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Reproductive phenology of yellow pitaya in a high-altitude tropical region in Brazil

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ABSTRACT. Pitaya species cultivation in Brazil is recent, and information on the production of the species *Selenicereus megalanthus*, known as yellow pitaya, is non-existent because research in the country has focused on the species *Hylocereus undatus*. The research was carried out with the objective of evaluating the reproductive phenology of the species *S. megalanthus,* in a high-altitude climate conditions in Brazil. The study orchard of yellow pitaya was located at an altitude of 726 metres, 18º 04' 15" S latitude and 43º 28' 15" W longitude, and has an Aw climate, classified as high-altitude tropical. Phenological evaluations were carried out through visual observations, from the beginning of floral button formation until the end of the fruit harvest, during three production cycles. On each plant, flower buds were marked to determine the time from floral button formation until flower anthesis and from flower fertilisation until fruit ripening. The period of flowering and harvesting of the yellow pitaya was determined according to the phenological stage records. Flowering began in the spring, with successive flowering events until the autumn. The time between floral button formation until anthesis ranged from 46 to 55 days. The time from flower fertilisation until fruit ripening ranged from 96 to 110 days. Fruit harvest began in the summer and ended in winter. The reproductive cycle of *S. megalanthus* is longer than *H. undatus* and *H. polyrhizus*, which are also cultivated in Brazil, ranging from 147 to 166 days from floral button formation to fruit harvest.

Keywords: *Selenicereus megalanthus*; exotic fruit; cactaceae; production season.

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Introduction

Pitaya cultivation is recent in Brazil and has expanded in recent decades. However, information related to yellow pitaya production is unknown. Thus, studies to evaluate the phenology of the pitaya species that are being introduced into new producing areas can contribute to the success of orchards. This is because a detailed knowledge of the production period is fundamental to orchard planning in relation to the size of the area to be cultivated for a return on investment, the choice of species for commercialisation at different times in the market, and the establishment of management practises to obtain high yields from the different cultivation locations.

The duration of the phenological phases and the period of production may vary according to pitaya species, climate and soil conditions of the cultivation sites, orchard management, and other environmental and genetic factors.

In Brazil, the time between floral button formation and fruit harvest of *Hylocereus undatus* specie ranges from 50-60 days (Marques, Moreira, Ramos, Araújo, & Silva, 2011) and from 52-66 days (Silva, Cavallari, Sabião, & Martins, 2015), and the fruit-to-harvest stage ranges from 30-32 days (Ortiz & Takahashi, 2015), indicating a short timeframe for marketing. In relation to season, for species *H. undatus* orchards established in temperate, Cwb-type climate conditions, either mild or mesothermic temperate, flowering begins in the summer and the fruit harvest ends in autumn, with three to five flowering events (Marques et al., 2011). In conditions of the subtropical Cwa classification, the production period takes place in the late spring to mid-autumn, with up to nine flowering events (Silva et al., 2015).

In relation to the pitaya species *Selenicereus megalanthus*, there are no reports studying Brazilian growing conditions, so studies on the productive period of this species are important to provide information to

producers and to enable the diversification of cultivated areas with pitaya species, with a distinct harvest period for fruit commercialisation during times of better market prices.

In other producing countries, differences in the production season have been observed as a function of climatic conditions. In Israel, the flowering of the yellow pitaya occurs mainly in the fall because in summer, the desert climate in Israel is characterised by high light and temperature intensity, and the flowering of cacti is inhibited because plants are under extreme conditions (Nerd, Sitrit, Kaushik, & Mizrahi, 2002). In Taiwan, flowering occurs in late spring, with an abundance of flower shoots in April due to favourable weather. In this region, the climate is not completely inhibitory to flowering in summer, allowing a small amount of flowering until the beginning of autumn (Jiang, Lin, Lee, Yen, & Yang, 2011). This suggests the need for research to provide information on the viability of cultivation in new areas, aiming to increase pitaya use for economic development.

In light of the above, research was performed with the objective of studying the reproductive phenology of the yellow pitaya plant, *Selenicereus megalanthus*, in a tropical, high-altitude climatic region of Brazil.

Material and methods

The research was carried out in an orchard located in Couto de Magalhães de Minas, Minas Gerais State, Brazil, located at 18° 04' 15" S latitude and 43° 28' 15" W longitude at an altitude of 726 metres. The region has an Aw climate type, classified as high-altitude tropical, characterised by a well-defined dry and rainy season. The average temperatures are as follows: 34.8°C maximum and 19.2°C minimum in the spring; 35.1°C maximum and 21.5°C minimum in the summer; 27.6°C maximum and 17.8°C minimum in the autumn; and 26.8°C maximum and 14.3°C minimum in the winter. Data were from observations recorded in the experimental area during the evaluation period.

The orchard was planted with ten-month-old plants of yellow pitaya (*S. megalanthus*) from cladode rooting. Plants were spaced with 3 metres between plants and 3 metres between the rows, with a density of 1,111 plants per hectare. The plants were supported by eucalyptus posts at 1.8 m high, and lateral shoots were eliminated until the plant height reached 1.7 m. From that height, all the shoots were left for the formation of the canopy for production.

The basic fertilization for planting was administered according to the soil analysis of the experimental area, which was of the Typic Haplorthox soil, with 60% sand, 27% clay and 13% silt and the following characteristics: pH (H_2O) = 5.0; P = 3.1 mg dm^{-3}; K = 40.7 mg dm^{-3}; Ca = 0.8 $cmol_c$ dm^{-3}; Mg = 0.3 $cmol_c$ dm^{-3}; Al = 0.6 $cmol_c$ dm^{-3}; organic matter = 0.25 dag kg^{-1}; base saturation (V) = 23% and T cation exchange capacity at pH 7.0 = 5.1 $cmol_c$ dm^{-3}.

Liming was performed to raise the base saturation to 60 %, with dolomitic limestone (PRNT = 87%) equivalent to 2 t ha^{-1}. In the plant holes, 50 g P and 20 L of bovine manure were added to the soil. Single superphosphate with 18% P_2O_5, 16% Ca, and 8% S was used as a source of P. After planting in the area, 100 g of N and 100 g of K_2O were applied per plant for fertilisation during growth. The source of N was urea and the source of K was potassium chloride. The amounts of N and K were divided into three applications each year.

Irrigation management was carried out during the period of low rainfall to maintain soil moisture for nutrient absorption at the time of fertilization. The control of weeds was carried out within a radius of 40 cm from the stem by hand weeding, and the remainder of the area was mowed.

In the experimental area described, 48 plants were evaluated and distributed in randomised blocks, with twelve blocks and four plants per plot. The evaluations to characterise the phenology of the reproductive cycle were carried out by visual observations made in the first, second and third productive cycle after the planting of the orchard. The floral buds in each plant were marked to determine the time between the floral button formation until flower anthesis and flower fertilisation until fruit ripening. Thus, the flowering season and time for the development of the floral button and fruit were determined. According to the phonological stage records, the periods of flowering and harvesting of the yellow pitaya were determined.

Results and discussion

Flowering of the pitaya *S. megalanthus* occurred between late spring and autumn. During this period, the plants produced three to five successive flowering events, lasting from 156 to 170 days, in the three cycles evaluated (Table 1). In the climatic and soil conditions where the orchard was planted, the flowering periods of the plants occurred between November and May.

Table 1. Days corresponding to the transition of the phenological stages observed in three production cycles of *S. megalanthus* in Couto de Magalhães de Minas, Minas Gerais State, Brazil. Formation of flower button (FB), flower anthesis (FA), flower fertilisation (FF), fruit harvest (FH), flowering period (FP), and harvest period (HP).

FB until FA	FA until FF	FF until FH	Number of flowering outbreaks	flowering period*	harvest period**
			1° production cycle		
46	1	100	4	165	170
			2° production cycle		
49	1	96	5	156	155
			3° production cycle		
54	1	110	3	170	180
			[1]average in days of stages		
50	1	102	4	164	168

*period corresponding to the beginning and end of flowering, **period corresponding to the beginning and end of the harvests, [1]average in days for three production cycles.

The flowering period of *S. megalanthus* is longer than *H. undatus* in Brazilian conditions. For red pitaya, flowering occurs from November to March in Cwb climatic conditions (Marques et al., 2011) and from November to April in Cwa climatic conditions (Silva et al., 2015).

Another difference noted for *S. megalanthus* in relation to *H. undatus* in Brazilian conditions is the time for development of the floral button, which is from 46 to 54 days from formation of the floral button up until anthesis (Table 1 and Figure 1A to D). *Hylocereus undatus* floral anthesis time varies from 18 to 23 days in Brazil (Marques et al., 2011) and Israel (Nerd et al., 2002). As in the other pitaya species, the anthesis of *S. megalanthus* flowers occurs at night and closes early in the morning. After flower fertilisation, fruit formation begins (Figure 1F). The development of the fruit will only occur if the flower has been fertilised, presenting desiccation of floral remains such as petals, stamens and stigma. These floral remains may fall or remain attached to the fruit until harvest (Figure 1G and H).

The differences in relation to the flowering period and in the time to anthesis of *S. megalanthus* in relation to *H. undatus* suggest the need for the introduction of different clones of this species, with a focus on the management of pollination to increase the size of the fruits. This is because, even being a self-compatible species, the viability of pollen is reduced because *S. megalanthus* is tetraploid (2n = 44), and meiosis occurs irregularly at anaphase I (Lichtenzveig, Abbo, Nerd, Tel-Zur, & Mizrahi, 2000). Increasing the amount of pollen through artificial pollination makes it possible to produce fruits of higher mass, seed content and solids content (Dag & Mizrahi, 2005).

During fruit development, the colour of the peel remains green (Figure 1G). The first indicative change in fruit coloration was observed from 85 and 92 days after anthesis, with a complete change in the colour of the fruit peel 8 to 10 days later, when the fruit presented a completely yellow peel (Figure 1H).

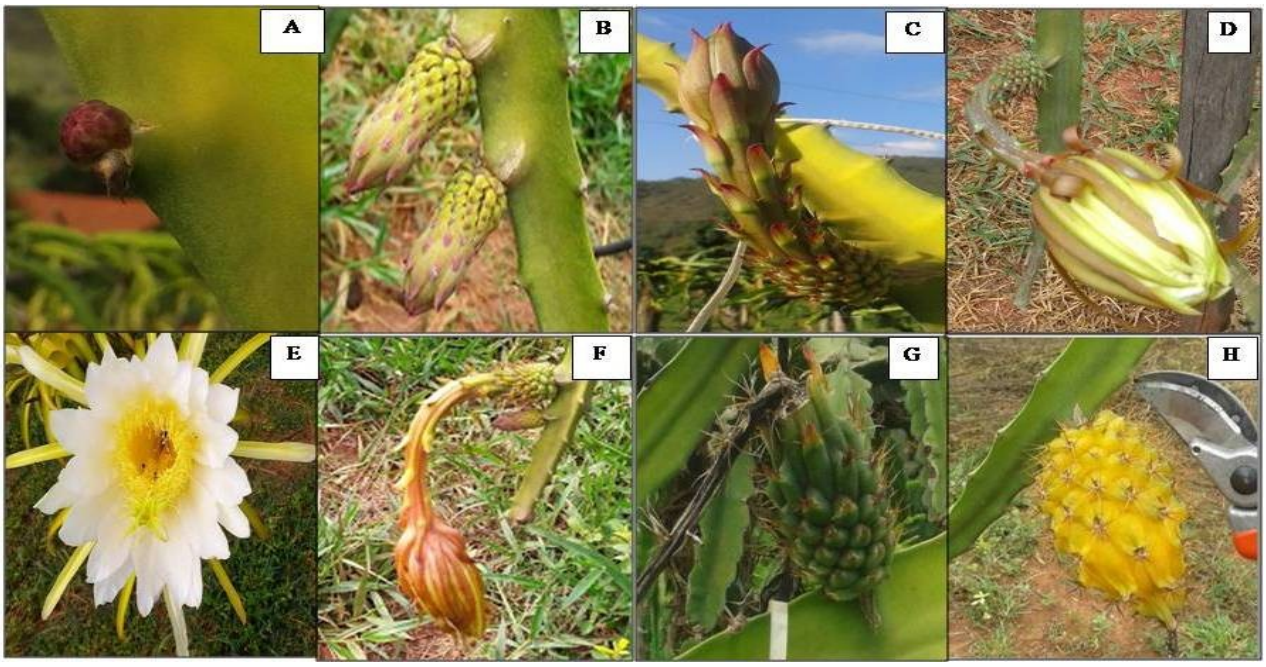

Figure 1. Phases of reproductive phenology of yellow pitaya: (A) appearance of the floral bud, (B, C) floral button elongation, (D) onset of sepal detachment, (E) before the flower, (F) pollinated flower, (G) growing fruit, and (H) maturation of the fruit of *Selenicereus megalanthus* in Couto de Magalhães de Minas, Minas Gerais State, Brazil.

The time after flower fertilisation until fruit harvest varied from 96 to 110 days in the three cycles evaluated. This is the biggest difference in relation to the phenological stages of *H. undatus* cultivated in Brazil, which reach full maturation from 30 to 43 days after anthesis of the flower depending on the place of cultivation (Marques et al., 2011; Silva et al., 2015; Ortiz & Takahashi, 2015).

The longer times for flower development and fruit ripening contribute to the increased duration of the cycle of the pitaya *S. megalanthus*, varying from 147 to 166 days, which makes it a strategic option for producers because they can alternate the harvesting periods with the different pitaya species that present a shorter cycle of 52 to 66 days (Silva et al., 2015).

The duration of the pitaya cycle is variable according to the climatic conditions because it was possible to observe faster development of flowers and fruits when flowering occurred in summer months with higher temperatures in the region of this study. Similar results were reported by Nerd and Mizrahi (1998), who also observed that the number of days of anthesis to the maturation of the yellow pitaya depended on the temperature.

According to observations of the stages of reproductive phenology of yellow pitaya, the production cycle of this species in Brazil is longer than the pitayas *H. undatus* and *H. polyrhizus* (Nerd et al., 2002). Therefore, the fruit harvest period is also longer, varying from 155 to 180 days, due to successive flowering events (Table 1). The beginning of the harvests began in the summer and late in winter, while the harvests of the other cultivated species are concentrated in the summer when the temperatures are higher and photoperiod long in the Brazilian conditions (Marques et al., 2011; Silva et al., 2015). Unlike other producing countries, where the extreme temperature conditions that occur in summer inhibit the flowering of pitaya species (Jiang et al., 2011), summer temperatures in Brazil are not limiting to the flowering of the species, which favours the longer production time of the yellow pitaya.

In this way, the climatic and soil conditions of the region, in addition to the management adopted in the orchard, should be considered in the expansion of cultivated areas, as they are fundamental aspects that will determine the production time and the productivity of the orchard.

The knowledge of the phenological phases makes it possible to plan orchards based on management techniques and production scheduling for the commercialisation of the fruits, considering the different markets. For the yellow pitaya, this planning allows for proper sizing of the cultivated areas for the commercialisation of the fruits in the off season, which is the time with the best market prices.

Conclusion

Selenicereus megalanthus cultivated in high-altitude tropical climate conditions blooms in the spring, with successive flowering events until the autumn. The fruit harvest starts in the summer and ends in the winter. The reproductive cycle of *S. megalanthus* is longer than *H. undatus* and *H. polyrhizus*, which are also cultivated in Brazil, ranging from 147 to 166 days from floral button formation to fruit harvest.

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