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Scientific Article

Postharvest durability of Heliconiaceae evaluated in a controlled environment in Mato Grosso state, Brazil

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Abstract

Postharvest preservation is essential to maintain the peculiar features, beauty and longevity of flower stalks. The purpose of this study was to evaluate the postharvest durability, based on the visual quality and fresh weight of flower stalks of *Heliconia psittacorum* (with three-color variations) and of *H. densiflora,* in a cold chamber at three temperatures (14 ºC, 18 ºC and 22 ºC) and in the laboratory (control treatment at 26 ºC). A completely randomized design with four replications and five stems per plot was used. In flower stalks of *H. densiflora* under laboratory conditions, first signs of senescence were observed after six days of evaluation. For *H. psittacorum,* first signs of senescence were observed between 6 and 12 days of evaluation. For flower stalks of *H. psittacorum* (inflorescence color 5R 4/10), storage at 14 °C is recommended for up to nine days. At 14 ºC or 22 ºC, *H. psittacorum* (inflorescence color 2.5Y 7/10) at 18 ºC or 22 ºC for up to six days, and *H. psittacorum (*inflorescence of 7.7 YR 7/10) at 14 ºC or 22 ºC for up to six days. For *H. densiflora*, storage at 18 °C is recommended for up to six days. For both species and bract color variations, the reductions of fresh weight were greatest in the refrigerated environments.
Keywords: fresh weight, flower senescence, tropical flowers, vase life.

Resumo

Durabilidade pós-colheita de Heliconiaceae avaliada em ambientes controlados no estado de Mato Grosso, Brasil

A conservação pós-colheita é essencial para que as hastes florais mantenham sua originalidade, beleza e longevidade. O objetivo deste trabalho foi avaliar a durabilidade pós-colheita, por meio da qualidade visual e massa fresca, de hastes florais de *Heliconia psittacorum* (com três variações de cores) e *H. densiflora*, em três temperaturas sob condições de câmara fria (14 ºC, 18 ºC e 22 ºC) e condição de laboratório (controle a 26 ºC). Foi utilizado o delineamento inteiramente casualizado com quatro repetições e cinco hastes por parcela. Em hastes florais de *H. densiflora,* mantidas sob condições de laboratório, os primeiros sinais de senescência foram apresentados aos seis dias de avaliação. Para *H. psittacorum,* os primeiros sinais de senescência foram apresentados dos seis aos doze dias de avaliação. Indica-se o armazenamento de hastes florais de *H. psittacorum* (inflorescência de coloração 5R 4/10) por até nove dias em temperatura de 14 ºC, *H. psittacorum* (inflorescência de coloração 2,5Y 7/10) por até seis dias, em temperaturas de 18 ºC ou 22 °C e *H. psittacorum* (inflorescência de coloração 7,5YR 7/10) por até seis dias, em temperaturas de 14 ºC ou 22 ºC. Para *H. densiflora* foi recomendado o armazenamento em temperatura de 18 ºC, por até seis dias. Para ambas as espécies e variações de cores de brácteas, as maiores reduções de massa fresca ocorreram em ambiente refrigerado.
Palavras-chaves: flores tropicais, massa fresca, senescência floral, vida de vaso.

Introduction

Heliconia spp. are promising tropical species for the market of ornamental plants, with desirable characteristics as cut flowers, in view of the beauty of the bracts that have a high diversity of colors and forms, an exotic appearance, postharvest durability, aside from a wide consumer acceptance (Loges et al., 2005). The ornamental plant market daily needs a diversity of tropical flowers that meet the consumer demands, aiming at minimized losses and maintenance of the product quality (Costa et al., 2011).

The resistance of the inflorescences to deterioration during shipping, ease of handling and packaging, stems firmness and durability are desirable postharvest characteristics for cut flowers destined for national and international consumer markets (Castro et al., 2006). The main cause of loss of inflorescence quality and reduction in floral longevity is an inadequate choice of temperature

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during shipping and storage, leading to a high discard percentage of cut flowers (Reid, 2001).

The determination of an adequate temperature range to ensure the maintenance of inflorescences in good state of conservation is fundamental for the quality stability of the product until it reaches the consumer (Reid, 1991). In this regard, low temperatures minimize water loss, delay senescence and avoid plant tissue deterioration, thus extending postharvest longevity (Silva, 2003).

The objective of this study was to determine the postharvest durability and variation in fresh weight of flower stalks of *Heliconia psittacorum* and *H. densiflora,* based on visual and physical parameters, at different temperatures and after different storage periods.

Material and methods

The flower stalks were cultivated on a field of the genebank (14º39 'S, 57º25' W; 321 m asl), planted in March 2014. The regional climate is tropical, with well-defined dry and rainy seasons and a mean annual rainfall between 1300 and 2000 mm year^{-1}, and a mean annual temperature between 16 and 36 °C (Martins et al., 2010). The soil was classified as Latossolo Vermelho distroférrico, clayey, with a flat to slightly undulating relief (EMBRAPA, 2018).

Flower stems of *Heliconia psittacorum* with three types of color variations were evaluated according to the Munsell Plant Tissue Color Book (2012), yellow (2.5Y 7/10), orange (7.5YR 7/10) and red (5R 4/10) and *H. densiflora* with orange-red bracts (5R 5/10). The stalks were maintained in water-filled containers to avoid excessive dehydration. The collected flower stalks had two to four open bracts and were cut at 20 cm above the soil, between 06:30 and 07:30 AM (Loges et al., 2005).

The storage of flower stalks was tested in three treatments in a cold chamber, for a period of up to 21 days, at temperatures of 14, 18 and 22 ºC and a relative humidity of 80% (Costa et al., 2011). The control treatment under laboratory conditions was run at a mean temperature of 26 ºC and relative humidity of 50% to 55%. Each treatment consisted of four replications of five stems.

The flower stalks cooled to the different temperatures in a cold chamber were packed in a cardboard box (adapted to the stem size) lined with bubble wrap (COSTA et al., 2011).

Postharvest evaluations of *H. psittacorum* and *H. densiflora* inflorescences subjected to cold chamber and control (laboratory conditions) treatments were performed every three days. The following four-grade scale was used, as proposed by Costa et al. (2011), with modifications.

Score 4: inflorescence with natural gloss and absence of dark spots on the bract apex (Figure 1A); Score 3: inflorescences with natural gloss and onset of senescence (dark spots) on the bract apex (Figure 1B); Score 2: inflorescences without natural gloss, dark spots larger than 5.0 cm below the bract apex or slightly stained bracts (Figure 1C); Score 1: inflorescence without natural gloss and bracts with intense dark spots (Figure 1D).

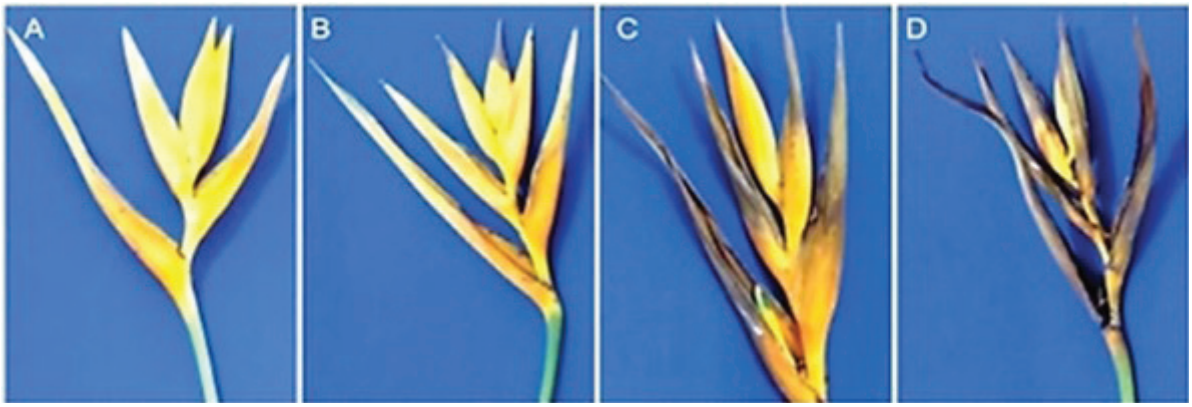

Figure 1. Senescence process of flower stems of *Heliconia psittacorum*. (A) score 4, (B) score 3, (C) score 2, (D) score 1 (discard).

All flower stalks of each treatment including the control were discarded when more than 50% were evaluated with score 1. Aside from the score scale, the stem fresh weight was assessed on a digital scale (model MS 30 K1). For the fresh weight percentage (FW), five stems per plot with four replications were used. The initial percentage of the flower stalk weight was considered 100%, based on which the subsequent values until disposal were determined (COSTA et al., 2011).

The experiment used a completely randomized factorial design to test three temperatures (14 ºC, 18 ºC and 22 ºC) and seven storage periods (3, 6, 9, 12, 15, 18 and 21 days), in four replications, with five flower stems per plot. The data were subjected to analysis of variance and the means compared by the Tukey test (P <0.05), using the statistical program SISVAR (FERREIRA, 2011).

Results

Postharvest visual quality

Among the *H. psittacorum* species maintained under laboratory conditions, the first signs of senescence were observed in *H. psittacorum* (inflorescences with 2.5Y 7/10 and 7.5YR 7/10), after nine days of evaluation, characterized by the presence of dark spots and drying of the bract apex (Table 1). In *H. psittacorum* (inflorescence with 5R 4/10), the first signs of senescence appeared after 12 days of storage (Table 1).

Table 1. Visual quality of *H. psittacorum* and *H. densiflora* inflorescences, evaluated over a period of 21 days, under laboratory conditions, without refrigeration (NR - Control) and in a refrigerated environment (WR).

Species/ inflorescence color		Storage (days)							
		0	3	6	9	12	15	18	21
H. psittacorum /2.5Y 7/10	NR	4.00 aA	4.00 aA	4.00 aA	3.00 bB	2.00 dC	1.00 bD	-	-
	WR	4.00 aA	3.66 aB	3.33 bC	2.33 dD	1.33 eE	0.50 cF	-	-
H. psittacorum /7.5YR 7/10	NR	4.00 aA	4.00 aA	4.00 aA	3.00 bB	2.00 dC	1.00 bD	-	-
	WR	4.00 aA	4.00 aA	4.00 aA	3.66 aA	2.66 bB	1.33 bC	0.33 cD	-
H. psittacorum /5R 4/10	NR	4.00 aA	4.00 aA	4.00 aA	4.00 aA	3.00 aB	2.00 aC	1.00 aD	-
	WR	4.00 aA	4.00 aA	3.66 bB	2.66 cC	2.00 dD	1.00 bD	0.66 bE	0.33 aF
H. densiflora/5R 5/10	NR	4.00 aA	4.00 aA	3.00 cB	2.00 eC	1.00 eD	-	-	-
	WR	4.00 aA	4.00 aA	3.33 bB	3.00 bB	2.26 cC	1.33 bD	0.66 bE	0.33 aF

Means followed by the same lowercase letter in a column and upper case letters in a row do not differ at 5% probability by the Tukey test.

Under laboratory conditions, the vase life of *H. densiflora* was shorter than that of *H. psittacorum* (Table 1). The first signs of senescence were observed after six days of evaluation, consisting of the presence of dark spots on the bract apex, advancing towards the basal region of the inflorescence, accompanied by withering process and loss of the visual quality of the inflorescence during the 12 evaluation days (Table 1).

In the cold chamber, the first signs of senescence on *H. psittacorum* (inflorescence 2.5Y 7/10) appeared on the third day of storage, characterized by intense dark spots in the apical region of the upper and lower bracts, spreading along the bracts, affecting the visual appearance of the inflorescences (Table 1). The best storage temperature for *H. psittacorum* (inflorescence 2.5Y 7/10) in the cold chamber was 22 °C, statistically not different from the control (26 °C) (Table 2).

Table 2. Visual quality of *H. psittacorum* and *H. densiflora* inflorescences, stored in a cold chamber (14 ºC, 18 ºC and 22 ºC) and in a laboratory environment at 26 ºC (Control).

Species/ inflorescence color	Temperature			
	14 ºC	18 ºC	22 ºC	26 ºC
H. psittacorum /2.5Y 7/10	1.25 bC	2.00 cB	2.25 bA	2.25 bA
H. psittacorum /7.5YR 7/10	2.75 aA	2.25 aC	2.50 aB	2.25 bA
H. psittacorum /5R 4/10	2.87 aA	1.75 dC	2.25 bB	2.75 aA
H. densiflora/5R 5/10	2.74 aA	2.10 cB	2.25 bB	1.75 cA

Means followed by the same lowercase letter in a column and upper case letters in a row do not differ at 5% probability by the Tukey test.

The initial signs of senescence on *H. psittacorum* inflorescences (7.5 YR 7/10) stored in a cold chamber were dryness and shriveling of the bract apex, followed by dark spots and loss of natural gloss after nine days (Table 1).

Heliconia psittacorum (5R 4/10) and *H. densiflora* (5R 5/10) proved most resistant in the cold chamber, completing the whole senescence process within 21 days (Table 1). The first signs of senescence were small dark spots on the bract apex after six storage days. The 5R 4/10 inflorescences were not only longer-lived, but could also be stored in a cold chamber (14° C) as well as at ambient temperature (26 °C) (Table 2).

In the cold chamber, the flower longevity of *Heliconia densiflora* exceeded nine days and lasted longer than under laboratory conditions (Table 1). The first signs of senescence appeared on the apex of the lateral bracts after six storage days at 18 ºC, consisting of superficial dark patches (Table 2).

Under laboratory conditions (control), the first signs of senescence were observed after six days, affecting the visual quality of the stem (score 3) and evolving until disposal after 12 days (Table 1). The best storage temperature for *H. densiflora* flower stalks was 14 °C (Table 2).

Fresh weight

The fresh weight of the flower stems of *H. psittacorum* and *H. densiflora* maintained in a laboratory environment (control) and those stored at 14 °C, 18 °C and 22 °C in a cold chamber decreased progressively throughout the evaluation period (Table 3 and Figure 2).

For all species and color variations of evaluated bracts, the fresh weight reductions were higher in refrigerated environments, except for *H. densiflora* (Table 3).

Table 3. Percentage of fresh weight of *H. psittacorum* and *H. densiflora* flower stems, evaluated over a period of 21 days, in an environment without refrigeration (NR- Control) and refrigerated environment (WR).

		Storage (days)							
Species/ inflorescence color		**0**	**3**	**6**	**9**	**12**	**15**	**18**	**21**
H. psittacorum/2.5Y 7/10	NR	100.00 aA	99.43 aA	97.29 aA	94.99 aA	92.51 aA	88.44 aA	-	-
	WR	100.00 aA	91.53 aA	88.71 aA	85.42 aA	57.74 bB	41.73 dC	-	-
H. psittacorum/7.5YR 7/10	NR	100.00 aA	99.23 aA	95.75 aA	95.27 aA	94.18 aA	90.69 aA	-	-
	WR	100.00 aA	96.68 aB	92.85 aB	88.04 aB	86.20 aB	82.11 aC	28.03 bD	-
H. psittacorum/5R 4/10	NR	100.00 aA	99.03 aA	96.77 aA	94.41 aA	94.34 aA	93.76 aA	88.58 aA	-
	WR	100.00 aA	97.22 aA	91.55 aA	88.73 aA	86.37 aA	59.50 cB	28.17 bC	27.66 bC
H. densiflora/5R 5/10	NR	100.00 aA	98.86 aA	84.99 aA	83.88 aA	83.66 aA	-	-	-
	WR	100.00 aA	94.26 aA	89.48 aB	87.33 aB	84.95 aB	75.70 bC	24.87 bD	24.30 bD

Means followed by the same lowercase letter in a column and upper case letters in a row do not differ at 5% probability by the Tukey test.

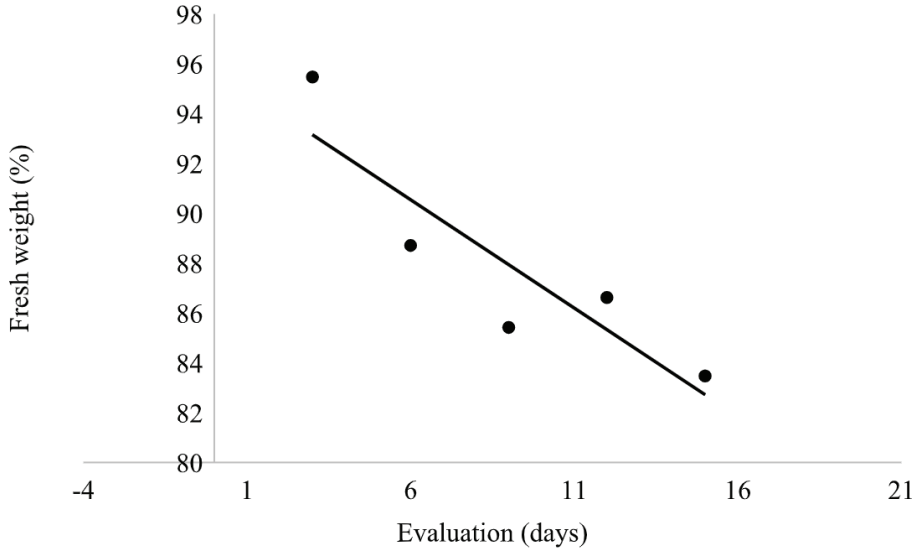

Figure 2. Fresh weight of *Heliconia psittacorum* inflorescences evaluated over a period of 21 days.

The *H. psittacorum* species with a 2.5Y 7/10 bract color showed a significant loss of fresh weight after 12 days of evaluation, followed by *H. psittacorum* of 5R 4/10 bracts at 15 days of evaluation (both in refrigerated environment) (Table 3). This observation also applies to the other two colors (5R 4/10 and 5R 5/10) (Table 3). The fresh weight percentage of *Heliconia densiflora* decreased gradually after six days of cold chamber storage (Table 3).

The temperature of 14 °C resulted in higher tissue turgidity of the *H. psittacorum* inflorescences of 5R 4/10 colored bracts (Table 4). All evaluated species maintained a turgidity of more than 70% at a temperature of 22° C (Table 4).

Table 4. Percentage of fresh weight of flower stems of *H. psittacorum* and *H. densiflora*, stored in a laboratory environment at 26 ºC (Control) and in a cold chamber (14 ºC, 18 ºC and 22 ºC).

Species/ inflorescence color	Temperature			
	14 ºC	**18 ºC**	**22 ºC**	**26 ºC**
H. psittacorum / 2.5Y 7/10	44.09 dC	56.34 bB	72.16 aA	71.58 bA
H. psittacorum / 7.5YR 7/10	79.75 cB	65.22 aB	70.24 aB	72.26 bA
H. psittacorum / 5R 4/10	91.92 aA	53.64 cC	71.65 aB	83.90 aA
H. densiflora/ 5R 5/10	87.36 bA	58.90 bC	71.56 aB	56.42 cA

Means followed by the same lowercase letter in a column and upper case letters in a row do not differ at 5% probability by the Tukey test.

Discussion

The factors that determine the longevity of cut flowers vary according to the species or cultivar. Ehylene sensitivity, water relations, respiration and cold injury can influence both the postharvest longevity of cut flowers as well as their resistance to shipping and storage (Finger and Barbosa, 2006).

There are considerable genetic differences between Heliconia species regarding vase life (Criley and Broschat, 1992), which is a criterion for the choice of promising lines for selection with a view to breeding studies. Storing *Heliconia bihai* cv. Lobster Claw inflorescences at a temperature of 12 °C extended the vase life to over seven days and at 19 °C to a period of up to eight days (Costa et al., 2011). Large Heliconia such as Sexy pink (*H. chartaceae*) reached seven days of vase life (Criley, 1990), while for *H. caribea* and *H. wagneriana,* a vase life of 15 or more days was reported (Criley, 1990).

For short Heliconia, as described in this study, the vase life varies among cultivars, the development stage and the time of day of flower cutting (Jaroenkit and Paull, 2003).

Similar results to those of this study were reported for *H. psittacorum*, with a vase life from 14 to 17 days (Criley and Broschat, 1992) and of up to 24 days for Golden Torch (Broschah et al., 1984).

According to Broschat and Donselman (1983), the ideal temperature for Heliconia storage is higher than 10 ºC. For the species evaluated in this study, of the three tested temperatures, the least recommended for the maintenance of visual quality and fresh weight percentage was 18 ºC.

A study of storage temperature and visual quality maintenance of *Strelitzia regiane* stems stored in cold chambers and at ambient temperature reported that the highest incidence of stains occurred on stems maintained at ambient temperature as of the fourth day after cutting and on flower stalks placed in a cold chamber (7.5 °C) on the eighth day (Vieira et al., 2014).

The signs of senescence in the Heliconia species of this study were similar to the cold symptoms on the species *H. caribaea*, characterized by the presence of dark spots near the junction of the bracts, six days after cutting. For *H. rostrata* refrigerated at 6.5 °C, the initial symptoms were more evident on the fifth day, with darkening of the bracts and rachis (Costa et al., 2015).

A few days after cutting the flowers in the field, weight loss is an inevitable process. This is mainly due to natural transpiration, considered one of the main deterioration causes of the product, resulting mainly in an alteration of the visual aspect, owing to wilting. Several postharvest handling techniques used today have contributed to minimize water losses from the stored product, increasing the vase-life duration (Kluge, 2002).

In this study, the fresh weight of all evaluated species and bract color variations was most reduced in the refrigerated environment. Excessive weight loss may limit flower longevity. Stems with a weight loss of more than 10% were considered withered and unfit for sale (HARDENBURG et al., 1986).

Conclusions

Temperatures of 22 °C and 26 °C and a relative humidity 80% and 55%, respectively, are indicated for storage of *H. psittacorum* (inflorescence 2.5Y 7/10) flower stems for up to three days.

Temperatures of 14 °C and 22 °C and a relative humidity of 80% are recommended for the storage of *H. psittacorum* flower stalks (7.5YR 7/10) for a period of up to six days. Signs of senescence are observed after nine days of storage.

Temperatures of 14 °C and 26 °C and a relative humidity of 80% are indicated for storage of *H. psittacorum* flower stalks (5R 4/10) for up to three days. Signs of senescence appear as of the sixth day.

A temperature of 14 °C and relative humidity of 80% are recommended for storing *H. densiflora* flower stalks for up to three days, where signs of senescence appear as of the sixth storage day.

Author Contribution

C.G.S.[0000-0002-4303-9445]: data collection in the field, analyses and manuscript drafting. **S.K.**[000-0001-7142-7456]: analyses and manuscript drafting. **R.P.A.F.**[0000-0001-8504-2928]: data collection in the field, analysis and manuscript drafting. **A.F.B**. [0000-0003-4060-7942]: field data collection, analysis and manuscript drafting. **C.A.S.**[0000-0001-7898-7931]: project development, research, methodology, data analysis and interpretation, critical revision and approval of the final version of the manuscript.

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