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Performance of Ethylene Non- Sensitive Cut Flowers and Foliage as Affected by Silicon- based Postharvest Treatments

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ABSTRACT

Lack of postharvest treatments during handling has limited the end-user vase life of cut flowers and foliage in Sri Lanka. Therefore, a commercial silicon (Si) based formulation was assessed for its efficacy as a vase solution treatment for ethylene non-sensitive cut flowers of *Chrysanthemum spp.*, *Leucanthemum vulgare*, and cut leaves of *Livistonia chinensis* and *Rhapis excelsa*. The stems were treated with vase solution Si (Na_2SiO_3) concentrations of 0 (Distilled water; control), 25, 50, 100, 200, 250 and 300 mgL^{-1}. All experiments were arranged in completely randomized design with five replicates. The Si treatments did not improve the vase life, relative fresh weight of stems or the rate of vase solution uptake in all species. Instead, it resulted phyto-toxicity in the cut flowers. However, Si improved the chlorophyll retention in cut *Livistonia* leaves.

KEYWORDS: Chlorophyll, Cut flowers, Cut foliage, Silicon, Vase life

INTRODUCTION

Sri Lanka is recognized as one of the best quality floriculture production centres in the world offering a range of cut flowers, cut decorative foliage and living plants. This sector earns high net foreign exchange to the country while contributing to employment generation. Sri Lanka earned US$ 14.86 million worth of foreign exchange in 2014 by exporting floriculture products indicating an average growth of 4.87% over 2013 (Anon, 2015). A potential exists for further expansion of floriculture industry in Sri Lanka.

Cut flowers' longevity is an important determinant of their quality and is expressed as "vase life", the time in which flowers are in the vase before they display some characteristics that make them unacceptable. The ability to retard senescence helps prolong the vase life of cut flowers (Van Doorn, 1997).

Pre-harvest silicon (Si) application has proven benefits to crop plants, including for ornamentals (Taylor and Francis, 2006; Carvelno–Zanao *et al.*, 2012). Silicon increased tolerance of Boron toxicity and reduced oxidative damage in barley (Taylor and Francis, 2009). Pre-harvest application of potassium silicate decreased the black spot infection in cut rose leaves (Carvelno-Zanao *et al.*, 2012). Pre-harvest Si application for potted miniature roses improved the stem developments while it enhanced the mechanical strength of inflorescence stem in herbaceous plants (Robichaux, 2008; Zhao *et al.*, 2013).

Accumulation of Si in the epidermal tissue of the plant has been suggested as the main mechanism which provides defence against insect and fungal attacks. The chemical properties of monosilicic acid maintain plant protection against the effects of heavy metals contamination. In addition, potassium silicate has a proven potential in controlling postharvest green mould (Abraham *et al.*, 2008). Silicon increased the plant chlorophyll contents and anti-oxidative enzyme activities in tomato plants (Taylor and Francis, 2005).

A few studies have reported on postharvest Si application to cut flowers. Silicon at 300 mg L^{-1} (Jamali and Rahemi, 2011) and 2.5 mM (Kazemi *et al.*, 2012a) in the vase solution were beneficial for cut carnation flowers. Delayed senescence with Si was also reported for cut gerbera (Kazemi *et al.*, 2012b) and cut lisianthus (Kazemi *et al.*, 2012c).

Due to non- application of postharvest treatments, the cut flower/foliage quality rapidly declines during the marketing channel in Sri Lanka (Ratnayake *et al.*, 2015). In the current study, therefore, a silicon-based commercial formulation was tested for its efficacy on improving the vase life of selected ethylene non-sensitive cut flower and foliage species. Pre-harvest application of this formulation has shown positive results for a range of field and fruit crops by increasing their leaf chlorophyll content, photosynthetic rate and the quality and quantity of yield (Geolife Group, 2014).

MATERIALS AND METHODS

Experimental Material and Set Up

The study was carried out at the Horticulture Laboratory, Wayamba University of Sri Lanka, Makandura, from December 2015 to May 2016.

Cut flowers of chrysanthemum (*Chrysanthemum morifolium* var. Resumee Purple, Peggy Stevens and Pompon) and Ox-eye daisy *(Leucanthemum vulgare)* were obtained from freshly arrived stocks at a retail centre in Negombo. Cut foliage stems of Chinese fan palm (*Livistonia chinensis*) were obtained from Omega Green Private Limited, Badalgama. Stems were transported to laboratory while stem ends were immersed in water. Cut leaves of lady palm (*Rhapis excelsa*) were obtained from University Premises at Makandura. Flowers and foliage were selected for uniformity and quality and also to avoid malformations or damages caused by handling and transport. Stems were re-cut under water to *ca.* 30 cm length and were placed into clean plastic bottles filled with treatment solutions. Mouth of the bottles was covered using Parafilm.

Temperature and relative humidity (RH) of the vase life evaluation environment were recorded using the temperature and humidity data logger (320 series, TECPEL Co. Ltd., Taiwan). pH measurements of fresh solutions (Table 1) were recorded (pH meter model A22220 AGB-72, London, UK).The mean temperature (Day/Night) and RH (Day/Night) were 31.4 °C/29.3 °C and 68.8%/76.6%, respectively. A 12 h photoperiod was provided using florescent light.

Treatments

Treatment solutions were prepared with a commercial silicon formulation (10% sodium silicate, 50% Potassium bicarbonate and 40% Citric acid) in distilled water. Vase solution Si (Na_2SiO_3) concentrations of 0, (Control; distilled water), 10, 25, 50,100, 200, 250 and 300 mg L^{-1} were used.

Determination of Vase Life, Relative Fresh Weight and Solution Uptake Rate

Cut flowers were assessed daily for their visual appeal. Overall appearance and the quality of flowers and foliage were recorded using a scale. Vase lives of *Chrysanthemum* and *L. vulgare* ended at >25% petal discoloration and/or wilting (flowers) and >25% blackening and/or wilting (leaves). Foliage stems of *R. excelsa* and *L. chinensis* terminated their vase life due to wilting and/or when the Green 139A to 147A colour range turned to Yellowish Green colour (Royal Horticultural Society Colour Chart, UK).

The relative fresh weight (RFW) and vase solution uptake rate (VSUR) of cut stems were calculated as described by (He *et al.*, 2006).

Leaf Chlorophyll Content

The total chlorophyll contents of *L. chinensis* leaves on day 0 and day 4 of the vase period were assessed by spectrophotometric analysis method. Fresh leaf samples of 0.5 g were homogenized using motor and pestle with 10 mL of 80% acetone. Absorbance of leaf extraction was measured using a spectrophotometer (UVmini-1240, SHIMADZU, Japan). Arnon's equations (1949; cited by Porra, 2005) for calculation of chlorophyll extracted in 85% acetone were used.

Chl a (mgg^{-1}) =0.0127 A_{663}–0.00269 A_{645};
Chl b (mgg^{-1}) =0.0029 A_{663}–0.00468 A_{645};
Total Chl (mgg^{-1}) =0.0202 A_{663}+0.00802 A_{645}.

Experimental Design and Statistical Analysis

Treatments were arranged in completely randomized design (CRD) with six replicates. Data analysis was done using MINITAB (Version 15; Minitab Inc., State College, Pennsylvania, USA). Where treatment effects were significant, mean separation was done by Mann Whitney test.

RESULTS AND DISCUSSION

Effect of Si on Vase Life

In spray *Chrysanthemum* var. Resumee Purple, both flowers and leaves of the stems placed in distilled water (control) had significantly higher vase lives of 10.2 d and 7.8 d, respectively than of those stood into Si treatment solutions of 100- 300 mg L^{-1} (Table 2). The Si treated stems displayed browning of flower stalk and petal margins, drooping flower heads, early withering and drop of petals and blackening of leaves and sepals. The symptoms were caused by phyto-toxicity in the Si formulation. Thus, those stems ended vase life earlier than the stems in the control. Lower Si concentrations were, therefore, tested for other chrysanthemum types. However, Si at 10 and 25 mg L^{-1} did not show significant increases in vase life either in flowers or leaves of *Chrysanthemum* var. Peggy Stevens. Moreover, at >50 mg L^{-1} Si, those stems too showed symptoms of phyto-toxicity and ended vase life earlier than the control. *Chrysanthemum* var. Pompon (Standard) also showed significantly lower vase lives of the stems treated with Si compared to the stems placed in to distilled water (Table 2).

In *L. vulgare,* Si concentrations up to 50 mg L^{-1} (inclusive) resulted in no significant difference in the vase life of flowers compared to control. However, Si concentrations of 100 mg L^{-1} and above significantly decreased the vase life of stems compared to control due to apparent phyto-toxicity. Browning and shedding of petals and stem breakage were the most common symptoms shown at higher Si concentrations.

R. excelsa and *L. chinensis* leaves placed in distilled water (control) showed mean vase lives of 10.8 d and 6.2 d, respectively. There were no significant treatment effects on the vase life of the cut leaves of those species (Table 2). The foliage vase life ended mainly due to wilting, tearing and tip burning in leaflets.

Effect of Si on Relative Fresh Weight (RFW) and Vase Solution Uptake Rate (VSUR)

The RFW had generally decreasing trend as shown for *L. chinensis* (Figure 1). In all other species tested, the cut stems in distilled water maintained a higher RFW throughout the vase period compared to Si treated stems.

The rate of solution uptake too showed a decreasing trend in all experiments as shown for *L. chinensis* (Figure 2). The highest VSUR was observed in 0 mg L^{-1} Si (Control) in all experiments (Data not shown). The decrease in water uptake leads to water deficit stress and reduced turgidity in cut flowers (van Doorn, 1997).

The common Si source used in vase solutions in previous studies was K_2SiO_3 (Potassium silicate) while the source was not specified in some other studies. Postharvest vase treatment with K_2SiO_3 was beneficial for cut carnation (Jamali and Rahemi, 2011). Being a highly ethylene sensitive species, authors attributed it to reduced ethylene production caused by Si. In the current study, however, Si source was a commercial formulation reported to contain 40% citric acid ($C_6H_8O_7$), 50% potassium bicarbonate ($KHCO_3$) and 10% sodium silicate (Na_2SiO_3) (MSDS). In a solution, citric acid and potassium bicarbonate react to form potassium citrate ($C_6H_5K_3O_7$) and CO_2. This compound should be slightly acidic. However, the pH values of used solutions arranged from 9.0- 10.0, *i.e.* basic (Table 1). This alkalinity could have been caused by high (50%) potassium bicarbonate content (base percentage) in this compound. The optimum solution pH which improves the water uptake of cut flowers is between pH 4– 5 (van Doorn, 1997). Therefore, the lowered solution uptake rates could be a result of inappropriate solution pH.

Table 1. pH of fresh treatment solutions

Silicon (Si) concentration	Solution pH
T_1	6.31
T_2	9.17
T_3	9.49
T_4	9.73
T_5	9.70
T_6	9.59
T_7	9.53
T_8	9.53

T_1- 0 mg L^{-1}, T_2- 10 mg L^{-1}, T_3- 25 mg L^{-1}, T_4- 50 mg L^{-1}, T_5- 100 mg L^{-1}. T_6- 200 mg L^{-1}, T_7- 250 mg L^{-1}, T_8- 300 mg L^{-1}

Silicon concentration of used solutions was in the range of 10 mg L^{-1} (0.55 mM; T_2) to 300 mg L^{-1} (16.65 mM; T_8). Both T_2 and T_4 contained *ca.* 2.5 mM of Si which were found beneficial in previous research on other cut flower species. However, those concentrations too showed phyto-toxicity symptoms. Citric acid at 1.8- 2.6 mM concentration (3.5 pH) had increased the vase life of cut flowers (Anon, 2003). Citric acid concentrations of used solutions were in the range of 0.28 mM (T_2) to 6.25 mM (T_8) and T_4 and T_5 contained citric acid close to the recommended level.

Nevertheless, those treatments were phyto-toxic. Which of the compounds in the formulation caused phyto-toxicity symptoms is, however, unclear.

Si Effect on Leaf Chlorophyll Content

Chlorophyll content did not show a statistically significant difference on day four of vase period compared to the value of fresh leaves (day 0) in *L. chinensis.*

Table 2. Mean vase lives of cut flowers and foliage as affected by vase solution Si concentrations

Si mg L^{-1}	Vase life (days)								
	Chrysanthemum morifolium						*Leucanthemum*	*Rapis*	*Livistonia*
	Spray				Standard Pompon				
	Resumee Purple		Peggy Stevens						
	Flower	Leaf	Flower	Leaf	Flower	Leaf			
T_1	10.2^a	7.8^a	14.0^a	12.2^a	11.4^a	8.4^a	6.0^a	10.8^a	6.2^a
T_2	-	-	12.4^a	11.0^a	9.4^b	5.8^b	5.8^a	9.4^a	
T_3	-	-	12.0^a	12.6^a	9.0^{ab}	6.6^b	4.8^a	9.8^a	3.6^a
T_4	-	-	7.8^b	7.2^b	11.2^{ab}	8.0^{ab}	4.6^a	9.6^a	4.0^a
T_5	8.3^b	3.0^b	5.6^b	7.0^b	7.2^c	5.6^b	4.2^b	10.4^a	4.8^a
T_6	6.5^b	2.3^b	5.8^b	5.2^b	6.8^c	5.4^b	3.8^b	11.8^a	3.4^a
T_7	5.2^b	2.7^b	-	-	-	-	-	-	4.6^a
T_8	5.7^b	2.2^b	-	-	-	-	-	-	

Within each column, values with same superscript letters are not significantly different at P=0.05 level. T_1- 0 mg L^{-1}, T_2- 10 mg L^{-1}, T_3- 25 mg L^{-1}, T_4- 50 mg L^{-1}, T_5- 100 mg L^{-1}. T_6- 200 mg L^{-1}, T_7- 250 mg L^{-1}, T_8- 300 mg L^{-1}

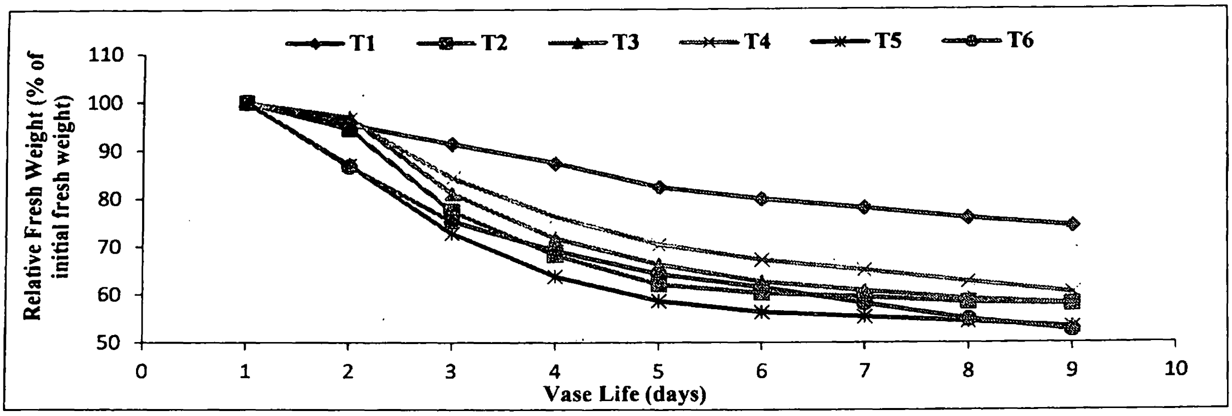

Figure 1. Change of relative fresh weight in *L. chinensis* over the vase period. *T_1- 0 mg L^{-1}, T_2- 25 mg L^{-1}, T_3- 50 mg L^{-1}, T_4- 100 mg L^{-1}, T_5- 200 mg L^{-1}, T_6- 250 mg L^{-1}*

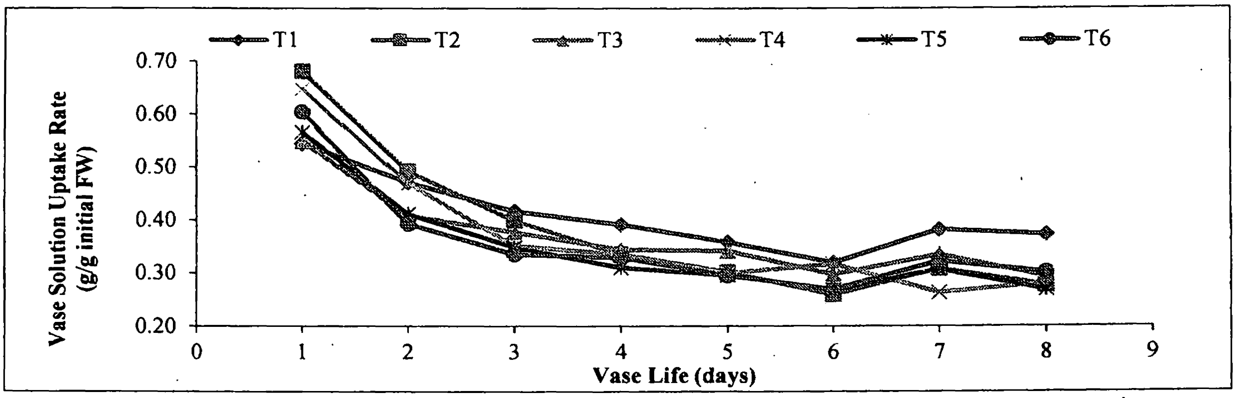

Figure2. Change of solution uptake rate in *L. chinensis* over the vase period. *T_1- 0 mg L^{-1}, T_2- 25 mg L^{-1}, T_3- 50 mg L^{-1}, T_4- 100 mg L^{-1}, T_5- 200 mg L^{-1}, T_6- 250 mg L^{-1}*

However, a higher chlorophyll level was maintained by Si treated cut leaves on day four in comparison to the level in the control (Table 3). In agreement with this, a vase solution Si treatment retarded chlorophyll degradation in cut carnation (Kazemi *et al.*, 2012a) while a pre-harvest Si application improved chlorophyll levels in tomato (Taylor and Francis, 2005). In the current study, although chlorophyll levels were retained, wilting and tip browning terminated the vase life of cut *L. chinensis* leaves.

Table 3. Changes in chlorophyll content of *Livistonia* leaves

Days	Leaf chlorophyll content ($mgg^{-1}FW$)
Day 0	
Fresh leaves	3.51[a]
Day 4	
0 mg L^{-1} Si	2.45[a]
25 mg L^{-1} Si	4.22[a]
50 mg L^{-1} Si	4.92[a]
100 mg L^{-1} Si	5.64[a]
200 mg L^{-1} Si	4.48[a]
250 mg L^{-1} Si	4.81[a]

Values with same superscript letters are not significantly different at P=0.05 confident levels (One-way ANOVA comparison)

CONCLUSIONS

Vase solution Si supplementation using the given commercial formulation is apparently ineffective for *Chrysanthemum* and *Leucanthemum vulgare* due possibly to the phyto-toxicity exerted by other compounds in the product and/or undesirable solution pH. Its effect on cut foliage needs to be further investigated. As shown for *L. chinensis*, it has a potential to retain the green colour of cut leaves. Furthermore, benefits of pre-harvest application of the Si formulation should be investigated in future research.

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