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ARTICLE

Methods for overcoming seed dormancy in blue palm

Métodos para superação da dormência de sementes da palmeira azul

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Abstract: The blue palm (*Bismarckia nobilis*) is one of the most used ornamental palms in landscaping, due to its size and slightly bluish fan-shaped leaves. However, its propagation is carried out through seeds and the germination of these seeds is extremely low, in addition to the plant growth being considered slow. This work aimed to compare the use of pre-germination treatments to break dormancy and accelerate germination of *B. nobilis* seeds. The effect of mechanical scarification (sanding the region opposite the embryonic axis), thermal (immersion in water at 40 ºC, 60 ºC and 80 ºC for 5 min) and chemical (immersion in sulfuric acid 98% for 15; 30; 45 and 60 min), as well as its imbibition in solutions containing GA_3 (gibberellic acid) at concentrations of 250; 500; 750 and 1000 mg L^{-1} on germination and speed of germination of seeds of the species. The results showed that the pre-germination treatments of mechanical and thermal scarification presented the best results compared to the other treatments.
Keywords: *Bismarckia nobilis*, gibberellic acid, mechanical scarification, pre-germination treatments, thermal scarification.

Resumo: A palmeira azul (*Bismarckia nobilis*) é uma das palmeiras ornamentais mais utilizadas no paisagismo, devido ao seu tamanho e folhas em leque levemente azuladas. Porém, sua propagação é realizada através de sementes e a germinação dessas sementes é extremamente baixa, além do crescimento da planta ser considerado lento. Este trabalho teve como objetivo comparar a utilização de tratamentos pré-germinativos para quebra de dormência e aceleração da germinação de sementes de *B. nobilis*. Foi avaliado o efeito da escarificação mecânica (lixamento da região oposta ao eixo embrionário), térmica (imersão em água a 40 ºC, 60 ºC e 80 ºC por 5 min) e química (imersão em ácido sulfúrico 98% por 15; 30; 45 e 60 min), bem como sua embebição em soluções contendo GA_3 (ácido giberélico) nas concentrações de 250; 500; 750 e 1000 mg L^{-1} na germinação e velocidade de germinação de sementes da espécie. Os resultados mostraram que os tratamentos pré-germinativos de escarificação mecânica e térmica apresentaram os melhores resultados em comparação aos demais tratamentos.
Palavras-chave: ácido giberélico, *Bismarckia nobilis*, escarificação mecânica, escarificação térmica, tratamentos pré-germinativos.

Introduction

The *Bismarckia nobilis* palm, or simply blue palm, is a slow-growing plant, originally from Madagascar. It stands out for the bluish gray color of its leaves, which make it one of the most eye-catching palm trees and much sought after by landscapers. It is excellent as a solitary specimen. Good for decorating patios and terraces in its youthful state. It can also be planted in illuminated interiors, adapting to tropical, subtropical climates and humid or dry environments (Noblick and Center, 2019).

The propagation of most palm trees is sexual, however, in general, germination is slow and uneven and influenced by several factors, such as maturation stage, presence or absence of pericarp, time between harvest and sowing, physical dormancy, temperature of the environment and substrate, among others. Seed dormancy varies considerably, but it can be said that under conditions without human influence, most palm tree seeds require more than a year to germinate (Ferreira, et al., 2021a).

According to Santos et al. (2022), dormancy can occur due to several factors, making it necessary to intervene through some type of treatment to stop this process. The possibility of treatments to break dormancy is quite extensive, such as, for example, immersion in growth-regulating chemical substances, chemical or mechanical scarification, exposure to light, stratification and even immersion in water at various degrees. Since the germination of palm seeds has been identified as slow, irregular, and often low (Feitosa et al., 2022).

Several studies were carried out with the objective of overcoming palm seed dormancy, using different techniques: pre-germination treatments, removal and scarification of the endocarp, use of gibberellic acid and soaking the seeds in water. *Elaeis guiinensis* (oil palm) seeds showed an increase in germination percentage after being incubated for 60 days at 40 ºC (Marcillo et al., 2022).

Astrocaryum aculeatum seeds had germination favored by the removal of the endocarp, imbibition in water at room temperature for nine days (Ferreira, et al., 2021b). The germination of macaúba diaspores (*Acrocomia aculeata*) is overcome by removing the opercular tegument associated with immersion of the seeds in gibberellic acid at a concentration of 2000 mg L^{-1}, for 24 hours (Oliveira et al., 2020). At higher temperatures, palm tree seeds germinate more easily. And several studies have shown that between 25 and 30 ºC increase the percentage of germination in different species (Sanglade et al., 2021). It was found that there are no works on the dormancy break of the blue palm during the literature review. The articles reviewed for this study are related to other palm genera, which in turn have seed structure like the species *Bismarkia nobillis*. Therefore, it is extremely important to study the preliminary methods for breaking dormancy in the blue palm, with the aim of identifying the one that provides better germination and the development of a propagation protocol, to optimize the propagation system of this palm plant.

Material and Methods

The experiments that make up this work were carried out between December/2018 and May/2019. The fruits of the blue palm tree were collected manually, when they were brown in color, in the municipality of Castanhal, Pará State, Brazil.

After collection, which was carried out in different matrices, the fruits were pulped. And two experiments were conducted sequentially. In the first experiment, the pre-germination treatments in *Bismarckia nobilis* consisted of: T1- Immersion in GA_3 solution (250 mg L^{-1}) for 24 hours; T2- Immersion in GA_3 solution (500 mg L^{-1}) for 24 hours; T3- Immersion in GA_3 (750mg L^{-1}) for 24 hours; T4- Immersion in GA_3 (1000mg L^{-1}) for 24 hours; T5-Manual Scarification (Sandpaper): the seeds were sanded (nº

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60 sandpaper), superficially, in the region opposite the embryonic axis and immersed in water for 24 hours, at a temperature of 25 **ºC;** T6- Control (without immersion or scarification).

In the second experiment, the following treatments were used: T1- Immersion in sulfuric acid (98%) for 15 minutes; T2- Immersion in sulfuric acid (98%) for 30 minutes; T3- Immersion in sulfuric acid (98%) for 45 minutes; T4-Immersion in sulfuric acid (98%) for 60 minutes; T5- Immersion in hot water (40 °C) for 5 minutes; T6- Immersion in hot water (60 °C) for 5 minutes; T7- Immersion in hot water (80 °C) for 5 minutes. The seeds that were submerged in concentrated sulfuric acid (98%) after immersion were washed in running water for 1 hour and immersed in water for 24 hours. The seeds immersed in hot water were allowed to rest in the same water, without heating.

25 seeds were used in each treatment in both experiments, with 4 replications, totaling 100 seeds per treatment. After the application of the dormancy-breaking treatments, the seeds were placed to germinate on the commercial Nutriplant substrate (Ivanov et al., 2021). The germination speed index (GVI) was calculated (Maguire, 1962). The data obtained were transformed into arcsine $\sqrt{}$ $(x/100)^{0.5}$ and submitted to analysis of variance. Treatment means were compared by Tukey's test at 5% using the AGROSTAT® software.

Germination was evaluated every 10 days, up to 150 days after sowing, counting the seeds that showed swelling of the "cotyledonary petiole", forming a structure called "germination bud" (He et al., 2022). From these data, percentage, speed index (Maguire, 1962) and mean germination time (Edwards, 1934) were calculated.

Results and discussion

The treatments used in the experiment to break seed dormancy were ineffective in favoring the standardization and acceleration of germination of blue palm seeds, resulting in a low seed rate germinated. Among all the treatments used, only in the one carried out with sulfuric acid did no seeds germinate.

The treatment with mechanical scarification did not differ statistically from the other treatments, however it had the highest average seed germination of blue palm, 4.16. The germination percentage was 50%, higher than other treatments which were 16%. 25%, 16%, 20%, and 18%, respectively with treatments with gibberellic acid, mechanical scarification, water bath and control (Table 1). The IVG of 1.49 was the highest among the treatments tested, both in experiment 1 and in experiment 2. Although there is no statistical difference between treatments.

In this test using gibberellic GA_3, no positive results were observed for seed germination. The treatments did not show significant differences between them (Table 1). However, when observing the analysis of the seed germination graphs (Fig. 1), there was a tendency towards stabilization and an increase in germination when compared to the control.

Table 1. Mean of germinated seeds, germination percentages and germination speed index (GVI) for blue palm seeds (*Bismarckia nobilis*).

Treatments	Mean of germinated seeds	Percentage of germination (%)	Germination Speed Index IVG
Gibberellic acid 250 ppm	1.33 a	16	0.34 a
Gibberellic acid 500 ppm	2.08 a	25	0.54 a
Gibberellic acid 750 ppm	1.33 a	16	0.36 a
Gibberellic acid 1000 ppm	1.66 a	20	0.51 a
Mechanical Scarification (Sandpaper)	4.16 a	50	1.49 a
Witness	1.50 a	18	0.47 a

Vertical means do not differ from each other by Tukey's test at 5% probability.

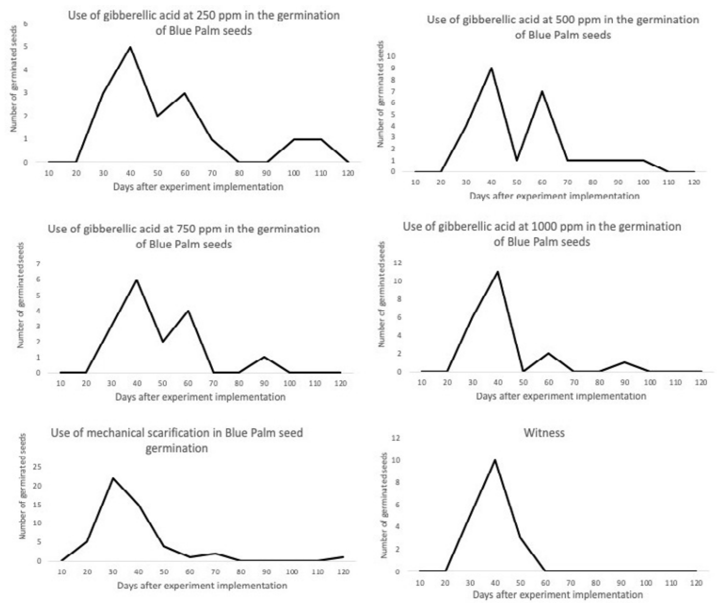

Fig. 1. Germination curve in seeds of *Bismarckia nobilis* Mart. subjected to different treatments.

Therefore, it can be inferred that other works with concentrations and immersion time different from this research can promote the blue palm germination process more effectively. In this work, no beneficial effect was observed from the use of GA_3 when compared to other treatments. Similar results were found with the *Astrocaryum huaimi* (Tucum palm) (Souza et al., 2014), *Hymenaea courbaril* (Jatobá) (Sousa et al., 2021) and the *Attalea maripa* (Inajá palm) (Silva et al., 2021). However, other studies using gibberellin favored the germination of *Roystonea hispaniolana* (royal palm) seeds (Morales-Payan and Santos, 1997); *Acrocomia aculeata* (macaw palm) (Ribeiro, et al., 2015).

Treatments with mechanical scarification (Sandpaper) showed numerical results superior to the control and gibberellic acid, but without statistical difference in the germination of seeds of this species when compared to these applied treatments. It can be seen in Fig. 1 that the treatment with mechanical scarification was the only one to reduce the initial germination time, with seeds germinating in the first 10 days. Both the percentage of germination and the IVG were higher than the other treatments, being 50% and 1.49 respectively.

Some works have observed positive effects in the use of mechanical scarification for palm seeds, *Archontophoenix alexandrae* (Nagao et al., 1980), *Euterpe edulis* (Ribeiro et al., 2015) and *Euterpe oleracea* (Feitosa et al., 2022), which concluded that mechanical scarification accelerates seed germination, obtaining satisfactory results, as in this and other works (Maciel et al., 2022).

The method with sulfuric acid (98%) resulted in 100% of dead seeds (Table 2). These results differed from those observed by other research who indicated this treatment as efficient in overcoming dormancy and promoting seed germination of the species sucupira-preta (*Bowdichia virgilioides*) (Santana et al., 2020) and jatobá (*Hymenaea courbaril*) (Motta et al., 2019) respectively.

The results with the application of sulfuric acid were the most efficient for breaking dormancy in research carried out in two species of Fabaceae (Carvalho et al., 2020). It is possible that the intervals of immersion of the seeds in the sulfuric acid were too long.

Sulfuric acid weakens the tegument, resulting in the removal of the macro sclereids layer and, consequently, exposure of the same (Simões et al., 2016). Due to the characteristics of the seed coats differing between structure and organization, the time required to promote the wear of the seed coat and make it permeable varies according to the quality of the seed and the species (Cipriani et al., 2019). This fact may be due to the application of sulfuric acid, which can act positively to overcome dormancy, as well as causing its loss. Therefore, research with lower concentrations and seed immersion times than those used in this research may favor seed germination.

Treatment with immersion in water proved to be promising for breaking blue palm seed dormancy (Table 2). However, in the treatment with a temperature of 80 ºC for 5 minutes, the seeds did not germinate. High temperatures can damage the seeds of certain species, leading, for example, to enzymatic alterations, reducing the amount of free amino acids and modifying the speed of metabolic reactions (Salinas and Reynoso, 2023; Tiwari et al., 2023).

Table 2. Mean of germinated seeds, germination percentages and germination speed index (GVI) for blue palm seeds (*Bismarckia nobilis* Mart.).

Treataments	Mean of germinated seeds	Germination percentage (%)	Germination Speed Index--IVG
Sulfuric acid for 15 minutes	0	0	0
Sulfuric acid for 30 minutes	0	0	0
Sulfuric acid for 45 minutes	0	0	0
Sulfuric acid for 60 minutes	0	0	0
40 ˚C por 5 minutes	2.73 a	41	1.06
60 ˚C por 5 minutes	3.46 a	52	1.13
80 ˚C por 5 minutes	0	0	0

Vertical means do not differ from each other by Tukey's test at 5% probability.

According to several authors, higher temperatures favor the germination of palm seeds, and the temperature affects the percentage of germination, mainly influencing the absorption of water by the seed and all the biochemical reactions and physiological processes that determine germination (Ávila et al., 2022; Beveridge et al., 2022; Souza et al., 2022; Rojas et al., 2023). Therefore, the temperature that favors the germination of blue palm seeds is between 40 and 60 **ºC.**

All treatments used to break the dormancy of the blue palm seed were not efficient, however there were treatments that indicated a positive signal such as mechanical scarification and water bath. Given this result, it can be inferred that there is integumentary or exogenous dormancy in blue palm seeds.

The techniques performed were done in isolated ways. It is necessary that another research with the combined use of these techniques can result in the efficiency in breaking dormancy and in the uniformity of germination, since after more than a year after the end of the experiment there were still seeds germinating, demonstrating the need to use techniques that can facilitate and standardize the germination of these seeds.

The germination of palm seeds, this can be classified into two types, according to the pattern of development of the essential structures of the seedling: remote germination and adjacent germination. In seeds that present remote germination, in the case of the present research, the embryonic axis expands, there is the emission of a structure from the cotyledon, called petiole, from which the emission of the primary root and aerial part of the seedling will occur. The cotyledon remains inside the seed, functioning as an organ for absorbing nutrients, called the haustorium. In palm seeds with remote germination, the primary root persists for some time and produces lateral roots (Mazzottini-dos-Santos et al., 2018; Moura et al., 2019; Mello et al., 2021; Sari et al., 2021). As seen in Fig. 2.

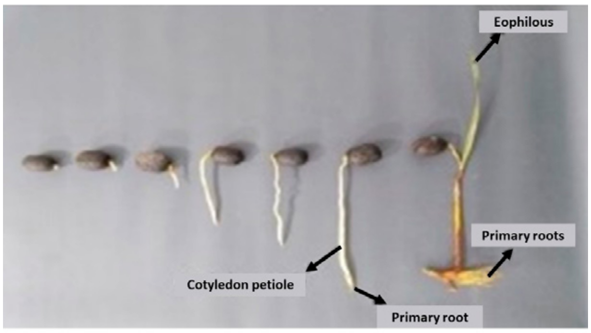

Fig. 2. Description of blue palm seed germination.

Conclusions

We concluded that the use of sulfuric acid (98%), with an immersion time of 15 to 60 minutes and immersion in water at 80 °C for 5 minutes are not recommended for breaking the dormancy of the blue palm seed, as it caused the loss of seeds.

The use of mechanical scarification and immersion in water showed better results when compared to the other treatments, although there was no statistical difference between them.

Although an effective treatment for breaking dormancy of the blue palm seed was not observed, this research pointed to the use of a water bath and mechanical scarification as promising. This suggests that further research investigate temperatures and immersion times different from those used here, associated with mechanical scarification.

Finally, considering the ornamental importance of the blue palm, it is important to find ways to accelerate and standardize its germination, to optimize the production of seedlings and, consequently, the use of this palm tree.

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Author contribution

ROM: conceptualization, investigation, data acquisition, literature review, methodology, data analysis and interpretation, writing – original draft. **VMM:** investigation, data acquisition, literature review, methodology, writing – original draft. **WLS:** investigation, data acquisition, literature review, data analysis and interpretation, visualization, writing – review & editing. **BOC:** literature review, data analysis and interpretation, visualization, writing – review & editing. **RNCCJ:** investigation, literature review, data analysis and interpretation, visualization, supervision, writing – review & editing. **KFLP:** conceptualization, investigation, data analysis and interpretation, visualization, formal analysis, project administration, supervision, writing – review & editing.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Data Availability Statement

Data will be made available on request.

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