Pak. J. Agri. Sci., Vol. 53(4), 925-931; 2016
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
DOI: 10.21162/PAKJAS/16.5569
http://www.pakjas.com.pk

VASE WATER QUALITY IMPACT POSTHARVEST PERFORMANCE OF CUT *Polianthes tuberosa* L.'SINGLE' SPIKES

Muhammad Asif[1,*], Iftikhar Ahmad[1], M. Qasim[1] and Mohsin Bashir[1]

[1]Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan.
[*]Corresponding author's e-mail: roymasif@yahoo.co.in

Tuberose (*Polianthes tuberosa* L.), a high temperature tolerant geophyte is being successfully grown with minimal care, which makes it the only choice for the cut flower growers during summer season in Punjab, Pakistan. Currently growers, retailers and consumers hold their cut tuberose spikes in tap water. However, presence of salts in tap water poses threat to cut spikes and may shorten their postharvest longevity. Therefore, a study was conducted to evaluate the effect of water collected from various sources on postharvest longevity and keeping quality of cut tuberose spikes. The results demonstrated that spikes kept in carbonated plus distilled water (1:1) had longest vase life, with highest water uptake, and relative fresh weight. Moreover, it delayed floret opening time, increased open florets percentage and produced superior quality spikes as compared to other water sources. Spikes kept in distilled, deionized and reverse osmosis water also extended postharvest longevity of cut tuberose spikes. On the other hand, canal water or tap water available in local markets found unfit for handling cut tuberose spikes as these reduced vase life. Therefore, it is recommended that carbonated plus distilled water (1:1), distilled, deionized or reverse osmosis water should be used by the stakeholders instead of tap or canal water for extending vase life and maintaining quality of cut tuberose spikes.

Keywords: Tuberose, postharvest management, flower longevity, stakeholders, carbonated water.

INTRODUCTION

Tuberose (*Polianthes tuberosa* L.) is native to Mexico and a member of family Amaryllidaceae. Tuberoses spikes have 10-20 pairs of florets, which open from base to upwards, makes excellent cut flowers and are popular for their fragrance (De Hertogh and Le Nord, 1993). It is very popular cut flower in Punjab-Pakistan and in fact is the only major cut flower available in the florist shops during summer and very much appreciated by the consumers for its fragrance (Ashfaq *et al*., 2015).

Water composition affects cut flower longevity and therefore, a major concern for florists and consumers (Marandi *et al.,* 2011). For instance, cut flowers take up acidic water quickly. The growth of microorganisms is checked by acidity of vase water (pH 3.0-5.5) (Kuiper *et al*., 1995). However, effects of vase water quality on longevity of cut flowers are variable and recommendations vary regarding the use of tap or deionized water (Ahmad *et al*., 2013). Some characteristics of water are very important and they should be understood due to their effect on flowers, viz. Temperature, pH, soluble salts, alkalinity and hardness. Unless water is pure, it will have dissolved mineral salts in it, which affect the pH and contribute to the salinity, hardness and alkalinity of the water. They can interfere with water uptake because they change the osmotic potential of the water. They can burn leaves and petals because they can accumulate in the tips. Therefore, water with low soluble salt content is best for holding cut stems (Gast, 1997). On the other hand, certain ions in water may delay senescence of leaves (Mayak *et al*., 1978). Saleem *et al*. (2014) studied keeping quality of cut gladiolus flowers kept individually in glass vases containing 200 mL water collected from different commercial flowers markets, viz. Faisalabad, Pattoki, Lahore and Rawalpindi together with distilled water, deionized water, canal water and carbonated water (diet 7 Up). They reported that vase water from different sources had inconsistent effect on relative fresh weight (RFW) of gladiolus stems during the vase life evaluation period.

As the composition of tap water varies from place to place, therefore, there is no authenticity about its use as vase water. Moreover, higher bacterial populations are often present in water used by growers, wholesalers, retailers and consumers to hydrate cut flowers (Macnish *et al*., 2005). 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). Tap water might significantly differ in mineral composition. Common salts in tap water include $CaSO_4$ and $Ca(HCO_3)_2$ and these salts determine water hardness. European guidelines suggested 100 mg L^{-1} calcium as the maximum concentration (Anonymous, 1980) while sulphate should be 25-250 mg L^{-1} in tap water. According to Regan and Dole (2010), tap water has many other elements such as copper (Cu), iron (Fe), potassium (K), magnassium (Mg), managanese (Mn), phosporous (P) and zink (Zn), which may adversely affect the vase life and were not included in the water. The presence of several different ions may have other physiological effects in addition the increase in EC.

Most researchers routinely used deionized water (DIW) for their postharvest studies; however, most farmers, retailers and consumers hold their flowers in ordinary tap water because it is cheap and readily available. As a result, the use of DIW has the danger of exaggerating results as it does not represent practical holding conditions of cut flowers (van Meeteren *et al*., 2001). Poor water uptake by cut flowers is the result of using hard water which contains minerals that make water alkaline, while the use of low pH in hydrating solutions improve water uptake and the overall flower keeping quality (van Doorn, 1997). Water available for postharvest handling of cut flowers varies from place to place. The quality and composition of the water is quite variable and this implies that the postharvest performance of cut flowers will also vary according to the type of water used to make vase solutions.

Keeping in view popularity of tuberose among local growers and high market demand in local flower markets and use of variable sources of water at retail and consumer level, it was necessary to develop proper postharvest handling protocols for this popular cut flower. Therefore, a study was conducted to evaluate the effects of water quality on postharvest longevity and keeping quality of cut *Polianthes tuberosa* L. 'Single' spikes.

MATERIALS AND METHODS

***Plant material*:** Flowers grown in open field were harvested from a commercial farm early in the morning before 10:00 a.m., packed in cardboard boxes and immediately transported in air-conditioned vehicle to Postharvest and Floriculture Laboratory, Institute of Horticultural Sciences, University of Agriculture, Faisalabad, Pakistan, within 5 hours of harvest. Upon arrival, spikes were recut to 60 cm length for the removal of any air embolism. All leaves were removed from lower side of spikes except upper two and spikes were placed in separate jars according to the treatments having 500 mL of distilled water, in a vase life evaluation room at 23±2°C temperature, 60±10% R.H. and a photosynthetically active photon flux of 12 µmol m^{-2} s^{-1} with 12h photoperiod from cool white florescence tubes.

Water samples were collected before start and at the end of experiment and analyzed to note their Initial physico-chemical properties (Table 1) and Change in pH and EC of

Table 1. Initial physico-chemical properties of different types of water used in the study.

Water types/sources	Sodium adsorption ratio	NO_3^- (mg L^{-1})	HCO_3^- (mg L^{-1})	Residual Sodium Carbonate (meq L^{-1})	Cl^- (mg L^{-1})	Na^+ (mg L^{-1})	Ca^{++} and Mg^{++} (mg L^{-1})	K^+ (mg L^{-1})	PO_4^{-3} (mg L^{-1})
Distilled water (DD)	0.50	12.1	3.0	0.5	2.0	4.4	2.5	6.0	0.11
Deionized water (DIW)	0.24	2.8	2.0	0.1	1.4	1.6	1.9	3.0	0.08
Reverse osmosis water	0.60	18.2	3.0	0.9	4.1	3.5	3.5	8.0	0.55
Lahore tap water	2.07	22.9	5.0	1.1	8.5	3.2	4.8	16.0	0.01
Faisalabad tap water	2.65	51.2	5.0	2.4	4.0	5.3	6.7	21.0	0.19
Islamabad tap water	0.47	33.6	4.0	1.1	3.7	3.8	4.5	12.0	0.47
Pattoki tap water	18.20	112.1	9.0	3.3	6.5	11.2	4.8	19.0	0.01
Canal water	3.60	41.6	4.0	2.0	3.3	3.2	4.5	11.0	0.32
Carbonated water+DD (1:1)	2.38	90.4	3.0	0.2	2.3	2.5	4.5	21.0	0.28

Table 2. Change in pH and EC of vase water, while total soluble solids (TSS) change in florets. Values are averages of 15 readings.

Water types/sources	pH		pH change	EC (dS m^{-1})		EC change	TSS		TSS change
	Initial	Final		Initial	Final		Initial	Final	
Distilled water (DD)	7.1	7.4	0.3	0.35	0.39	0.04	7.9	7.0	- 0.9
Deionized water (DIW)	7.2	7.5	0.3	0.02	0.03	0.01	8.0	7.2	- 0.8
Reverse osmosis water (ROW)	7.5	7.7	0.2	0.53	0.55	0.02	7.8	7.2	- 0.6
Lahore tap water	8.1	8.3	0.2	0.95	0.98	0.03	7.9	7.4	- 0.5
Faisalabad tap water	8.4	8.7	0.3	1.20	1.24	0.04	7.8	7.2	- 0.6
Islamabad tap water	8.2	8.5	0.3	0.82	0.86	0.04	8.0	7.5	- 0.5
Pattoki tap water	7.8	8.1	0.3	2.30	2.33	0.03	7.8	7.3	- 0.5
Canal water	8.3	8.8	0.5	1.22	1.25	0.03	7.8	7.3	- 0.5
Carbonated water + DD (1:1)	3.7	3.8	0.1	0.41	0.45	0.04	7.8	8.1	+ 0.3

vase water, while total soluble solids (TSS) change in florets (Table 2). Treatments included water from eight sources, viz. distilled water (DD), de-Ionized water (DI), reverse osmosis water (ROW), tap water used by the flower retailers at Lahore, Faisalabad, Islamabad or Pattoki flower market, canal water, and carbonated water (7up) + DD (1:1).

***Measurements*:** For spike characteristics, data were collected on vase life, time from harvest to the condition when half of the florets were wilted or had bent neck (Ahmad *et al*., 2011), water uptake, measured in mL on day five of vase life by recording remaining volume of vase water and calculated as: Water uptake (mL) = ($S_0 - S_5$), where, S_0 is the amount of vase water on day 0 and S_5 is the amount of vase water on the day 5 (Kazemi and Ameri, 2012), and relative fresh weight (% of initial FW), on day 5 was calculated as:

$$\text{Water uptake (mL)} = (S_0 - S_5)$$

Where FW_5 was the fresh weight (g) of stem on day 5 and FW_0 was the fresh weight (g) of the same stem on day 0 (He *et al*., 2006; Ahmad *et al*., 2011). Number of days was counted from day 0 to when 50% of the total florets were completely opened on the spike and dry weight of same spike was measured whose fresh weight was measured earlier on day 0 from each replication. For dry weight estimation, cut spikes were packed in brown paper bags and kept in oven at 70°C for 48 hours (Ahmad, 2009), and dry weight percentage was calculated by using following formula: Dry weight % age = (DW/FW) × 100. Flower quality was rated by three different judges (postgraduate floriculture students) adopting the method described by Cooper and Spokas (1991) and Dest and Guillard (1987), in numbers using a scale ranging from 1 to 9, where 1 = Poor quality, 5 = Medium quality, 9 = Good quality.

For floret characteristics, average life of floret (h) was calculated by counting the numbers of hours starting from the opening of bud till floret lose its freshness. Length of two fully opened uppermost florets from each spike in each replication was measured on the last day of vase life with a measuring scale. Total number of open florets was calculated at termination as: Open florets (%age) = (florets opened/ total florets) × 100.

Initial and final pH and EC of vase water were recorded using pH and EC meter (Hanna-HI9813-6) to observe changes in pH and EC during the study. Total soluble solids of florets were measured on day 0 and at the end of vase life using six fully open florets to obtain sap from each replication. TSS in the sap was measured with the help of hand refractometer with a rage of 0 to 30 °Brix by placing one drop on the prism as described by Bayleyegn *et al.* (2012). Between samples, prism of refractometer was washed with alcohol, rinsed by distilled water and dried using tissue paper.

***Statistical analysis*:** Experiment was arranged in a completely randomized design with five replications in each treatment having three cut spikes in each experimental unit (glass Jar). Data were analyzed using General Linear Model (GLM) procedures of the Statistix 8.1 analytical software. Means were separated using Least Significant Difference test (LSD) at $P \leq 0.05$ (Steel *et al*., 1997).

RESULTS

***Change in total soluble solids (TSS) of florets (°Brix)*:** Data regarding difference between initial and final TSS contents of florets showed a decreasing trend in all water sources except in carbonated plus distilled water 1:1 in which increase in TSS was noted (Table 2). The maximum TSS loss was observed in florets of those spikes which were kept in distilled water (0.9 °Brix) followed by deionized water (0.8 °Brix). However, minimum loss in TSS (0.5 °Brix) was observed in Lahore, Islamabad, and Pattoki tap water or canal water each. On the other hand, increase (0.3 °Brix) in TSS was observed in the florets of spikes which were kept in solution containing carbonated plus distilled water (1:1).

Spike characteristics:

***Vase life (d)*:** Data revealed highly significant differences ($P \leq 0.0001$) among various sources of water for vase life (Table 3). Spikes kept in carbonated plus distilled water (DD) (1:1) had longest vase life (8.6 d) than other treatments and lasted 4.2 days longer than spikes kept in canal or tap water from Pattoki with vase life (4.4 d). Similarly, vase life of the spikes kept in distilled and deionized water had 7 and 6.8 days respectively. Spikes kept in tap water from the retail flower markets of Islamabad, Lahore, Faisalabad and Pattoki or canal water had shortest vase life and statistically had no difference among each other.

***Water uptake (mL)*:** Data showed highly significant differences ($P \leq 0.0001$) among various sources of water for water uptake (Table 3). Spikes kept in carbonated plus distilled water (1:1) absorbed significantly greater volume of water (128 mL) than other sources of water, which was 40 mL greater than the water absorbed by the spikes kept in canal water, which had minimum water uptake (88 mL). Volume of water taken up by the spikes kept in distilled water (113 mL), deionized water (111 mL) and reverse osmosis water (108 mL) was greater than tap water from different sources but statistically similar. Moreover, non-significant differences were noted in the volume of water taken up by spikes kept in tap water from Lahore (101 mL), Faisalabad (101 mL), Islamabad (102 mL) and Pattoki (100 mL) and statistically less than carbonated water, DD water, or DI water but greater than canal water.

***Relative fresh weight (RFW) (% of initial FW)*:** Data depicted highly significant differences ($P \leq 0.0001$) among various sources of water for relative fresh weight (Table 3). Spikes kept in carbonated plus distilled water (1:1) exhibited highest relative fresh weight (118.9%) on day five of the

Table 3. Effect of different water sources on various spike characteristics of tuberose.

Water types/sources	Vase life (d) *	Water uptake* (mL)	Relative fresh weight** (%)^z	Days to open 50% Florets*	Dry weight (%)^{y,**}	Spike quality*
Distilled water (DD)	7.0±0.32 b^x	113±1.4 b	115.0±0.5 ab	3.6±0.24 b	10.9±0.2 bc	7.0±0.3 b
Deionized water (DI)	6.8±0.2 bc	111±1.5 bc	112.5±2.2 bc	3.4±0.24 b	10.8±0.2 bc	6.5±0.2 bc
Reverse osmosis water (RO)	6.2±0.2 c	108±1.4 bcd	109.9±2.0 cd	3.2±0.20 bc	11.0±0.3 bc	6.4±0.1 c
Lahore tap water	4.9±0.2 d	101±1.4 cd	105.9±0.6 d	2.6±0.24 cd	11.3±0.3 bc	5.4±0.2 d
Faisalabad tap water	4.6±0.24 d	101±1.1 cd	105.6±0.8 d	2.4±0.24 d	11.2±0.4 bc	4.9±0.1 ef
Islamabad tap water	5.0±0.24 d	102±0.7 cd	105.9±0.8 d	2.4±0.20 d	11.8±0.4 b	5.3±0.2 de
Pattoki tap water	4.4±0.01 d	100±1.2 d	106.1±0.5 d	2.2±0.24 d	10.6±0.4 c	4.6±0.1 f
Canal water	4.4±0.24 d	88±0.7 e	105.6±3.6 d	2.2±0.24 d	11.4±0.6 bc	4.4±0.2 f
Carbonated water + DD (1:1)	8.6±0.24 a	128±1.1 a	118.9±1.2 a	4.4±0.02 a	13.4±0.4 a	7.9±0.2 a
Significance^w	≤0.0001	≤0.0001	≤0.0001	≤0.0001	0.0003	≤0.0001

^{z}Relative fresh weight of spike (% of initial FW) = $(FW_5/FW_0) \times 100$; ^{y}Dry weight (%) = (DW/FW) x 100; ^{x}Means separation within column by Least significant difference test at $P \leq 0.05$; ^{w}P values were obtained using General Linear Model (GLM) procedures of Statistix 8.1; *Values are averages of 15 replicate spikes; **Values are averages of 5 replicate spikes.

vase life but statistically similar with RFW of spikes kept in distilled water (115%). Non-significant differences were observed in the RFW of spikes kept in the reverse osmosis water (109.9%), Lahore tap water (105.9%), Faisalabad tap water (105.6%), Islamabad tap water (105.9%), Pattoki tap water (106.1%) and canal water (105.6%).

***Days to open 50% florets (d)*: ** Highly significant differences (P≤0.0001) were recorded among various sources of water for days to open 50% florets (Table 3). Spikes kept in carbonated plus distilled water (1:1) took more days to open 50% florets (4.4 d) than the spikes kept in other water sources which were 2.2 days longer than the spikes kept in Pattoki or canal water (2.2 d). Days taken to open fifty percent florets by spikes kept in distilled water, demonized water and reverse osmosis water were 3.6, 3.4 and 3.2 days respectively and were statistically at par. Moreover, non-significant differences were observed regarding days to open 50% florets among the spikes kept in tap waters from retail flower markets of Lahore (2.6 d), Faisalabad (2.4 d), Islamabad (2.4 d) and Pattoki or canal water (2.2 d).

***Dry weight (%)*: ** Data revealed highly significant differences (P≤0.0003) among various sources of water for dry weight percentage (Table 3). Spikes kept in carbonated plus distilled water (1:1) showed 13.4% dry weight, which was significantly higher than spikes kept in other water sources and 2.8% greater than the spikes kept in Pattoki tap water, which exhibited minimum dry weight percentage (10.6%). However, non-significant differences were observed among the dry weight percentages of the spikes kept in distilled (10.9%), deionized (10.8%), reverse osmosis (11%), tap water from Faisalabad (11.2%), Lahore (11.3%) and Islamabad (11.8%) or canal water (11.4%).

***Spike quality*: ** Significant differences in the spike quality were observed (P≤0.0001) among various sources of water (Table 3). Significantly superior spike quality (7.9) was recorded for spikes kept in carbonated plus distilled water (1:1) than the spikes kept in other water sources, followed by spikes kept in distilled water (7.0) and deionized water (6.5). Spike quality kept in canal water was inferior (4.4).

Florets characteristics:

***Floret life (h)*: ** Highly significant differences (P≤0.0001) were observed among various sources of water for floret life of tuberose spikes. Significantly longer floret life (87.2 h) was observed in spikes which were kept in carbonated plus distilled water (1:1) as compared to other water sources and was 34.2 h. longer than minimum floret life noted in spikes kept in canal water (53.0 h). Non-significant difference was observed in the florets life of the spikes kept in distilled water and deionized water, viz. 77.8 and 74.9 h, respectively. However, their floret life was greater than the floret life of spikes kept in all other water sources except carbonated plus distilled water (1:1) (Table 4).

***Floret length (cm)*: ** Significant differences were observed (P≤0.0001) among various sources of water for floret length (Table 4). Longest floret length (5.4 cm) was noted in spikes kept in carbonated plus distilled water at (1:1). It was 0.8 cm longer than the floret length noted in the spikes kept in canal water (4.6 cm). Non-significant difference was observed in the floret lengths of spikes kept in distilled water (5.1 cm), deionized water (5.1 cm) and reverse osmosis water (5.0 cm). Likewise, floret length recorded in spikes kept in the tap waters of Islamabad (4.9 cm), Lahore (4.9 cm), Faisalabad (4.9 cm), and Pattoki (4.9 cm) also exhibited non-significant differences among each other.

***Open floret (%)*: ** Highly significant differences (P≤0.0001) were recorded among various sources of water for open florets percentage (Table 4). Highest percentage (83.0%) of opened florets was observed in the spikes kept in carbonated plus distilled water (1:1) than all other water sources and was 45% greater than the minimum percentage (38.0%) recorded in canal water. Non-significant difference was observed between deionized (64.4%) and reverse osmosis

Table 4. Effect of different water sources on various floret characteristics of tuberose spikes.

Water types/sources	Life (hr)*	Length (cm)*	Open florets (%)**
Distilled water (DD)	77.8±0.3 b[z]	5.1±0.05 b	70.0±1.4 b
Deionized water (DIW)	74.9±0.2 b	5.1±0.07 bc	64.4±1.8 c
Reverse osmosis water (ROW)	70.0±0.2 c	5.0±0.1 bcd	60.6±1.4 c
Lahore tap water	64.9±0.2 d	4.9±0.1 d	50.2±1.8 d
Faisalabad tap water	62.2±0.2 de	4.9±0.1 de	49.6±1.8 d
Islamabad tap water	60.0±0.2 e	4.9±0.1 cd	47.4±1.1 d
Pattoki tap water	61.0±0.0 e	4.9±0.05 de	45.2±3.1 d
Canal water	53.0±0.2 f	4.6±0.1 e	38.0±1.3 e
Carbonated water + DD (1:1)	87.2±0.2 a	5.4±0.1 a	83.0±1.2 a
Significance[y]	≤0.0001	≤0.0001	≤0.0001

[z]Means separation within column by Least significant difference test at $P \leq 0.05$; [y]P *v*alues were obtained using General Linear Model (GLM) procedures of Statistix 8.1; NS = Non-significant at *P*>0.05; *Values are averages of 30 replicate florets; **Values are averages of 15 replicate spikes.

water (60.4%) for this parameter. Furthermore, the open florets percentage of tuberose spikes kept in tap water of Lahore (50.2%), Faisalabad (49.6%), Islamabad (47.7%), and Pattoki (45.2%) were at par.

***Change in EC (dS m^{-1}) and pH*:** Vase water pH and EC of all treatment increased during vase life evaluation period (Table 4). Maximum increase in the pH of vase solution (0.5) was recorded in spikes which were kept in canal water. Whereas, minimum escalation in pH was recorded in spikes kept in carbonated plus distilled water (1:1). On the other hand, maximum increases in EC (0.04) was noted in the vase solution comprised of distilled water, Faisalabad or Islamabad tap water and carbonated Plus distilled water (1:1). Minimum increase in EC was observed in deionized water (0.01).

DISCUSSION

In present study, the spikes kept in carbonated plus distilled water (1:1) performed best for spike characteristics, viz. vase life, water uptake, relative fresh weight, days to open 50% florets, dry weight percentage and spike quality (Table 3). Besides, the floret characteristics, viz. floret life, floret diameter, floret length and open florets percentage (Table 4) were also better for spikes kept in carbonated plus distilled water (1:1). The better performance of various studied attributes in vase solution containing carbonated water might be attributed to the presence of anti-microbial compound and low pH, which effectively controlled microbial populations and blockage of stem ends with bacteria and thus regulating the flow of vase water through the stem vessels (Saleem *et al*., 2014).

On the other hand, spikes kept in canal water had poor performance in all studied parameters, which might be ascribed to stem end blockage of spikes due to profusion of microbes and dirt particles present in canal water (Saleem *et al*., 2014; Macnish *et al*., 2008). Similar results were also reported by de Witte and van Doorn (1988), Hoogerwerf and van Doorn (1992) and Macnish *et al*. (2005). Similarly, spikes kept in distilled water also maintained good keeping quality in studied attributes.

Water is the most important component of floral preservatives as it keeps flowers turgid. It is the medium for the solutes diffusion, maintenance of plant tissue turgor, solvent for most biochemical reactions and helps to maintain tissue temperature (van Meeteren *et al*., 2001). Water composition affects cut flower longevity and therefore, a major concern for florists and consumers (Marandi *et al*., 2011). For instances, cut flowers take up acidic water quickly. The growth of microorganisms is checked by acidity of vase water (pH 3.0-5.5) (Kuiper *et al*., 1995). Water characteristics like pH, temperature, soluble salts, alkalinity and hardness have pronounced effect on flower longevity. Water has dissolved mineral salts which affect the pH and contribute to the salinity, hardness and alkalinity of the water. They interfere with water uptake because they change the osmotic potential of the water. They also caused leaves and petals necrosis due to higher salts accumulation in the tips. Therefore, use of quality water with low soluble salt contents is a prerequisite for handling cut flowers (Gast, 1997).

The study reconfirmed the suitability of distilled water for extending the longevity of flowers (Rogers, 1973). Distilled water significantly increased the vase life compared to tap water (Jowkar and Salehi, 2005). Stems placed in distilled water had greatest water uptake, whereas, stems in tap water reported the least water uptake (Saleem *et al*., 2014). The cut flowers kept in distilled water lost minimum fresh weight. Besides, the stems kept in distilled water had higher water uptake (Ahmad *et al*., 2013). The presence of ions in the vase solution may increase the overall vase life (da Costa, 2015).

The poor performance of tuberose spikes kept in tap water from various sources of tap water could be due to greater variation in physico-chemical properties which greatly affect postharvest longevity and water relations of the cut flowers (Saleem *et al*., 2014). Dias and Patil (2003) reported a negative water balance where tap water was used which was attributed to an excessively high transpiration loss. Besides, use of tap water for handling cut flowers is prohibited since long time because of varying salts composition of tap water which causes variations in the keeping quality of cut flowers (van Meeteren *et al*., 2000). Moreover, higher bacterial populations are often present in water used by growers, wholesalers, retailers and consumers to hydrate cut flowers (Macnish *et al*., 2005) which might also be a reason of low vase life.

Tap water is mostly used as vase solution by the florists; however, its composition also affects the efficacy of chemical solutions being used as preservatives, including pulsing, holding and bud opening solutions (Brecheisen *et al*., 1995). It is evident from the results that TSS of florets decreased at the end of vase life in all water sources except in carbonated plus distilled water (1:1) where TSS contents increased. It may be due to the fact that carbonated water has high quantity of sugar, which was absorbed by the spikes and translocated to the florets and thus increase the TSS. The pH and electrical conductivity (EC) of vase solution disturbs the cut flowers keeping quality by affecting various spike and floret characteristics as observed in present study in which various sources of water were used. As different sources of water had different physico-chemical properties, therefore this variation changes the pH and EC of the vase solution and thereby vase life of tuberose cut flowers as observed in present study (Table 1).

In present investigation, various sources of tap water along-with canal, distilled, Deionized, Reverse osmosis and carbonated water were used. All these sources had different physiochemical properties (Table 1). Therefore, they had different pH and EC and thereby affected spike (Table 3) and floret (Table 4) characteristics of tuberose cut flowers differently. It was observed that pH and EC of the vase solution increased while TSS decreased except carbonated plus distilled water (1:1) in which TSS increased. Electrical conductivity (EC) of vase solution is one of the parameters that influence the water uptake by cut spikes. The excellent keeping quality of tuberose cut flowers kept in carbonated plus distilled water (1:1) might also be attributed to lower pH and EC of vase water (Table 1) which improved water uptake and extended the keeping quality. Similar results were observed by Kuiper *et al*. (1995), who reported that cut flowers take up acidic water quickly. Besides, the growth of microorganisms is checked by acidity of vase water (pH 3.0-5.5). On the other hand, shorter vase life of tuberose cut spike (Table 3) and florets (Table 4) characteristics in vase solution containing canal water and various sources of tap water might be related to higher pH, EC and soluble salts (Table 1). Presence of ions in the vase solution may increase the overall vase life and improve water uptake of flowers with favorable optimal EC between 0.60 to 0.87 dS m^{-1} (da Costa, 2015).

The study concluded that tuberose spikes kept in carbonated plus distilled water (1:1) had longer vase life, highest water uptake, more relative fresh weight, delayed florets opening time, more open florets percentage and superior quality as compared to all other water sources followed by in distilled, deionizes and reverse osmosis water. So, their use as vase water/solution is recommended for the stakeholders instead of tap water to maintaining quality of cut tuberose spikes for extended period of time.

REFERENCES

Ahmad, I. 2009. Production potential and postharvest management of cut rose flowers in Punjab (Pakistan). Ph.D. Thesis, Inst. Hort. Sci., University of Agriculture, Faisalabad, Pakistan.

Ahmad, I., D.C. Joyce and J.D. Faragher. 2011. Physical stem-end treatment effects on cut rose and acacia vase life and water relations. Postharvest Biol. Technol. 59:258-264.

Ahmad, I., J.M. Dole, A.S. Carlson and F.A. Blazich. 2013. Water quality effects on postharvest performance of cut calla, hydrangea, and snapdragon. Sci. Hortic. 153:26-33.

Anonymous. 1980. Council directive 80/778/EEC of 15 July 1980 on the quality of water intended for human consumption. Off. J. Eur. Communities L229, 30 August, 1980.

Ashfaq, M., M. Usman and Q. Mohy-ud-din. 2015. Production, Management and Marketing of Cut Flowers, 1st Ed. University Press, University of Agriculture, Faisalabad, Pakistan.

Bayleyegn, A., B. Tesfaye and T.S. Workneh. 2012. Effects of pulsing solution, packaging material and passive refrigeration storage system on vase life and quality of cut rose flowers. Afri. J. Biotechnol. 11:3800-3809.

Brecheisen, S., H.P. Haas and R. Rober. 1995. Influence of water quality and chemical compounds on vase life of cut roses. Acta Hort. 405:392-400.

Cooper, R.J. and L.A. Spokas. 1991. Growth, quality and foliar iron concentration of Kuntucky bluegrass treated with chelated iron source. J. Amer. Soc. Hort. Sci. 116:798-801.

da Costa, L.C., F.F. de Araújo, T.D.C. Mendes and F.L. Finger. 2015. Influence of electrical conductivity on water uptake and vase life of cut gladiolus stems. Ornamental Hort. 21:221-226.

De Hertogh, A. and M. Le Nord. 1993. The Physiology of Flower Bulbs, pp.589-601. Elsevier, Sci. Pub. The Netherlands.

de Witte, Y. and W.G. van Doorn. 1988. Identification of bacteria in the vase water of roses, and the effect of the isolated strains on water uptake. Sci. Hortic. 35:285-291.

Dest, W.M. and K. Guillard. 1987. Nitrogen and phosphorus nutritional influence on bentgrass. J. Amer. Soc. Hort. Sci. 112:769-773.

Dias, S.M.F. and A.A. Patil. 2003. Chemically fortified solutions to enhance the longevity of cut rose cv. Arjun. Karnataka J. Agric. Sci. 16:324-326.

Gast, K.L.B. 1997. Postharvest handling of fresh cut flowers and plant material. Cooperative Extension Service, Manhattan, Kansas. pp.1-11.

He, S.G., D.C. Joyce, D.E. Irving and J.D. Faragher. 2006. Stem end blockage in cut Grevillea 'Crimson Yul-lo' inflorescences. Postharvest Biol. Technol. 41:78-84.

Hoogerwerf, A. and W.G. van Doorn. 1992. Numbers of bacteria in aqueous solutions used for postharvest handling of cut flowers. Postharvest Biol. Technol. 1:295–304.

Jowkar, M.M. and H. Salehi. 2005. Effects of different preservative solutions on the vase life of cut tuberose flowers at usual home conditions. Acta Hort. 669:411-415.

Kazemi, M. and A. Ameri. 2012. Postharvest life of cut gerbera flowers as affected by nano- silver and acetylsalicylic acid. Asian J. Biochem. 7:106-111.

Kuiper, D., S. Ribot, H.S. van Reenen and N. Marissen. 1995. The effect of sucrose on the flower bud opening of ‘Madelon’ roses. Sci. Hortic. 60:325-336.

Macnish, A.J., R.T. Leonard and T.A. Nell. 2008. Treatment with chlorine dioxide extends the vase life of selected cut flowers. Postharvest Biol. Technol. 50:197-207.

Macnish, A.J., R.T. Leonard, K. Hughes and T.A. Nell. 2005. Bacteria-free solutions. Florists’ Rev. June, 2005, pp. 57–60.

Marandi, R.J., A. Hassani, A. Abdollahi and S. Hanafi. 2011. Improvement of the vase life of cut gladiolus flowers by essential oils, salicylic acid and silver thiosulfate. J. Medicinal Plants Res. 5:5039-5043.

Mayak, S., A.M. Kofranek and T. Tirosh. 1978. The effect of inorganic salts on the senescence Dianthus caryophyllus flowers. Physiol. Plant. 43:282-286.

Regan, E.M. and J.M. Dole. 2010. Postharvest handling procedures of *Matthiola incana* ‘Vivas Blue’. Postharvest Biol. Technol. 58:268-273.

Rogers, M.N. 1973. A historical and critical review of postharvest physiology research on cut flowers. HortScience 8:189-194.

Saleem, M., M.A. Khan, I. Ahmad and R. Ahmad. 2014. Vase water effects on postharvest longevity and water relations of *gladiolus grandiflorus* ‘White Prosperity’. Pak. J. Agri. Sci. 51:137-141.

Steel, R.G.D., T.H. Torrie and D.A. Dicky. 1997. Principles and Procedures of Statistics: A biometric approach, 3rd Ed. McGraw Hill. Inc., NY, USA.

van Doorn, W.G. 1997. Water relations of cut flowers. Hort. Rev. 18:1-85.

van Meeteren, U., H. van Gelder and W. van Ieperen. 2000. Reconsideration of the use of deionized water as vase water in postharvest experiments on cut flowers. Postharvest Biol. Technol. 18:169-181.

van Meeteren, U., H. van Gelder, W. van leperen and C. Slootweg. 2001. Should we reconsider the use of deionized water as control vase solution? Acta Hort. 543:257-264.