horticultura brasileira

Research

CARRERA-ALVARADO, G; BALTAZAR-BERNAL, O. 2021. Solutions to conserve the vase life of *Heliconia* 'Tropics'. *Horticultura Brasileira* 39: 349-356. DOI: http://dx.doi.org/10.1590/s0102-0536-20210401

Solutions to conserve the vase life of *Heliconia* 'Tropics'

Gisela Carrera Alvarado [1]; Obdulia Baltazar-Bernal [1]

[1]Colegio de Postgraduados, Campus Córdoba. Carretera Federal Córdoba-Veracruz km 348, Congregación Manuel León. 94946, municipio de Amatlán de los Reyes, Ver., México; carrera.gisela@colpos.mx; obduliabb@colpos.mx (author for correspondence)

ABSTRACT

Heliconia 'Tropics' has high market acceptance and blooms year-round. Still, there is little information on solutions to prolong its vase life. The objective of this research was to assess pulse solutions to prolong the vase life of *Heliconia* 'Tropics' in three cutting stages. Floral stems in a closed, semi-open and commercial grown stages from three years old plants grown in an outdoor setting were evaluated. Three experiments were evaluated: sucrose at 10, 20 and 30% (w/v); Hydraflor® 100 at 0.25, 0.50 and 0.75 g L^{-1}; and citric acid (CA) at 25, 50, 100, 150 and 200 ppm, and a control (tap water). The floral opening, fresh weight of the floral stems, solution consumption and vase life were measured every two days. Based on the best results of these experiments, the following combinations were assessed: 10% sucrose + 0.50 g L^{-1} Hydraflor® 100; 10% sucrose + 150 ppm CA; 10% sucrose + 0.50 g L^{-1} Hydraflor® 100 + 150 ppm CA; 0.50 g L^{-1} of Hydraflor® 100 + 150 ppm CA and a control. A 10% sucrose + 0.50 g L^{-1} of Hydraflor® 100 pulse for 24 h had a 22.8-day vase life and was superior to the floral stems in the control treatment (15.6 days) at the semi-open cut stage. This was associated with greater water consumption, lower fresh weight loss and greater floral opening.

Keywords: *Heliconia psittacorum* x *H. spathocircinata*, tropical flowers, sucrose, Hydraflor® 100, citric acid, pulse solution.

RESUMO

Soluções para conservar a vida de *Heliconia* 'Tropics' em vaso

Heliconia 'Tropics' tem boa aceitação no mercado e floresce o ano todo. Mesmo assim, há poucas informações sobre soluções para prolongar sua vida de vaso. O objetivo desta pesquisa foi avaliar soluções conservantes para prolongar a vida de vaso de *Heliconia* 'Tropics' em três estágios de corte. Foram avaliados caules florais em estágios de flores fechadas, semiabertas e comerciais de plantas de três anos, cultivadas em ambiente aberto. Foram avaliados três experimentos: sacarose a 10, 20 e 30% (p/v); Hydraflor® 100 a 0,25, 0,50 e 0,75 g L^{-1}; e ácido cítrico (CA) a 25, 50, 100, 150 e 200 ppm, e um controle (água de torneira). A abertura floral, a massa fresca dos caules florais, o consumo de solução e a vida de vaso foram medidos a cada dois dias. Baseado nos melhores resultados desses experimentos, as seguintes combinações foram avaliadas: 10% sacarose + 0,50 g L^{-1} de Hydraflor® 100; 10% de sacarose + 150 ppm CA; 10% de sacarose + 0,50 g L^{-1} de Hydraflor® 100 + 150 ppm CA; 0,50 g L^{-1} de Hydraflor® 100 + 150 ppm CA e um controle. Sacarose a 10% + 0,50 g L^{-1} de Hydraflor® 100 conservantes por 24 h resultou em vida de vaso de 22,8 dias e foi superior às hastes florais do tratamento controle (15,6 dias) na fase de corte semiaberto. Isso foi associado ao maior consumo de água, menor perda de massa fresca e maior abertura floral.

Palavras-chave: *Heliconia psittacorum* x *H. spathocircinata*, flores tropicais, sacarose, Hydraflor® 100, ácido citrico, solução para vaso.

Received on July 24, 2020; accepted on April 29, 2021

In cut flowers, quality is closely related to pre- and post-harvest handling. During postharvest, the plant's handling and their postharvest process, as well as inadequate storage conditions can result in excessive loss of these products, flowers or inflorescences. It is estimated that 30 to 40% of the total flower production is lost due to inadequate postharvest handling (Yadav *et al.*, 2014). In addition, the differentiated quality of the floricultural production defines the destination of the commercialization, either for the internal, or external market destined to exports. Consequently, in Mexico, only a low percentage of production is exported (20%) and the rest is used to cover the prosperous domestic market (AIPH, 2017).

Reid (2009) states that maintaining good quality in cut flowers depends on the stored nutrients within the stems, leaves and petals; where carbohydrates are the main energy source for inflorescences, for the biochemical and physiological processes during the postharvest life (Halevy & Mayak, 1978).

The quality of some tropical cut flowers can be maintained and extended with hydration treatments (Folha *et al.*, 2016) or pulsing after harvest (Costa *et al.*, 2015; Baltazar-Bernal & Zavala-Ruíz, 2016). Pulsing is a treatment that loads tissues with high sucrose concentrations with a biocide, a weak acid, an anti-ethylene agent and/or a phytoregulator, generally before their commercialization in national or export markets (Halevy *et al.*, 1978) to increase vase life.

Sucrose is an additional source of the carbohydrates consumed by respiration (Morais *et al.*, 2015; Dias, 2016); it favors water flow and minerals in the xylem and acts on the stomatal closure, thus reducing water loss through transpiration, in addition, accumulates in floral tissues, increases its osmotic concentration and maintains turgor (Halevy *et al.*, 1978), which justifies

the positive effect on the vase life; furthermore, its application has been reported to influence harvested flowers opening in a closed cut state (Reid, 2009).

The pulsing has been successfully tested on various tropical flowers: in *Alpinia purpurata* a 2% sucrose + citric acid (CA) pulse is recommended (Mattiuz *et al.*, 2005); in *Polianthes tuberosa* a vase solution of 450 ppm of CA maintains the stem's quality by preventing microorganisms growth in the vase solution due to pH reduction (Jowkar & Salehi, 2005). In *Gardenia jasminoides*, 200 ppm of CA increases vase life (Çelikel *et al.*, 2020); in *Zingiber spectabile* Hydraflor® 100 (16 mL L^{-1}) improves vase life and stem quality (Coelho *et al.*, 2012).

Within the heliconia family, *Heliconia* 'Tropics' (*Heliconia psittacorum* x *H. spathocircinata*) is a cut flower that has a great ornamental acceptance by consumers, due to its attractive color, inflorescence size, flowering throughout the year and easy packing since its bracts are arranged in a single plane (Baltazar *et al.*, 2011; Costa *et al.*, 2015). *Heliconia* 'Tropics' replaces the "bird of paradise" flowers in the Mexican market, and along with its demand, the area sown with this cultivar in Mexico is increasing.

Due to the increase in the planted area with *Heliconia* 'Tropics' because of its demand is pertinent to investigate: the pulsing with different solutions accessible to small producers to prolong the flower´s vase life.

The objective here was to determine the effects of a pulsing treatment that allows prolonging the vase life of *Heliconia* 'Tropics' using sucrose, Hydraflor® 100 and CA, by themselves and in combination at three cut-off points.

MATERIAL AND METHODS

The research took place from November 2015 to March 2016, at the Colegio de Postgraduados, Campus Córdoba facilities, state of Veracruz, Mexico (18°51'21''N, 96°51'35''W, 647 m altitude); its climate is Am, warm humid with abundant rains in summer, with 22°C annual mean temperature, 28°C mean maximum and 16°C mean minimum; 1,800 mm mean annual precipitation, from May to October the precipitation exceeds 60 mm, and the average relative humidity is 62% (García, 2005). *Heliconia* 'Tropics' (*Heliconia psittacorum* x *H. spathocircinata*) flower stems were used, grown outdoors for three years, at three cut stages: closed, semi-open (one open bract) and commercial (two open bracts) (Figure 1), harvested before 8:00 AM in the ornamental horticulture area.

The research consisted of five experiments: during the first, the effect of a pulse of 0 (tap water with pH 7.1 and 0.4 mmho/cm EC), 10, 20 and 30% (w/v) sucrose for 24 h; in the second experiment, the effect of a Hydraflor® 100 from Floralife®, Walterboro, USA, preservative solution at concentrations of 0 (tap water), 0.25, 0.50 and 0.75 g L^{-1} pH 7.1, 5.5, 4.2 and 3.9 respectively were evaluated; in the third, the effect of a preservative solution of CA at 0 (tap water), 25, 50, 100, 150 and 200 ppm with pH 7.1, 6.7, 6.4, 5.8, 5.2 and 4.6 respectively, were evaluated. All three experiments were tested at the three cut-off stages.

Based on the best previous three experiments results, the fourth evaluated experiment was 10% sucrose + 150 ppm CA, 10% sucrose + 0.50 g L^{-1} Hydraflor® 100, 10% sucrose + 0.50 g L^{-1} Hydraflor® 100 + 150 ppm CA, 0.50 g L^{-1} Hydraflor® 100 +150 ppm CA and tap water at the semi-open and commercial cut-off points (Figures 1B and 1C, respectively). The fifth experiment evaluated the effect of pulsing 10% sucrose + 0.50 g L^{-1} Hydraflor® 100 for 0, 4, 8, 12, 24 and 48 hours at the semi-open cut-off stage (Figure 1C).

In all the experiments, the stems were set to 80 cm in length and were kept in a room at 22°C±2, 57 µmol m^{-2} s^{-1} of light and 75% RH. Temperature, relative humidity, and light were recorded using external automatic recording equipment, Onset HOBO brand, model U12-012. The evaluated variables were:

Fresh weight loss: fresh weight of the flower stems were evaluated every two days, with a digital scale, until the end of their vase life. The fresh weight loss calculation was reported as the total fresh weight loss at 14 days of vase life (VL) and was expressed in g of fresh weight.

Floral opening: evaluated every two days and up to 14 days of VL during the experiment, the distance at the maximum width of the open bracts was measured and reported as the difference in the initial and final floral opening in cm.

Water consumption: the volume of the vase liquid solution was recorded every two days and up to 14 days during the VL (accounting for the water loss by evapotranspiration) and recorded as water consumed in mL.

Vase life (VL): measured as the number of days from the cut-off date to the day when at least one of the following symptoms appeared: necrosis in a bract, bract wilting, bending of the stem.

Statistical analysis

A completely randomized experimental design was used, with a factorial arrangement in the structure of the treatments. In the first four experiments, the factors were the harvest stages and the solution concentrations. In each treatment of the five experiments, eight repetitions were used, each flower stem as an experimental unit. The obtained data were analyzed using an analysis of variance (ANOVA) and a Tukey mean comparison test ($\alpha = 0.05$), with the SAS® 9.4 statistical package software (2012).

RESULTS AND DISCUSSION

Experiment 1 - Effect of pulsing with sucrose

The flower stems from the three cut stages developed no new bracts, even with a pulsed treatment at a high concentration (30%). However, a significant effect ($P = 0.0216$) of the pulsing was observed on the floral opening of the inflorescences at the semi-open cutting point. The flower stems with an open bract (semi-open cut-off point), pulsed with 20% sucrose, had the greatest opening difference (6.75

cm), followed by those pulsed with 10 and 30% sucrose from the same cutting point. Sucrose pulsing has been used for several years in roses, carnations and later in bird of paradise (*Strelitzia reginae*) flowers (Halevy *et al.*, 1978) to maintain the sugar level of the stems, as sucrose is the substrate for respiration, and in this way, guarantee the floral opening is closed cut points (De la Cruz *et al.*, 2007; Reid, 2009).

Several studies have shown changes in the sugar levels in the flowers at the time of opening. These changes particularly consist in sugars reduction, such as glucose and fructose in peony (Xiang-Feng *et al.*, 2009), and Fresia (Shu *et al.*, 2010). That is, the role of sugars in promoting flower opening, which explains higher opening values in pulsed inflorescences.

Regarding the loss of fresh weight in the flower stems, a clear trend in the treatments is not observed either, the closed or commercial cut-off points, but the sucrose at 20% concentration generated the greatest loss of fresh weight at the semi-open cut point (Table 1). In regard to water consumption, it was significantly lower in non-pulsed flower stems ($P = 0.0001$) than in pulsed ones with 20 and 30% sucrose at all cut-off points. In the three cut-off points, the sucrose concentration that generated the highest water consumption was 20%. The highest solution consumption occurred during the first four days (Figure 2).

The interaction between the cut-off point and pulsing solution had a significant effect ($P = 0.0001$) on the vase life of the inflorescences in the closed/semi-open cut-off points with a 10% sucrose pulsing (Table 1). The longest vase life was found with the 10% sucrose pulsing, with a VL of 25.6, 25.4 and 24.3, which increased by 2, 4.2 and 3.6 days in the closed, semi-open and commercial cut-off points, respectively, compared with the VL of the non-pulsed stems (Table 1).

Reid (2009) mentions that adding a carbohydrates source, such as sucrose, to vase solutions, results in an extension of the vase life if the microorganism's growth is controlled. Therefore, according to this author, the vase life increase of heliconia in acid solutions is due to the inhibition of vascular blockage by microorganisms and increased water absorption.

Experiment 2 - Hydration with Hydraflor® 100

The stems treated with Hydraflor® 100 showed similar behavior to those treated with sucrose; that is, there was no new bracts development at any cut point. Hydraflor® 100 and the interaction cut-off point and Hydraflor® 100 had a significant effect $P = 0.0001$ and $P =$

Figure 1. Heliconia 'Tropics' (*H. psittacorum* x *H. spathocircinata*) cutting stages: A) closed, B) semi-open, and C) commercial. Veracruz, Mexico, Colegio de Postgraduados, Campus Córdoba, 2016.

Table 1. Means comparison of four measured variables in floral stems of *Heliconia* 'Tropics' (*H. psittacorum* x *H. spathocircinata*) pulsed for 24 h with different concentrations of sucrose, evaluated at day 14 of their vase life. Veracruz, Mexico, Colegio de Postgraduados, Campus Córdoba, 2016.

Cut stage	Sucrose (%)	Floral opening (cm)	Fresh weight loss (g)	Water consumption (mL)	Vase life (days)
Closed	0	0	8.19^{b}	47.25^{f}	23.63^{bcd}
	10	0	9.43^{ab}	48.25^{ef}	25.63^{a}
	20	0	9.70^{ab}	54.88^{cd}	23.38^{cd}
	30	0	11.37^{ab}	51.88^{de}	23.50^{cd}
Semi-open	0	2.53^{bcd}	9.09^{b}	48.50^{ef}	21.13^{e}
	10	4.62^{ab}	9.35^{b}	55.50^{cd}	25.38^{ab}
	20	6.75^{a}	12.81^{a}	65.63^{a}	25.00^{abc}
	30	4.46^{bc}	9.18^{b}	52.13^{de}	24.25^{a}
Commercial	0	1.60^{d}	9.61^{ab}	54.00^{cd}	20.75^{e}
	10	0.93^{d}	10.32^{ab}	56.37^{cd}	24.38^{abcd}
	20	2.31^{cd}	9.12^{b}	61.75^{ab}	24.25^{abcd}
	30	1.25^{d}	10.54^{ab}	58.50^{bc}	23.13^{d}
CV (%)		0.93	0.35	0.13	0.09
Significance ($p \leq 0.05$)					
CS		0.0001	0.8867	0.0001	0.0453
Sucrose		0.0216	0.4029	0.0001	0.0001
CS x Sucrose		0.1506	0.3004	0.0109	0.0073

Means with the same letter between columns are not statistically different. Tukey, $P < 0.05$.

Table 2. Means comparison of four variables measured in floral stems of *Heliconia* 'Tropics' (*H. psittacorum* x *H. spathocircinata*) treated with different concentrations of Hydraflor® 100, evaluated at day 14 of their vase life. Veracruz, Mexico, Colegio de Postgraduados, Campus Córdoba, 2016.

Cut stage	Hydraflor® 100 (g L^{-1})	Floral opening (cm)	Fresh weight loss (g)	Water consumption (mL)	Vase life (days)
Closed	0.00	0.00	5.46^{bc}	37.50^{fg}	18.00^{bcd}
	0.25	0.00	3.46^{efg}	48.13^{bc}	17.50^{cde}
	0.50	0.00	2.58^{g}	55.00^{a}	19.75^{ab}
	0.75	0.00	0.92^{h}	38.88^{fg}	19.25^{abc}
Semi-open	0.00	3.41^{ab}	6.34^{b}	36.00^{g}	16.50^{def}
	0.25	3.15^{ab}	4.58^{cdef}	40.75^{ef}	16.50^{def}
	0.50	2.10^{bc}	0.94^{h}	43.75^{de}	20.50^{a}
	0.75	0.98^{c}	4.95^{bcde}	45.00^{bcd}	15.50^{ef}
Commercial	0.00	0.95^{c}	8.16^{a}	31.37^{h}	15.87^{ef}
	0.25	3.95^{a}	5.08^{bcd}	44.25^{cde}	16.50^{def}
	0.50	1.44^{c}	3.79^{defg}	48.63^{b}	18.25^{bcd}
	0.75	1.50^{c}	3.23^{fg}	41.25^{def}	15.75^{ef}
CV (%)		0.83	0.62	0.18	0.14
Significance ($p \leq 0.05$)					
CS		0.0896	0.0001	0.0014	0.0004
Hydraflor® 100		0.0001	0.0001	0.0001	0.0001
CS x Hydraflor®100		0.0002	0.0001	0.0001	0.0935

Means with the same letter between columns are not statistically different. Tukey, $P < 0.05$.

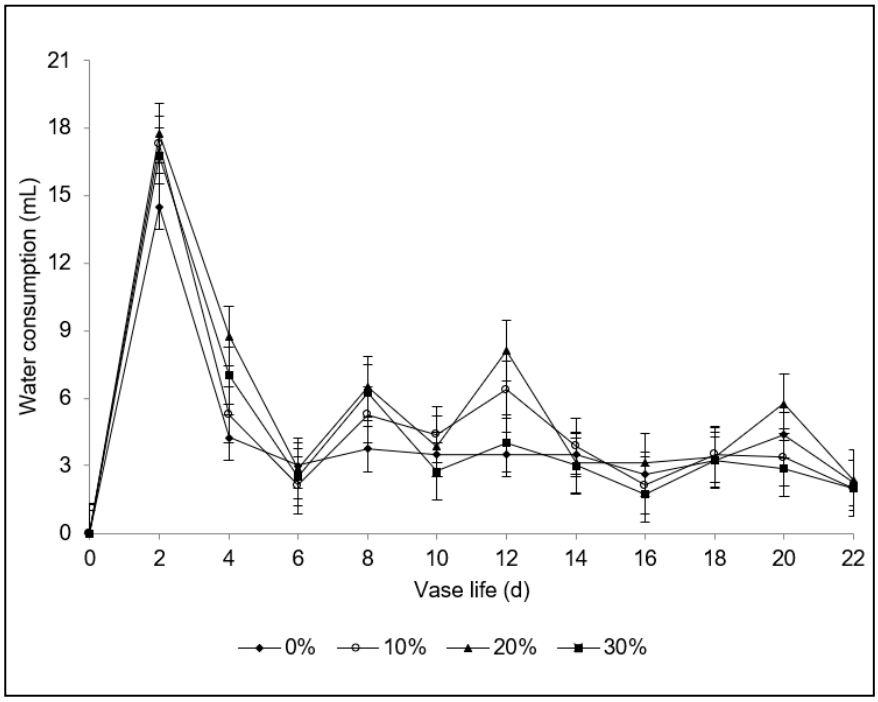

Figure 2. Water consumption during postharvest life of *Heliconia* 'Tropics' (*H. psittacorum* x *H. spathocircinata*) in a semi-open stage pulsed with sucrose at 0, 10, 20 and 30% (p/v). Veracruz, Mexico, Colegio de Postgraduados, Campus Córdoba, 2016.

0.0002 each, on the difference in floral opening of the already opened bracts. At the semi-open cut-off point, the higher the Hydraflor® 100 concentration in the vase solution, the smaller the difference in the floral opening; therefore, the control presented the largest opening (3.41 cm); while, in the stems at the commercial stage, the opening difference was greater in those treated with Hydraflor® 100 compared to the stems of the control treatment (0 g L^{-1}), which were of 0.95 cm (Table 2).

The application of sucrose or Hydraflor® 100 in the vase solution, despite contributing to the opening of the already opened bracts, did not allow to increase the number of bracts in the inflorescences of Heliconia 'Tropics'. Costa *et al.* (2011) and Carrera-Alvarado *et al.* (2020) stated that the opening of floral bracts in heliconia flowers is disabled once the plant's stem is separated. Contrary to that in the bird of paradise flowers (*Strelitzia reginae*), which opens its buds even when harvested in a closed point and has greater longevity, compared to those harvested when the first bract begins to open (Dias, 2016).

Regarding the loss of fresh weight, it had a significant effect ($P \leq 0.0001$) on the cut points of the flower stems, the Hydraflor® 100 concentration and the interaction (Table 2). On the treatments, the fresh weight loss of the flower stems was significantly higher ($P = 0.0001$) in the control treatment (0 g L^{-1}), compared to that of the stems treated with Hydraflor® 100, in the three cutting points. At the highly closed cut-off point, the control lost 7.85% of the fresh weight of the floral stem, while with 0.75 g L^{-1} Hydraflor® 100 only 1.08% was lost. At the semi-open cut-off point, the control treatment (0 g L^{-1}) lost 8.42% of the fresh weight of the floral stem, while with 0.50 g L^{-1} Hydraflor® 100, only 0.42% of the fresh weight was lost. In this same stage, the flower stems treated with Hydraflor® 100 increased their fresh weight, unlike the control treatment, in which, after the second day of VL, the fresh weight decreased (Figure 3). In the flowers at the commercial cut-off point, the control (0 g L^{-1}) lost 10.0% of its fresh weight

Table 3. Means comparison of four variables assessed in floral stems of *Heliconia* 'Tropics' (*H. psittacorum* x *H. spathocircinata*) pulsed with four different solutions and a control (tap water) for 48 h, evaluated at day 14 of their vase life. Veracruz, Mexico, Colegio de Postgraduados, Campus Córdoba, 2016.

Cut stage	Treatment	Floral opening (cm)	Fresh weight loss (g)	Water consumption (mL)	Vase life (days)
Semi-open	Control (tap water)	1.51^{bcd}	10.59^{abc}	46.25^{bc}	19.63^{de}
	10% sucrose + 150 ppm CA	1.06^{cde}	12.07^{ab}	42.75^{cd}	21.63^{cd}
	10% sucrose + 0.50 g L^{-1}Hydraflor® 100	3.10^{a}	6.68^{d}	54.75^{a}	27.63^{a}
	10% sucrose + 150 ppm CA + 0.50 g L^{-1}Hydraflor® 100	2.29^{ab}	9.55^{bc}	46.88^{bc}	25.50^{ab}
	150 ppm CA + 0.50 g L^{-1}Hydraflor® 100	1.78^{bc}	9.50^{bcd}	55.75^{a}	21.88^{cd}
Commercial	Control (tap water)	0.56^{de}	11.07^{abc}	42.38^{cd}	18.25^{e}
	10% sucrose + 150 ppm CA	0.79^{cde}	13.41^{a}	40.13^{d}	24.13^{bc}
	10% sucrose + 0.50 g L^{-1}Hydraflor® 100	0.48^{e}	9.15^{cd}	51.75^{ab}	26.00^{ab}
	10% sucrose + 150 ppm CA + 0.50 g L^{-1}Hydraflor® 100	1.09^{cde}	11.83^{abc}	41.25^{cd}	21.63^{cd}
	150 ppm AC + 0.50 g L^{-1}Hydraflor® 100	0.85^{cde}	11.31^{abc}	44.75^{cd}	20.00^{de}
CV (%)		0.93	0.30	0.16	0.16
Significance ($p \leq 0.05$)					
CS		0.0001	0.0112	0.0002	0.0082
Treatment		0.0667	0.0005	0.0001	0.0001
CS x Treatment		0.0250	0.8728	0.2636	0.0015

Means with the same letter between columns are not statistically different. Tukey, $P < 0.05$.

of the floral stems, while with 0.75 g L^{-1} Hydraflor® 100 treatment only 4.60% was lost.

The interaction between the cut-off point and the Hydraflor® 100 pulse had a significant effect (P = 0.0001), thus the water consumption was higher in the stems treated with Hydraflor® 100, especially those in a 0.50 g L^{-1} concentration, consuming up to 17 mL more than the stems in the control treatment (0 g L^{-1}), in stems at a closed and commercial cut point and up to 7 mL more in the stems at a semi-open cut point. Therefore, hydration with Hydraflor® 100 to 0.50 g L^{-1} is an optimal concentration for water consumption in the three cut-off points. The longest vase life was observed in the concentration of 0.50 g L^{-1} of Hydraflor® 100 in the three cut points, increasing 1.7, 4.0 and 2.4 days in the stems with closed, semi-open and commercial cut points, respectively, compared with the stems in the control treatment (Table 2).

These results show that Hydraflor® 100 significantly increases the water consumption in flower stems compared to those in the control treatment (0 g L^{-1}). This response is associated with the fact that the solution with the moisturizer has lower pH (5.5, 4.2 and 3.9) than tap water (7.4). According to Reid (2009), water frequently contains minerals that turn it alkaline (high pH), which drastically reduces its movement within the stems, so that to counteract this effect, water must be acidified to extend vase life (Baltazar-Bernal & Zavala-Ruiz, 2012; Coelho *et al.*, 2012). At the same time, acidifying the solution allows the metabolic activity in the stem to be maintained, which is associated with higher water consumption. Furthermore, low pH has been reported with a reduction in phenolic oxidation (Halevy *et al.*, 1978; Sardinha *et al.*, 2019) and a decrease in bacterial growth, which delay xylem disruption (Jowkar & Salehi, 2005). However, no significant differences were obtained in the interaction cut-off point and Hydraflor® 100, which concurs with Lessa *et al.* (2015) who report that tap water was sufficient to maintain the vase life of *Zingiber spectabile*.

Experiment 3- Citric acid effect

No significant effects (P = 0.9428) of the citric acid were observed on the vase life of cut stems in a closed development stage, unlike the stems in semi-open and commercial cut-off stages, where the longest vase life was recorded in stems treated with a 150 ppm CA (22.6 and 21.4 days respectively), increasing, in both cases, 4.6 days the vase life compared to stems treated with 0 ppm CA (data not shown).

In experiments 1, 2 and 3, no great influence of the pulsing or preservative solutions was observed on the vase life of the closed cut-off flowers; since the flower stems of the control treatment also showed a long vase life (18 to 23 days). This result is probably due to: 1) being in an early development stage, the floral surface exposed to transpiration is smaller than that of the inflorescences of the semi-open and commercial cut stages where the bracts are already open; 2) in the closed stage of development, endogenous sugar levels are high, since it has been shown that the development and opening are associated with overall high levels of reducing sugars, while senescence is associated with low levels (Sane & Khan, 2013), so exogenous application of sugars is unnecessary.

Experiment 4 - Evaluation of solutions for pulsing

In Table 3, results show that in flower stems in a semi-open cutting stage the largest opening (3.10 cm) is obtained

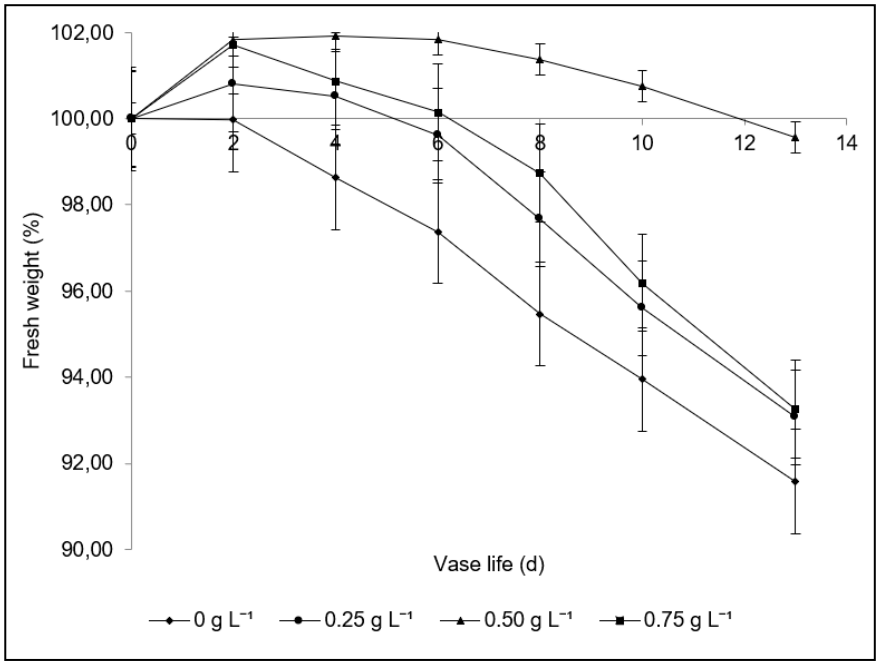

Figure 3. Changes on fresh weight during postharvest life of *Heliconia* 'Tropics' (*H. psittacorum x H. spathocircinata*) in semi-open stage treated with Hydraflor ® 100 at 0, 0.25, 0.50 and 0.75 g L^{-1}. Veracruz, Mexico, Colegio de Postgraduados, Campus Córdoba, 2016.

Table 4. Means comparison of four variables measured in floral stems of *Heliconia* 'Tropics' (*H. psittacorum* x *H. spathocircinata*) pulsed with 10% sucrose + 0.50 g L^{-1} Hydraflor® 100 at different times, evaluated on day 14 of their vase life. Veracruz, Mexico, Colegio de Postgraduados, Campus Córdoba, 2016.

Pulse time (h)	Floral opening (cm)	Fresh weight loss (g)	Water consumption (mL)	Vase life (days)
0	1.92^{b}	27.84^{a}	45.17^{e}	15.67^{d}
4	4.60^{a}	15.21^{b}	46.17^{de}	17.33^{cd}
8	3.33b^{a}	14.00^{b}	49.50^{cd}	17.33^{cd}
12	3.43b^{a}	12.07^{b}	56.17^{a}	19.5b^{c}
24	2.93b^{a}	9.22^{b}	52.50^{bc}	22.83^{a}
48	2.93b^{a}	13.87^{b}	53.80^{ab}	21.67^{ba}
CV (%)	0.56	0.60	0.09	0.17
Significance ($p \leq 0.05$)				
Pulse time	0.2740	0.0178	0.0001	0.0007

Means with the same letter between columns are not statistically different. Tukey, $P < 0.05$.

with the pulsing of 10% sucrose + 0.50 g L^{-1} Hydraflor® 100, 1.59 cm more than the control treatment ($P = 0.0250$). The flower stems in a commercial cut stage showed less bract opening than that stems with a semi-open cut stage. The treatment that reported the highest result (0.53 cm more than the control) was that with 10% sucrose + 150 ppm CA + 0.50 g L^{-1} Hydraflor® 100. In the two cut-off points (semi-open and commercial) ($P = 0.0112$), the treatment with 10% sucrose + Hydraflor® 100 (0.5 g L^{-1}) had a significant effect ($P = 0.0005$) on the loss of fresh weight, with losses less than 9% of its initial weight, while the rest of the treatments had losses of around 16%. This same treatment registered a higher water consumption and vase life ($P = 0.0001$) in the two cut-off points, increasing up to eight more days of vase life, compared to the stems in the control treatment (tap water). Therefore, the sucrose effect was enhanced with Hydraflor® 100.

In previous experiments, longer vase life was associated with higher water consumption and lower weight loss as the result of using sucrose and Hydraflor® 100, by itself or in combination in the vase solution. Given that, during the vase life of the stems pulsed with sucrose, there was a higher water consumption than that of the non-pulsed stems (Figure 2); and the flower stems treated with Hydraflor® 100 increased their fresh weight during the first three days, unlike the stems of the control treatment (Figure 3). Halevy & Mayak (1981) reported that the flowers that maintain or increase their weight, achieve a longer vase life than those in which the weight decrease. Sucrose has been reported to improve the water balance in cut flowers, by regulating their osmotic potential and the water retention capacity of their tissues, which may explain the weight and vase life increased (Reid, 2009; Sane & Khan, 2013). In cut flowers of Rosa cv. Royalty, longer vase life was associated with higher water consumption, along with slow loss of fresh weight (De la Cruz *et al.*, 2007), as well as in heliconia inflorescences (Mangave *et al.*, 2014; Patel *et al.*, 2017).

Experiment 5 - Evaluation of pulsing with 10% sucrose + 0.50 G l^{-1} hydraflor® 100

The pulsing time had no significant effect on the floral opening of the control treatment but had a significant effect on the fresh weight loss ($P \leq 0.0178$), water consumption ($P \leq 0.0001$) and vase life ($P \leq 0.0007$). The flower stems pulsed for 12 hours had a higher water consumption (56.17 mL), followed by the stems pulsed for 48 hours (53.80 mL) and 24 hours (52.50 mL). Regarding the VL of *Heliconia* 'Tropics' stems pulsed for 24 hours with 10% sucrose + 0.50 g L^{-1} Hydraflor® 100, it increased up to 7.1 days more than non-pulsed stems (15.6 days), that is, it reached a vase life of 22.8 days (Table 4).

Pulsing with 10% sucrose + 0.50 g L^{-1} Hydraflor® 100 significantly increased the vase life of *Heliconia*

'Tropics', by conserving the metabolic activity of the stems, which facilitated the maintenance of water absorption and its flow. This was probably caused by sucrose, slightly reducing the osmotic potential, and Hydraflor® 100 slightly reducing the solution's pH. This concurs with Halevy *et al.* (1978), who reported that in bird of paradise flowers (*Strelitzia reginae*) vase life increased up to 8 days by pulsing with 10% sucrose + 50 ppm of $AgNO_3$ and 150 ppm CA for 24 h. Asrar (2012) also reported that a 2% sucrose + 200 ppm 8-HQS pulse in snapdragon cut flowers resulted in longer vase life because the pulse played a fundamental role in promoting water absorption and in the metabolic processes of flower stems. Likewise, in *Heliconia* Golden Torch, a spray with 100 mg L^{-1} GA and 50 mg L^{-1} bovine serum albumin improved vase life, and was associated with increased fresh weight and water absorption (Mangave *et al.*, 2013). In *Heliconia wagneriana*, a 10% sucrose pulsing for 60 minutes maintained the quality of the inflorescences 20% longer than in control stems that had high transpiration and low water consumption (Costa *et al.*, 2015). In *Oncidium varicosum* orchids a 5% sucrose + 100 mg L^{-1} 8-HQC + 50 mg L^{-1} $AgNO_3$ vase solution maintained the relative water content and the carbohydrates and soluble sugars content in the flowers, thus preserving the vase life for longer compared to stems of a control treatment (Mattiuz *et al.*, 2015).

According to the results here presented, it can be concluded that all the used solutions increased the vase life of *Heliconia* 'Tropics'; however, the 10% sucrose + 0.50 g L^{-1} Hydraflor® 100 pulsing for 24 hours maintained the vase life for 22.8 days. This is associated with greater water absorption, greater floral opening, and less fresh weight loss. This solution maintained the metabolic activity of the stems, which provided and maintained the water flow. This was possibly caused by the sucrose solution that slightly reduces osmotic potential, associated with a slight decrease in pH caused by Hydraflor® 100. Therefore, this treatment has potential as a preservative solution for cut flowers of *Heliconia* 'Tropics' in a semi-open cut stage.

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