An Acad Bras Cienc (2022) 94(Suppl. 3): e20211200 DOI 10.1590/0001-3765202220211200
Anais da Academia Brasileira de Ciências | *Annals of the Brazilian Academy of Sciences*
Printed ISSN 0001-3765 I Online ISSN 1678-2690
www.scielo.br/aabc | www.fb.com/aabcjournal

ENGINEERING SCIENCES

Natural and artificial pollination of white-fleshed pitaya

RENATA A. MOREIRA, MARIANE A. RODRIGUES, RAFAELA C. DE SOUZA, ALEXANDRE D. DA SILVA, FÁBIO O.R. SILVA, CAROLINA G. LIMA, LEILA A.S. PIO & MOACIR PASQUAL

Abstract: To produce pitaya (*Hylocereus* spp.), it is essential that pollination occur, either artificially or by pollinating agents. This study evaluated the viability of self-pollination, cross-pollination, and natural pollination, as well as pollen viability, stigma receptivity and ideal pollination window in pitaya flowers (*Hylocereus* spp.). An experiment was conducted with a randomized block design consisting of four treatments: T1: manual self-pollination; T2: nocturnal open pollination; T3: diurnal open pollination; and T4: manual cross-pollination - red-fleshed pitaya [*Hylocereus polyrhizus*] pollen placed on white-fleshed pitaya [*Hylocereus undatus*] stigma. The experiment had four replicates, with two plants per replicate (two flowers per plant), totaling 16 flowers per treatment. The analyzed variables were fruit weight, length, diameter, titratable acidity, pH, soluble solids, and SS/TA ratio; the germination percentage of pollen grains; and the receptivity of stigmas. Artificial pollination (self- and cross-pollination) of white-fleshed pitaya (*Hylocereus undatus*) is viable, resulting in larger fruits than natural pollination, with cross-pollination being the most recommended. Throughout the floral opening period, the pitaya flower (*Hylocereus* spp.) has receptive stigma capable of receiving pollen. The flowers exhibit the highest pollen germination rate at 7 p.m, which is the ideal pollination window for pitaya.

Key words: Dragon fruit, pollen grains, *Hylocereus polyrhizus, Hylocereus undatus*, stigma receptivity.

INTRODUCTION

Pitaya (*Hylocereus* spp.) is a cactus originating from tropical and subtropical America that belongs to the group of tropical fruits considered promising for commercial cultivation (Dios et al. 2014). Due to its yield earliness, hardiness, novelty, and high economic return, pitaya cultivation has aroused the interest of global producers (Ibrahim et al. 2018), with Vietnam as the largest producer, followed by China (IBGE 2017). Pitaya fruit has also gained prominence in the exotic fruit market due to its organoleptic characteristics, especially due to its pleasant and sweet taste, which attracts even more people to its consumption. It has high nutritional and antioxidant potential, due to the significant amount of phenolic compounds, betalains, vitamins B, C and E, as well as minerals such as iron, copper and zinc, making it an ally of the prevention of diseases such as respiratory, circulatory and cardiovascular disease, ulcers, diabetes, Alzheimer's. Recently its anticancer effect is being investigated, showing already promising results (Pio et al. 2020). It can be consumed in either a natural or processed form into a range of industrialized products such as ice cream, jams, juices, syrups, and sweets (Nurul & Asmah 2014).

For pitaya fruit to form, it is essential that the flower be pollinated, either artificially or by pollinating agents (Menezes et al. 2017). Pollination involves the transfer of pollen grains from the anthers of a flower to the stigma of the same flower (self-pollination) or of another flower of the same species or different species (cross-pollination) (Dar et al. 2017). The pitaya can show allogamous, autogamous or mixed pollination depending on the variety (Pio et al. 2020). Pollination is influenced by biotic agents, such as insects or pollinating animals, or abiotic agents, such as wind and water (De Brito & De Souza 2020). Flowers that are not pollinated do not produce fruits and are aborted, resulting in low productivity. A lack of pollination may be linked to several factors, such as the distance between the stigma and anther or heavy rainfall, which can wash away pollen and drive away pollinators (Aragão et al. 2019), thus inhibiting the success of natural pollination.

Artificial manual pollination with different genotypes and species could help increase fruit set and fruit weight and quality (Tran et al. 2015). Artificial pollination may have different results depending on the pollen donor cultivar. The origin of the variety derived from the pollen can influence the time between pollination and fruit harvest. Manual pollination in *Hylocereus* is considered simple and is facilitated by the floral characteristics. This process should be performed at night, as the flowers open (Muniz et al. 2020). The floral opening begins at approximately 7 p.m. and remains until the early hours of the following morning, with a total opening time of approximately 15 hours (Menezes et al. 2017). Although pitaya flowers begin opening at night, more flower visitors come during the day (Muniz et al. 2019), thus decreasing the success of natural pollination since it gives pollinators a very short time to act. This study provided important information for crop management, establishing a better pollination schedule, resulting in better and larger fruits.

This study evaluated the feasibility of self-pollination, cross-pollination, and natural pollination, as well as pollen viability, stigma receptivity and the ideal pollination window in pitaya flowers (*Hylocereus* spp.).

MATERIALS AND METHODS

Experimental site and plant material

The experiments were set up at the Fruticulture Sector of the Department of Agriculture of Federal University of Lavras (Universidade Federal de Lavras – UFLA), Minas Gerais state, Brazil. UFLA is located at 21°14'S, 45°00'W, at 841 m of altitude, and annual average temperature of 22°C. The climate of the region is classified as Cwa (subtropical, with cold, dry winters and hot, humid summers) (Souza et al. 2017).

We have gathered data from meteorological station number 83687 of the Instituto Nacional de Meteorologia (INMET). Cumulative rainfall was calculated from the sum of all registered precipitation either during the season of each pollination treatment or during the month. For temperature and relative humidity, mean and standard deviation were also calculated either during the season of each pollination or during the month.

A total of 64 flowers (opening that night) from 32 six-year-old red-fleshed pitaya plants (*Hylocereus undatus*) were used in the study. The plants were spaced 2.0 × 2.5 m apart, supported on individual 1.80-m-tall eucalyptus stakes. Flowers were selected in the afternoon when white petals were observed between the sepals, indicating opening that night. To avoid natural pollination, the flowers were covered with a 400-ml plastic cup before anthesis (Figure 1).

Figure 1. Flower with signs of opening and flower covered with plastic cup.

An experiment was conducted with a randomized block design composed of four treatments: T1: manual self-pollination (pollen placed on the stigma of the same flower); T2: nocturnal open pollination (flowers not covered with a plastic cup during the night); T3: diurnal open pollination (flowers not covered with a plastic cup during the day); and T4: manual cross-pollination (red-fleshed pitaya [*Hylocereus polyrhizus*] pollen placed on white-fleshed pitaya [*Hylocereus undatus*] stigma). The experiment had four replicates, with two plants per replicate (two flowers per plant), totaling 16 flowers per treatment. The treatments were applied and evaluated in two crop years (2019 and 2020).

At 8 pm, the plastic cups were removed, at which time cross-pollination (T4: pollen from red-fleshed pitaya flowers (*H. polyrhizus*) on the stigma of white-fleshed pitaya flowers (*H. undatus*)) and self-pollination (T1: pollen collected from white-fleshed pitaya (*H. undatus*) and placed on the stigma of the same flower) were performed. The flowers were then emasculated and covered with the plastic cup again. For the T2 treatment (nocturnal open pollination), the cups were removed at 8 p.m. and returned at 5:30 a.m. the next morning. For treatment T3 (diurnal open pollination), the cups were removed at 5:30 am. After 2 days, the flowers had wilted, and all remaining cups covering flowers were removed.

The fruits were harvested at physiological maturity (change in peel color from green to red) (Rangel Junior et al. 2021), approximately 40 days after pollination, and analyzed in the postharvest laboratory of the Fruticulture Sector, Department of Agriculture, UFLA, Minas Gerais.

Physical and chemical evaluations

The 16 fruits from each treatment were collected (four replicates, two plants per plot and two fruits per plant). The fruits were harvested and immediately carried to the laboratory for analysis. To analyze the fruits, a completely randomized design was used, with five replicates, considering three fruits per replicate. The variables analyzed were fruit weight, length, diameter, titratable acidity (TA), pH, soluble solids (SS), and SS/TA ratio. Fruits were weighed on a digital scale, and the results are expressed in g. Fruit length and diameter were measured with a digital caliper and are expressed in mm. For TA (%), 1 g of fruit pulp was weighed on an analytical scale and transferred to an Erlenmeyer flask, to which 20 ml of distilled water was added. Three drops of 0.1% phenolphthalein were added to this solution, followed by titration under stirring with

0.1 N NaOH solution. The results are expressed in g of malic acid per 100 g of pulp (AOAC 2007). The pH was measured with a bench pH meter (model MPa-210A) after mixing 1 g of pulp with 20 ml of water. SS was determined with a Vtest DBR45 digital refractometer, and the results are expressed as percentages (%). The SS/TA ratio was the ratio between SS and TA.

Pollen viability

The pollen viability of the species used in the above experiment (*S. undatus* and *S. polyrizhus*) was determined *in vitro* at the time of flower opening (7 p.m.) and on the following morning at 7 a.m., when the flowers began to close. Before collection, in the afternoon, we selected 16 flowers of each species that could open that night. Half of the flowers were covered with cups to verify the use of this protection method. The collection of pollen grains was done with a brush and they were stored in a flask until transport to the laboratory. The collected pollen was placed in medium containing 6 g/L of agar, 100 g/L of sucrose, 518 mg/L of calcium nitrate, and 636 mg/L of boric acid, with the pH adjusted to 5, and cultured at 25 °C (Fagundes et al. 2021). Germination percentage was recorded under a binocular microscope (4×) 30 minutes after plating and 12 hours later by counting the germinated pollen grains. Pollen grains were considered germinated when the pollen tube measured at least twice the diameter of the pollen grain (Figueiredo et al. 2013).

Stigma receptivity

The receptivity of the stigma in both species was evaluated using a 3% hydrogen peroxide solution with subsequent visualization according to the method of Dafni (1992) and Mandujano (2013). Floral receptivity was evaluated as the ratio between the number of viable stigmas and the number of evaluated stigmas. The hydrogen peroxide solution was used on a group of 15 flowers at the time of pollen collection.

Statistical analysis

The data obtained in the physical and chemical analyses of the fruits and in the pollen viability and stigma receptivity experiments were tested for normality using Shapiro-Wilk. Were subjected to analysis of variance, and the means were compared by Tukey's test in Sisvar software (Ferreira 2011).

RESULTS

Physical and chemical evaluations

Table I shows the results of the first pollinations performed on 02/13/2019, with fruits collected 37 days after pollination. The application of the manual pollination technique (cross-pollination and self-pollination), higher fruit weight, length, and diameter were obtained than under the other treatments. Flowers spontaneously pollinated by insects (nocturnal and diurnal open pollination) had fruits with lower acidity values and consequently higher pH values than fruits subjected to manual pollination (cross-pollination and self-pollination). SS was influenced by the type of pollination. The highest SS/TA ratio was found in fruits from flowers pollinated by insects.

The flower abortion percentage in nocturnal open pollination (60%) was higher than under diurnal open pollination (40%), while in self- and cross-pollination there was no abortion.

The second pollination was performed on the following day (02/14/19). Analyzing the fruits harvested 37 days after pollination, it was observed that the treatments in which manual pollination was performed (cross-pollination and self-pollination) also showed better results than the treatments in which manual pollination was not performed (nocturnal and diurnal open

Table I. Fruit weight (W), length (L), diameter (D), pH, titratable acidity (TA), soluble solids (SS), and SS/TA ratio. Pollinations performed on 02/13/19. Treatments: cross-pollination (CP), self-pollination (SP), diurnal open pollination (OD), and nocturnal open pollination (ON).

Treatments	W (g)	L (mm)	D (mm)	pH	TA (%)	SS (°Brix)	SS/TA
CP	636.28 a	116.2 a	96.58 a	3.1 c	0.78 a	14.5 a	19.2 b
SP	577.31 a	115.3 a	92.24 a	3.2 b	0.70 a	12.7 b	18.2 b
OD	211.90 b	75.40 b	69.22 b	3.3 b	0.38 b	13.6 ab	35.4 a
ON	212.80 b	76.62 b	61.99 b	3.7 a	0.38 b	13.4 ab	34.9 a
CV (%)	9.34	8.87	5.51	2.34	15.25	6.20	10.17

Means followed by the same letter in a column do not differ by Tukey's test at 5% probability.

pollination) (Table II). The four groups had no significant difference in pH or TA, but there was a difference in SS, with the nocturnal open pollination treatment having the lowest value. The SS/TA ratio was also higher in daytime open pollination. There was no flower abortion in any of the treatments except for nocturnal open pollination (40%).

In the second year of the experiment, pollinations were performed on 12/06/2019 and 03/04/2020. The fruits were harvested 39 days and 41 days after anthesis (when the peel color changed to red), respectively. The results were similar to those of the first year regarding fruit weight, length, and diameter, manual pollination (cross-pollinatio n and self-pollination) showing the best results (Table III). The highest TA percentage was found in cross-pollinated fruits. Higher °Brix values were found in fruits from manual pollination (cross-pollination and self-pollination). However, the highest SS/TA ratio was found in nocturnal open pollination. The flower abortion percentage in nocturnal open pollination was 31%, followed by diurnal open pollination (25%), while in self- and cross-pollination there was no abortion.

In the last pollination, performed on 03/04/2020, only cross-pollination had better performance in fruit weight, length, diameter, SS, and SS/TA ratio. The pollination type had no effect on TA (Table IV). In cross-pollination there was no abortion, while in nocturnal open pollination (60%) was higher than under diurnal open pollination (40%), followed by self-pollination (13%).

Marques et al. (2012) observed that the cross-pollination in red dragon fruit (*Hylocereus* spp.) is performed by *Apis mellifera* bees in a study conducted in the municipality of Lavras, Minas Gerais, Brazil. Even with insects pollinating pitaya, manual pollination is necessary, especially cross-pollination, which not only increases the percentage fruit set but also results in larger fruits, a higher percentage of commercial fruits, and higher yield, as well as economic benefits. Although manual pollination resulted in more fruits, there was no need for thinning, since these treatments resulted in fruits of excellent quality and size. So, our results are quite relevant.

Stigma receptivity

All stigmas were receptive during pollen collection, i.e., throughout floral opening, the pitaya flower had receptive stigma that could receive pollen (Figure 2).

Table II. **Fruit weight (W), length (L), diameter (D), pH, titratable acidity (TA), soluble solids (SS), and SS/TA ratio. Pollinations performed on 02/14/19. Treatments: cross-pollination (CP), self-pollination (SP), diurnal open pollination (OD), and nocturnal open pollination (ON).**

Treatments	W (g)	L (mm)	D (mm)	pH	TA (%)	SS (°Brix)	SS/TA
CP	668.1 a	123.8 a	95.1 a	3.0 a	0.99 a	13.4 a	11.0 b
SP	500.2 b	108.0 b	85.9 a	3.0 a	0.95 a	13.5 a	11.5 b
OD	232.5 c	73.1 b	81.1 ab	3.0 a	0.94 a	14.0 a	17.7 a
ON	192.2 c	72.5 b	61.0 b	2.9 a	1.12 a	11.4 b	10.3 b
CV (%)	12.72	5.64	7.56	2.66	8.21	3.1	9.65

Means followed by the same letter in a column do not differ by Tukey's test at 5% probability.

Table III. **Fruit weight (W), length (L), diameter (D), pH, titratable acidity (TA), soluble solids (SS), and SS/TA ratio. Pollinations performed on 12/06/19. Treatments: cross-pollination (CP), self-pollination (SP), diurnal open pollination (OD), and nocturnal open pollination (ON).**

Treatments	W (g)	L (mm)	D (mm)	pH	TA (%)	SS (°Brix)	SS/TA
CP	531.0 a	114.8 a	93.2 a	0.82 b	0.40 a	15.0 a	37.7 b
SP	473.0 a	112.8 a	91.5 a	1.92 a	0.37 b	15.0 a	40.4 b
OD	231.0 b	82.6 b	72.4 b	1.10 b	0.36 b	13.6 ab	37.8 b
ON	261.0 b	89.5 b	73.9 b	1.83 a	0.22 c	12.9 b	59.4 a
CV (%)	22.05	9.86	9.03	15.7	3.19	5.03	5.25

Means followed by the same letter in a column do not differ by Tukey's test at 5% probability.

Table IV. **Fruit weight (W), length (L), diameter (D), pH, titratable acidity (TA), soluble solids (SS), and SS/TA ratio. Pollinations performed on 03/04/20. Treatments: cross-pollination (CP), self-pollination (SP), diurnal open pollination (OD), and nocturnal open pollination (ON).**

Treatments	W (g)	L (mm)	D (mm)	pH	TA (%)	SS (°Brix)	SS/TA
CP	711.0 a	103.5 a	111.6 a	2.9 a	0.77 a	17.7 a	23.1 a
SP	280.0 b	85.52 b	74.9 b	2.8 a	0.77 a	13.8 b	18.0 b
OD	231.0 b	74.11 b	71.4 b	2.8 a	0.77 a	13.5 b	17.5 b
ON	237.0 b	79.11 b	75.3 b	2.5 b	0.77 a	11.5 c	15.0 c
CV (%)	22.32	10.11	10.58	2.21	3.89	8.54	5.32

Means followed by the same letter in a column do not differ by Tukey's test at 5% probability.

Pollen viability

In *H. polyrhizus*, it was observed that there was no significant difference for the percentage of germination of pollen grains 30 minutes after their inoculation in the culture medium collected at the same times. There was a significant difference only between the pollen collection times, 7 p.m. showing pollen grains with greater germination potential. For the pollen grains collected at 7 a.m., i.e., when the flowers were already wilting, germination was very low, either when using or not using the

Figure 2. Viscous and humectant aspect of the stigma after immersion in hydrogen peroxide. Stigmas that present bubbles are considered receptive. Where a: Stigma of receptive white-fleshed pitaya flower; b: Receptive red pulp pitaya flower stigma.

plastic cups to protect the flowers, without a significant difference (Table V).

When the germination pollen was evaluated 12 hours after inoculation of pollen grains these values were much higher than the values found in the evaluations performed 30 minutes. At 7 pm, when the flowers are opening, the percentage of germination did not show any significant difference, while the collections at 7 a.m. the next day showed a significant difference between not using and using a plastic cup to cover the flower, showing that this object was efficient in protecting the flowers (Table V).

This is also observed in *H. undatus* 30 minutes after inoculation, as there was no significant difference when comparing the treatments using and not using the plastic cups with the same collection and observation times. There was only a significant difference between the pollen grain collection times, with 7 p.m. standing out (Table VI).

Analyzing 12 hours after inoculation of the pollen grains collected at 7 p.m., the germination rates followed the pattern observed for the red-fleshed species (*H. polyrhizus*), with no significant difference between using and not using a plastic cup for protection (Table VI). There were differences between the pollen collection times, the germination rate being much higher for pollen collected at 7 p.m. than at 7 a.m. The use of the plastic cup caused the germination percentage of the pollen grains to be higher at 7 a.m., compared to not using a plastic cup at the same time (Table VI).

There was a gain of approximately 30% in the germination rate when waiting 12 hours between pollen collection and the avaliation germination test in all circumstances. The germination potential of *H. undatus* pollen collected at 7 p.m. and evaluated 12 hours later had the highest germination potential found.

DISCUSSION

Physical and chemical evaluations

There was heavy rainfall in the same pollination period (Figure 3 and 4); however, with the application of the manual pollination technique (cross-pollination and self-pollination), higher fruit weight, length, and diameter were obtained than under the other treatments, showing the importance of this intervention. It seemed that the pitaya plant had a flower protection mechanism on rainy days because during rain events, the flowers did not fully open and

Table V. Germination of *H. polyrhizus* (red-fleshed pitaya) pollen grains of evaluated 30 minutes and 12 hours after inoculation in culture medium. T1 = 7 p.m., without cup cover; T2 = 7 p.m., with cup cover; T3 = 7 a.m., without cup cover; and T4 = 7 a.m., with cup cover.

Treatments	% Germination 30 minutes	% Germination 12 hours
T1	46.3 a	79.3 a
T2	34.4 a	77.7 a
T3	7.5 b	21.2 c
T4	4.2 b	55.2 b

Means followed by the same letter in a column do not differ by Tukey's test at 5% probability.

arched downward, keeping the pollen grains from getting wet (Dickerson et al. 2014, Ravi et al. 2016). The plastic cups that covered the flowers also protected the pollen and the stigma, leading to good results of fruit size. On the other hand, in the fourth pollination, water deficit may have impaired self-pollination. In the region of the experiment, temperatures are usually milder due to the rains that occur during the flowering and fruiting period of the pitaya. The abrupt increase in temperature during this period may have generated stress in the plant that somehow impaired pollen viability, contributing to fruit abortion or reduction in size.

Renfiyeni (2018) investigated with the effect of pollination models on the yield of red-fleshed pitaya (*H. polyrhizus*) and obtained higher fruit weight, diameter, and length with cross-pollination than self-pollination and open pollination. Indriyani (2019), in a study of the effect of the pollination technique on the development of pitaya fruits, observed that both natural pollination (open pollination) and artificial cross-pollination yielded the largest fruits. This was because during the experiment, many insects were observed in the flowers, performing pollination; however, the highest percentage of fruits larger than 400 g was actually obtained by artificial cross-pollination. Krause et al. (2012) evaluated the yield and quality of passion fruit and found that artificial pollination resulted in larger fruits than natural pollination due to the better distribution of pollen grains in the stigmas.

Table VI. Germination of pollen grains of *H. undatus* (white-fleshed pitaya) evaluated 30 minutes and 12 hours after inoculation in culture medium. T1 = 7 p.m., without cup cover; T2 = 7 p.m., with cup cover; T3 = 7 a.m., without cup cover; and T4 = 7 a.m., with cup cover.

Treatments	% Germination 30 minutes	% Germination 12 hours
T1	63.3 a	95.3 a
T2	63.2 a	91.9 a
T3	7.0 b	14.1 c
T4	1.8 b	35.8 b

Means followed by the same letter in a column do not differ by Tukey's test at 5% probability.

As the amount of viable pollen grains deposited on the stigma of the flowers increases, so does the fruit size, number of seeds, and fruit set percentage (Martins et al. 2014). These results further demonstrate the importance of well-performed pollination, whether artificial or natural. In manual pollination, the amount of pollen deposited in the stigma is usually greater than the natural one.

Menezes et al. (2017) found similar fruit TA values with spontaneous pollination, but the pH values found were higher than those observed in this study. The values of SS found are similar to those obtained by Moreira et al. (2011). SS contain vitamins, acids, and other compounds but are more than 90% sugars, so SS is an indirect measure of sugar content (Fachi et al. 2016).

Flower pollination and fertilization favor fruit growth. In the present study, in which the experiment was conducted where there was rain during anthesis, the frequency and intensity of insect pollinator visits to the flowers may have been reduced, because insects do not visit the pitaya flowers during rain, disfavoring diurnal and nocturnal open pollination. However, this is the real-world condition for numerous pitaya producers, since the flowering season often coincides with rainy periods.

Although rain was an impediment, it has been shown that the number of visiting insects in pitaya flowers is much higher during the daytime than at nighttime (Muniz et al. 2019, Aragão et al. 2019) thus decreasing also the success of nocturnal open pollination. When studying the effects of different pollination treatments on fruit development and pitaya

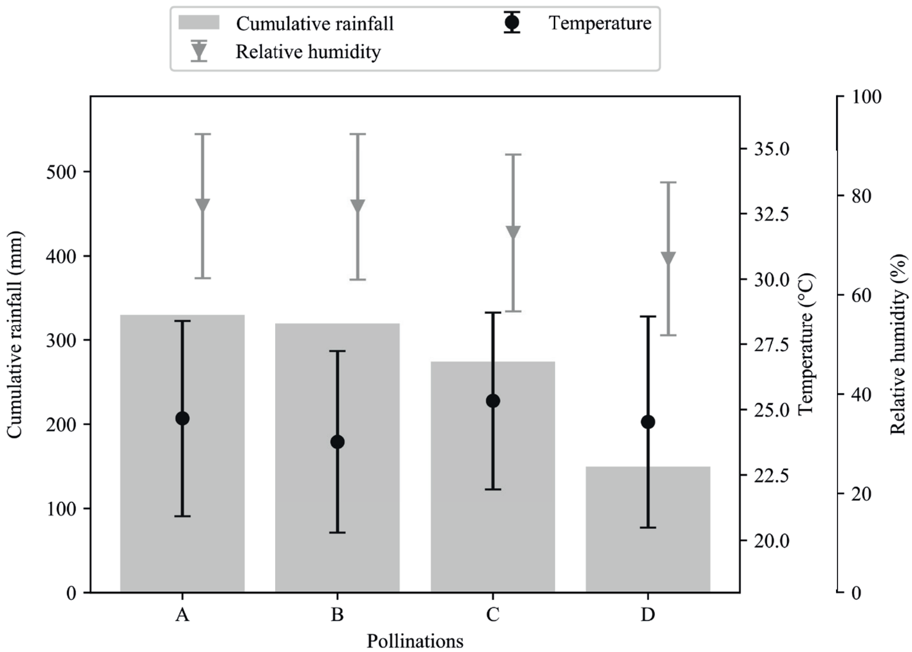

Figure 3. **Cumulative rainfall, mean temperature, and relative humidity during the pollination period until fruit harvest, where A: pollination performed on 02/13/2019; B: pollination performed on 02/14/2019; C: pollination performed on 12/06/2019; D: pollination performed on 03/04/2020.**

production, Liang et al. (2011) observed that the percentage fruit set and mean fruit weight under artificial cross-pollination and artificial self-pollination were significantly higher than those under natural pollination treatments and also observed that the mean percentage flower bud drop of was 61.9% under open pollination. In the study by Silva et al. (2011) evaluating the quality of pitaya fruits as a function of pollination time, pollen source, and cover color, 100% fruit set was observed in plants that were cross-pollinated.

Despite the plastic cups, that cover the flowers, also protect the pollen and the stigma, another way to avoid losing pollen grains when flowers get wet is to store the grains for later use in the next flowering. Pollen can remain viable from several minutes to tens of years varies from species (Shivanna 2019), for pitaya, pollen sealed and stored below 4 °C can still be used for pollination for the next day or even the day after next day in production, but the fruit setting percentage and fruit size were found to drop (Li et al. 2020). Further study need be carrying out on pitaya pollen storage.

Stigma receptivity

Muniz et al. (2019) observed that the stigma of pitaya was receptive in all periods tested, from 8 p.m. to 7 a.m. the next morning and even until 9 a.m. on cloudy days. The same was observed in the present study.

Pollen viability

In vitro germination is a technique that simulates stigma conditions, inducing pollen tube germination, and has a high correlation with field fertilization (Almeida & Severo 2011).

The determination of pollen viability is important for gene flow analyses in plant breeding programs and is also used in ecological, taxonomic, and palynological studies (Frescura et al. 2012). Pollen viability is among the factors that affect the production of fruits and seeds and may compromise successful plant breeding programs that require the formation of viable

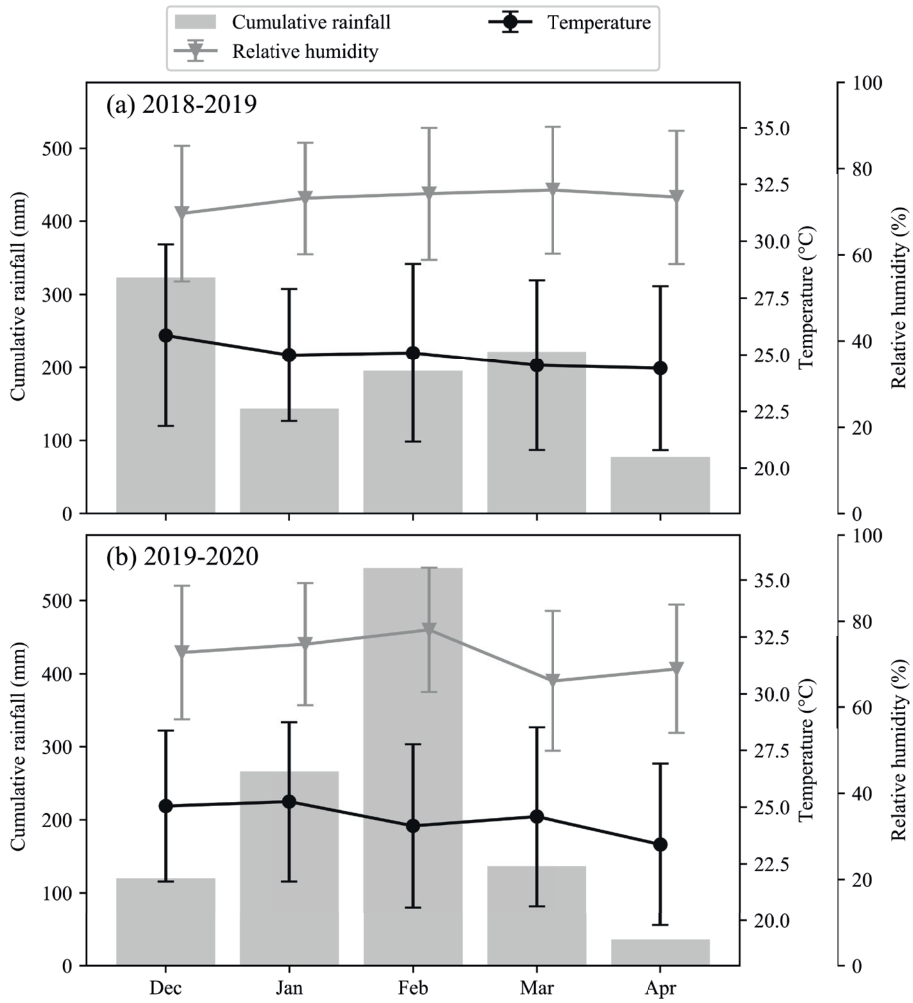

Figure 4. **Cumulative rainfall, mean temperature and relative humidity during the experimental period. (a) 2018-19; (b) 2019-2020.**

and balanced gametes (De Jesus et al. 2018). Pollen viability and stigma receptivity are important factors for the reproductive success of a species (Dos Santos et al. 2020).

CONCLUSIONS

This study provides important information for the pitaya producer to succeed in his enterprise, such as the ideal pollination window of flowers, which is 7 p.m., as pollen is more viable at this one. The higher the amount of pollen deposited on the stigma, the higher the fruit set rate and the number of seeds. Consequently, fruit size and fruit quality improve. Cross-pollination increases fruit size even in autogamous varieties. It is therefore recommended for the producer to have at least two varieties compatible with each other in his planting, for pollen exchange.

Artificial pollination (self- and cross-pollination) of white-fleshed pitaya (*Hylocereus undatus*) is viable, resulting in larger fruits than natural pollination, with cross-pollination being the most recommended. Throughout the floral opening period, the pitaya flower (*Hylocereus* spp.) has receptive stigma capable of receiving pollen. The flowers exhibit the highest pollen germination rate at 7 p.m, which is the ideal pollination window for pitaya.

Acknowledgments

The authors thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – (CAPES), the Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq and the Fundação de Amparo à Pesquisa do Estado de Minas Gerais - FAPEMIG for funding this study.

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How to cite

MOREIRA RA, RODRIGUES MA, SOUZA RC, DA SILVA AD, SILVA FOR, LIMA CG, PIO LAS & PASQUAL M. 2022. Natural and artificial pollination of white-fleshed pitaya. An Acad Bras Cienc 94: e20211200. DOI 10.1590/0001-3765202220211200.

Manuscript received on August 27, 2021;
accepted for publication on March 21, 2022

RENATA A. MOREIRA[1]
https://orcid.org/0000-0001-6586-4780

MARIANE A. RODRIGUES[1]
https://orcid.org/0000-0003-2838-2293

RAFAELA C. DE SOUZA[2]
https://orcid.org/0000-0002-6939-0452

ALEXANDRE D. DA SILVA[1]
https://orcid.org/0000-0002-6785-4954

FÁBIO O.R. SILVA[1]
https://orcid.org/0000-0002-6127-2048

CAROLINA G. LIMA[1]
https://orcid.org/0000-0002-4409-2221

LEILA A.S. PIO[1]
https://orcid.org/0000-0001-5246-5035

MOACIR PASQUAL[1]
https://orcid.org/0000-0001-5612-9186

[1]Universidade Federal de Lavras, Departamento de Agricultura, Caixa Postal 3037, Aquenta Sol, 37200-900 Lavras, MG, Brazil

[2]Universidade Federal de Lavras, Departamento de Biologia, Caixa Postal 3037, Aquenta Sol, 37200-900 Lavras, MG, Brazil

Correspondence to: **Renata Moreira Amato**
E-mail: renata_amato@hotmail.com

Author contributions

Renata Amato MOREIRA: Data curation; Formal analysis; Investigation; Methodology; Resources; Writing-original draft. Mariane Aparecida RODRIGUES: Data curation, Methodology; Writing-original draft.Writing-review & editing. Rafaela Carvalho de SOUZA: Writing-review & editing. Alexandre Dias da SILVA and Carolina Gâmbaro LIMA: Data curation; Investigation. Fábio Oseias dos Reis SILVA: Methodology; Resources. Leila Aparecida Salles PIO and . Moacir PASQUAL: Supervision; Writing-review & editing.