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Scientific Article

Reproduction dynamics and thermal requirement of dragon fruit species in northern amazon

Comportamento reprodutivo e requerimento térmico de pitaias no extremo norte da amazônia

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ABSTRACT – The objective of this work was to assess the reproductive phenology and thermal requirements of two dragon fruit species grown under the climate conditions of northern Amazon. The experiment was carried out in the municipality of Boa Vista, Roraima, Brazil, during two production cycles (2020-2021 and 2021-2022). Two dragon fruit species were used: *Hylocereus costaricensis,* which produces cylindrical fruits with a red skin and purple pulp; and *Hylocereus polyrhizus*, which produces elongated fruits with red skin and pulp. Ten plants of each species were selected and divided into four quadrants; ten cladodes were selected per quadrant and two flower buds were selected per cladode, totaling 800 flowers for each species. The plants were monitored from the beginning of flower bud intumescence until fruit harvest. Phenological periods were evaluated from production pruning to fruit harvest, based on the phenological stage descriptions of the Biologische Bundesanstalt Bundessortenamt and Chemical Industry (BBCH) scale. Climate conditions affected the species over the years, mainly due to variations in air temperature preceding phenophases. Variations between years increased the production cycle in 20 days for *H. costaricensis* and 34 days for *H. polyrhizus* from the first (2020-2021) to the second (2021-2022) production year. Organoleptic properties of species showed excellent results, including soluble solids (SS), titratable acidity (TA), and SS to TA ratio. Complete physiological maturity of *H. costaricensis* and *H. polyrhizus* fruits occurred at 31 and 38 days after anthesis, respectively, when the fruits presented an intense red skin and pulp.

Keywords: Amazon. BBCH Scale. Degree-days. Phenophases. *Hylocereus polyrhizus* L.. *Selenicereus costaricensis* L..

RESUMO – Objetivou-se estudar a fenologia reprodutiva e o requerimento térmico de duas espécies de pitaia nas condições climáticas do extremo Norte da Amazônia. O experimento foi realizado no município de Boa Vista, Roraima durante dois ciclos produtivos (2020/2021 e 2021/2022). Utilizou-se duas espécies de pitaia, a *Selenicereus costaricensis,* com frutos de casca vermelha e polpa roxa e formato cilíndrico e a *Hylocereus polyrhizus*, com frutos de casca e polpa vermelha e formato alongado. Selecionou-se 10 plantas de cada espécie, dividindo-as em quatro quadrantes, sendo selecionado 10 cladódios por quadrante e 2 gemas floral por cladódio, totalizando 800 flores por espécie, as quais foram acompanhadas da intumescência da gema até a colheita dos frutos. Avaliou-se os períodos fenológicos da poda até a colheita dos frutos, baseando-se na descrição dos estádios fenológicos da escala Biologische Bundesanstalt Bundessortenamt and Chemical Industry (BBCH). As condições climáticas influenciaram as espécies entre os anos, principalmente devido as variações de temperatura do ar no momento da que antecede as fenofases. As variações entre os anos ocasionaram um aumento no ciclo produtivo de 20 dias para *S. costaricensis* e 34 dias para *H. polyrhizus* entre o primeiro (2020/2021) e segundo (2021/2022) ano produtivo. As propriedades organolépticas das espécies apresentaram excelentes resultados, como sólidos solúveis, acidez titulável e relações sólidos solúveis/ acidez titulável, inerente as espécies. A maturidade fisiológica completa de frutos de *H. costaricensis* e *H. polyrhizus* ocorre aos 31 e 38 dias após a antese (DAA), quando os frutos apresentam coloração vermelho intenso da casca e da polpa.

Palavras-chave: Amazônia. Escala BBCH. Graus-dias. Fenofases. *Hylocereus polyrhizus* L.. *Selenicereus costaricensis* L..

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INTRODUCTION

Dragon fruit (*Hylocereus* spp., Cactaceae) has high potential for exotic fruits markets due to its distinct appearance and excellent properties (ARIVALAGAN et al. 2021; ATTAR et al., 2022). Despite these crops are easily adapted to different environments due to its hardiness, the cultural management of dragon fruit species in commercial crops requires attention due to the interaction between the species and the environment. The literature shows significant effect of edaphoclimatic conditions on the timing of cultural practices, resulting in fruit yield variations from 3.0 to 40 Mg ha^{-1} (FALEIRO et al., 2022). Thus, understanding the phenological development of plants in different crop regions is important because of variations in phenological stage periods may result in inappropriate timing of cultural practices, i.e., when plants are not able or already passed the ideal stage for better response to the required stimuli.

Studies on dragon fruit species have shown that climate changes, temperature, and rainfall significantly affect the dynamics of *Hylocereus undatus, H. costaricensis, and H. ocamponis* (SOSA et al., 2020). Moreover, effects of light and temperature at the flower bud emergence, pre-anthesis, and anthesis stages were found for *H. polyrhizus* and *H. undatus* (MUNIZ et al., 2019). Thus, dragon fruit species probably exhibit variations in phenophases according to the crop region.

Phenology is the timing or recurring patterns of physiological changes with sequential phenotypic expression that affect growth and reproduction events, which are affected by environmental conditions. This process shows the timing and synchronicity between phenophases (BAGATINI; KLABUNDE, 2020). The production cycle, peaks, and seasonality are important phenological characteristics of species traditionally grown in different regions; these data assist in the planning of management and cultural practices during the crop cycle (CHAGAS et al., 2022; MOURA et al., 2019). The climate conditions of the state of Roraima, Brazil, are excellent for growing fruit trees, vegetables, and grains with high yields and good organoleptic properties.

The high temperatures and solar radiation in the region result in early production cycles of fruit tree species and, consequently, in specific differences that can affect the management and cultural practices, as found for *Annona scamosa* (ARAÚJO et al., 2021; MOURA et al., 2019) and *Eugenia stipitata* (MOURA et al., 2020a) and dragon fruit species (BAGATINI; KLABUNDE, 2020; MUNIZ et al., 2019). Thus, information on the phenological dynamics, combined with evaluation of growing degree-days, can provide better understanding of the beginning of specific phenological stages (MOURA et al., 2020a).

The use degree-days as a unit of accumulated heat assists in determining climate effects on the development of plants during the production cycle by showing the temperature requirement to the beginning of each phenophase and its duration (beginning to end) (MENDES et al., 2017; SAKAR et al., 2019). It also assists in estimating yields and organoleptic quality of crops (KISHORE, 2019; MOURA et al., 2020b).

In this context, the lack of information on phenological dynamics and accumulated heat by required by dragon fruit species in the Amazon region, specifically in the state of Roraima, highlights the need for information on phenological processes and thermal requirements of these species. In this sense, the objective of this work was to assess the reproductive phenology and thermal requirements of two dragon fruit species grown under the climate conditions of northern Amazon.

MATERIAL AND METHODS

Characterization of the area

The experiment was conducted during two production years (2020-2021 and 2021-2022) in a commercial dragon fruit orchard in Boa Vista, Roraima, Brazil (2°52'48"N, 60° 39'54"W, and mean altitude of 80 m). The region presents mean annual rainfall depth of 1.716 mm, mean relative air humidity of 76.6%, and mean daily temperatures between 23.9 and 38 °C, with an annual mean of 27.4 °C (ARAÚJO et al., 2024). The climate of the region is Aw, according to the Köppen classification, with two well-defined seasons, a rainy season from April to August and a dry season from October to March (ALVARES et al., 2013).

Data of minimum, mean, and maximum temperature, mean relative humidity, and rainfall depths during the experimental period were collected from an automatic meteorological station installed in the area (Figure 1).

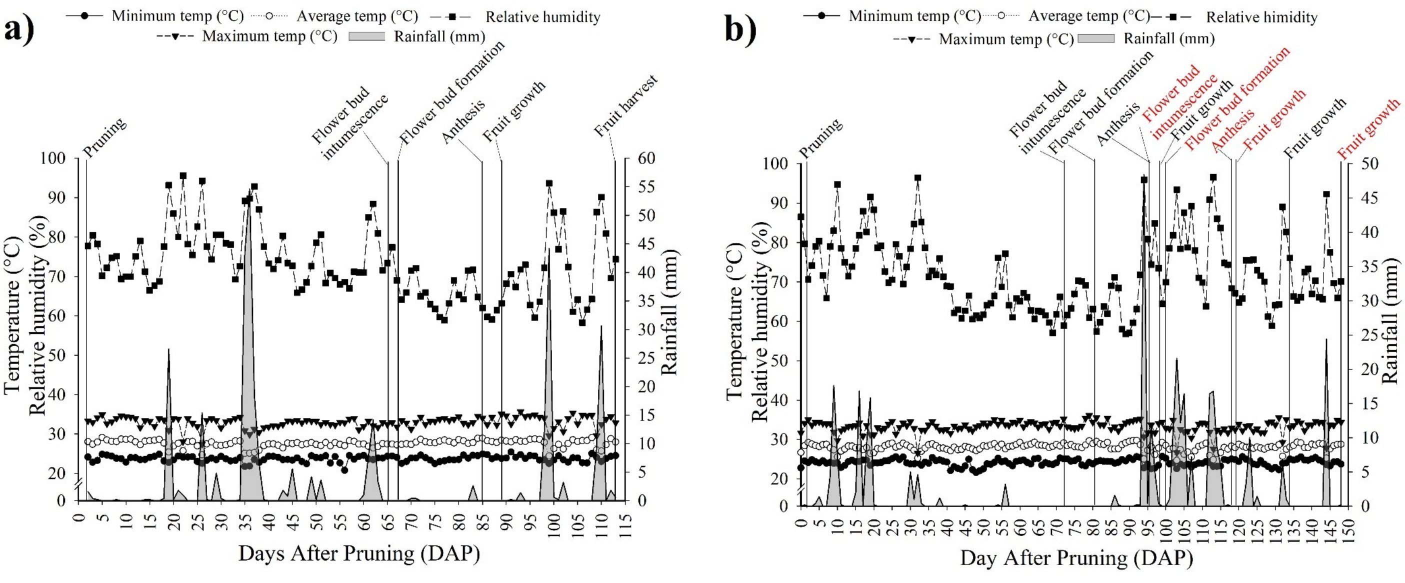


Figure 1. Minimum, mean, and maximum air temperatures (°C), relative air humidity (%), and rainfall depths (mm) during the experimental period in 2020-2021 (a) and 2021-2022 (b). In Figure B, phenological stages are shown in in black for *Hylocereus costaricensis* and in red for *Hylocereus polyrhizus*.

Plant material and crop management

Two dragon fruit species with 6 years of age were used: *Hylocereus costaricensis,* which produces cylindrical fruits with a red skin and purple pulp; and *Hylocereus polyrhizus*, which produces elongated fruits with red skin and red pulp. The species were grown with wood log supports (10 cm diameter and 1.80 m height), with a spacing of 3 × 3 m.

Samples of the soil 0-20 cm layer were collected before the experiment for chemical analysis (Table 1).

Table 1. Analysis chemical of soil in the layer 0 – 20 cm collected before of realization of experiment.

pH	P	K^+		Ca^{2+}	Mg^{2+}
$CaCl_2$	mg dm^{-3}		cmol$_c$ dm^{-3}		
5.92	78.83	0.15		3.43	1.41
Al^{3+}	Na^+	H + Al	SB	CEC (pH 7.0)	CECe
			cmol$_c$ dm^{-3}		
0	0.01	1.99	5	6.99	5
Zn^{2+}	Mn^{2+}	Cu^{2+}	Fe^{2+}	B	BS
		mg dm^{-3}			%
13.96	124.21	3.45	160.99	0.14	71.53

Ca^{2+}, Mg^{2+}, and K^+ extracted by Mehlich-3; P extracted by Mehlich 1; SB = sum of bases; CEC = cation exchange capacity; CECe = effective cation exchange capacity; BS = base saturation.

The experiments started on December 22, 2020 and November 22, 2021. The plants of both species were subjected to a production pruning with removal of unproductive branches, branches with diseases, branches with heavy shade, and shortening of branches close to the soil, to prepare the plant for a new production cycle.

Weeds were removed every 15 days using a brush cutter between rows and manual weeding using hoes in the planting row under the canopy projection. An automatic micro -sprinkler irrigation system was used with a flow rate of 40 L $hour^{-1}$; the plants were irrigated in dry days (without rainfall) for 60 minutes every two days.

Soil fertilizers were applied after the production pruning, using 120 g of N (260 g of urea 46% N); 220 g of P (1,222 g of simple superphosphate 18% P_2O_5), and 180 g of K (300 g of potassium chloride 60% K_2O) per plant. In addition, ten liters of bovine manure and 5 liters of ovine litter (ovine manure + rice rusk) per plant were applied.

Experimental design

A randomized block experimental design with two treatments was used, with 5 blocks and two evaluation plants per block. The treatments consisted of two dragon fruit species, *H. costaricensis* and *H. polyrhizus*. Each plant in each sample unit was divided into four quadrants and ten cladodes were selected per quadrant. Two flower buds were selected in each cladode, totaling 800 flowers for each species (MOURA et al., 2020a). The plants were monitored from the beginning of flower bud intumescence to fruit harvest.

Variables analyzed

The flowers were marked approximately 3 days before anthesis and evaluated every day, selecting completely formed buds, to evaluate reproduction dynamics from the beginning of reproductive bud emergence to fruit harvest, when the fruits presented fully red skin, according to the characteristic of the species, which was visually evaluated. The BBCH scale proposed by Meier et al. (2009) was used, recording the main growth stages: vegetative bud development (0), shoot development (1), development of primary shoots (3), reproduction development or flower bud intumescence (5), flowering (6), fruit development (7), fruit maturation (8), and senescence or beginning of dormancy (9). However, the description of stages five to eight was used in the present study.

Physical analyses were carried out using two fruits per plant, totaling 20 fruits per species, which were evaluated for longitudinal and transversal diameters (mm) and pulp thickness (mm) using a digital caliper (± 0.01 mm) (Shan, China). Fresh fruit weight was measured using an analytical balance and expressed as grams (± 0.01 g). Fruit firmness was determined using a manual penetrometer (Effegi) with an 8-mm tip, and expressed as N.

Physical and chemical analyses were carried out for 12 fruits after harvest. The fruits were evaluated for fruit weight, pulp weight, and skin weight using an electronic digital balance and expressed as grams. Fruit pH was estimated using a potentiometer with automatic temperature adjustment (mPA -210; Tecnal®, Brazil) previously calibrated with buffering solutions at pH 7.0 and 4.0 (AOAC, 2012). The data were expressed as pH units.

Soluble solids (SS) were determined directly in a homogenized pulp juice using a digital refractometer (PR-100; Atago, Japan) and expressed as °Brix (AOAC, 2012). Titratable acidity (TA) was determined by the electrometric procedure: 1.0 g of pulp in a 125-mL Erlenmeyer flask completed to 50 mL with distilled water was titrated with a NaOH 0.1 N solution until reaching the pH of 8.2 (AOAC, 2012), using an automatic titrator (Titrette®; Brand, USA), and expressed as mg of malic acid per 100 g of pulp (mg 100 g^{-1}). The SS to TA ratio was also determined.

Vitamin C was estimated by titration with a Tilman solution (0.02% 2,6-dichlorophenol indophenol), using 5 g of samples diluted in 0.5% oxalic acid in a volumetric flask of

100 mL, and expressed as mg of ascorbic acid per 100 g of pulp (mg 100 g^{-1}) (TERADA et al., 1978).

Temperature data were used to calculate the accumulated heat, in growing degree-days (GDD), using the formula *GDD = [(Tmax + Tmin) / 2) - Tb]*, where, *Tmax* is the maximum daily temperature, *Tmin* is the minimum daily temperature, *Tb* is the base temperature at which growth starts (°C), and *n* is the specific number of growth phenophases. The temperature of 12 °C was used for *Tb* (ERWIN, 1996).

Statistical analysis

The data were subjected to the Shapiro-Wilk normality test and the Bartlett homogeneity test, which showed that the data were within normality and homogeneity. The data were then subjected to multivariate analysis through Principal Component Analysis (PCA) using the R program (R CORE TEAM, 2020).

RESULTS AND DISCUSSION

The phenological dynamics of the dragon fruit species *H. costaricensis* and *H. polyrhizus* grown in Roraima, Brazil, were affected by climate variations during the crop cycle. Plants of both species presented low variation between phenophases during the first production year (2020-2021), differing from the second year (2021-2022) when the species *H. polyrhizus* had a longer cycle (Table 2).

Table 2. Days after production pruning for the beginning of phenological stages of dragon fruit species grown.

Phenophases	*Hylocereus costaricensis*		*Hylocereus polyrhizus*	
	Production pruning			
	Dec 22 2020	Nov 22 2021	Dec 22 2020	Nov 22 2021
Beginning of flower bud emergence (Figures 2A, 3A)	57	71	58	60
Flower bud intumescence (Figures 2B, 3B)	64	73	64	95
Flower bud formation (Figures 2C, 3C)	67	81	67	100
Flower at pre-anthesis (Figures 2G, 3F)	80	94	80	115
Open flower, release of pollen (Figures 2H, 3G)	81	95	81	116
Senescent flower (Figures 2I, 3H)	82	96	82	117
Beginning of fruit growth (Figures 2J, 3I)	84	98	84	118
End of fruit growth (Figures 2M, 3N)	107	125	107	141
Fruit harvest (Figures 2P, 3P)	114	134	114	148

The phenological reproduction dynamics of dragon fruit plants were similar between production years for both species (*H. costaricensis* and *H. polyrhizus*). Climatic factors had no significant effects on both species in the first production year (2020-2021) (Table 2) due to small air temperature variation during the highest rainfall peak at the beginning of reproduction bud development and the period after the anthesis, when fruits were growing, requiring constant temperature and light and low relative humidity for a fast growth (Figure 1A). However, the plants were strongly affected by climate variations, mainly the lower rainfall depths in 2021-2022.

The response of species to the climatic factors in 2021-2022 were more evident for effects of temperature during the production period, as shown by the accumulated heat, described in growing degree-days, and the period (days) of each phenophase (Table 3).

Table 3. Period (days) (DAY) and accumulated heat (degrees-days) (DD) required to complete each phenological stage in the dragon fruit species *Hylocereus costaricensis* (HC) and *Hylocereus polyrhizus* (HP).

Phenological stage	HC and HP		HC		HP	
	2020 / 2021		2021 / 2022			
	DAY	DD	DAY	DD	DAY	DD
Flower bud intumescence	64	1183	73	1384	95	1805
Development of floral organs	18	331	23	440	23	415
Flowering	3	56	3	53	3	55
Growth of fruits	23	449	27	512	23	432
Maturation of fruits	8	149	9	166	8	151
Beginning of harvest intumescence	51	949	62	1153	54	998
Harvest pruning	114	2114	134	2518	148	2785

Dragon fruit species (*H. costaricensis* and *H. polyrhizus*) required similar accumulated heat (degree-days) in the first production year (2020-2021). In the second production year (2021-2022), the species were significantly affected by climate conditions, including temperature, in which are the species required more degree-days due to the higher number of days of main phenological stages, mainly for the species *H. polyrhizus*, which presented higher number of days in each growth stage.

Phenological dynamics of *Hylocereus costaricensis*

H. costaricensis presented the early first evidence of flower bud differentiation (Figure 2A) in 2020-2021, with a difference of 14 days compared to 2021-2022 (Table 2), and a difference of 9 days for flower bud intumescence (Figure 2B) between 2020-2021 and 2021-2022 (Table 2). The period from occurrence of dormancy to the beginning of flower bud intumescence (Table 3) required an accumulated heat of 1183 degree-days.

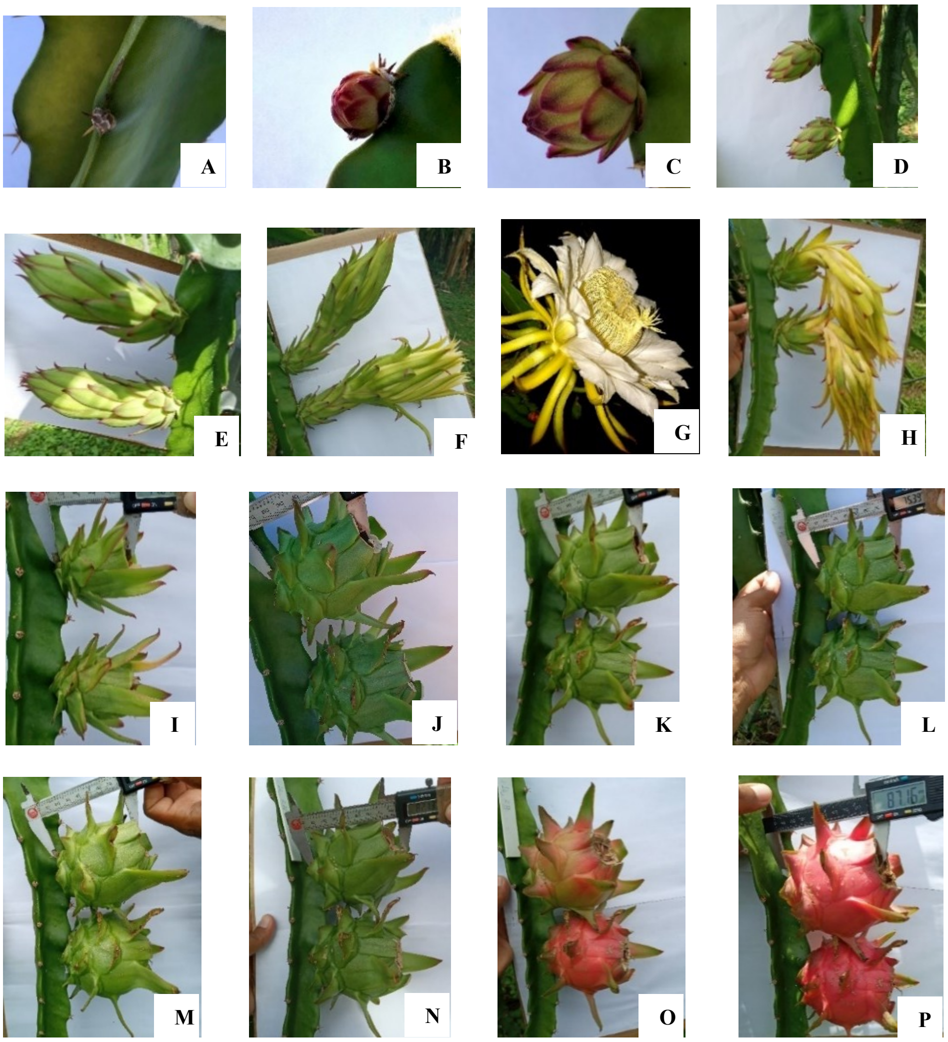


Figure 2. Sequence of phenological events of species *H. costaricensis*.

The flower bud formation process starts with the effective flower bud growth (Figure 2C), between 3±1 days and lasts for a growth period of 13 days, when the flower ceases the grow of the bulb and starts pre-anthesis (Figure 2F). The period from the beginning of flower bud formation to the bulb intumescence stage (pre-anthesis) showed a difference of 14 days between production years (Table 1). The complete development of floral organs lasted 18 and 23 days and required an accumulated heat of 331 to 440 degree-days, (Table 3).

Flowering lasted 3 days between pre-anthesis (beginning of flower opening) to the sepal and petal senescence (Figure 2I), and required 53 to 56 degree-days, varying according to the temperature between the years (Table 3). The flowers remained open for 12±2 hours.

The stage of effective fruit growth (Figure 2J) in length and diameter starts soon after the decrease in sepals and petals of fertilized flowers (2 days after anthesis). The most effective fruit growth stage of *H. costaricensis* lasted from 23 to 27 days, until the final growth stage before fruits start to change color from green to light red (Figure 2M). During this period, the plants required an accumulated heat of 449 to 512 degree-days (Table 3). There were differences of 14 and 18 days for the beginning and final fruit growth stages, respectively, between the first and second production year.

The ripening process starts with decreases in fruit growth (Figure 2N) and changes in fruit color to intense red until fruit harvest (Figure 2P). Thus, the fruits were suitable for harvest between 33 and 39 days after anthesis due to effects of climatic factors. The fruit maturation process for *H. costaricensis* lasted 8±1 days and required 149 to 166 degree-days.

H. costaricensis, presented a period of 50 to 61 days between the beginning of flower bud intumescence to fruit harvest (Table 3), requiring-se of unit of accumulated heat between 949 to 1153 degree-days as a function of climatic factors between the years 2020-2021 and 2021-2022, respectively. Considering the complete cycle (production pruning to fruit harvest), the plants required of 2114 degree-days for the first year and 2518 for the second year (2021-2022) for to complete the cycle (Table 3).

Phenological dynamics of *Hylocereus polyrhizus*

H. polyrhizus presented the first evidences of flower bud differentiation (Figure 3A) with a difference of only 2 days between production years (Table 2). However, the time for emergence of bud intumescence (Figure 3B) was 31 days longer in the second production year (2021-2022) (Table 2). The period from the occurrence of dormancy to flower bud intumescence (Table 3) required and accumulated heat of 1805 degree-days.

The developmental process of floral organs started with the effective growth of flower buds (Figure 3C), which occurred within 3 days in the first and 5 days in the second year after the bud intumescence and lasted 18 to 23 days (Table 3), period in which the flower ceases flower bulb growth and starts pre-anthesis (Figure 3F). Flower bud formation and the bulb intumescence stage (pre-anthesis) presented differences of 33 and 35 days, respectively, between production years (Table 2). The complete development of floral organs required 331 to 415 degree-days for *H. polyrhizus* (Table 3).

The flowers started a sequential opening after flower bulb intumescence and remained open for 12±2 hours. The beginning of flower opening was at 20:00h, when the stigma was visible, starting the pollen dehiscence, and was completely opened at 22:00h (Figure 3H). The flower bud closing started in the first hours of the morning, at approximately 8:00h (Figure 3I). The flowering process lasted from 3 days after pre-anthesis to the flower senescence and required an accumulated heat of 55 to 76 degree-days due to climate variations between the years (Table 3).

Fruit growth (Figure 3I) in length and diameter started soon after the decrease of sepals and petals of fertilized flowers (Table 2). The effective fruit growth stage lasted 23 days for *H. polyrhizus* (Figure 3N) and required 432 to 449 degree-days (Table 3). The period between the beginning and end of fruit growth lasted 34 days in both production years.

The fruit ripening process starts when the fruits reach maximum growth, with changes in color from green to light red (Figure 3O). *H. polyrhizus* showed no variation in days for fruit harvest, which were suitable for harvest at 32 days after anthesis in both production years (Table 2). Therefore, the fruit maturation stage (color change) lasted 8 days, requiring 149 to 151 degree-days. The period between the beginning of flower bud intumescence and harvest of *H. polyrhizus* fruits lasted 51 to 54 days (Table 3) and required an accumulated heat of 949 to 998 degree-days, due to differences in climatic factors between years. The complete cycle, from production pruning to fruit harvest (Table 2), the plants required 2785 days to complete the cycle.

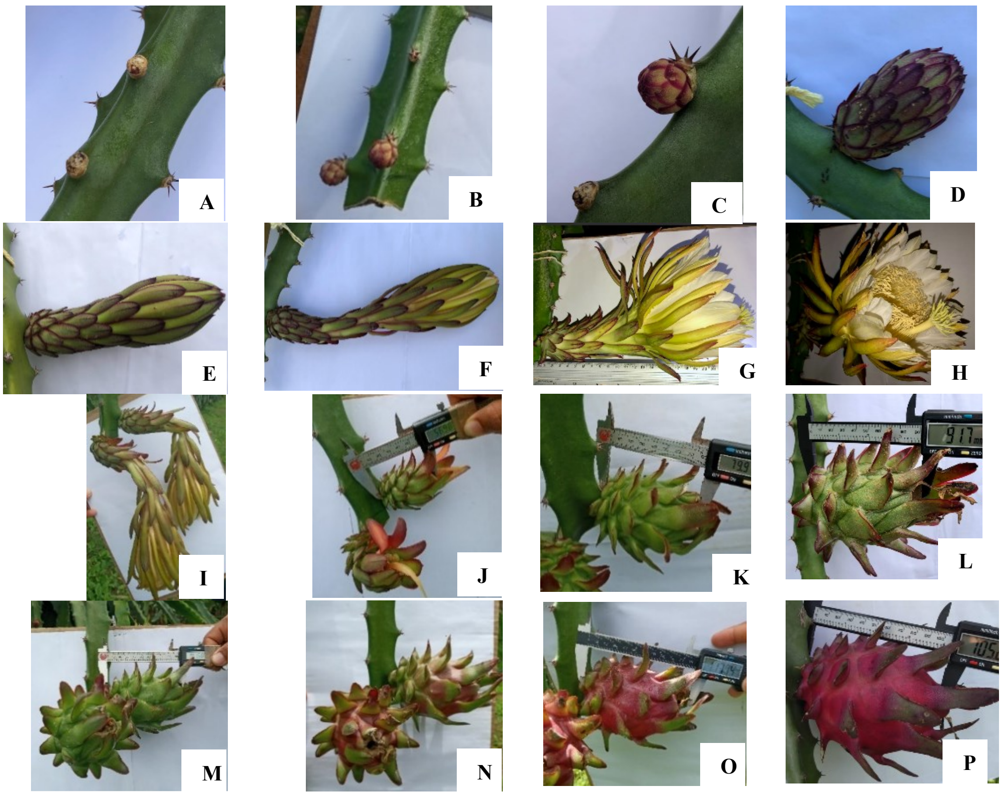


Figure 3. Sequence of phenological events of the species *Hylocereus polyrhizus*.

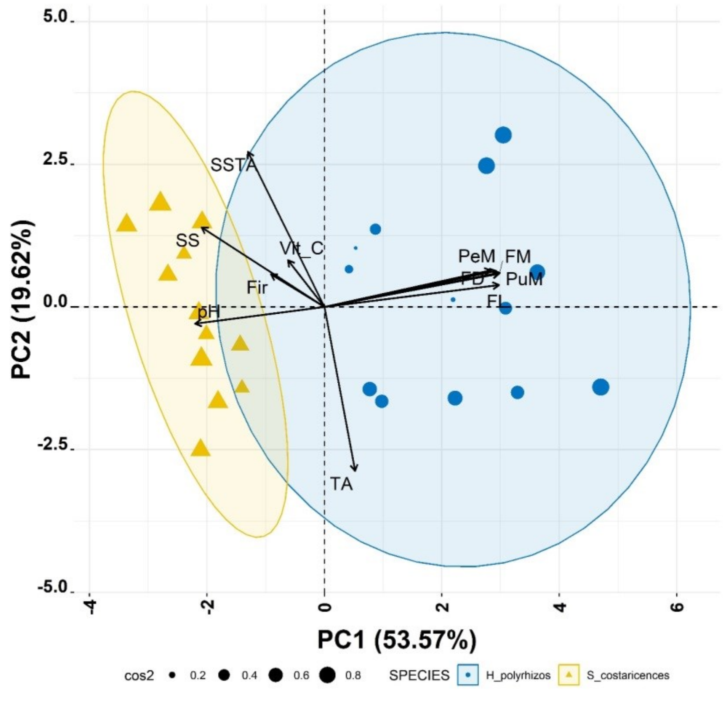
Temperature decreased 3 days before the start of flower bud intumescence (Figure 1B) for both species; however, *H. costaricensis* was less affected by high water deficits than *H. polyrhizus*, which required a rainfall depth of 49.2 mm (92, 93, 94 days) three days before the beginning of flower bud intumescence, with a consequent decrease in temperature (Figure 1B). The plants responded differently to environmental adversities during phenological developments, requiring specific stimuli, such as temperature or rainfall, to activate bud intumescence, mainly during the period of development of floral organs (ARAÚJO et al., 2021). Moreover, changes in the crop phenology caused by variations in climatic factors can result in longer period of phenophases (MOURA et al., 2020a).

The flower opening period was similar to those reported for *H. undatus* and *H. polyrhizus* grown in the Semiarid of the Northeast region of Brazil (MUNIZ et al., 2019) and for *H. undatus* grown in the oriental coastal region of India (10 to 12 h) (KISHORE, 2016). Thus, low temperature and high relative humidity conditions result in a longer period for the development of flower bud, with 15-hour anthesis in regions with mild climate conditions (MARQUES et al., 2011).

Climatic factors affected the fruit maturation stage due to the higher rainfall depths and lower temperatures in the second cycle, with both species presenting long fruit harvest periods after anthesis (above 30 days). In the first cycle, there was lower rainfall depths and higher temperatures, resulting in a shorter maturation period for *H. costaricensis* (22 days) and *H. polyrhizus* (24 days).

In the tropical climate conditions of eastern India, the ideal maturity for harvest was observed between 25 to 26 days after anthesis (KISHORE, 2016). In the Semiarid region of Brazil, the harvest of *H. undatus* and *H. polyrhizus* fruits lasted 30 days after the natural pollination (MUNIZ et al., 2019). In addition, in regions with mild climate conditions the period from anthesis to harvest was between 36 and 42 days in São Paulo (SILVA et al., 2015) and 41 days in southern Minas Gerais (MENEZES et al., 2015).

The principal component analysis presented an accumulated variance percentage of 73.19% for Components 1 (PC1) and 2 (PC2). Components 1 and 2 presented 53.57% and 19.62%, respectively (Figure 4).



Fruit diameter (FD), Fruit length (FL), Fruit mass (FM), Peel mass (PeM), Fruit firmness (Fir), Vitamin C (Vit_C), Pulp mass (PuM), Soluble solids and titratable acidity ratio (SSTA), Soluble solids (SS), Titratable acidity (TA) and hydrogen potential (pH)

Figure 4. Principal component analysis for the dragon fruit species *Hylocereus polyrhizus* and *Hylocereus costaricensis* as a function of physical and physical-chemical properties of fruits.

The variables that presented higher contributions and correlations with CP1 were: fruit weight (r^2=0.97; p=0.001), skin weight (r^2=0.96; p=0.001), pulp weight (r^2=0.97; p=0.001), fruit length (r^2=0.97; p=0.001), fruit diameter (r^2=0.96; p=0.001), soluble solids (r^2=0.98; p=0.001), and pH (r^2= - 0.72; p=0.001). The variables that presented higher contributions and correlations with CP2 were: titratable acidity (r^2= - 0.72; p=0.001), soluble solids to titratable acidity ratio (r^2= 0.70; p=0.001) and vitamin C content (r^2=0.70; p=0.001).

The physical and physical-chemical properties of *H. polyrhizus* fruits (elongated) and *H. costaricensis* fruits (cylindrical shape) were excellent. Regarding differences between species, *H. polyrhizus* fruits had higher correlation for physical properties, and *H. costaricensis* had higher correlation for chemical properties (Figure 4). Climatic factors directly affect fruit growth, with decreases in fruit size in regions with high temperatures and rainfall depths (SILVA et al., 2015).

H. polyrhizus produced elongated, larger fruits with red skin and pulp, but with lower skin firmness and inferior organoleptic properties (pH, soluble solids, and SS to TA ratio), which resulted in the distinct flavor of the species (Figure 4). *H. costaricences* produced cylindrical, smaller fruits exhibiting red skin and pulp, but with superior organoleptic properties and higher vitamin C contents, which is inherent to the species.

Physical properties that affect fruit size and chemical properties that affect organoleptic quality of fruits of these species involve many processes connected to the plant physiology of each species and the interaction between the species and the environment, management, and environmental factors (MOURA et al., 2020a; MOURA et al., 2023). Thus, considering that the dragon fruit species were grown in the same environment with the same crop management, they require different cultural practices for the best results in production characteristics.

Adapting crops to different environmental conditions has been challenging for researchers. Species that produce fleshy fruits present, in general, several limitations, including the need for irrigation, which results in direct effects on the fruit production and organoleptic properties, including flavor and physical properties (SIMON et al., 2022) Several plant species present positive response to increased or reduced irrigation, such as *Annona squamosa* (MOURA et al., 2023), *Prunus persica* (MIRÁS-AVALOS et al., 2013) and *Vaccinium corymbosum* (EHRET et al., 2012).

CONCLUSIONS

Complete physiological maturity of fruits of *Hylocereus costaricensis* and *H. polyrhizus* plants grown under the climate conditions of the northern Amazon, Brazil, occurs between 36 to 33 days after anthesis, when the entire fruit exhibits an intense red color with a red pulp, and is suitable for harvest. The fruits exhibited excellent physical and physical-chemical characteristics, which varied according to the species and climate conditions.

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