IMPACTO CIENTÍFICO
EDITORA

PITAYA FLOWERING IN THE CERRADO WITH THE APPLICATION OF GROWTH REGULATORS AT THE END OF THE OFF-SEASON

FLORAÇÃO DE PITAYA NO CERRADO COM A APLICAÇÃO DE REGULADORES DE CRESCIMENTO NO FINAL DA ENTRESSAFRA

FLORACIÓN DE PITAYA EN EL CERRADO CON LA APLICACIÓN DE REGULADORES DE CRECIMIENTO AL FINAL DE LA TEMPORADA BAJA

10.56238/edimpacto2025.051-011

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ABSTRACT

Pitaya cultivation has expanded in Brazil primarily due to the nutritional value of its fruits and the expected expansion of cultivated areas. However, the crop's fruiting seasonality limits fruit supply between May and November in the Brazilian Midwest. In an attempt to overcome this seasonality, the effects of applying gibberellic acid (GA_3) and paclobutrazol at the end of the off-season were evaluated, aiming to accelerate floral induction and fruiting of pitaya, as well as to understand the role of gibberellin in pitaya fruiting. The experiment was conducted in a commercial orchard, with plants 19 months old after planting. The design was a randomized complete block design, with six treatments, four replicates, and five plants per plot. Treatments consisted of applications of 0, 75, 150, 300, and 600 mg L^{-1} of GA_3, in addition to a treatment with 100 mg L^{-1} of paclobutrazol, on September 7, 2023. The pitaya showed sensitivity to the application of the substances. Paclobutrazol completely inhibited fruit set, even under inductive environmental conditions, highlighting the crucial role of gibberellin in pitaya fruit set. The different doses of GA_3 provided different responses in flowering and fruit set peaks. Regardless of the GA_3 doses applied, earlier flowering was observed compared to plants in the orchard that did not receive the GA_3 treatment and in neighboring growers. No statistical differences in early flowering were observed between the GA_3 doses. The earlier fruiting period provided by GA3 application at the end of the off-season highlights the potential of GA_3 application as a tool to expand the production window. However, it is necessary to adjust the dose, timing, and application method to maximize treatment effectiveness.

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Keywords: *Hylocereus sp*. Floral Induction. Fruiting.

RESUMO

O cultivo da pitaya tem se expandido no Brasil principalmente pelo valor nutricional dos frutos e com expectativa de ampliação das áreas cultivadas. No entanto, a sazonalidade da frutificação da cultura limita a oferta de frutos entre os meses de maio a novembro no Centro-Oeste brasileiro. Na tentativa de superar essa sazonalidade, avaliou-se os efeitos da aplicação, no final da entressafra, do ácido giberélico (GA_3) e do paclobutrazol, visando antecipar a indução floral e a frutificação da pitaya, assim como para entender o envolvimento da giberelina na frutificação da pitaya. O experimento foi realizado em pomar comercial, com plantas com 19 meses após a implantação. O delineamento foi em blocos ao acaso, com seis tratamentos e quatro repetições e cinco plantas por parcela. Os tratamentos consistiram na aplicação de 0, 75, 150, 300 e 600 mg L^{-1} de GA_3, além de um tratamento com 100 mg L^{-1} de paclobutrazol, no dia 07 de setembro de 2023. A pitaya apresentou sensibilidade à aplicação das substâncias. O paclobutrazol inibiu completamente a frutificação, mesmo sob condições ambientais indutivas, evidenciando o papel crucial da giberelina na frutificação da pitaya. As diferentes doses de GA_3 proporcionou diferentes repostas nos picos de floração e frutificação. Independentemente das doses de GA_3 aplicadas, observou-se antecipação da floração em relação às plantas no pomar que não receberam o tratamento com GA3 e de produtores vizinhos. Entre as doses de GA3, não se observou diferenças estatísticas na antecipação da floração. A antecipação da frutificação proporcionada com a aplicação de GA3 no final da entressafra aponta o potencial da aplicação do GA_3 como ferramenta para ampliar a janela de produção, no entanto, é necessário ajustar a dose, época e forma de aplicação para maximizar a eficiência do tratamento.

Palavras-chave: *Hylocereus sp*. Indução Floral. Frutificação.

RESUMEN

El cultivo de pitaya se ha expandido en Brasil, principalmente debido al valor nutricional de sus frutos y a la expansión prevista de las áreas cultivadas. Sin embargo, la estacionalidad de la fructificación del cultivo limita la disponibilidad de fruta entre mayo y noviembre en el Medio Oeste brasileño. Para superar esta estacionalidad, se evaluaron los efectos de la aplicación de ácido giberélico (GA_3) y paclobutrazol al final de la temporada baja, con el objetivo de acelerar la inducción floral y la fructificación de la pitaya, así como comprender el papel de la giberelina en la fructificación. El experimento se realizó en un huerto comercial, con plantas de 19 meses de edad después de la siembra. El diseño fue un diseño de bloques completamente al azar, con seis tratamientos, cuatro réplicas y cinco plantas por parcela. Los tratamientos consistieron en aplicaciones de 0, 75, 150, 300 y 600 mg L^{-1} de GA_3, además de un tratamiento con 100 mg L^{-1} de paclobutrazol, el 7 de septiembre de 2023. La pitaya mostró sensibilidad a la aplicación de las sustancias. El paclobutrazol inhibió completamente el cuajado de frutos, incluso en condiciones ambientales inductivas, lo que destaca el papel crucial de la giberelina en el cuajado de frutos de pitaya. Las diferentes dosis de GA_3 proporcionaron diferentes respuestas en los picos de floración y cuajado de frutos. Independientemente de las dosis de GA_3 aplicadas, se observó una floración más temprana en comparación con las plantas del huerto que no recibió el tratamiento con GA_3 y en los productores vecinos. No se observaron diferencias estadísticas en la floración temprana entre las dosis de GA_3. El período de fructificación más temprano proporcionado por la aplicación de GA3 al final de la temporada baja resalta el potencial de la aplicación de GA_3 como una herramienta para expandir la ventana de producción. Sin embargo, es necesario ajustar la dosis, el momento y el método de aplicación para maximizar la eficacia del tratamiento.

Palabras clave: *Hylocereus sp*. Inducción Floral. Fructificación.

1 INTRODUCTION

Flowering involves the signaling and expression of specific genes that are responsible for the formation of plant reproductive structures. The signaling for flowering in some species occurs due to variations in meteorological factors, which result in changes in genetic and molecular mechanisms, such as gene expression, hormonal balance and the sensitivity of plant tissues that determine the formation of reproductive structures (Samach and Wigge, 2005; Phengphachanh et al., 2012; Andrés and Coupland, 2012; Verhage et al., 2014; Osnato, 2022; Wu et al., 2022). This response, intrinsic to some plants, conditions flowering to specific meteorological conditions of photoperiod, light intensity, temperature and water availability, among other factors.

Pitaya, belonging to the genus *Hylocereus* of the Cactaceae family, is increasingly cultivated in tropical and subtropical regions due to its high tolerance to drought and heat stress (Yang et al., 2024). Dragon fruits are known worldwide as *dragon fruits* . In Brazil, dragon fruit is considered an exotic fruit due to the fact that it is little known, exuberant and marketed with high value, especially in demanding markets, being considered the fruit that is conquering Brazil (Faleiro, 2022). It is expected that the cultivation of dragon fruit in Brazil will grow in the coming years, given the demands of the domestic and foreign markets for fresh fruits and the agroindustry, which are growing rapidly.

The main stages of pitaya growth consist of the formation of vegetative shoots, thorns (modified leaf), growth of shoots, emergence of inflorescence, flowering, fruit formation and fruit maturation, and the formation of reproductive structures occurs in mature shoots, at least 3 to 4 months old (Chu and Chang, 2022; Kishore, 2016). Understanding the flowering and fruiting of plants can contribute to improving productivity and fruit quality (Costa et al., 2014) and profitability for farmers.

The pitaya has seasonality in flowering, concentrating in the seasons of the year with the highest photoperiod, being classified as a long-day plant (Jiang, 2020). Jiang et al. (2012) indicated that the critical length of the day for white pitaya flowering is 12 h, and Chu and Chang (2022) highlight that the phenological stage of the plant depends on the variety, the length of the day, and the climate. Kishore (2016) reported that pitaya flowering coincided with the prevalence of longer day length (≥13 h), high precipitation, high humidity (>80%) and moderate temperature range (averaging around 28 ^{oC}) and any change in temperature and relative humidity affects shoot induction. Nerd et al. (2002) reported that high summer temperatures inhibit pitaya flowering.

The pitaya has considerable plasticity for molecular adjustments in response to heat. Yang et al., (2024) identified specific molecular functions regarding the response to heat and promotion of flower bud differentiation, demonstrating a new perspective on the possibility of improving the species' adaptation to a high-temperature environment, as well as on the regulation of flowering, allowing adaptation to different climatic conditions.

The dependence on climatic factors for the flowering of pitaya requires specific management to induce flowering under non-inductive conditions, to enable fruit production in the off-season. The supplementation of sunlight with artificial lighting has shown satisfactory results for flowering and fruit quality. Silva et al., (2025) point out that light supplementation mitigates problems related to the critical photoperiod of pitaya, increases productivity in the off-season, extends harvest windows, improves sensory and nutritional profiles, and consequently increases market value and profitability. On the other hand, the authors consider it essential to standardize experimental parameters, such as light spectrum, intensity, duration and specific responses of the cultivar, ensuring efficiency and cost-effectiveness, due to the variation in the responses found.

It should be noted that responses to light complementation depend on genotype, phenological stage, and other factors such as temperature and relative humidity, and the response is usually slow (Tran et al., 2015; Chu and Chang, 2020; Al-Qthanin et al., 2024), requiring understanding the influence of environmental factors on plant development to improve and implement management techniques in the face of observed patterns (Al-Qthanin et al., 2024).

Meteorological factors such as photoperiod, temperature and humidity are directly associated with the synthesis of hormonal molecules, gene expression and the sensitivity of plant tissues. The increase in the photoperiod and higher temperatures favor the synthesis of gibberellins, auxin and in conditions of low humidity, increase the production of ABA (Samach and Wigge, 2005; Aksenova et al. 2006; Gray et al., 1998; Castroverde and Dina 2021; Ding and Yang, 2022; García-Martinez and Gil, 2002; Atif et. al., 2020). Gibberellin is directly involved in flowering in long-day plants and with evidence of the mechanisms by which floral induction occurs (Mutasa-Gottgens and Hedden, 2009). Paclobutrazol, on the other hand, acts as an inhibitor of gibberellin biosynthesis (García-Martinez and Gil., 2002), and can be used in studies on the action of gibberellins on plants.

Thus, the application of growth regulator molecules that are involved in flowering can induce flowering under non-inductive environmental conditions and allow the scaling of pitaya production. Wu et al., (2022) found that transcription factors related to auxin, ABA, brassinosteroids, and ethylene were fundamental for the formation of pitaya flower bud, with the highest expression of transcripts related to indoleacetic acid at the undifferentiated flower bud stage, pointing to the role in flower bud formation.

In view of this dynamic, the application of growth regulators has become a management alternative to optimize and scale production, replacing complementary lighting in pitaya orchards. The application of gibberellic acid has been used to induce flowering in *Humulus lupulus* L (Bauerle, 2022), kalanchoe (Coelho et al., 2018), pitaya (Takata et al., 2016; Khaimov & Mizrahi, 2006), among other species.

Given the seasonality of pitaya production, there is a great variation in the price of fruits between regions and times of the year, and it is opportune to define strategies to produce in the off-season, increase the production window, and provide greater profitability. In 2020, at Ceasa de Goiânia-GO, the price per kilo of red pitaya ranged from approximately R$ 30.00 (March) to R$ 85.00 (off-season months). In 2020, at Ceagesp (Companhia de Entreposto e Armazéns Gerais de São Paulo), the price was approximately R$ 7.00/kg (January to May) and R$ 20.00 to R$ 30.00 (off-season) (Santos et. al., 2022).

In view of the above, in order to induce pitaya fruiting in the off-season, the application of gibberellic acid and paclobutrazol in the flowering dynamics of pitaya cultivated in the Cerrado between the months of September 2023 and May 2024 was evaluated.

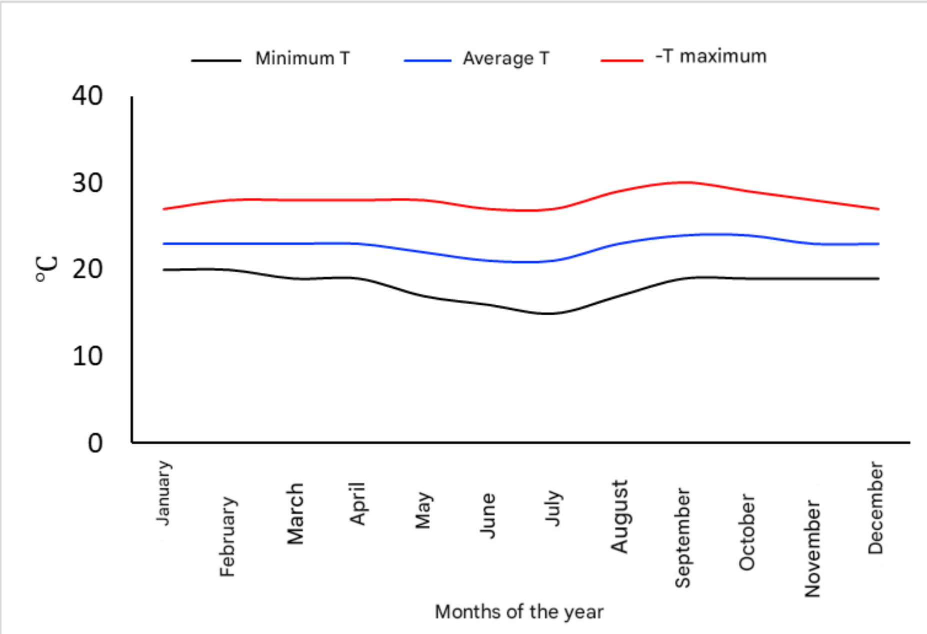
2 METHODOLOGY

The experiment was carried out at the Retiro das Caldas Farm, in the municipality of Anápolis - Goiás, at 16°27'3.10" S, 48° 54′ 00" W, latitude of -16.3287, longitude of -48.9534 and altitude of 980 m, in a commercial cultivation of red pitaya, 19 months after the planting of the crop. The cultivated pitaya, *Hylocereus* sp., red inside and out, is a hybrid from crosses between species, with satisfactory productive performance, resistance to diseases, with red and sweet pulp, natural pollination and production begins one year after planting from cladodes, reaching the peak in production in the second year.

The classification of the region's climate according to the Köppen-Geiger classification is of the Cwb climate type, more common in temperate regions, which is characterized by being humid temperate with dry winter and temperate summer (Cardoso et al., 2014). Figures 1, 2 and 3 show the variation in temperatures, number of hours of daylight, relative humidity and precipitation throughout the year in the municipality of Anapólis-GO.

Figure 1

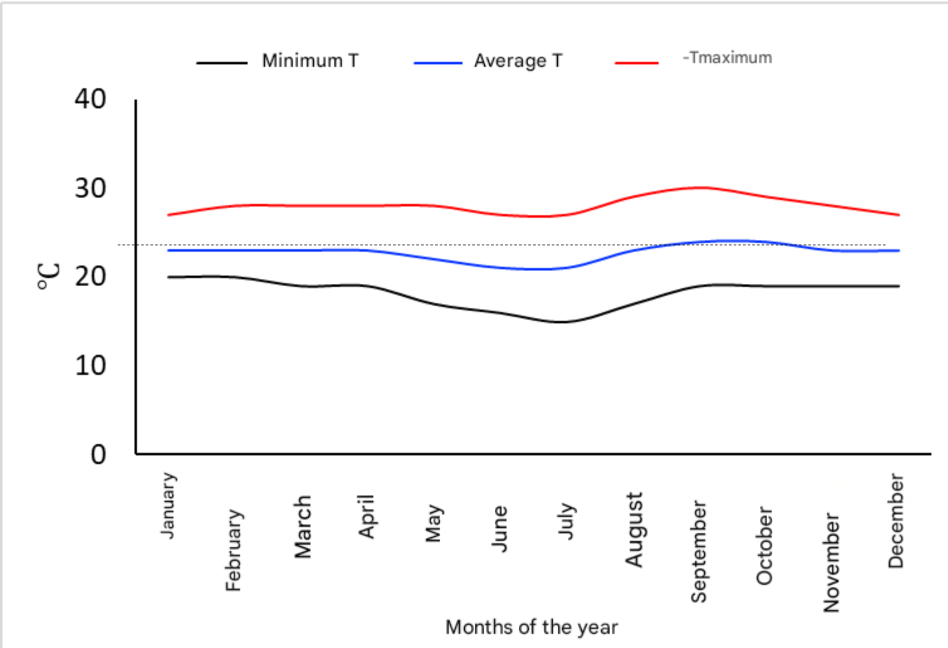
Average temperatures throughout the year in Anápolis-GO



Source: Adapted from https://pt.weatherspark.com/y/30121/Clima-caracter%C3%ADstico-em-An%C3%A1polis-Goi%C3%A1s-Brasil-durante-o-ano#Figures-Temperature

Figure 2

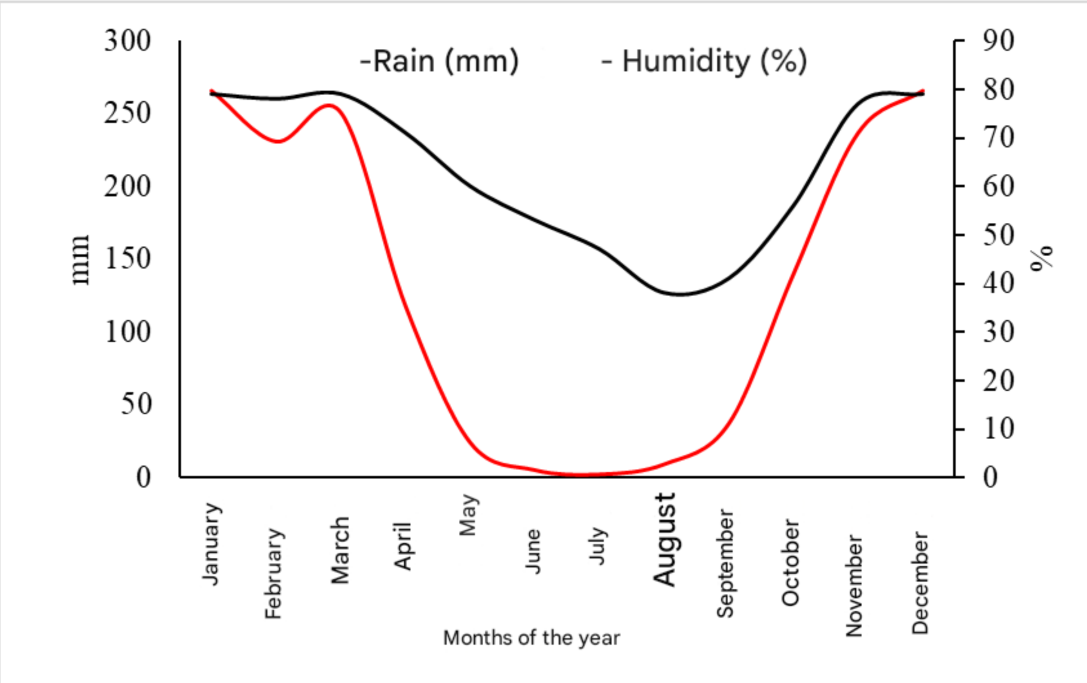
Variation of the photoperiod in Anápolis - GO



Source: Adapted from https://pt.weatherspark.com/y/30121/Clima-caracter%C3%ADstico-em-An%C3%A1polis-Goi%C3%A1s-Brasil-durante-o-ano#Figures-Temperature

Figure 3

Variation in precipitation and relative humidity in Anápolis - GO



Source: Adapted from https://pt.climate-data.org/america-do-sul/brasil/goias/anapolis-3192/#climate-table

The preparation of the area for the implementation of the orchard consisted of cleaning, demarcation and opening of pits 0.50 m deep for the implementation of concrete piles 2.20 m high and 0.1 m wide After soil analysis, crowns were made around the stakes with a radius of 0.50m and 250g of dolomitic limestone was applied.

The planting of pitaya was carried out in February 2022, with cuttings of mature cladodes, about 50 cm long and 15 cm in diameter, with a spacing of 2.0 m between rows and 2.0 m between plants. In each stake, 5 (five) cladodes were placed, with the base at 0.05 cm depth in the ground, tied to the stake with string. After planting, about 50 L of cattle manure was distributed around the cladodes.

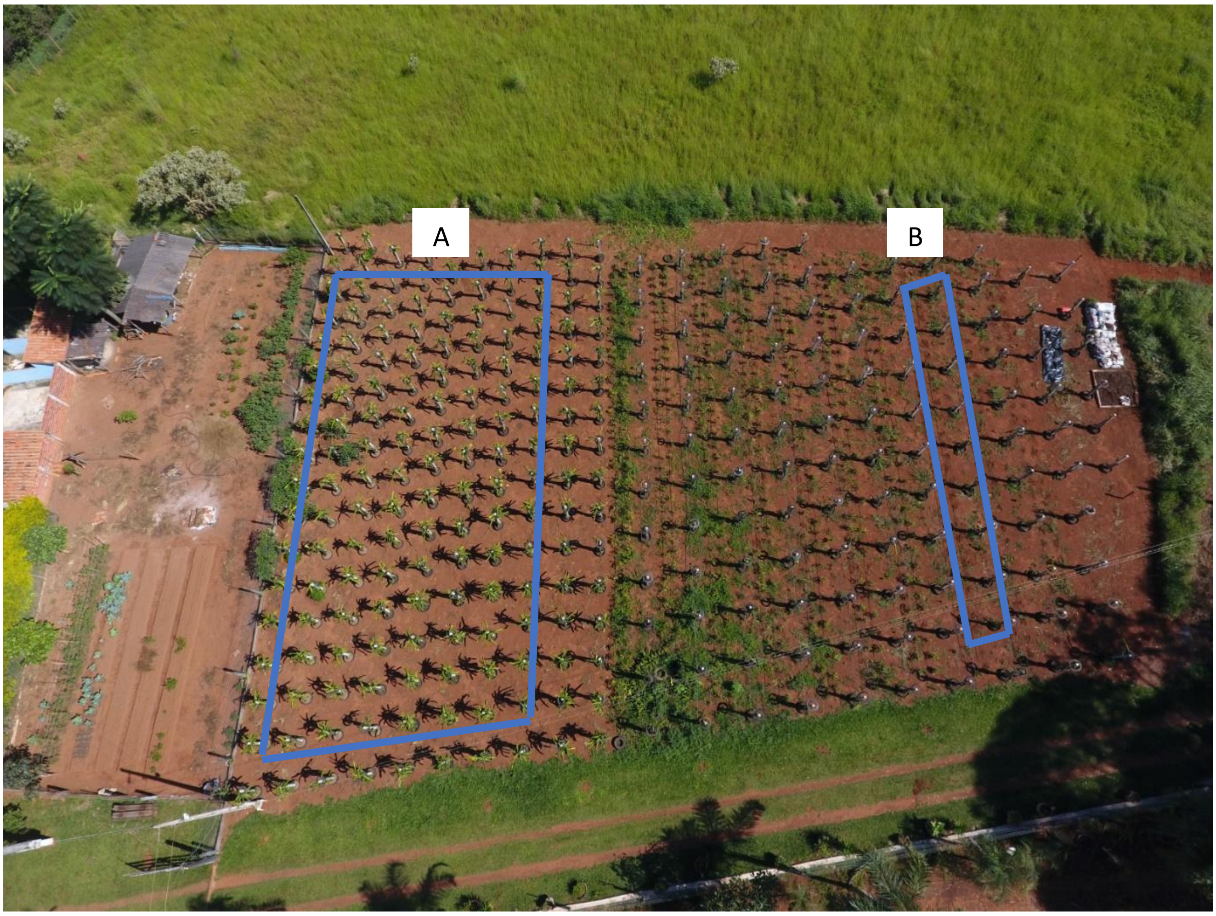
Crop management consisted of manual weeding between rows and between plants, spraying with sunscreen (ProtectE700®), at the beginning of flowering (September 2023) and in the vegetative phase, after pruning, (May 2024), sprinkler irrigation was carried out every three days, with a customized system of emitters with a flow rate of 750 liters per hour at a height of 2.00 meters.

Two prunings were also carried out, the first being the formation of a crown, where the lateral shoots of the plant were removed and maintaining a single main shoot, which when it reached the height of the crown support, was pruned to emit lateral shoots, forming an umbrella-shaped crown. The second pruning took place after harvest, aiming to remove injured cladodes, avoiding diseases and over-densification of cladodes per canopy.

In the production area, the border plants were discarded (figure 4) and plots with five tutors were defined in a draw for GA3-based treatments.

Figure 4

Layout of the experimental area in the pitaya orchard, with the planting rows used for the experiment. A – Application of the different concentrations of GA_3 and B application of 100 mg $^{L-1}$ of Paclobutrazole.



The experimental design was randomized blocks, with six treatments, five doses of GA3 (0, 75, 150, 300 and 600 mg $^{L-1}$), one treatment with the application of 100 mg $^{L-1}$ of paclobutrazole, four blocks and five plants in each experimental unit. The application of the growth regulators took place between 4 and 6 pm, on September 7, 2023, completely spraying the cladodes of the plant canopy, up to the point of drainage of the solution.

During the entire fruiting period of the plants, the number of cladodes, flower buds, flowers, and fruits per plant was evaluated between September 2023 and May 2024. The data obtained were submitted to ANOVA and the means were analyzed with linear regression.

3 RESULTS

The results show the sensitivity of pitaya to the application of growth regulators. The application of GA_3, regardless of the dose, anticipated flowering in relation to other plants in the orchard that did not receive treatment with gibberellin and from neighboring producers, while paclobutrazol completely inhibited fruiting throughout the season.

The application of growth regulators promoted changes in the reproductive dynamics of pitaya throughout the production cycle, between September 2023 and May 2024 (Figures 5, 6 and 7). The number of flower, flower, and fruit buds varied between gibberellic acid doses (Tables 1, 2, and 3) and was continuous during the period from September 2023 to May 2024, with four peaks in the intensity of reproductive structures, with the highest occurring on 12/15/2024, 01/03/2024, and 01/29/2024 for flower buds, flowers and fruits, respectively (Figures 5, 6 and 7). The application of 100 mg L^{-1} of paclobutrazol completely suppressed flowering, evidencing its potential as a fruiting inhibitor. The number of cladodes did not change during the evaluation period, with an average of 20.74±2.08 in each plant. Although variations were observed between GA_3 doses, it was not possible to adjust a linear model that explained the trend of reproductive response to gibberellin applications.

The peak of the absolute value of flower buds (26.8) was observed on December 15, 2023, with the application of 300 mg $^{L-1}$ of GA3, and then there was a continuous downward trend until the end of flowering, on May 5, 2024, with slight peaks in reproductive structures (Figure 5). Subsequently, the maximum point of flowers per plant (26.4) occurred on January 3, 2024, and the highest number of fruits per plant (25.95) occurred on January 29, 2024, both also associated with the application of 300 mg L^{-1} of GA_3 (Figures 6 and 7). The application of GA3 did not provide a significant increase in the number of fruits compared to the control.

The results showed synchronized intervals between the emergence of reproductive structures, being 19 days after the peak of flower bud emission to occur the peak number of flowers, and 26 days after the peak of flowering to occur the peak of fruiting.

Figure 5

Number of flower buds in the pitaya production cycle under GA 3 doses

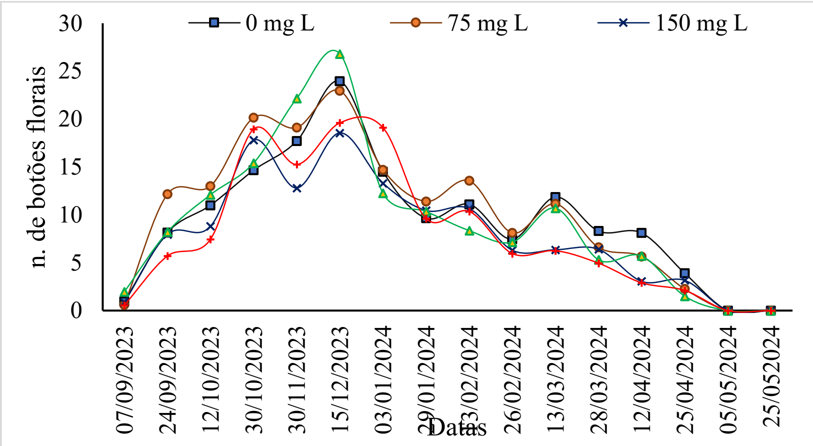


Figure 6

Number of flowers in the pitaya production cycle under GA doses$_3$

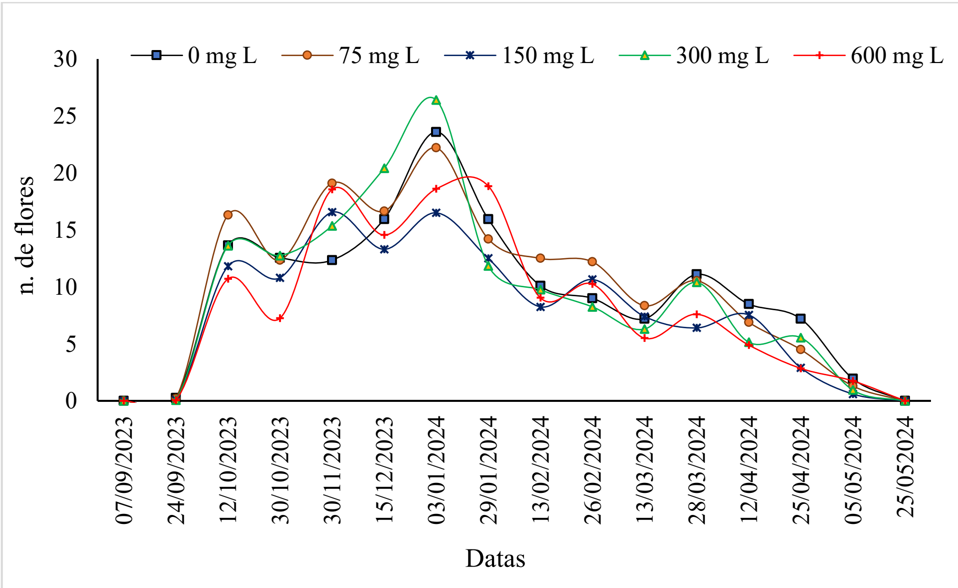
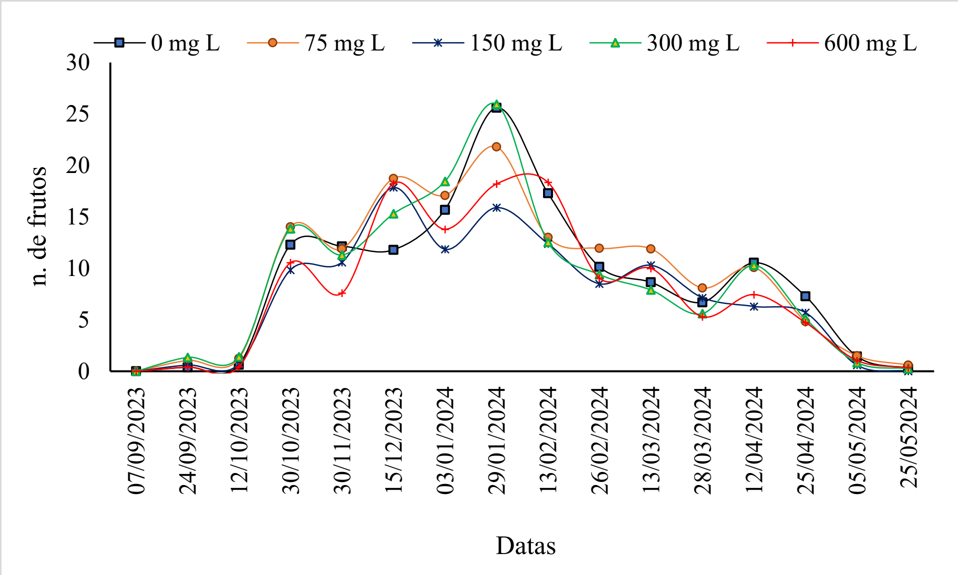


Figure 7

Number of fruits in the pitaya production cycle under GA 3 doses



The conversion between buds flowers into fruits, as well as from flowers to fruits, showed a slight increase with the doses of GA3 applied, reaching efficiency above 90% (Figure 8). In all doses of GA3 applied there were no morphological changes in vegetative and reproductive structures. About 140 fruits were obtained from each plant in the productive cycle (Figure 9), with an average of 250 g each fruit.

Figure 8

Conversion of flower buds to fruits and of flowers to fruits to pitaya under doses of GA_3

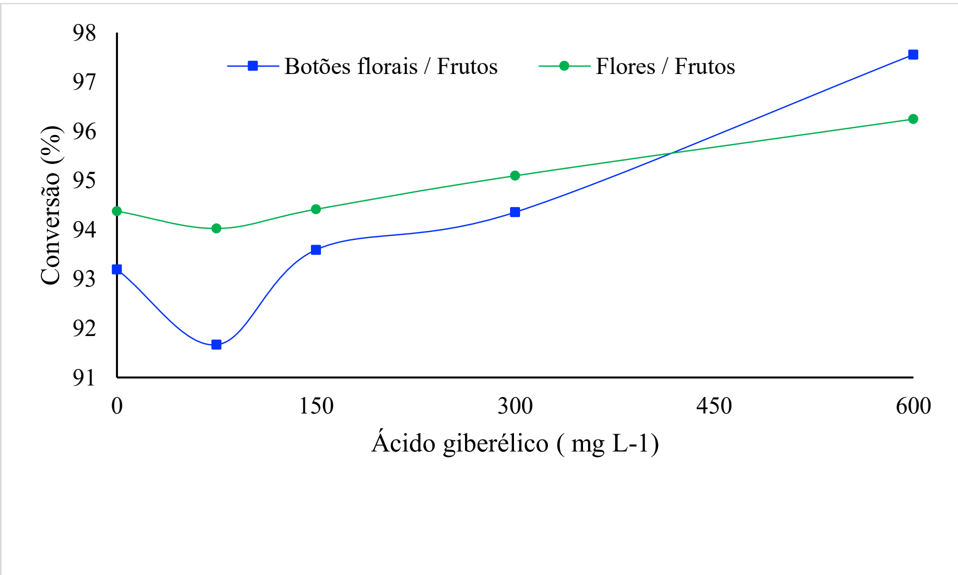


Figure 9

Total number of fruits in pitaya under $GA_{3\ doses}$ throughout the production cycle

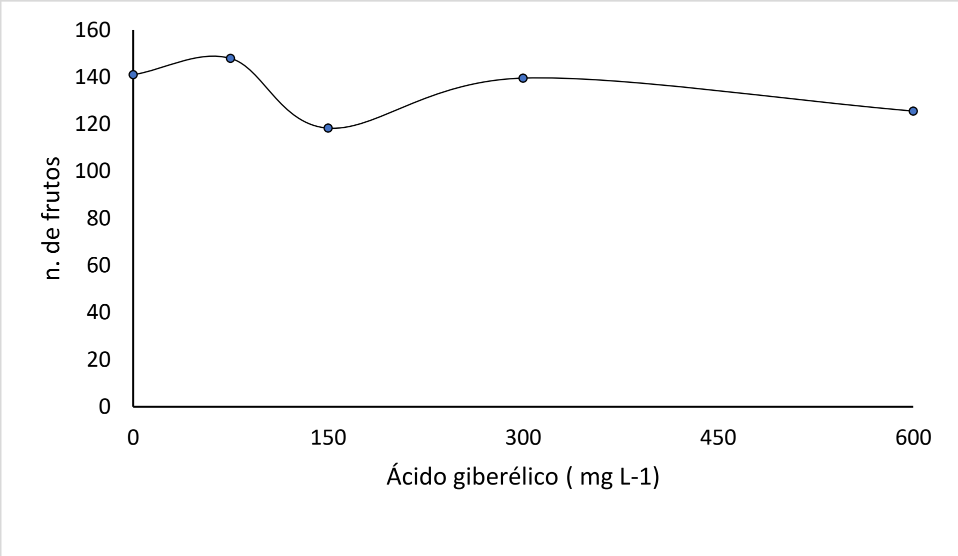


Table 1

Number of flower buds per plant under dose and days after application of growth regulators in pitaya

Data	GA3 concentrations (mg $^{L-1}$)					Paclobutrazole
	0	75	150	300	600	
07/09/2023*	0,95±0,42	0,6±0,25	0,85±0,45	1,95±0,62	0,55±0,23	- **
24/09/2023	8,15±1,32	12,15±2,34	7,95±1,57	8,2±1,55	5,7±1,33	-
12/10/2023	11±1,30	13±1,95	8,8±1,27	12,1±1,34	7,45±1,13	-
30/10/2023	14,65±1,05	20,15±3,51	17,8±2,27	15,4±1,23	18,95±2,55	-
30/11/2023	11,7±1,56	19,1±1,74	12,8±0,95	22,15±2,7	15,25±1,54	-
15/12/2023	23,95±3,40	22,95±2,09	18,55±1,72	26,8±3,07	19,6±1,89	-
03/01/2024	14,5±2,16	14,7±1,16	13,3±1,67	12,25±1,04	19,1±1,24	-
29/01/2024	9,65±1,21	11,4±0,89	10,45±1,35	10,35±0,58	9,6±0,94	-
13/02/2024	11,1±0,91	13,55±1,36	10,65±1,36	8,35±0,75	10,35±1,78	-
26/02/2024	7,45±1,06	8,1±1,33	6,3±0,58	7,15±0,84	5,95±0,95	-
13/03/2024	11,85±1,10	11,15±1,38	6,35±0,71	10,7±1,59	6,25±0,84	-
28/03/2024	8,3±1,47	6,6±1,23	6,4±1,47	5,3±1,34	4,95±1,01	-
12/04/2024	8,1±0,96	5,65±1,19	3,05±0,56	5,7±1,10	2,9±0,55	-
25/04/2024	3,9±0,73	2,25±0,37	3,15±0,52	1,5±0,33	2,1±0,35	-
05/05/2024	0,0±0,00	0,0±0,00	0,0±0,00	0,0±0,00	0,0±0,00	-
25/05/2024	0,0±0,00	0,0±0,00	0,0±0,00	0,0±0,00	0,0±0,00	-

*Growth regulators application day. Averages ± standard error. ** There was no flowering.

Table 2

Number of flowers per plant under dose and days after application of growth regulators in pitaya

Data	GA3 concentrations (mg $^{L-1}$)					Paclobutrazole
	0	75	150	300	600	
07/09/2023*	0,0±0,0	0,0±0,0	0,0±0,0	0,0±0,0	0,0±0,0	- **
24/09/2023	0,25±0,12	0,2±0,09	0,1±0,07	0,05±0,048	0,05±0,048	-
12/10/2023	13,65±1,53	16,3±2,21	11,8±1,52	13,6±1,73	10,7±1,37	-

30/10/2023	12,55±1,53	12,35±1,74	10,8±1,33	12,75±1,41	7,25±1,13	-
30/11/2023	12,35±1,25	19,1±3,05	16,55±2,22	15,35±1,22	18,55±2,47	-
15/12/2023	15,95±1,87	16,65±1,64	13,3±0,92	20,4±2,58	14,55±1,58	-
03/01/2024	**23,6±3,32**	**22,2±1,90**	**16,5±2,0**	**26,4±3,04**	18,06±1,67	-
29/01/2024	15,95±1,94	14,2±1,21	12,5±1,68	11,85±0,96	18,85±1,22	-
13/02/2024	10,1±1,39	12,5±1,17	8,25±1,30	9,75±0,64	9,05±0,88	-
26/02/2024	9,0±0,88	12,2±1,45	10,65±1,26	8,25±0,75	10,25±1,74	-
13/03/2024	7,2±0,97	8,35±1,2	7,4±0,76	6,3±0,81	5,5±0,90	-
28/03/2024	11,1±1,01	10,55±1,15	6,4±0,94	10,4±1,66	7,6±1,38	-
12/04/2024	8,5±1,42	6,9±1,12	7,55±1,19	5,15±1,36	4,9±1,02	-
25/04/2024	7,2±1,02	4,5±0,80	2,9±0,52	5,55±1,1	2,85±0,55	-
05/05/2024	1,95±0,44	1,3±0,49	0,6±0,21	0,95±0,22	1,75±0,49	-
25/05/2024	0,0±0,0	0,0±0,0	0,0±0,0	0,0±0,0	0,0±0,0	-

*Growth regulators application day. Averages ± standard error. ** There was no flowering.

Table 3

Number of fruits per plant under dose and days after application of growth regulators in pitaya

Data	GA3 concentrations (mg $^{L-1}$)					Paclobutrazole
	0	75	150	300	600	
07/09/2023*	0,0 ± 0,0	0,0±0,0	0,0±0,0	0,0±0,0	0,0±0,0	- **
24/09/2023	0,4±0,24	1,05±0,47	0,6±0,49	1,35±0,53	0,4±0,20	-
12/10/2023	0,65±0,27	1,25±0,47	0,7±0,48	1,4±0,53	0,45±0,22	-
30/10/2023	12,3±1,88	14,05±2,30	9,85±1,72	13,85±1.77	10,55±1,34	-
30/11/2023	12,15±1,46	11,9±1,61	10,6±1,22	11,3±1,45	7,6±1,13	-
15/12/2023	11,8±1,31	18,75±2,98	17,85±2,04	15,3±1,21	**18,25±2,47**	-
03/01/2024	15,7±1,79	17,1±1,58	11,85±1,35	18,45±2,58	13,8±1,52	-
29/01/2024	**25,6±2,66**	**21,8±1,86**	**15,9±1,87**	**25,95±3,06**	18,2±1,68	-
13/02/2024	17,3±1,78	13,0±0,84	12,4±1,48	12,55±1,25	18,35±1,24	-
26/02/2024	10,15±1,40	11,95±0,86	8,5±1,07	9,4±0,60	9,05±0,87	-
13/03/2024	8,65±0,74	11,9±1,49	10,3±1,30	7,9±0,72	10±1,76	-
28/03/2024	6,7±0,87	8,1±1,17	7,15±0,79	5,6±0,66	5,3±0,88	-
12/04/2024	10,55±1,00	10,1±1,14	6,3±0,92	10,3±1,67	7,45±1,38	-
25/04/2024	7,3±1,54	4,85±1,03	5,7±1,31	5,1±1,34	4,75±0,99	-
05/05/2024	1,45±0,22	1,5±0,34	0,6±0,19	0,85±0,24	1,05±0,28	-
25/05/2024	0,25±0,14	0,6±0,25	0,0±0,0	0,25±0,12	0,35±0,18	-

*Growth regulators application day. Averages ± standard error. ** There was no flowering.

4 DISCUSSION

The results show the sensitivity of pitaya to the application of growth regulators. The doses of gibberellin, in the applied form, did not cause anomalies in the plants and also did not provide superior results to the control. The application of paclobutrazol compromised fruiting throughout the season. The flowering of pitayas in the experimental area with the application of GA_3, regardless of the doses, occurred about 45 days before flowering in other points of the orchard and commercial crops close to the experiment. This anticipation made it possible to sell the fruits at the end of the off-season, a period in which the market price of pitaya is higher, representing a relevant competitive advantage for the producer.

Flowering in many plant species is triggered by seasonal signals, such as photoperiod and temperature, which alter molecular, genetic, physiological and anatomical mechanisms. Alteration of hormonal balance in response to these environmental variations can induce or inhibit physiological responses, such as floral induction. In long-day conditions it increases gibberellin synthesis (García-Martinez and Gil, 2002).

The pitaya is considered a long-day plant and therefore relies on high endogenous levels of gibberellins for flowering. Under conditions of short days and with lower temperatures, as observed between April and October, under the conditions of this experiment, endogenous GA levels tend to decrease, and the plant does not flower, concentrating fruiting in the conditions of the experiment in the period with the highest photoperiod. Cold is another factor that may see a decrease in bioactive GA (Achard et al., 2008).

On the other hand, the application of growth regulators, such as active gibberellins, such as GA3, makes it possible to induce a physiological response, even under non-inductive environmental conditions, while the application of paclobutrazol blocks the synthesis of gibberelein and inhibits physiological responses. However, the efficiency of this response depends on factors such as the sensitivity of the tissues, the ability to recognize the molecule applied, and the cellular competence to trigger changes in the molecular, genetic, physiological, and/or anatomical mechanisms necessary for the transition from the vegetative to the reproductive stage.

Under the conditions of the study, pitaya demonstrated sensitivity to GA_3 and paclobutrazole molecules, however, further studies are needed to validate doses and timing of GA_3 application to optimize pitaya fruiting in the off-season.

The application of gibberellins, before or simultaneously with photoinduction, proved to be an efficient strategy to increase the production of flowers in hops, regardless of the photoperiod (Bauerle (2022). In *Amorphophallus muelleri* Blume (Araceae) the efficiency of the application of GA_3 is related to the age of the bulb, and the increase in doses significantly increased the flowering rate, however, excessive doses of GA_3 caused anomalies in the vegetative and reproductive organs of the plant (Santosa et al., 2019). These results reinforce the importance of careful management of plant regulators, considering factors intrinsic to the species and the phenological stage of the plant, to optimize floral induction without compromising the integrity of plant structures.

To induce pitaya flowering in the off-season, studies have demonstrated the feasibility of strategies such as supplemental artificial lighting, including the use of LED lamps, and the application of plant growth regulators (Shah et al., 2025; Xiong et al., 2020). However, the answers obtained vary widely between experiments, being attributed to the specific edaphoclimatic conditions of each cultivation environment, as well as to intrinsic factors of plant tissues, such as cell sensitivity and phenological stage of plants.

The efficiency of the application of growth regulators depends on the meteorological conditions of the cultivation site, as in addition to influencing tissue sensitivity, it also alters endogenous hormone levels (Castroverde and Dina, 2021; Zhang et al., 2020). Thus, in each growing condition the plant has a specific balance, which implies the specific need for the dose and time of application to maximize the effects on flowering and fruiting.

In this sense, it is noteworthy that in the reproductive cycle of pitaya there was no change in the number of shoots. The hormonal balance favorable to reproduction inhibits vegetative development. Although most studies focus on the effect of the photoperiod on the last steps of the GA biosynthesis pathway, there is also evidence that the previous steps are affected by the photoperiod, through effects triggered by phytochromes, cryptochromes and other photoreceptor molecules (García-Martinez and Gil, 2002).

The production of pitaya fruits varies between genotypes and cultivation conditions. Tran et al (2015) reached a maximum of six fruits per plant and the conversion of flowers into fruits varied widely between genotypes and management with light complementation, while Nguyen et al., (2021) found that the number of fruits per plant varied between seasons, cultivation conditions, and lighting with incandescent lamps, with a power of 60W, and made it possible to reach up to 39.5 fruits per plant at the peak of production. Takata et al., (2016) found that the number of fruits per plant varied between doses of GA_3 and between the seasons of the year of application, reaching a maximum of 25 fruits per plant with application of GA3.

The period of flower bud emission varies between cultivars and growing conditions. Costa et al., (2014) found that the period from the emergence of the flower bud to the opening of the flower elapsed about 21 days, and from anthesis to fruit harvest, about 35 days in pitaya cultivated in Lavras-MG, while under the conditions of the present experiment the average was 45 days.

In the cultivation conditions, the period between September and March has a photoperiod above 12 hours, as well as higher temperatures and precipitation. Considering that the critical photoperiod is 12 h (Jiang et al., 2012), or 13h according to Kishore (2016), induction only occurs between these periods, and may be restricted to December and January. Under the conditions of the study, it is evident that the critical photoperiod of the pitaya is around 12 hours.

5 CONCLUSION

The pitaya studied showed sensitivity to the application of growth regulators at the end of the off-season.

The doses of GA3 applied did not cause anomalies in the reproductive structures.

The fruiting of pitaya showed dependence on the action of gibberellins, and the application of paclobutrazol compromised fruiting during the harvest period.

The highest number of flower buds and flowers per plant occurred around the summer solstice.

The study points to a promising strategy with the need for adjustments in dose, timing and conditions for the application of GA3 to optimize fruiting in pitaya under non-inductive conditions.

ACKNOWLEDGMENTS

To the Federal Institute of Goiás – Ceres Campus and the Foundation for Research Support of the State of Goiás (FAPEG) for supporting the experiment and to the Retiro das Caldas Farm for making the plants available to carry out the study.

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