Temporal stability of *Heliconia* spp. flower stem production[1]

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ABSTRACT

The instability of heliconia flower stem production may be related to climatic variation. Therefore, that information is very important for planning the species production throughout Brazil, mainly in northeast region. The objective of this work was analyzed the previous effects of photoperiod, air temperature and precipitation in the flower stem production of *Heliconia psittacorum* cv. Red Opal, *H. psittacorum* x *H. spathocircinata* cv. Golden Torch, *H. stricta* cv. Fire Bird and *H. rauliniana*, and the monthly temporal stability. The flower stems with two to three open bracts were harvested twice a week between May, 2004 and March, 2012 from a field in Camaragibe – PE, Rain Forest Zone of Pernambuco, Brazil. Pearson's linear correlation demonstrate flower stem production occur in response to the environment stimulus. *H. rauliniana* inflorescence initiation response mainly to the shortest photoperiod and cv. Fire Bird to highest photoperiod. Production of the cv. Golden Torch was more stable in April, with reduction in September (39.46%) and an increase in December (87.02%), compared with the annual average. The cv. Red Opal produced more in September (31.43%), with a reduction in February (44.8%) and stable in July. *H. rauliniana* production was stable in September and increase in November (274.8%). The cv. Fire Bird production was stable in April, with the lowest production in November and the highest in March (65%).

With this information is possible to predict the cultivar production in the Rain Forest Zone of Pernambuco State, Brazil.

Keywords: Agricultural monitoring, Agrometeorology, Tropical flowers, Temporal variability.

RESUMO

Estabilidade temporal na produção de hastes florais de *Heliconia* spp.

A instabilidade da produção de hastes florais de helicônia pode estar relacionada à variação climática, e, portanto, informações detalhadas são necessárias para o planejamento da produção. O objetivo deste estudo foi analisar o efeito do fotoperíodo, temperatura do ar e precipitação na produção de hastes florais de *H. psittacorum* cv. Red Opal, *H. psittacorum* x *H. spathocircinata* cv. Golden Torch, *H. stricta* Fire Bird and *H. rauliniana* e avaliar a estabilidade temporal. As hastes florais com duas a tres brácteas abertas foram colhidas duas vezes por semana entre maio de 2004 e março de 2012, em área de cultivo na Zona da Mata de Pernambuco, Camaragibe – PE, Brasil. A correlação linear de Pearson's demonstrou que as condições climáticas interferem na produção de hastes florais. Períodos com fotoperíodo mais curto induziram o início da formação da inflorescência de *H. rauliniana.* Por outro lado, fotoperíodo mais longo aumentou o florescimento de cv. Fire Bird. A produção da cv. Golden Torch foi mais estável em abril, com uma maior redução em setembro (39,46%) e um aumento 87,02% em dezembro. A cv. Red Opal produziu mais em Setembro (31,43%), apresentando redução em Fevereiro (44,8%) e sendo estável em julho. A produção de *H. rauliana* foi estável em setembro e superior em novembro (274,8%). A produção da cv. Fire Bird foi estável em abril, com menor produção em novembro e maior em março (65%). O conhecimento de estabilidade temporal para as cultivares permite o planejamento da produção heliconia na Zona da Mata de Pernambuco, Brasil.

Palavras-chave: Monitoramento agrícola, Agrometeorologia, Flores tropicais, Variabilidade temporal.

1. INTRODUCTION

Floriculture industry has invested in supplying the Brazilian domestic market to protect itself from international crises (JUNQUEIRA and PEETZ, 2014). *Heliconia* is a tropical genus with 29 species naturally occurring in Brazil, five of its endemic (BRAGA, 2015). In Pernambuco State, northeast region of Brazil, approximately 21 species and cultivars are produced as cut flowers. Nevertheless, some of these, native or not, present seasonal production with periodic flowering behavior (LOGES et al., 2015).

Research with the *Heliconia* genus flowering behavior demonstrate that factors such as leaf number and the environment condition, mainly photoperiod, during the flowering cycle, period from shoot emission to inflorescence harvest, could influence the inflorescence development (Criley et al., 1999; Criley et al., 2003). Criley et al. (1999) observer that once the pseudostem has a certain leaf number, inflorescence initiation could occur in response to a stimulus such as photoperiod, normally requiring slightly more than one-half of the development period or cycle of the plant. Criley et al. (2004), based on this theoretical

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half-time period for leaf production and half-time period for heliconia inflorescence development, observed flower initiation after short-day period in the cv. Hot Rio Nights, suggesting the photoperiod influence.

The flower steam production increase with shorter photoperiod than eight hours to *H. aurantiaca* and *H. stricta* cv. Dwarf Jamaican (GEERTSEN, 1992; CRILEY, 2000) and shorter than twelve hours to *H. wagneriana* (CRILEY, 2000).

The heliconia growers, by themselves, started to select the best genotypes to be used as cut flowers. The most important criteria taken into consideration to select the species and cultivars were the stable flower stem production along the year (LOGES et al., 2015). This stability (predictability of genotype response to an improving environment) is an important parameter to be observer in all the crops (CRUZ and REGAZZI, 1994). In the case of heliconia production, that can be measured by cultivars periodic flower stem evaluations for a long the time. The information of different generations in different years is essential for a better estimate of stability (VALÉRIO et al., 2009).

The objective of this work was analyzed the effects of photoperiod, air temperature and precipitation in the flower stem production of four *Heliconia* genotypes.

2. MATERIAL AND METHODS

The flower stem production was conducted between December 2003 and June 2006 (first experiment) and September 2007 and March 2012 (second experiment) in the Heliconia Germplasm Collection of the UFRPE, Camaragibe - PE, Brazil, latitude 7°56'33''South, longitude 35°1'50"West and 100 m altitude. The climate classification is type As' according to Köppen's. The average annual air temperature in the region is 25.1 ºC, average monthly rainfall is 171 mm, with a maximum of 377 mm and a minimum of 37 mm (dados coletados no ITEP – Instituto de Tecnologia de Pernambuco em 2008).

Four *Heliconia* genotypes, with different, characteristics were selected and evaluated: *H. psittacorum* cv. Red Opal, with small inflorescences and high productivity; *H. psittacorum* x *H. spathocircinata* cv. Golden Torch, for the good market acceptance and produced throughout Brazil; *H. stricta* cv. Fire Bird, with a midsized inflorescence; *H. rauliniana* with pendent inflorescences (Figure 1). Flower stems with two or three open bracts were harvested twice a week to monitor the flower stems production (FSP) per plant per month.

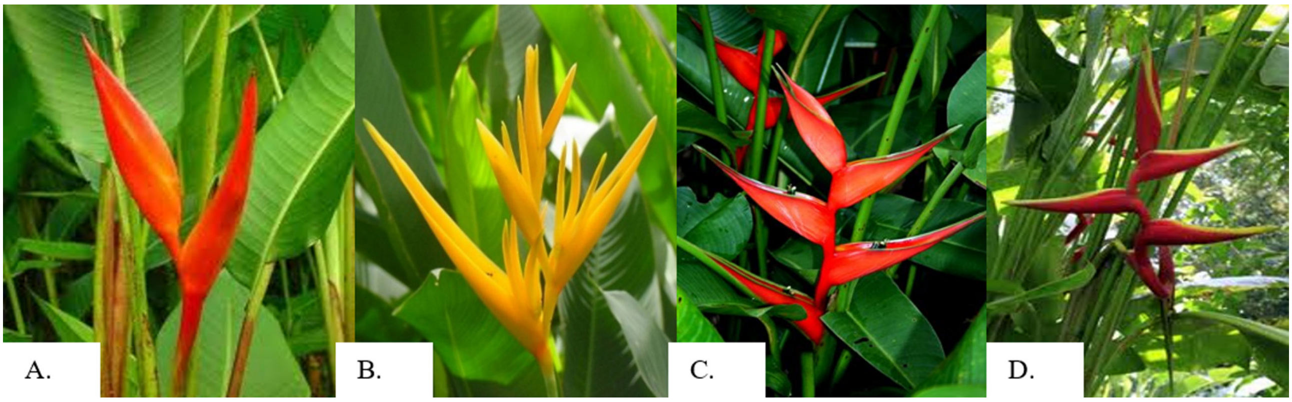

Figure 1. Inflorescences of *H. psittacorum* Red Opal (A), *H. psittacorum* x *H. spathocircinata* cv. Golden Torch (B), *H. stricta* cv. Fire Bird (C) and *H. rauliniana* (D).

The crop was managed as recommended by Loges et al. (2014) and irrigated when needed by a micro sprinkler system (first experiment) and 2.5 m high gun sprinklers system (second experiment).

Meteorological variables were calculated from daily data and included the average monthly air temperature (MT); the minimum (Tmin) and maximum air temperatures (Tmax), as well as the sum of the daily rainfall to obtain the monthly accumulated precipitation (PREC). These data were obtained from January 2003 to June 2006 and from September 2007 to March 2012, from a meteorological station located approximately 3 km from the experimental area (LAMEP/ITEP - Laboratório de meteorologia de Pernambuco/Instituto de Tecnologia de Pernambuco). The photoperiod (PH) or effective daylength was the number of hours of experimental area exposure to sun light during 24-hour period (VAREJÃO-SILVA, 2006) and was obtained by equation (1).

$$N = (2 / 15)\ \text{arc.cos}\ (-\text{tg}\ \phi\ \text{tg}\ \delta)$$

where: ϕ - Local latitude; δ- Solar declination (Equation 2), both expressed in degrees.

$$\delta = 23{,}45\ \text{sen}\ [360º\ (284 + D) / 365] \qquad (2)$$

where: D - Julian day, which is the number of the considered day.

The principal statistical parameters (mean, variance, standard deviation, coefficient of variation, minimum, maximum, skewness, kurtosis and normal distribution) using the Kolmogorov-Smirnov test at 5% probability were obtained using the program STATISTICA 7.

The temporal stability of flower stem production (FSP) was determined using the technique developed by Vachaud (1985), based on the calculation of the relative difference, which allowed the analysis of the differences between independent values, the observed values and the average of these values. The relative difference of FSP for the four heliconia genotypes was calculated according to Equation (3):

$$DR_{ij}(\theta) = \frac{\theta_{ij} - \bar{\theta}_j}{\bar{\bar{\theta}}_j} * 100 \tag{3}$$

where: DR_{ij} - Relative difference between the individual determination for a location i at a time j; $\theta ij\ \theta ij$ - Moisture content at the location i and time j; $\bar{\theta} j\ \bar{\theta} j$ - Average production for all the positions in time j N positions, at time j.

The average for the relative difference () was calculated using Equation (4):

$$\overline{DR}\ (\theta) = \frac{1}{m}\sum_{j=1}^{n} \mathbf{DR}\ (\theta) \tag{4}$$

where: DR (Θ) - Relative difference between the individual determination for a location i at time j; m and n - number of observations at time j.

Pearson's correlation coefficient correlated the monthly meteorological variables MT, PREC and PH with flower stem production (FSP) two months earlier to cv. Golden Torch, three months earlier to cv. Red Opal, four months earlier to cv. Fire Bird and five months earlier to *H. rauliniana*. That methodology, adapted from CRILEY et al. (2004), consider half-time of flowering cycle to cv. Golden Torch and cv. Red Opal (Costa et al., 2007), cv. Fire Bird (personal information) and to *H. rauliniana* (Loges et al., 2013). The covariance between two variables was calculated, according to Equation (5) and then Pearson's coefficient of linear correlation (r), whose estimator is shown in Equation (6).

$$S_{X,Y} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{n-1} \tag{5}$$

where, $S_{X,Y}$ - Sample covariance between X and Y variables; x e y - Arithmetic means of each variable; n – Sample size; x_i e y_i - Simultaneous observations of variables.

$$r = \frac{S_{x,y}}{S_x S_y} \tag{6}$$

where: r – Pearson's Correlation coefficient; $S_{X,Y}$ - Sample covariance between X and Y variables; S_X e S_Y- Sample standard deviations.

3. RESULTS AND DISCUSSION

In both experiment the cv. Golden Torch was the first one to flower, five and seven months after planting (MAP), cv. Red Opal was the second one, cv. Fire Bird the third and *H. rauliniana* the last one to flower (Figure 2).

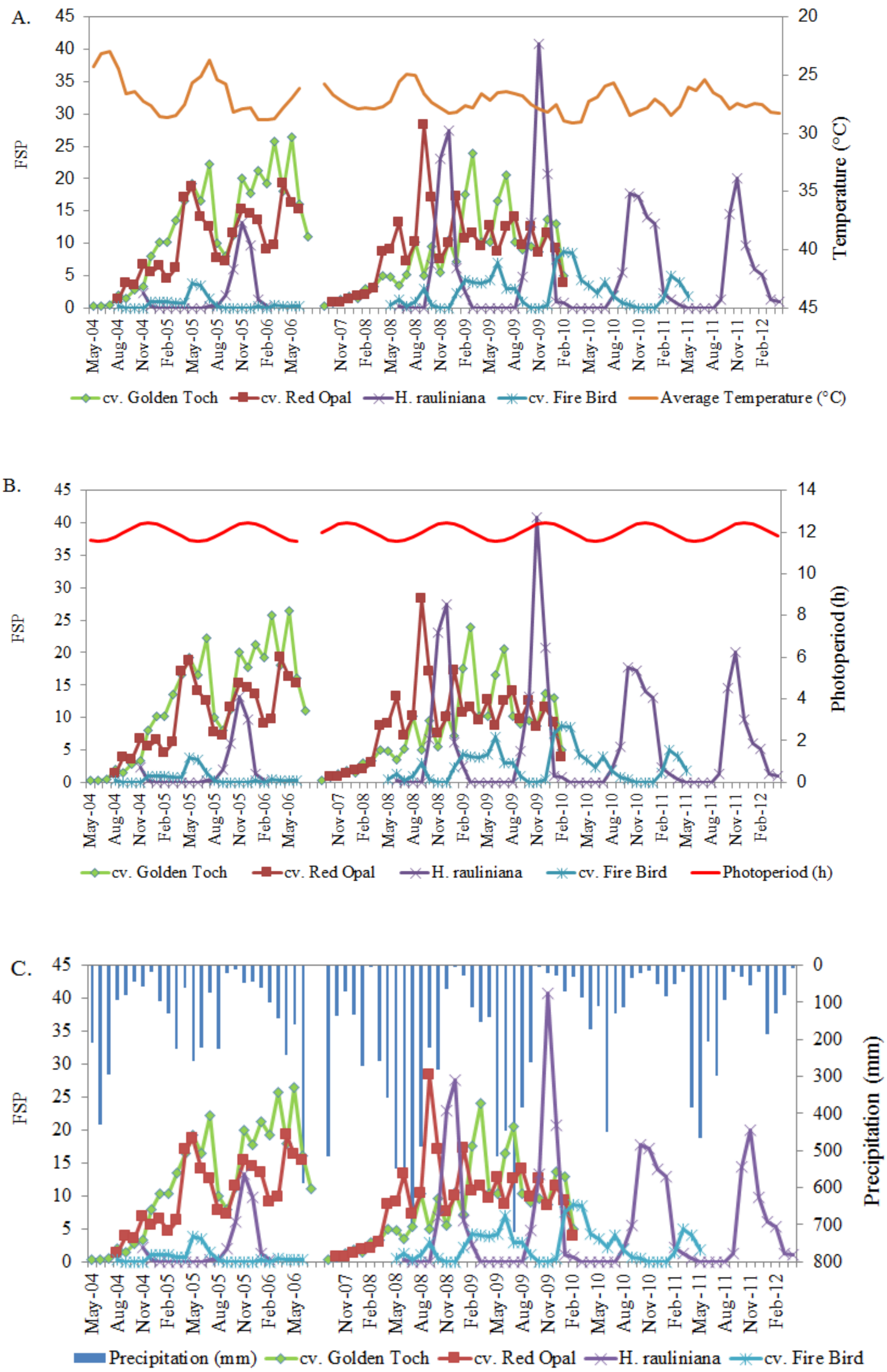

Figure. 2. Flower stems production (FSP) per plant per month of *H. psittacorum* cv. Red Opal, *H. psittacorum x H. spathocircinata* cv. Golden Torch, *H. stricta* cv. Fire Bird and *H. rauliniana*, associated to monthly temperature (A), photoperiod (B) and precipitation (C).

Pearson's linear correlation were observed between monthly air temperature (TM), precipitation (PREC) and photoperiod (PH) with the flower stem production (FSP) and demonstrate that inflorescence initiation could occur in response to the environment stimulus.

Despite the reduce difference between the month temperature in region of Camaragibe – PE, the flower stems production (FSP) were influenced by it (Figure 2 and Table 1). The highest temperatures two months early favor the FSP for cv. Golden Torch. The cv. Red Opal doesn't demonstrate FSP correlation with environment conditions, producing all the year.

The Pearson correlation coefficients (Table 1) of flower stem production was negative with temperature (-0.35) and photoperiod (-0.66) and positive with precipitation (0.61). This indicated that highest values of FSP for *H. rauliniana* was observed five months after the period with shortest photoperiod (Figure 2), lowest temperature and highest precipitation (717.69 mm in July). This suggests that inflorescence initiation response mainly to the short photoperiod stimulus, coinciding with the period of highest precipitation and lowest temperature in this region.

On the other hand, cv. Fire Bird present positive Pearson correlation coefficients of flower stem production with photoperiod (0.46) and temperature (0.40). Thus, highest values of FSP for cv. Fire Bird was observed four months after the period with highest photoperiod and temperature (Figure 2).

Table 1. Pearson correlation coefficients between flower stems production (FSP) and mean air temperature (TM), precipitation (PREC) and photoperiod (PH) per month.

Genotype	TM x FSP	PREC X FSP	PH X FSP
H. psittacorum x *H. spathocircinata* cv. Golden Torch	0.47**	-0.28	0.19
H. psittacorum cv. Red Opal	0.29	0.16	-0.06
H. rauliniana	-0.35**	0.61**	-0.66**
H. stricta cv.Fire Bird	0.40**	0.30	0.46**

**Signficant at 1% probability

The Kolmogorov-Smirnov test, with a probability of error of 5%, demonstrated that only cv. Golden Torch and cv. Red Opal showed a normal distribution for the data set (Table 2). The mean and median values for the flower stem monthly production data are very close for both cultivars, indicating a symmetry in the data distribution. However different pattern was observed in cv. Golden Torch when analyzing the skewness (0.46) and kurtosis (-0.74) values.

According to Isaaks and Srivastava (1989), the asymmetry coefficient is more sensitive to extreme values when compared with the mean, median and standard deviation, and thus a single extreme value can compromise the results of the asymmetry coefficient. This can be observed in cv. Fire Bird and *H. rauliniana,* which had asymmetry values of 2.19 and 1.51 respectively, demonstrating that there are more extreme values in the data sets (Table 2). The FSP extreme values and outliers observed are associated with the seasonal variation of these cultivars, with none production in some months (Figure 2). The same effect was observed by Criley (2000) for *H. stricta* cv. Dwarf Jamaican grown in a controlled environment.

The high values of the coefficient of variation can be explained by the fact that flower production over time is unstable, especially for seasonal species influenced by environment stimulus.

Table 2. Statistical parameters for the monthly flower stem production (FSP) of *Heliconia* spp.

	Genotype			
	***H. psittacorum* x *H. spathocircinata* cv. Golden Torch**	***H. psittacorum* cv. Red Opal**	***H. rauliniana***	***H. stricta* cv. Fire Bird**
Average	10.15	9.86	5.01	1.81
Median	10.00	9.63	1.00	0.88
Variance	53.00	31.28	67.68	4.99
SD	7.28	5.59	8.23	2.23
CV%	72	57	164	123
Minimum	0.25	0.75	0.00	0.00
Maximum	26.50	28.25	40.75	8.75
Asymmetry	0.46	0.54	2.19	1.51
Kurtosis	-0.74	0.94	5.39	1.84
D	0.112 n	0.055 n	0.286 Ln	0.225 Ln

SD: Standard deviation. CV: coefficient of variation. D: Maximum deviation from the normal distribution. n: data a normal distribution. Ln: Data showing lognormal distribution (error probability of 5% by the Kolmogorov-Smirnov test).

The mean and median values in cv. Golden Torch and cv. Red Opal are very close, indicating a symmetry in the data distribution (Figure 3). The cv. Fire Bird also showed seasonality characteristics but with less extreme values than *H. rauliniana*. However, from both genotypes most of the data set is close to the lower interquartile limit, indicating that most of the data are zero or close to zero observed by none FSP in some months of the year (Figure 3).

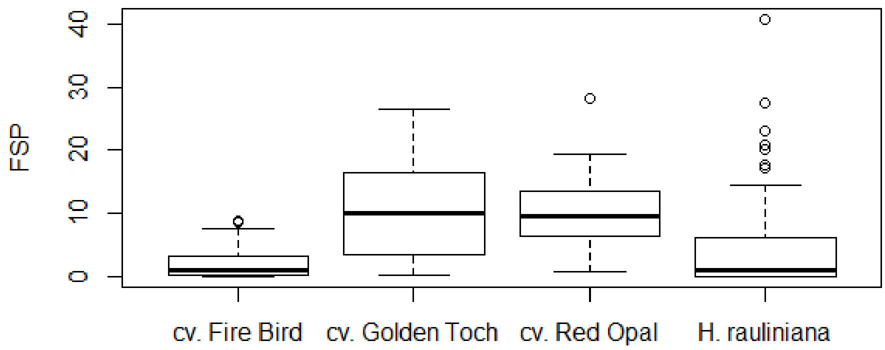

Figure. 3. Monthly flower stems production (FSP) of *H. psittacorum* Lf Red Opal, *H. spathocircinata x H. psittacorum* x cv. Golden Torch, *H. stricta* cv. Fire Bird and *H. rauliniana.*

The FSP average value for all cultivars during the study period was 5.82 (Figure 4). The cv. Fire Bird had an average value of 1.81 FSP, the lowest value compared to the others. *H. rauliniana* was also below the average, with a mean value of 5.00 FSP. However, the cv. Golden Torch and cv. Red Opal had the highest averages of FSP (10.14 and 9.85, respectively). The months of May, 2006 and December, 2009 produced the highest monthly production of the four cultivars (14.33 and 14.5, respectively). November, 2011 showed the highest production peak average (20 FSP).

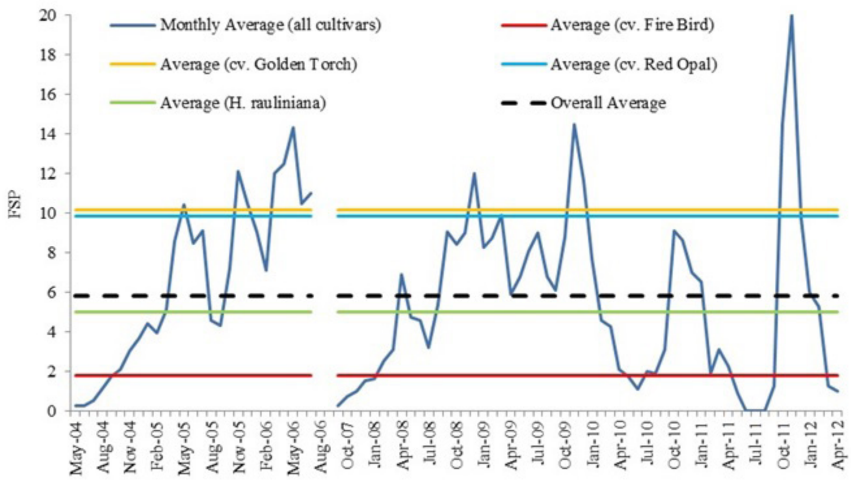

Figure 4. Flower stems production (FSP) per month of *H. psittacorum* cv. Red Opal, *H. spathocircinata psittacorum* x cv. Golden Torch, *H. stricta* cv. Fire Bird and *H. rauliniana*.

The standard deviation associated with the relative difference estimates the degree of reliability of the measure of relative difference (MELO FILHO and LIBARDI, 2005). Base on the smaller the standard deviation, was observed that cv. Golden Torch was more stable for the month of April, with FSP values similar to the year average. Consequently, for cv. Golden Torch, flower stem production in September is 39.46% (± 23.5%) lower than the year average. On the other hand, in December it is 87.02% higher, although this estimate is not very reliable due to the high deviation (0.95) (Figure 5A).

In February, was observed FSP lower relative mean difference (44.8%) from cv. Red Opal (Figure 5B). In September, the FSP was 31.43% higher compared to the average but with a very high standard deviation (0.90). The lowest relative difference was observed in July, month in which flower stem production is closer to the annual average. In December, the increase in production was 19.57% (± 17.7%) compared with the average FSP for the period studied.

Stable flower stem production of *H. rauliniana* occurred in September, with a more pronounced production increase in November, when the relative difference was 274.8% (±

139.81%) (Figure 5C). This production increase was due to the seasonal variation of *H. rauliniana*, directly correlated with environment stimulus (Figures 2).

For the cv. Fire Bird (Figure 5D), the most stable month was April, which had lower values of relative difference and deviation whereas production in November declined most, with an average relative difference of 87.6% (± 27.5%) compared to the annual average. March showed a greater production increase with an average relative difference of 65.4% (± 65.0%).

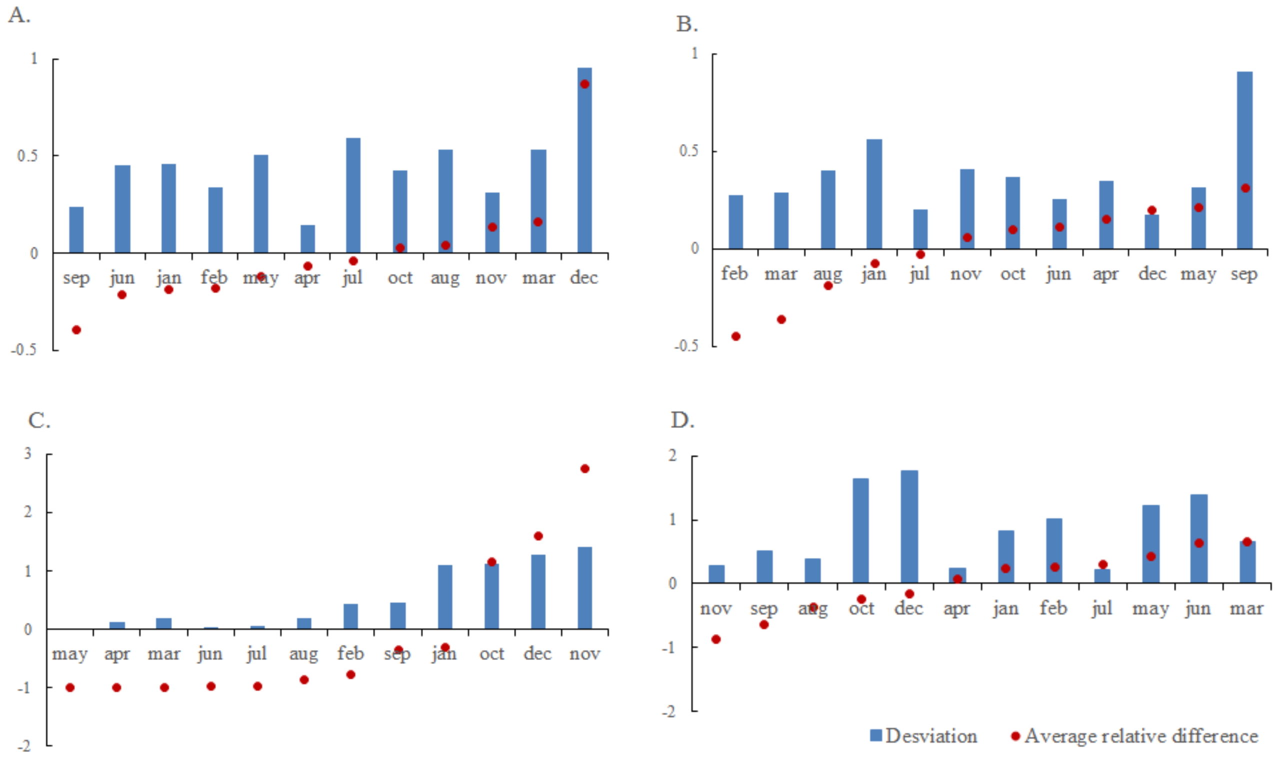

Figure 5. Deviation and average relative difference base on the flower stems production (FSP) per month.of *H. spathocircinata psittacorum* x cv. Golden Torch (A), *H. psittacorum* cv. Red Opal (B), *H. rauliniana*. (C) and *H. stricta* cv. Fire Bird (D)

4. CONCLUSIONS

Highest temperatures two months early increase flower stem production of *H. spathocircinata psittacorum* x cv. Golden Torch. Production of the cv. Golden Torch was more stable in April, with reduction in September and increase in December. *H. psittacorum* cv. Red Opal produced more flower stem in September with a reduction in February and are stable in July and doesn't response to the environment stimulus since produce all the year. Highest values of photoperiod and temperature increase *H. stricta* cv. Fire Bird flower stem production four months later. The production was stable in April, with the lowest production in November and the highest in March. *H. rauliniana* inflorescence initiation was observed five months after the period with shortest photoperiod, lowest temperature and highest precipitation and the production was stable in September and increase in November.

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