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Sucrose, salicylic acid and citric acid solutions to extent vase life of *Vriesea incurvata* Gaudich. (Bromeliaceae) floral scapes

Soluciones de sacarosa, ácido salicílico y ácido cítrico prolongan la vida útil en florero de escapos florales de *Vriesea incurvata* Gaudich. (Bromeliaceae)

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Abstract

Vriesea incurvata is a native bromeliad from Brazilian Atlantic Rainforest and commercialized as an ornamental pot plant. The morphological characteristics of its floral scape may also indicate it as a new product to use as a cut flower. However, its postharvest behavior was unknown. This study was conducted to determine its vase life by applying distilled water (control) and solutions containing sucrose (50 g L^{-1}), salicylic acid (50 μM), and citric acid (50 g L^{-1}) for periods of 8 and 24 h. Floral scapes maintained in solutions showed vase life greater than 16 days when compared to the control (distilled water). However, solutions with sucrose evidenced the best behaviors related to the maintenance of physiological and aesthetic features during the vase life of the floral scapes. It is concluded that solutions with sucrose, salicylic acid, and citric acid applied for 8 and 24 h extend the vase life of the *V. incurvata* floral scapes. Sucrose applied for 8 h promotes the maintenance of color, brightness, and turgidity; improves water balance, and reduces the relative fresh weight losses of floral scapes throughout the vase life, extending their longevity up to 24 days.

Keywords: aesthetic characteristics, bromeliads, cut flowers, sucrose, vase life.

Resumen

Vriesea incurvata es una bromelia nativa de la Selva Atlántica Brasileña y se comercializa como planta ornamental de maceta. Las características morfológicas de su escapo floral también pueden indicarla como un nuevo producto para uso como flor cortada. Sin embargo, su comportamiento poscosecha era desconocido. Este estudio se realizó para determinar su vida útil en florero mediante la aplicación de agua destilada (control) y soluciones de sacarosa (50 g L^{-1}), ácido salicílico (50 μM) y ácido cítrico (50 g L^{-1}) por períodos de 8 y 24 h. Escapos florales mantenidos en las soluciones presentaron una vida útil en florero superior a 16 días en comparación con el control (agua destilada). Sin embargo, las soluciones con sacarosa evidenciaron los mejores comportamientos relacionados al mantenimiento de las características fisiológicas y estéticas durante la vida útil en florero de los escapos florales. Se concluye que las soluciones con sacarosa, ácido salicílico y ácido cítrico por períodos de 8 y 24 h extienden la vida útil en florero de los escapos florales de *V. incurvata*. La solución con sacarosa aplicada por 8 h promueve el mantenimiento del color, brillo y turgencia; mejora el balance hídrico; y reduce las pérdidas de masa fresca relativa de los escapos florales durante la vida útil en florero, extendiendo su longevidad hasta 24 días.

Palabras claves: bromelias, características estéticas, flor cortada, sacarosa, vida útil en florero.

Introduction

The flower market is characterized by the frequent launching of new ornamental products requiring additional attributes which can compete with products already established as rose, carnation, and *Alstroemeria*. The most important characters among the prerequisites for a plant to be considered suitable for commercialization as a cut flower are postharvest longevity and aesthetic characteristics (Rafdi *et al.*, 2014).

Vriesea incurvata Gaudich (Bromeliaceae) is an epiphyte herbaceous plant (± 50 cm height), without thorns, and native to the Brazilian Atlantic Rainforest. It shows dense red inflorescence and subspiky (± 30 cm) with a pattern of annual flowering. Usually, it begins issuing floral scapes in February with a peak of anthesis from March to May, extending in bloom until October (Negrelle & Muraro, 2006). Its compact size, as well as its floral characteristics, gives it strong ornamental and landscape appeal, being one among the ten most extracted and commercialized bromeliad in Paraná Coast-Brazil (Negrelle & Anacleto, 2012).

Just like other bromeliads (Junqueira & Peetz, 2008), the commercialization of *V. incurvata* has been basically as a potted plant. However, in this market so competitive and demanding of new products such as the flower industry, *V. incurvata* also has the potential to be used as a cut flower given the aesthetic features of its inflorescence, reaching an average vase life of 14.9 ± 1.5 days in distilled water (Pulido *et al.*, 2017).

Postharvest longevity is considered a fundamental prerequisite for the commercialization of cut flowers (Rafdi *et al.*, 2014). In species of large-volume in the world trade, the vase life is only 6.5 days for Rose cv. Carola (Wu *et al.*, 2016), and 8.9 days for Carnation cv. White Natila (Begri *et al.*, 2014). Comparatively, the long period of the longevity of *V. incurvata* floral scapes, makes it a viable alternative to include as a new product to use as cut flower, both locally and internationally.

In this perspective, a question arises to be answered: could the vase life of *V. incurvata* floral scapes be extended with the use of solutions, increasing their commercial potential?

Floral senescence is influenced by several factors such as water stress, depletion of carbohydrates, micro-organisms, and ethylene effects (Serek *et al.*, 2006). In order to delay the floral senescence, preservative solutions are used in postharvest to increase the vase life of cut flowers by improving the distribution of assimilates, water regulation, protection of floral scape in front of microbial agents, and reducing the ethylene effect (Ahmad *et al.*, 2014).

In this context, in order to contribute to the expansion of bromeliads used as ornamental resource, it is presented the result of the vase life evaluation of *V. incurvata* floral scapes by the application of solutions with sucrose, salicylic acid and citric acid for periods of 8 and 24 h.

Material and methods

Local and collection of plant material.

Floral scapes of *V. incurvata* were collected in the remaining Atlantic Rainforest (25 ° 48' S and 48° 55' W, altitude 393 m, in Guaratuba, Paraná, Brazil). The climate is tropical wet with no dry season and frost-free, with an average temperature in the coldest month of 18° C, according to Köppen-Geiger classification (Rubel & Kottek, 2010).

According to Pulido *et al.* (2017), the ideal harvest point for *V. incurvata* is defined as floral scapes equal to or greater than 40 cm in length, flowers with closed, turgid, bright, and firm bracts, and orange coloring with red-orange margins. After the floral scapes harvesting from the mother plant base they were kept in plastic boxes with covers, wrapped in dry paper, and transported to the laboratory.

Preparation of plant material.

In the laboratory, floral scapes with defects or injuries resulting from transportation were discarded. Floral scapes were submitted to the cleaning procedure, which consisted in the manual removal of possible basal leaves. Later, floral scapes were cut in the basal part in bevel and standardized at 40 cm in length. Then, floral scapes were weighed and labeled. Each floral scape was placed in a vase (1 L of capacity, 21 cm x 8 cm) with 200 mL of distilled water. The upper part of the vase was packed with plastic film leaving a central perforation for the output of the floral scape. Vases were kept indoor (postharvest room) with temperature of 20 ± 2° C, relative humidity of 80 ± 3 %, and luminosity of 7.4- 8.3 $\mu mol\ m^{-2} s^{-1}$.

Conducting the experiments.

Floral scapes were treated for 8 and 24 h with solutions of salicylic acid (50 µM), citric acid (50 $g\ L^{-1}$), and sucrose (50 $g\ L^{-1}$). Solutions were prepared in distilled water. Distilled water was used as control.

This experiment was conducted in a completely randomized design, in a factorial scheme composed of six postharvest treatments plus the control and five evaluation dates (1, 7, 14, 21, and 28 days). For each combination of factors, six repetitions were used, each one conformed by a floral scape for each vase.

Postharvest evaluation criteria.

The longevity of each floral scape was determined by the number of days from the filling to the manifestation of senescence acute symptoms, including the presence of darkening, inflorescences abscission, wilted of inflorescences and tipping the scapes. Vase life was recorded daily by visual observation of floral scapes.

Floral scapes were removed from the vase solutions and weighed in 1, 7, 14, and 28 days to evaluate the fresh weight. Relative fresh weight of floral scapes was calculated using the formula RFW (%) = $(FW_t / FW_{t=1}) \times 100$; where FW_t is the fresh weight of scape (g) at t: 7, 14, 21, and 28 days, and $FW_{t=1}$ is the fresh weight of this scape (g) of t: 1 day (He *et al*., 2006).

Water uptake was calculated from the formula WU (g scape^{-1} day^{1}) = $(S_{t-1} - S_t)$; where S_t is the weight of solution (g) at t: 7, 14, 21, and 28 days, and S_{t-1} is the weight of solution (g) from the previous day. Water loss was calculated by the formula WL (g scape^{-1} day^{-1}) = $(C_{t-1} - C_t)$; where C_t is the sum of scapes weights and vase (g) at t: 7, 14, 21, and 28 days and C_{t-1} is the sum of scapes weights and vase (g) from the previous day (He *et al*., 2006).

Intensity (C*), hue (H°) and luminosity (L*) of the bracts color were recorded using the colorimeter (Konica Minolta, CR-400®). Readings were taken in the floral scapes, touching the colorimeter sensor to the surface of the base pointer (inflorescence closed bracts). Weekly, he values of L* (100 = white; 0 =

black), a* (positive = red$^{0°}$; negative = green$^{180°}$) and b* (positive = yellow$^{90°}$;

negative = blue$^{270°}$) were recorded. Later there were applied the formulas of chromaticity $C^* = [(a^*)^2 + (b^*)^2]^{1/2}$ and Hue angle, $H° = \tan^{-1}(b^*/a^*)$.

V. incurvata floral scapes were submitted to the weekly evaluation of their quantitative and qualitative characteristics by six previously trained professionals. Preliminary studies were carried out to determine the postharvest evaluation criteria of floral scapes. Each criterion was scored by assigning grades: (1: minimum-4: maximum). The evaluation criteria were: A) Turgidity = 4, turgid; 3, averagely turgid; 2, slightly turgid; 1, wilted; B) Color inflorescence = 4, colorful/strong; 3, medium-colored; 2, discolored; 1, very discolored; C) Brightness inflorescence = 4, with brightness and no dryness at the bracts ends; 3, with brightness and light dryness at the bracts ends; 2, with light brightness and dryness at the bracts ends; 1, with no brightness and dryness at the bracts ends; D) presence of injuries in the floral scape = 4, < 5 % with injury; 3, < 10 % with injury; 2, < 30 % with injury; 1, > 30 % with injury; E) Stiffness of the floral scape = 4, hard; 3, moderately hard; 2, slightly flexible; 1, flexible; F) Commercial perception = 4, excellent; 3, good; 2, regular; 1, bad.

Statistical analysis.

Data were analyzed using R version 3.3.1 with the analysis of variance (ANOVA). Averages significantly different were compared by Scott-Knott test at $p \leq 0.05$.

Results

V. incurvata floral scapes maintained in solutions showed vase life greater than floral scapes maintained in distilled water (16 days). Sucrose 24 h (25.7 days) and sucrose 8 h (24.2 days) solutions recorded the greatest longevities of floral scapes. The vase life of floral scapes was extended in at least 8.2 days using the sucrose solution applied for 24 and 8 h, when compared to the control (distilled water) (Figure 1).

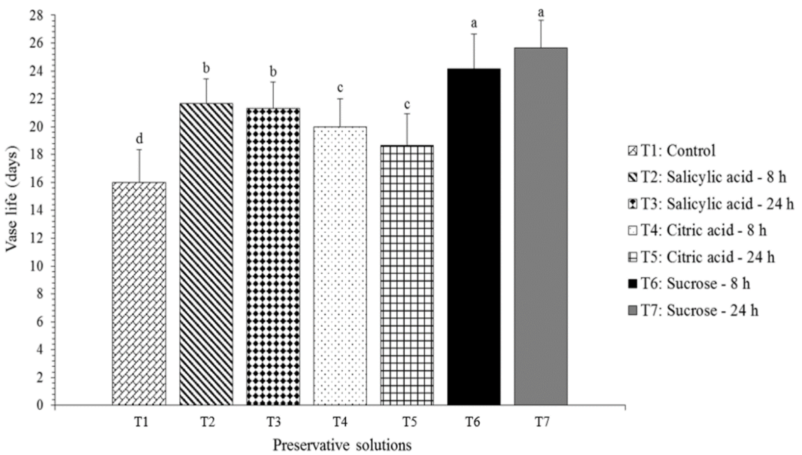

Figure 1. Effect of solutions on vase life of *V. incurvata* floral scapes. Means followed by the same letter do not differ by the Scott-Knott test ($p \leq 0.05$). The values are averages of six replications, each one formed with a floral scape ± S.D.

Relative fresh weight (RFW) decreased during the vase life of *V. incurvata* floral scapes. Solutions allowed that there was lower fresh weight loss, with better results with the use of sucrose and salicylic acid (Figure 2A).

Water uptake (WU) was increased throughout the vase life of *V. incurvata* floral scapes until 14 days, followed by a slight decrease at 21 days and a pronounced increase in the final postharvest period (Figure 2B). Solutions allowed greater water uptake by the floral scapes, with better results with the use of sucrose and salicylic acid (Figure 2B).

Water loss (WL) of *V. incurvata* floral scapes during the first 14 days of vase life was similar, decreasing during the postharvest period, with better results with the use of sucrose, followed by salicylic acid and citric acid (Figure 2C).

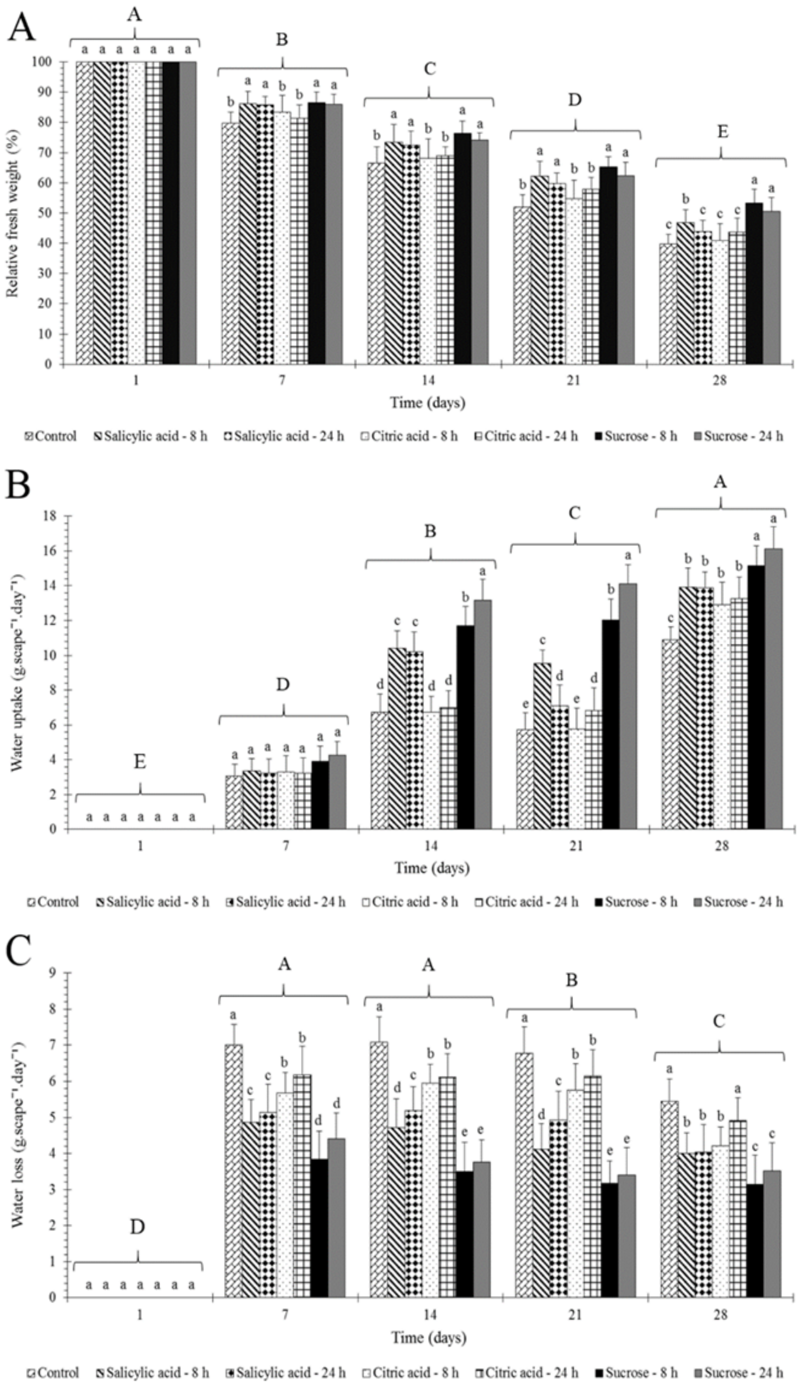

Figure 2. Effect of solutions on relative fresh weight, RFW (A); water uptake, WU (B); and water loss, WL (C), of V. *incurvata* floral scapes. Means followed by the same letter, minuscule letter in lower part and capital letter in the upper part, do not differ by the Scott-Knott test ($p \leq 0.05$). The values are averages of six replications, each one formed with a floral scape ± S.D.

After the floral scapes harvest, strong orange color was observed in the bracts, with chromaticity values from 31.9 to 32.3 and Hue angle values from 41.6 to 42.7 (Figure 3). Bracts color intensity was decreasing throughout the vase life of *V. incurvata* floral scapes. From the seventh day of vase life, red color shades were observed in the bracts, with Hue angle values from 35.7 to 39.7. Then, during the whole postharvest period, there was bracts color degradation, changing the colors from red-orange to yellow-orange shades (Figure 3B).

Sucrose solutions provided the highest maintenance of the bracts color intensity during the vase life of floral scapes (Figure 3).

Bracts color luminosity (L*) was not affected over the vase life of *V. incurvata* floral scapes nor by the solutions (data not shown).

V. incurvata floral scapes kept in sucrose solutions received the highest grades regarding the behavior of the characteristics as turgidity, color, brightness, presence of injuries, and commercial perception (Table 1). Additionally, salicylic acid solutions also received higher grades than controls regarding the behavior of turgidity and brightness characteristics of the inflorescence (Table 1). For the stiffness characteristic of the floral scape, it was rated as 4 (Rigid) throughout all the postharvest period (data not shown).

In the final period of floral scapes senescence of *V. incurvata* were observed decreasing percentages of relative fresh weight (RFW), pronounced increase of water uptake (WU) and decrease of water loss (WL) (Figure 2). However, chromaticity and Hue angle were observed at a lower intensity, and a gradual increase on the bracts color shade was reflected in the darkening and yellow-orange color of the bracts (Figure 3).

Discussion

Vriesea incurvata floral scapes even when kept in vases containing only distilled water showed a longevity of 16 days, which can be considered a reasonable vase life in the absence of any other postharvest treatment and higher than the average of many temperate species (Begri *et al.*, 2014; Wu *et al.*, 2016). Although the preservative solutions can be a great

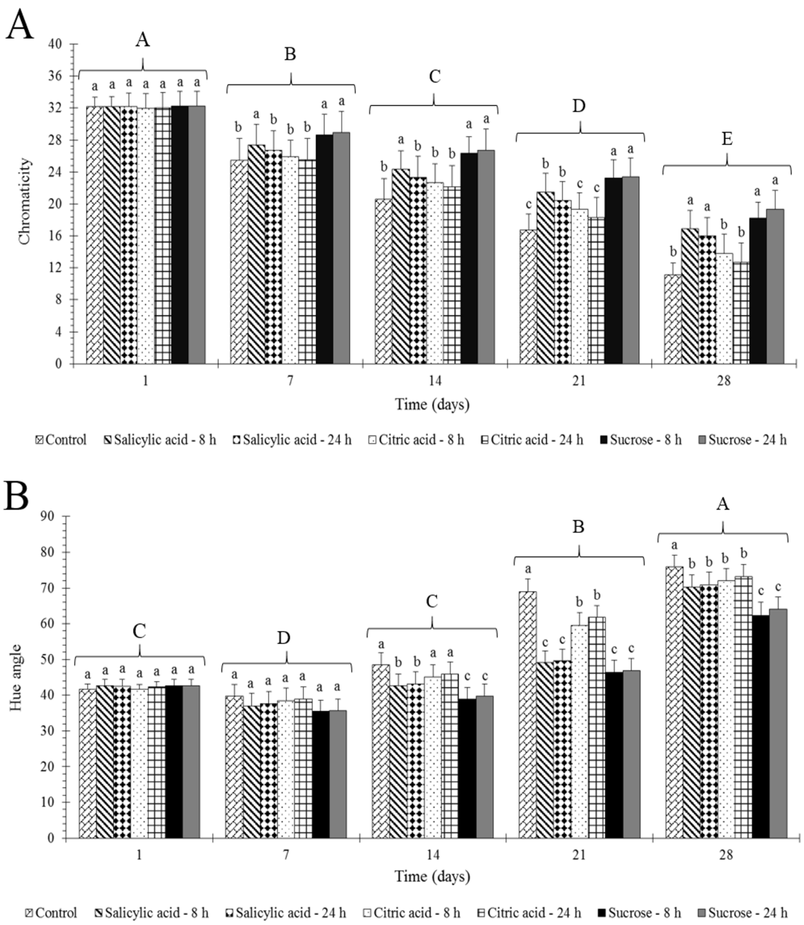

Figure 3. Effect of solutions on chromaticity (A) and Hue angle (B) of *V. incurvata* floral scapes. Means followed by the same letter, minuscule letter in lower part, and capital letter in the upper part, do not differ by the Scott-Knott test (p ≤ 0.05). The values are averages of six replications, each one formed with a floral scape ± S.D.

Table 1. Grades attributed to turgidity, color inflorescence, brightness inflorescence, presence of injuries, and commercial perception of *V. incurvata* floral scapes submitted to different solutions and immersion periods.

Treatments		Vase life (days)				
Solutions	Immersion (hours)	1	7	14	21	28
				Turgidity		
Control	0	4.00 aA	3.33 bB	3.00 bB	1.33 cC	1.00 bC
Salicylic acid	8	4.00 aA	4.00 aA	3.66 aB	3.50 aB	1.66 aC
Salicylic acid	24	4.00 aA	3.83 aA	3.66 aA	3.33 aB	1.50 bC
Citric acid	8	4.00 aA	3.66 bA	3.33 bB	3.00 bB	1.33 bC
Citric acid	24	4.00 aA	3.66 bA	3.16 bB	2.83 bB	1.16 bC
Sucrose	8	4.00 aA	4.00 aA	3.83 aA	3.66 aA	2.00 aB
Sucrose	24	4.00 aA	4.00 aA	3.83 aA	3.66 aA	2.00 aB
				Color inflorescence		
Control	0	4.00 aA	3.33 bB	3.00 bB	1.33 cC	1.00 bC
Salicylic acid	8	4.00 aA	3.83 aA	3.66 aA	3.16 aB	1.50 aC
Salicylic acid	24	4.00 aA	3.66 aA	3.50 aA	3.00 bB	1.50 aC
Citric acid	8	4.00 aA	3.50 bB	3.33 bB	2.83 bC	1.33 bD
Citric acid	24	4.00 aA	3.33 bB	3.16 bB	2.66 bC	1.16 bD
Sucrose	8	4.00 aA	4.00 aA	3.83 aA	3.50 aA	1.83 aB
Sucrose	24	4.00 aA	4.00 aA	3.83 aA	3.50 aA	1.83 aB
				Brightness inflorescence		
Control	0	4.00 aA	3.33 bB	3.00 bB	1.33 cC	1.00 bC
Salicylic acid	8	4.00 aA	4.00 aA	3.66 aB	3.50 aB	1.50 bC
Salicylic acid	24	4.00 aA	3.83 aA	3.50 aB	3.33 aB	1.33 bC
Citric acid	8	4.00 aA	3.66 bA	3.17 bB	2.83 bB	1.33 bC
Citric acid	24	4.00 aA	3.66 bA	3.00 bB	2.66 bB	1.17 bC
Sucrose	8	4.00 aA	4.00 aA	3.83 aA	3.67 aA	2.00 aB
Sucrose	24	4.00 aA	4.00 aA	3.83 aA	3.83 aA	2.33 aB
				Presence of injuries		
Control	0	4.00 aA	3.00 bB	3.00 bB	1.00 cC	1.00 bC
Salicylic acid	8	4.00 aA	3.17 bB	3.00 bB	3.00 aB	1.17 bC
Salicylic acid	24	4.00 aA	3.00 bB	3.00 bB	3.00 aB	1.33 bC
Citric acid	8	4.00 aA	3.00 bB	3.17 bB	2.66 bC	1.17 bD
Citric acid	24	4.00 aA	3.00 bB	3.00 bB	2.50 bC	1.17 bD
Sucrose	8	4.00 aA	3.50 aB	3.00 bC	3.00 aC	1.50 aD
Sucrose	24	4.00 aA	3.67 aB	3.50 aB	3.00 aC	1.67 aD
				Commercial perception		
Control	0	4.00 aA	3.00 bB	3.00 cB	1.67 cC	1.00 bD
Salicylic acid	8	4.00 aA	3.83 aA	3.33 bB	3.00 bB	1.33 bC
Salicylic acid	24	4.00 aA	3.67 aA	3.33 bB	3.00 bB	1.33 bC
Citric acid	8	4.00 aA	3.33 bB	3.00 cC	2.83 bC	1.00 bD
Citric acid	24	4.00 aA	3.33 bB	3.00 cC	2.67 bC	1.00 bD
Sucrose	8	4.00 aA	4.00 aA	3.50 bB	3.33 aB	1.83 aC
Sucrose	24	4.00 aA	4.00 aA	3.83 aA	3.50 aB	2.00 aC

Means followed by the same letter, capital letter in the row, and minuscule letter in the columns, do not differ by the Scott-Knott's test ($p \leq 0.05$). Each floral scape was evaluated with a rating scale by six evaluators.

way in maintaining flowers, it is well known that not all marketing areas in the Southern Hemisphere apply them. Likewise, it could be emphasized that this durability occurred in the absence of refrigerated conditions, which is frequent in low technology scenarios in which this bromeliad is commercialized, next to Brazilian Atlantic Rainforest regions. If this new use of *V. incurvata* is established locally and in the international market, avid for new products (Junqueira & Peetz, 2008), it will certainly be necessary to evaluate the ideal conditions of refrigerated storage to increase the durability without causing damage by chilling, common in cut flowers (Reid & Jiang, 2012).

The best results related to the prolongation of vase life of *V. incurvata* floral scapes, specifically regarding to fresh weight, water uptake, and loss were obtained with solutions of sucrose 24 and 8 h. This is in agreement with preliminary results that demonstrated the positive effect of sucrose solutions in vase life of other ornamental plants (Pattaravayo *et al.*, 2013). Sucrose solutions may have led to the stomatic closure of the *V. incurvata* bracts, reducing water loss. Energy supply (mainly via hydrolysis of starch and sucrose) is essential in postharvest of cut flowers. For Verlinden and Vicente (2004), the use of sucrose solutions acts directly in the water balance maintenance with less loss of turgidity, thus allowing greater water uptake and increased osmotic concentration.

The maintenance of color and brightness of floral scapes near those of the harvest occasion are characteristics very valued by the flowers consumers. The results reported that the *V. incurvata* floral scapes present a decreasing behavior of the intensity (chromaticity) and hue (Hue angle) of the bracts color, similar to what occurs in other cut flowers. (Pietro *et al.*, 2012; Tognon *et al.*, 2015). Soon after harvest, the floral scapes showed bright orange-colored bracts which became orange-red, orange-yellow, and eventually darkened over the vase life, similar to what occurs during the senescence process of the most part of the flowers (Macnish *et al.*, 2010). The maintenance of the bracts color intensity and tone throughout all vase life (chromaticity, Hue angle and rating scale) was also reported with the use of sucrose solutions, confirming its positive effects on stomatic closure and turgidity, as mentioned above, as well as agreeing with other authors who observed the same response (Perik *et al.*, 2014).

Considering that the sucrose solutions were similar in the two application periods (8 or 24 h), it is recommended to use for 8 h. This will favor the product postharvest operational management and the logistics distribution (Junqueira & Peetz, 2011).

On the other hand, the citric acid solutions showed the worst response regarding the maintenance of relative fresh weight, water uptake and loss, color, brightness, and turgidity of floral scapes when compared to solutions with sucrose and salicylic acid. These results suggest that possibly the citric acid concentration in the experiments was not the most adequate solution for the maintenance of *V. incurvata* floral scapes; however, its antimicrobial function in vase solutions should not be rejected. Citric acid and distilled water provided water deficit in the floral scapes, reflected in the relative fresh weight, water uptake and loss, and turgidity of floral scapes. According to Van Doorn (1996), the water deficit can cause a reduction of turgidity, discoloration of flowers and/or other organs, and the acceleration of senescence symptoms.

Conclusions

Sucrose, salicylic acid, and citric acid solutions applied for 8 and 24 h extend the vase life of the *V. incurvata* floral scapes. However, sucrose solutions are more efficient to promote the maintenance of color, brightness, and turgidity; improves water balance; and reduces the relative fresh weight losses of floral scapes. To extend the vase life for up to 24 days and favor the operational management of floral scapes in postharvest, the use of sucrose solution applied for 8 h is recommended.

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