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Effects of chemical preservatives and water quality on postharvest keeping quality of cut Lisianthus (Eustoma grandiflorum L)

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HMJ; conceived idea, designed the study, prepared manuscript, MJN; conceived idea, designed study,collected data & analysis, laboratory analysis, preparation of manuscript, WK; conceived idea, designed study, prepared manuscript

ABSTRACT

This study was carried out to investigate effects of various chemicals added to vase solutions and also effects of water quality on the post-harvest physiology of Lisianthus (*Eustoma grandiflorum* L.) cut stems. The vase life, floret opening and water balance of Lisianthus cut stems were improved when cut flowers were held in vase solutions containing either 8-HQC, $AgNO_3$, NaOCl or their combinations. Vase solution containing 8-HQC at 250 ppm and NaOCl at 50 ppm produced the best results whereby vase life increased from 10 to 29 days, floret opening from 46 to 82%. Cumulative water uptake increased from 114 to 236 gm/hr *per* inflorescence compared to control cut flowers held in de-ionized water. The rate of water uptake, however, declined as flowers senesced in all vase solutions. However, $Al_2(SO_4)_3$ alone or in combination with NaOCl did not improve the vase life of cut flowers. Vase life and floret opening of cut flowers held in vase solutions made with water from various sources decreased significantly ($P>0.05$) compared to those held in de-ionized water. However, there was a significant ($P<0.05$) increase of the same parameters when 8-HQC and NaOCl were incorporated in vase solutions made from the various water sources and pH adjusted to 3.5. In conclusion, incorporation of 8-HQC and NaOCl into vase solutions improved the postharvest physiology of cut Lisianthus flowers. Incorporating biocides in vase solutions, made with water from any source and adjusting their pH to 3.5, improved the vase life, floret opening, and water uptake of cut flowers by two-fold regardless of the water source and quality.

Keywords Cut-flowers, *Eustoma grandiflorum*, floret opening, post-harvest, storage period, vase life.

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INTRODUCTION

In the absence of chemical floral preservatives, the short vase life and postharvest problems of Lisianthus (*Eustoma grandiflourm* L.) cut flowers continue to pose a challenge to the florist industry in Kenya and elsewhere. Some of the postharvest disorders associated with Lisianthus cut flowers include premature flower bud wilting, loss of leaf turgidity, weak flower pedicels and discoloration of basal floral stems (Hutchinson *et al*., 2011; Reid, 2000; Liao *et al*., 2001). Postharvest flower keeping quality of many cut flowers has been improved by the use of carbohydrate pulling as an energy source and suitable chemical preservatives including biocides (Halevy and Mayak, 1981). Biocides such as silver nitrate (AgNO3) aluminum sulphate ($Al_2(SO_4)_3$),8-hydroxyquinonline citrate (8-HQC), citric acid, sodium hypochlorite (NaOCl) and ascorbic acid, have been used successfully in different formulations and combinations to enhance the vase life and flower keeping quality of many cut flowers (Saini *et al*., 1994; Reddy *et al*., 1995). Reid (2000) and Liao *et al*. (2001) recommended the use of $Al_2(SO_4)_3$ at 200 and 150 ppm, respectively, for postharvest pre-treatment of cut Lisianthus. However, Cho *et al*., (2001) reported no improved postharvest qualities of cut Lisianthus when flowers held in vase solutions containing $Al_2(SO_4)_3$ at 200ppm and 8-HQC at 250ppm. Unlike researchers who routinely use

deionized water (DW) for their postharvest studies, most farmers, retailers and consumers hold their flowers in ordinary tap water because it is cheap and available. As a result, the use of DW has the danger of exaggerating positive results as it does not represent practical holding conditions of cut flowers (Van Meeteren *et al*., 2001). Water quality as described by pH value, electro-conductivity (EC), hardness, contents of phytotoxic elements and microorganisms which causes vascular occlusions, influence the postharvest longevity and quality of cut flowers (Haas and Roeber, 1993). The use of hard water which contains minerals that make water alkaline, results in poor water uptake by cut flowers 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.

This study was, therefore, conducted to evaluate the effects of chemical preservatives and water quality on postharvest vase life and keeping quality of cut Lisianthus.

MATERIALS AND METHODS

Plant Materials

The study was conducted using the popular 'Kyoto purple' cultivar of Lisianthus flowers obtained from Eustoma (K) Ltd., a commercial flower farm situated in Thika, 20 kilometres from the University of Nairobi in Kenya. Inflorescences were harvested in the field at the recommended commercial stage which is one flower bud open (Halevy and Kofranek, 1984). No field pre-treatment was done. The average number of flower buds *per* inflorescence was 10-15 and only disease-free, marketable inflorescences greater than 60 cm in length were selected for the study. The flowers were wrapped in polyethylene sleeves to avoid water loss, then packed in standard boxes used for export and transported immediately using an ordinary covered van. On arrival in the University of Nairobi Postharvest Laboratories, stems were re-cut to 60 cm and lower leaves were defoliated to avoid their immersion in the holding vase solutions. Experiments started immediately after re-cutting and defoliation.

Vase Solution Treatments:

Cut Lisianthus flowers were held in containers filled with different vase solutions. Chemical biocides used for the study and water quality treatments are indicated in the Table 1 below:

Table 1: Chemical Biocide and Water Quality Treatments used in the postharvest study of Lisianthus cut flowers

Chemical Biocide Treatments[a]	**Water Quality Treatments**
Deionised water (DW)	Rain water that was harvested from roof tops
NaOCl (50ppm)	Tap water from the City Council of Nairobi
8 –HQC (250ppm)	River water from Chania River supplying water to Eustoma Kenya
$AgNO_3$ (50ppm)	Lake water from Lake Naivasha where most cut flowers in Kenya are grown
$AgNO_3$ (100ppm)	Dam water from the University of Nairobi farm
$Al_2(SO_4)_3$ (100ppm)	De-ionized water commercially sourced served as the control.
8-HQC (250ppm) + NaOCl (50ppm)	
$AgNO_3$ (50ppm) + NaOCl (50ppm)	
AgNO3 (100ppm) + NaOCl (50ppm)	
$Al_2(SO_4)_3$ (50ppm) + NaOCl (50ppm)	
$Al_2(SO_4)_3$ (100ppm) + NaOCl (50ppm)	
$Al_2(SO_4)_3$ (150ppm) + NaOCl (50ppm)	
$Al_2(SO_4)_3$ (200ppm) + NaOCl (50ppm)	

[a]*All treatment vase solutions contained 2% sucrose and their pH adjusted to 3.5 using citric acid. Vase solutions were made using deionized water.*

Before the use of these water types as vase solutions, a qualitative water analysis was carried out to determine their pH, chemical composition and EC values. A chosen biocide was used in vase

solutions made from various water sources. The pH of vase solutions was either left at initial values or those higher were adjusted to 3.5.

Water samples analysis was done in the Department of Soil Science laboratory at the University of Nairobi. Calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions were analysed using the Atomic Absorption Spectrophotometry method (Model Buck Scientific 210 V15, 1997). Sodium (Na^{+}) and potassium (K^{+}) ions were analysed using flame photometry whereas chloride (Cl^{-}), hydroxide (OH^{-}), carbonates (CO_3^{2-},) and bicarbonates (HCO_3^{2-}) ions were determined using the Titrimetric procedures as detailed in the U.S.D.A. Handbook No. 60 by Richards (1954). pH was measured using a pH meter. Post-harvest evaluation of cut flowers was carried out in the postharvest laboratory of the Department of Plant Science and Crop Protection, where temperatures ranged between 20 and 23^{o}C. Photoperiod was set at 12 hours and relative humidity ranged between 70 and 80%. Lighting was provided by cool, white fluorescent tubes and ranged between 15 and 20 μmol^{-2} S^{-1} at bench level.

Experimental Design, Data Collection and Data Analysis:

Experiments were carried out using the completely randomised design (CRD) method (Steel and Torrie, 1981). Unless otherwise specified, there were five inflorescences *per* treatment, each replicated four times. The vase life and floret opening of cut flowers were considered terminated when the number of senesced florets exceeded the number of open ones. Floret opening was expressed as the percentage of open florets to the total florets on an inflorescence. Water uptake by cut flowers was measured following procedures outlined for Gerbera by Van Meeteren (1978). Three inflorescences *per* treatment were held individually in 250 ml flat-bottomed conical flasks containing 100ml of DW or vase preservative solution. The tops of flasks were tightly sealed with aluminium foil to avoid any water loss that may arise through evaporation. Water uptake by cut flowers was measured by taking the weight of the conical flask and water without the inflorescence. Weight measurements were taken at the same time (0900 hours) every two days. From the change in weight between two successive measurements divided by the number of hours during the interval (48 hours), the rate of water uptake in g/hour/inflorescence was calculated. Deionised water or respective vase preservatives were refilled to the 100ml mark after every 48 hours. To eliminate water deficit caused by air embolism upon removal of the inflorescence from the solution, one-half centimetre basal stem was cut off after every measurement. This procedure was followed up to the 14th day of flower display.

Data collected were analyzed using General Linear Model two-way analysis of variance in CO-STAT software (CoHort Software, Berkeley, CA). Means were separated by the Honestly Significant Difference (Tukey's) procedure at 5% level of significance (Snedecor and Cochran, 1989). Floret opening percentage data were arcsine transformed before analysis to obtain normality. Graphical representations, where necessary, were evaluated using the calculated LSD at P=0.05.

RESULTS

Vase life and floret opening

The vase life of cut Lisianthus stems held in de-ionized water (DW) was 10 days with 46% florets opening (Table 2).The longest vase life of 26-29 days and the highest floret opening of 80-91%, was observed for cut stems held in either 50ppm $AgNO_3$ or in 250ppm 8-HQC combined with 250ppm and NaOCl. Increasing the concentration of AgNO3 to 100ppm in the 8-HQC combination was however inhibitory while addition of 50-150ppm $Al_2(SO_4)_3$ alone or in combination with NaOCl, had no influence. All silver nitrate treatments, with or without NaOCl, significantly (P>0.05) increased (P < 0.05; 80-91%) floret opening in flowers held in 8HQC alone or in combination with NaOCl.

Table 2*:* Vase life and floret opening of Lisianthus (*Eustoma grandiflorum* L.) cv 'Kyoto purple' cut flowers as influenced by various chemical biocides

Treatment	[y] Vase solution	Vase life (days)	Floret opening (%)
T_0	Deionised water (DW)	10.4 ^{e*}	45.8^{e}
T_1	NaOCl (50ppm)	15.3 ^{cd}	66.9 ^{bc}
T_2	8-HQC (250ppm)	20.2 ^{b}	80.0 ^{a}
T_3	$AgNO_3$ (50ppm)	26.4 ^{a}	85.0 ^{a}
T_4	$AgNO_3$ (100ppm)	18.7 ^{bc}	81.6 ^{a}
T_5	$Al_2 (SO_4)_3$ (100ppm)	7.0 ^{e}	57.6 ^{cd}
T_6	8-HQC (250ppm)+NaOCl	28.8 ^{a}	90.8 ^{a}
T_7	$AgNO_3$ (50ppm) +NaOCl	17.9 ^{bcd}	68.8 ^{b}
T_8	$AgNO_3$ (100ppm) +NaOCl	21.0 ^{b}	87.5 ^{a}
T_9	$Al_2 (SO_4)_3$ (50ppm) +NaOCl	7.2 ^{e}	46.2 ^{e}
T_{10}	$Al_2 (SO_4)_3$ (100ppm) +NaOCl	8.0 ^{e}	31.7 ^{f}
T_{11}	$Al_2 (SO_4)_3$ (150ppm) +NaOCl	7.3 ^{e}	60.2 ^{bc}
T_{12}	$Al_2 (SO_4)_3$(200ppm) +NaOCl	14.5 ^{d}	50.0 ^{de}

***Means within columns with the same letter are not significantly different according to Tukey's HSD test at 5% level.*
[y], All vase solutions contained 2% sucrose, and had their pH adjusted to 3.5 using citric acid. Where used, the concentration of NaOCl was 50ppm.

Water analysis revealed that all water sources had pH 7.2 for tap and dam waters, 8.5 for Lake Naivasha water and 5.6 for DW (Table 3). Rain water and DW had the lowest salt level with an EC value of $9x10^{-4}$ S/m whereas lake water had the highest salt content with an EC value of $2.4x10^{-1}$ S/m. Lake Naivasha water also had the highest pH, highest calcium and magnesium content and abnormally high levels of chloride ions measuring up to 70 $MeqL^{-1}$ compared to only 0.25 $MeqL^{-1}$ in DW. All water sources had traceable quantities of carbonate ions save for the Lake Naivasha water.

Results of vase life and floret opening are presented in Table 4. Cut flowers held in dam water recorded the shortest ($P < 0.05$) vase life of 2 days and least floret opening percentage of 12.8%. For the un-acidified water sources, cut Lisianthus held in DW recorded the highest floret opening percentage (42%) and best vase life (8 days). A biocide (250ppm 8-HQC) and low pH of various waters resulted in flower vase life and floret opening were increasing ($P > 0.05$) regardless of water quality. Overall, cut flowers held in DW containing a biocide recorded the highest ($P < 0.05$) vase life and floret opening of 28 days and 93%, respectively. There was no significant difference ($P>0.05$) in cut flowers held in DW, rain, tap, river and dam waters that contained the biocidal mixture. However, cut flowers held in biocide-containing lake water had a floret opening that was significantly ($P < 0.05$) lower than the rest of the water sources that contained the biocidal mixture. The pH (at 3 levels) of DW had no effect on cut flower longevity (Table 4). Floret opening however improved ($P < 0.05$) for cut flowers held in DW at pH of 3.5 compared to those held at a pH of 10.0.

Rate of water uptake

The rate of water uptake of cut inflorescence stems held in different chemical biocide solutions, declined with time (Table 5). Overall, water uptake first increased up to the fourth day in all solutions, and then declined differentially thereafter. Inflorescences held in solutions containing a mixture of 8-HQC (250ppm) and NaOCl (50ppm) recorded the highest rate ($P < 0.05$) of water uptake throughout the study period. Flowers held in DW recorded the lowest water uptake, followed

Table 3: Water quality and content of the various water sources commonly used by cut flower producers in Kenya

			Meq L^{-1}						
Water source	pH	EC (dsm^{-1})	Na^+	K^+	Ca^{2+}	Mg^{2+}	OH^-	CO_3^{-2}	Cl^-
(DW)	5.6±0.1	$9.0x10^{-4}$	0.03	Trace	Trace	Trace	Trace	Trace	Trace
Rain water	7.7±0.1	$9.6x10^{-4}$	0.01	0.01	0.30	0.20	Trace	Trace	0.35
Tap water	7.2±0.1	$8.0x10^{-3}$	0.10	0.23	0.40	1.00	Trace	Trace	2.90
River water	7.4±0.1	$2.6x10^{-3}$	0.25	0.05	0.30	1.30	Trace	Trace	1.70
Lake water	8.5±0.1	$2.4x10^{-1}$	1.6	0.04	7.50	8.10	Trace	0.50	70.00
Dam water	7.2±0.1	$8.1x10^{-2}$	1.8	0.28	0.70	1.70	Trace	Trace	5.55

**Means within columns with the same letter are not significantly different according to Tukey's HSD test at 5% level.*
[y], All vase solutions contained 2% sucrose, and had their pH adjusted to 3.5 using citric acid. Where used, the concentration of NaOCl was 50ppm.

by those held in $Al_2(SO_4)_3$ solutions. There was no significant difference ($P>0.05$) in the cumulative water uptake in flowers held in various concentrations of $Al_2(SO_4)_3$, either used alone or in combination with NaOCl.

For flowers held in water solutions from different sources, the rate of water uptake fluctuated from time to time with an overall declining trend with senescence (Table 6).

There was a decline in water uptake by cut flowers which differed with the type and pH of water used as vase solution. For the untreated waters, the highest rate of water uptake ($P<0.05$) was recorded in flowers held in DW at pH 5.6 and 3.5 after 4 days and least in those held in dam water. When a biocide was included and pH standardised at 3.5, DW still recorded the highest ($P < 0.05$) water uptake. Flowers held in Lake Naivasha water recorded the least ($P < 0.05$) rate of water uptake even when the water solutions contained a biocide (T_8-T_{13}). Overall, the lower the pH of vase water, the higher the rate of water uptake and regardless of a biocide.

DISCUSSION

DISCUSSION

The postharvest life and floret opening of cut stems of Lisianthus cv. 'Kyoto Purple' cultivar, was greatly improved by use of various biocides. For instance, 8-Hydroxyquinoline citrate (8-HQC) increased life and floret opening at a concentration of 250ppm. In contrast, Cho *et al*. (2001) reported that 8-HQC (250ppm) + 1.5% sucrose, did not improve vase life and floret opening of Lisianthus cultivar 'Heidi Pink'. The salt 8-HQC has been reported to improve the vase life and keeping quality of gypsophila (Mastalerz, 1977), *brodiaea* flowers (Han *et al.,* 1990), roses (Gao and Wu, 1990) and gladiolus spikes (Singh and Sharma, 2003). In the present study silver nitrate ($AgNO_3$) improved vase life and floret opening of cut Lisianthus compared to those held in DW. Increased vase life and floret opening has also been reported (Saini *et al*., 1994; Anjum *et al*., 2001) in cut tuberose flowers held in solutions containing $AgNO_3$. However, Han *et al*. (1990) found no beneficial effect of $AgNO_3$ in *brodiaea* flowers.

The use of $Al_2(S0_4)_3$ as a biocide in the current study somehow increased the vase life and floret opening of cut Lisianthus but not at all concentrations. In other studies, Reid (2000) recommended a concentration of 200ppm $Al_2(S0_4)_3$ whereas; Liao *et al*. (2001) recommended 150ppm for Lisianthus cut flowers. However, Cho *et al*. (2001) reported no improved benefit of holding Lisianthus flowers in 200ppm $Al_2(S0_4)_3$. This inconsistency in results may be an indicator of the high genetic variability of material used; bearing in mind that Lisianthus flower is propagated by seed. Whichever the case, it is shown by the current study that $Al_2(S0_4)_3$ was not the best biocide to use for improving postharvest quality of the cultivar 'Kyoto purple'.

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Table 4: Influence of water quality and pH on the vase life and floret opening of Lisianthus *(Eustoma grandiflorum* L.) cv 'Kyoto purple' cut flowers

Treatment	[y] Vase Solution	pH of vase solution	Vase life (Days)	Floret Opening (%)
To	DW	5.6 ± 0.1	7.8[d]*	42.4[c]
T1	Rain water	7.7 ± 0.1	4.2[e]	28.8[de]
T2	Tap water	7.2 ± 0.1	5.2[e]	27.7[e]
T3	River water	7.4 ± 0.1	7.2[d]	35.4[cd]
T4	Lake water	8.5 ± 0.1	7.0[d]	32.9[de]
T5	Dam water	7.2 ± 0.1	2.2[f]	12.8[f]
T6	DW +NaOH	10.0 ± 0.1	7.1[d]	29.9[de]
T7	DW	3.5 ± 0.1	10.4[d]	45.8[c]
T8	DW + Biocide	3.5 ± 0.1	28.4[a]	92.8[a]
T9	Rain water + Biocide	3.5 ± 0.1	26.3[b]	92.5[a]
T10	Tap water+ Biocide	3.5 ± 0.1	25.2[b]	91.6[a]
T11	River water + Biocide	3.5 ± 0.1	26.7[ab]	92.0[a]
T12	Lake water + Biocide	3.5 ± 0.1	21.9 [c]	70.3[b]
T14	Dam water + Biocide	3.5 ± 0.1	25.5[b]	88.6[a]

**Means within columns with the same letter are not significantly different according to Tukey's HSD test at 5% level.*
[y], All vase solutions contained 2% sucrose

Table 5: Effects of biocides on the rate of water uptake of Lisianthus *(Eustoma grandiflorum* L.) cv 'Kyoto purple' cut flowers

Treatment	[y] Vase solution	Time (Days) Rate of water uptake (gms/hr/flower)							Cumulative
		2	4	6	8	10	12	14	(gms/flower)
T_0	Deionised water (DW)	0.55^{a*}	0.59^{b}	0.56^{a}	0.31^{d}	0.14^{e}	0.12^{c}	0.11^{c}	114.48^{e}
T_1	NaOCl (50ppm)	0.58^{a}	0.63^{b}	0.59^{a}	0.56^{abc}	0.48^{abcd}	0.43^{ab}	0.36^{abc}	174.24^{cd}
T_2	8-HQC (250ppm)	0.67^{a}	0.72^{ab}	0.69^{a}	0.68^{ab}	0.65^{ab}	0.60^{ab}	0.49^{ab}	215.76^{ab}
T_3	$AgNO_3$ (50ppm)	0.69^{a}	0.73^{abc}	0.71^{a}	0.68^{ab}	0.66^{ab}	0.61^{ab}	0.50^{ab}	219.84^{a}
T_4	$AgNO_3$ (100ppm)	0.65^{a}	0.69^{ab}	0.67^{a}	0.64^{abc}	0.61^{abcd}	0.56^{ab}	0.51^{ab}	207.84^{abc}
T_5	$Al_2(SO_4)_3$ (100ppm)	0.52^{a}	0.55^{b}	0.53^{a}	0.49^{bcd}	0.38^{d}	0.36^{bc}	0.29^{bc}	149.76^{d}
T_6	8-HQC (250ppm)+NaOCl	0.73^{a}	0.85^{a}	0.75^{a}	0.72^{a}	0.69^{a}	0.64^{a}	0.55^{a}	235.92^{a}
T_7	$AgNO_3$ (50ppm) +NaOCl	0.67^{a}	0.71^{ab}	0.68^{a}	0.65^{ab}	0.61^{abcd}	0.55^{ab}	0.48^{ab}	208.80^{abc}
T_8	$AgNO_3$ (100ppm) +NaOCl	0.68^{a}	0.75^{ab}	0.73^{a}	0.65^{ab}	0.63^{abc}	0.61^{ab}	0.53^{ab}	219.84^{a}
T_9	$Al_2(SO_4)_3$ (50ppm) +NaOCl	0.55^{a}	0.58^{b}	0.54^{a}	0.43^{cd}	0.40^{cd}	0.39^{ab}	0.38^{ab}	156.96^{d}
T_{10}	$A_{l2}(SO_4)_3$ (100ppm) +NaOCl	0.54^{a}	0.58^{b}	0.53^{a}	0.48^{bcd}	0.44^{bcd}	0.43^{ab}	0.41^{ab}	163.68^{d}
T_{11}	$Al_2(SO_4)_3$ (150ppm) +NaOCl	0.56^{a}	0.61^{b}	0.59^{a}	0.56^{abc}	0.51^{abcd}	0.46^{ab}	0.42^{ab}	177.60^{cd}
T_{12}	$Al_2(SO_4)_3$(200ppm) +NaOCl	0.57^{a}	0.63^{b}	0.61^{a}	0.55^{abc}	0.52^{abcd}	0.49^{ab}	0.43^{ab}	181.92^{bcd}

*Means within columns with the same letter are not significantly different according to Tukey's HSD Test at 5% level.
[y], All vase solutions contained 2% sucrose, and had their pH adjusted to 3.5 using citric acid. Concentration of NaOCl was 50ppm.

Table 6: Influence of water quality and pH on the rate of water uptake (gms/hr/flower) by cut Lisianthus (*Eustoma grandiflorum* L.) cv 'Kyoto purple' flowers

Treatment	[y]Vase solution	pH of Vase water	Time (Days)						
			2	4	6	8	10	12	14
T_0	DW	5.6 ± 0.1	0.72^{ab}	0.79^{ab}	0.56^{cd}	0.31^{de}	0.14^{d}	0.12^{c}	0.11^{c}
T_1	Rain water	7.7 ± 0.1	0.67^{bcd}	0.50^{cd}	0.24^{g}	0.20^{e}	0.16^{d}	0.15^{c}	0.14^{c}
T_2	Tap water	7.2 ± 0.1	0.56^{cd}	0.49^{cd}	0.26^{fg}	0.18^{e}	0.13^{d}	0.12^{c}	0.11^{c}
T_3	River water	7.4 ± 0.1	0.63^{bcd}	0.71^{b}	0.46^{de}	0.30^{de}	0.17^{d}	0.14^{c}	0.14^{c}
T_4	Lake water	8.5 ± 0.1	0.54^{d}	0.53^{c}	0.38^{e}	0.30^{de}	0.19^{d}	0.14^{c}	0.12^{c}
T_5	Dam water	7.2 ± 0.1	0.56^{cd}	0.37^{d}	0.20^{g}	0.17^{e}	0.14^{d}	0.13^{c}	0.12^{c}
T_6	DW. +NaOH	10.0 ± 0.1	0.74^{ab}	0.71^{b}	0.41^{e}	0.30^{de}	0.21^{d}	0.21^{c}	0.18^{c}
T_7	DW.	3.5 ± 0.1	0.72^{ab}	0.81^{b}	0.60^{b}	0.40^{cd}	0.33^{cd}	0.29^{bc}	0.24^{c}
T_8	D.W. + Biocide	3.5 ± 0.1	0.73^{ab}	0.85^{ab}	0.75^{a}	0.79a	0.65^{a}	0.67^{a}	0.58^{ab}
T_9	Rain water+ Biocide	3.5 ± 0.1	0.81^{a}	0.92^{a}	0.69^{ab}	0.74^{ab}	0.63^{a}	0.67^{a}	0.63^{a}
T_{10}	Tap water+ Biocide	3.5 ± 0.1	0.63^{bcd}	0.71^{b}	0.56^{cd}	0.51^{c}	0.48^{bc}	0.55^{ab}	0.53^{ab}
T_{11}	River water+ Biocide	3.5 ±0.1	0.68^{abc}	0.74^{b}	0.61^{bc}	0.57^{bc}	0.51^{abc}	0.57^{ab}	0.56^{ab}
T_{12}	Lake water+ Biocide	3.5 ± 0.1	0.58^{cd}	0.54^{c}	0.43^{e}	0.42^{cd}	0.39^{c}	0.45^{b}	0.46^{b}
T_{13}	Dam water+ Biocide	3.5 ± 0.1	0.75^{ab}	0.83^{ab}	0.56^{cd}	0.56^{bc}	0.48^{bc}	0.56^{ab}	0.53^{ab}

*Means within columns with the same letter are not significantly different according to Tukey's HSD Test at 5% level.

[y], All vase solutions contained 2% sucrose, and had their pH adjusted to 3.5 using citric acid. Concentration of NaOCl was 50

The positive effect observed in cut flowers held in NaOCl has also been reported in maiden fern (Van Doorn *et al*., 1990), stock flowers (Celikel and Reid, 2002), and leather leaf fern (Henny and Fooshee, 2003).

When flowers are detached from the plant, water loss continues through transpiration. The ideal flower preservative is that which allows water absorption in flower tissues and reduces water loss (Salunkhe *et al*., 1990). Water absorption from the preservative solution maintains a better water balance and flower freshness (Reddy and Singh, 1996), and protects the flower from early wilting resulting in enhanced vase life. It was generally observed, in the current study, that a decline in water uptake occurred with time. This gradual declining trend in water uptake has been reported in other cut flowers including roses (Carpenter and Rasmussen, 1973; Mayak *et al*., 1974; De Stigter, 1980) and tuberose (Anjum *et al.,* 2001; Hutchinson *et al.,* 2003; Hutchinson *et al*., 2011). The increase in vase life and floret opening due to biocides is attributed to increased water uptake, thus maintaining a favourable water balance and delayed bacterial contamination in the flower vases. These explanations have previously been suggested by several researchers such as Van Doorn *et al*. (1990), Van Doorn (1997), Liao *et al.* (2001), Celikel and Reid, 2002) and Henny and Fooshee (2003). Additionally, salts of HQC and $Al_2(S0_4)_3$ has been reported to reduce transpirational water loss as well as acting as chelating agents in cut flowers (Rogers, 1973; Liao *et al.,* 2001). Silver ions in silver nitrate could also interfere with wound ethylene binding sites (Paull and Goo, 1985).

Proliferating bacteria in vase solutions have been reported to shorten the life of cut flowers through blockage of the xylem vessels (De Stigter, 1980; Van Doorn *et al*. 1990; Jones and Hill, 1993), resulting in reduced water uptake and poor water balance. A variety of germicides have been proposed to prevent rapid proliferation of bacteria and other microbes in vase solutions (Van Doorn and Perik, 1990). Despite these interventions, the response of many cut flowers to germicides is highly variable among species (Fujino *et al.,* 1983). All biocides tested in the present study namely; 8-HQC, $AgNO_3$, $Al_2(SO_4)_3$, NaOCl or their combinations were found to retain their bactericidal properties for 2-4 days maximum before bacterial growth resumed in vase solutions (Data not shown). Perhaps it would be beneficial to replace vase solution every 4 days to maintain flower integrity.

Flowers in vase solutions containing biocides had higher rates of water uptake than those held in deionised water. In all the treatment solutions, water uptake decreased slowly in the first few days with small daily rises after which it fell more rapidly thereafter. This pattern of conductivity was observed for other plant species (Halevy and Mayak, 1981; Evans *et al.,* 2002). The increase in flow resistance could be directly caused by stem plugging by micro-organisms (Halevy and Mayak, 1981; Van Doorn *et al.* 1990), or indirectly through the release of metabolites into the water by the microbes, which block the floral vascular system (Accati *et al*., 1981). In the absence of microbial blockage, the increase in resistance to water flow could be due to air embolism (Durkin, 1979), vascular occlusions which could be gummy substances, (pectinaceous or carbohydrate (Parups and Molnar, 1972) or broken down products of cell walls (Rasmussen and Carpenter, 1974). Enzymes, whose activity is influenced by cell pH, are involved in the breakdown of pectins and other cell constituents (Rasmussen and Carpenter, 1974). Vascular occlusions could also be due to ethylene-stimulated production of gums at the cut ends of floral stems (Van Doorn *et al*., 1990). The vase life and percentage of open florets of Lisianthus cut flowers was influenced by changes in the rate of water uptake. Cut flowers which had the highest water uptake and fresh weights had the longest vase life and highest floret opening. Net water uptake in relation to vase life has been used to determine the postharvest quality of cut flowers. Buys and Cours, (1980) reported a significant positive correlation between the amount of water uptake and vase life of cut flowers. This phenomenon is however not universal since Anjum *et al*. (2001) found no correlation between water uptake and vase life of tuberose cut flowers.

CONCLUSION

The biocides evaluated namely; 8-HQC, $AgNO_3$, $Al_2(SO_4)_3$, NaOCl or their combinations, in vase water may, to varying degree, increase the life and overall keeping quality of cut Lisianthus. These biocides all improved water uptake, flower fresh weights, resulting in delayed senescence of cut flowers. Cut flowers held in vase solutions containing 8-HQC or $AgNO_3$ were more superior to

those held in $Al_2(SO_4)_3$, or NaOCl. Among the tested biocides, a combination of 8-HQC at 250ppm and NaOCl at 50ppm proved to be the most effective biocide for cut Lisianthus. The suitability of $Al_2(SO_4)_3$, as a biocide which has previously been recommended for this cut flower, was questionable especially for flowers grown under Kenyan conditions or at least 'Kyoto Purple' cultivar that was evaluated in the current study.

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Conflict of interest None

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