved water status of the leaves and thereby extended the longevity of cut *Chamelium unicatum* foliage (Joyce *et al*., 2000). Tap water may significantly vary in mineral composition. Common salts in tap water included Ca $(HCO_3)_2$ and $CaSO_4$, and these salts determined water hardness. European guidelines suggested 100 mg $L^{-1}$ calcium as the maximum concentration in tap water (Anonymous, 1980). Sulfate should preferably be 25 - 250 mg $L^{-1}$, and calcium 60 mg $L^{-1}$ and $HCO^{-3}$ 30 mg $L^{-1}$ as minimum concentrations, when de-hardening is practiced.
Tap water is mostly used as vase solution; however, its composition also affects the efficacy of chemical solutions being made from it, including pulsing, holding and bud opening solutions (Brecheisen *et al*., 1995). High bacterial populations are often present in water used by growers, wholesalers, retailers and consumers to hydrate cut flowers (Macnish *et al.,* 2005). Moreover, distilled and deionized water is also being used in Europe for cut flowers handling

due to being readily available and less expansive (van Meeteren and van Gelder, 1999).

Although there is plenty of literature available on enhancing the postharvest life of cut flowers by addition of different biocides and preservatives (Ichimura *et al*., 1999; Regan and Dole, 2010; Ahmad *et al*., 2013b), there is scarce information available on quality of vase water for the industry. Therefore, a study was conducted to compare water from eight different sources used by the industry for holding cut gladiolus to determine their effect on vase life and water relations of gladiolus. It was hypothesized that water used by the industry from different sources has different effects on postharvest performance of cut gladiolus.

## MATERIALS AND METHODS

A survey of different flower markets of Punjab was conducted (data not presented) regarding the water being used for handling cut flowers. Based on the information obtained from the survey, water from different sources was collected and kept in air tight bottles for two to three days at room temperature before setting up the study. Cut *Gladiolus grandiflorus* 'White Prosperity' was grown at Floriculture Research Area, University of Agriculture, Faisalabad, Pakistan and stems were harvested between 0800-0900 h in February, 2011, at commercial maturity, when 1-2 lower florets started showing color. All leaves were trimmed except the terminal one on each stem. The harvested stems were kept vertical in buckets containing Faisalabad tap water to avoid negative geotropism. After trimming leaves, the stems were shifted to postharvest floriculture laboratory within 1 h of harvest, sorted into eight similar groups according to stem caliper and total number of florets, re-trimmed from bases to final length of 75 cm and kept individually in glass vases containing 200 mL water from respective sources. Each treatment had 10 replications of stems placed individually in vases.

Water samples were collected before start of experiment as well as at the end of vase life and analyzed for their physico-chemical characteristics (Table 1) and salt levels (Table 2). The vases with cut stems were arranged in postharvest evaluation laboratory maintained at 20±2ºC and 60±10% relative humidity under a photosynthetically active radiation flux of ~20 µmol $m^{-2}$ $s^{-1}$ from white florescent tubes on a daily 12 h of photoperiod. Treatments included tap water from commercial flowers markets of Faisalabad, Pattoki, Lahore, Rawalpindi, distilled water, deionized water, canal water and carbonated water (diet 7 Up).

Data collected included vase life (period from placing stems in vase water until they were dead), relative fresh weight

**Table 1. Initial and final physico-chemical composition of different sources/ types of water**

| Treatments | pH | | EC (dS $m^{-1}$) | | Sodium adsorption ratio | | Residual sodium carbonate (meq $L^{-1}$) | |
|---|---|---|---|---|---|---|---|---|
| | Initial | Final | Initial | Final | Initial | Final | Initial | Final |
| Faisalabad tap water | 6.0 | 5.4 | 1.13 | 1.08 | 2.65 | 3.40 | 3.4 | 3.6 |
| Pattoki tap water | 5.4 | 5.2 | 3.30 | 3.27 | 28.6 | 32.76 | 7.3 | 10.0 |
| Lahore tap water | 5.4 | 5.3 | 0.55 | 0.54 | 2.07 | 4.77 | 1.1 | 2.0 |
| Rawalpindi tap water | 5.7 | 5.0 | 0.22 | 0.44 | 0.47 | 2.88 | 0.8 | 1.0 |
| Distilled water | 7.1 | 5.2 | 0.39 | 0.39 | 4.50 | 4.16 | 1.0 | 0.8 |
| Deionized water | 5.9 | 4.2 | 0.01 | 0.01 | 0.24 | 0.32 | 0.1 | 0.2 |
| Canal water | 5.1 | 5.0 | 0.26 | 0.25 | 3.60 | 0.84 | 1.0 | 1.2 |
| Carbonated water (diet 7 Up) | 2.1 | 2.1 | 0.71 | 0.99 | 3.38 | 6.54 | 0.2 | 0.8 |

**Table 2. Initial and final salt levels of different sources /types of water**

| Treatments | $NO_3^-$ (mg $L^{-1}$) | | $HCO_3^-$ (mg $L^{-1}$) | | $Cl^-$ (mg $L^{-1}$) | | $Na^+$ (mg $L^{-1}$) | | $Ca^{+2}$ and $Mg^{+2}$ (mg $L^{-1}$) | | $K^+$ (mg $L^{-1}$) | | $PO_4^{-3}$ (mg $L^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Initial | Final | Initial | Final | Initial | Final | Initial | Final | Initial | Final | Initial | Final | Initial | Final |
| Faisalabad tap water | 81.2 | 76.9 | 6.0 | 6.0 | 4.0 | 5.5 | 4.3 | 3.8 | 7.0 | 8.0 | 29.0 | 21.0 | 0.09 | 0.24 |
| Pattoki tap water | 123.1 | 71.3 | 11.0 | 13.0 | 12.5 | 12.0 | 18.9 | 20.1 | 4.7 | 3.0 | 29.0 | 32.0 | 0.01 | 0.16 |
| Lahore tap water | 26.9 | 18.2 | 7.0 | 6.0 | 12.5 | 1.3 | 2.9 | 3.5 | 4.9 | 4.0 | 19.0 | 7.0 | 0.01 | 0.75 |
| Rawalpindi tap water | 36.8 | 24.9 | 4.0 | 4.0 | 1.7 | 2.5 | 2.6 | 1.4 | 3.2 | 5.0 | 10.0 | 27.0 | 1.27 | 0.24 |
| Distilled water | 24.7 | 19.7 | 4.0 | 2.0 | 4.0 | 3.7 | 4.5 | 4.0 | 3.0 | 1.2 | 38.0 | 8.0 | 0.31 | 0.38 |
| Deionized water | 2.8 | 3.7 | 2.0 | 2.0 | 1.4 | 1.2 | 1.5 | 0.2 | 1.9 | 2.8 | 3.0 | 22.0 | 0.09 | 0.16 |
| Canal water | 11.6 | 8.1 | 3.0 | 4.0 | 3.3 | 2.4 | 2.2 | 2.4 | 4.5 | 3.9 | 10.0 | 10.0 | 0.31 | 0.31 |
| Carbonated water (diet 7 Up) | 180.4 | 174.2 | 5.0 | 3.0 | 3.2 | 8.9 | 3.1 | 8.5 | 5.5 | 3.2 | 27.0 | 37.0 | 0.38 | 3.55 |

(RFW), calculated according to the formula: RFW (% of initial fresh weight) = $(FW_t/FW_{t=0}) \times 100$; where $FW_t$ is the fresh weight of stem (g) at t= 0, 1, 2, 3, etc., and $FW_{t=0}$ is the fresh weight of the same stem (g) at t= day 0 (He *et al.*, 2006; Ahmad, *et al*., 2011), average daily water uptake rate (WUR) calculated by the formula: WUR (g stem$^{-1}$ day$^{-1}$) = $(S_{t-1} - S_t)$; where, $S_t$ is the weight (g) of vase containing water (g) at $t$ = day 1, 2, 3 and etc., $S_{t-1}$ is the weight of vase containing water (g) on the previous day (He *et al.*, 2006; Ahmad, *et al*., 2011), initial and final fresh weights (g) of a stem, fresh weight change, calculated according to the following equation: FWC (g) = FFW – IFW; where FFW is the final fresh weight and IFW is the initial fresh weight, days to first wilt (d), and number of florets opened (%) = (florets opened/ total florets) × 100. Cut stems were observed daily for visual appeal during the vase life evaluation period and were considered to have reached the end of their vase life when 50% or more florets on an inflorescence exhibited unattractive appearance due to petal wilt, petal drying, or bent neck (Joyce *et al*., 2000; Ahmad *et al.*, 2011).

Experiment was set up in a completely randomized design and data were analyzed using analysis of variance (ANOVA) with General Linear Models (GLM) procedures of the Statistical Analysis System (SAS, version 9.3, SAS Inst. Inc. Cary, NC, USA). Means were separated using Tukey's Studentized range test at $P \leq 0.05$.

## RESULTS AND DISCUSSION

Relative fresh weight (RFW) (% of initial weight) increased up to day 3 of vase life (Fig. 1) for tap water from Pattoki and Rawalpindi, along with distilled water and canal water and until day 4 for tap water from Faisalabad, and Lahore, along with deionized and carbonated water. Thereafter, a rapid decrease was observed in stems kept in canal water followed by Pattoki water. Higher RFW was maintained by carbonated water until end of the vase life followed by Faisalabad tap water and deionized water. Stems placed in carbonated water had maximum RFW, whereas, those in canal water had minimum RFW. Vase water from different sources had inconsistent effect on RFW (%) of gladiolus stems during the vase life evaluation period. Carbonated water maintained higher RFW throughout the vase period, which might be due to the presence of anti-microbial compound and low pH, which had detrimental effects on microbial populations thereby controlling the blockage of stem ends with bacteria and thus regulating the flow of vase water through the stem vessels. Our results confirmed the findings of Macnish *et al*. (2008) who reported longer vase life of selected cut flowers by controlling the proliferation of aerobic bacteria in vase water. Van Meeteren *et al.* (2000) also suggested that several ions at low concentrations commonly present in tap water could positively influence the water balance of cut chrysanthemums whereas by using deionized water, fresh weight decreased rapidly after 1 - 3 d of vase life.

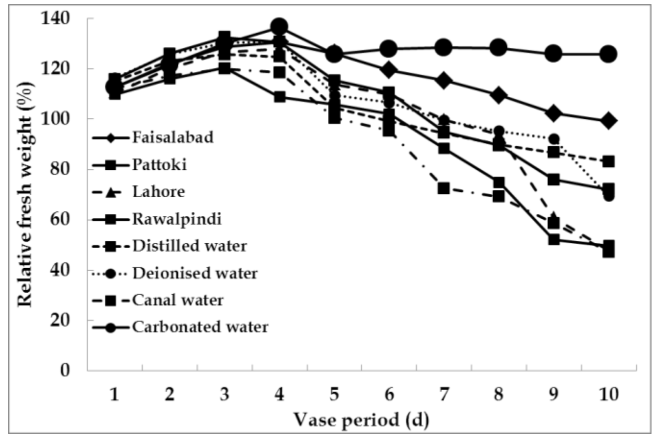


**Figure 1. Changes in relative fresh weight of gladiolus stems during vase period in different sources/ types of vase water. Symbols are averages of 10 replicate stems**

Stems placed in distilled water had greatest WUR (g g$^{-1}$ day$^{-1}$), whereas, the stems in tap water from Pattoki had least water uptake rate (Fig. 2). Tap water from Faisalabad, Lahore and Rawalpindi maintained higher uptake rate up to day 2 of vase life followed by a rapid decrease in WUR after day 2 until end of the vase life in all types of water. Tap water from Pattoki had greatest decrease in WUR while carbonated water had the smallest decrease in WUR during vase life evaluation period. Water uptake rate of gladiolus stems also varied inconsistently among different water types/ sources; however, carbonated water maintained a relatively higher WUR compared with other water types/ sources (Fig.2). These results confirmed the findings of Nagarajaiah and Reddy (1991) who used different $CaCl_2$ concentrations in vase water which improved water uptake by cut rose stems. van Meeteren *et al.* (2000) also reported similar results using DI water as vase water and recommended using tap water instead of deionized water for cut flower handling. Positive effect of carbonated water on relative fresh weight, water uptake rate, fresh weight change, and vase life suggested that it may be used as alternate to tap water, deionized water, or distilled water for extending the cut flowers longevity and maintaining water relations of cut flowers. Carbonated water might have lowered the bacterial contamination in vase solutions due to its antimicrobial properties and low pH, which maintained water uptake by the stems and increased longevity. Positive effect of carbonated water on longevity and water relations of several specialty cut flowers has also been recorded (I. Ahmad, unpublished).

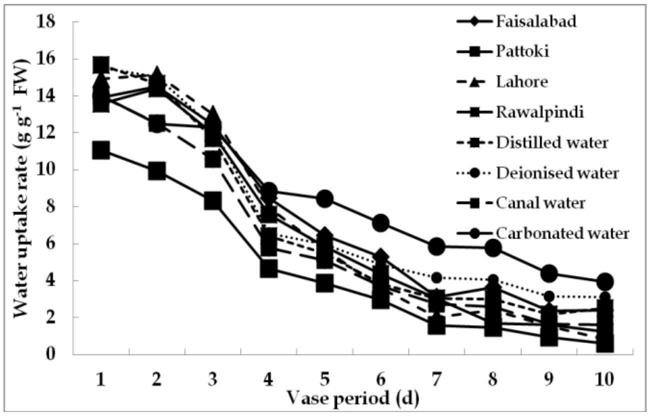


**Figure 2. Changes in rate of water uptake of gladiolus stems during vase period in different sources/ types of vase water. Symbols are averages of 10 replicate stems**

Stems in carbonated water had greater final than initial fresh weight, resulting in a higher fresh weight change compared with other water sources/ types, which had decreased final fresh weight and thereby negative fresh weight change except deionized water (Table 3). Cut gladiolus stems placed in carbonated water had longest vase life, while all other water types/ sources had statistically similar vase life (Table 3). Stems kept in Pattoki tap water had shortest vase life, indicating that growers and florists from Pattoki should not use tap water for handling cut gladiolus stems due to higher electrical conductivity, presence of heavy metals and higher salts levels (Tables 1 and 2). Stems placed in distilled water exhibited first wilt symptoms earlier than other water types/ sources (Table 3). For number of opened florets, stems placed in carbonated water had greater florets opened than other water types/ sources, while the stems placed in canal water had least florets opened at the end of vase life (Table 3).

Relatively low relative fresh weight, water uptake rate, fresh weight change, vase life, first wilt, and floret opening for the stems placed in canal water showed its highly detrimental effects on longevity of cut gladiolus stems. Stems in canal water had a slight increase the RFW initially up to day 3 of vase life, which may be due to the presence of relatively higher concentration of dissolved metal ions by creating a positive potential for absorption of dissolved metal ions by the stems. However, after that a rapid decrease in RFW suggested stem end blockage due to profusion of microbes and dirt particles present in canal water (de Witte and van Doorn, 1988; Hoogerwerf and van Doorn, 1992; Macnish *et al.*, 2005). These findings suggested that the growers and florists should be careful selecting vase water for handling their cut flowers and should always use good quality water to ensure the maximum postharvest longevity.

***Conclusion*****:** In summary, carbonated water proved best for extending cut gladiolus longevity. The growers and florists should preferably avoid using tap water particularly in Pattoki region due to the presence of higher concentrations of deleterious salts and either use carbonated water, deionized water, or distilled water for hydrating the cut gladiolus stems for the longest vase life.

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**Table 3. Effect of different water sources/ types on vase life, fresh weight change, days to first wilt, and number of opened florets of *Gladiolus grandiflorus*.**

| Treatments | Vase life (days) | Fresh weight change[1] (g) | Days to first wilt (days) | Number of opened florets (%) |
|---|---|---|---|---|
| Faisalabad tap water | 10.7 ab[2] | -5.5 bc | 6.5 ab | 76 bc |
| Pattoki tap water | 9.3 c | -0.9 bc | 6.8 a | 67 c |
| Lahore tap water | 9.7 bc | -4.2 bc | 6.2 ab | 74 bc |
| Rawalpindi tap water | 9.9 abc | -6.5 bc | 6.7 ab | 70 bc |
| Distilled water | 10.4 abc | -3.3 bc | 5.8 b | 70 bc |
| Deionized water | 10.3 abc | 2.2 b | 6.1 ab | 81 ab |
| Canal water | 9.5 c | -8.9 c | 6.1 ab | 66 c |
| Carbonated water (diet 7 Up) | 11.0 a | 21.8 a | 6.5 ab | 91 a |
| Significance | * | *** | ns | ** |

[1]Final fresh weight – Initial fresh weight; Values are averages of 10 replicate stems; [2]Mean values within a column followed by different letters indicate significant differences according to Tukey's Studentized test at $P \leq 0.05$; $^{ns,*,**}$Non-significant or significant at $P \leq 0.05$, or $P \leq 0.01$, respectively

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