SEED GERMINATION AND PRODUCTION OF SWAMP PALM SEEDLINGS (*Mauritia flexuosa* L.f.)

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ABSTRACT – Swamp palm (*Mauritia flexuosa* L.f.) is a typical palm tree from the Amazon and Cerrado of Brazil, whose fruits are used in cooking and the pharmaceutical industry. Seed germination of this palm is slow, irregular and often low, which makes its cultivation limited, being exploited in extractive systems. Also, little is known about seedling development, and this knowledge is important to define a protocol for the production of seedlings of this species. This research aimed to develop a protocol for the seed germination of swamp palm under semi-aseptic conditions and to evaluate the seedling development of swamp palm under different production systems. There was no germination in treatments without scarification. The best germination protocol for swamp palm was scarification with operculum removal in seeds recently extracted from the fruit with application of gibberellic acid (plant growth regulator) because it increased the rate and accelerated germination. However, imbibition in aerated water (with H_2O_2) proved to be suitable up to two days. The best method for seedlings production of swamp palm is the use of conventional bag (20×30 cm) with soil and manure or for producers with greater investment capacity, the use of tubes (180 cm^3) for two months and subsequent transplanting to a conventional bag with soil and manure until completing six months.

Keywords: Plant growth regulator; Palm trees; Cerrado biome.

GERMINAÇÃO DE SEMENTES E PRODUÇÃO DE MUDAS DE BURITI (Mauritia flexuosa L.f.)

*RESUMO – O buriti (**Mauritia flexuosa** L.f) é uma palmeira típica da Amazônia e do Cerrado do Brasil, que tem seus frutos utilizados na culinária e na indústria farmacêutica. A germinação dessa palmeira é lenta, irregular e frequentemente baixa, o que torna seu cultivo limitado, sendo explorada em sistemas extrativistas. Também, pouco se conhece sobre o desenvolvimento de mudas, e esse conhecimento é importante para definir um protocolo para produção de mudas desta espécie. Esta pesquisa teve como objetivo desenvolver um protocolo para a germinação de sementes de buriti em condições semi- assépticas, e avaliar o desenvolvimento de mudas de buriti em diferentes sistemas de produção. Não houve germinação nos tratamentos sem escarificação. O melhor protocolo de germinação para as sementes de buriti foi a escarificação com retirada do opérculo em sementes recém extraídas do fruto com o uso de ácido giberélico (regulador de crescimento de plantas), pois isso aumentou a taxa e acelerou a germinação. Entretanto, a embebição em água aerada (com H_2O_2) mostrou-se adequada até dois dias. O melhor método para produção de mudas de buriti é o uso de sacola convencional (20×30 cm) com terra e esterco ou para produtores com maior capacidade de investimento, o uso de tubetes (180 cm^3) por dois meses e posterior transplantio para sacola convencional com terra e esterco até completar seis meses.*

Palavras-Chave: Regulador de crescimento de plantas; Palmeiras; Bioma cerrado.

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1. INTRODUCTION

Swamp palm fruits have been used in cooking, especially in the preparation of sweets, jellies, juices, ice creams and in cosmetic products, due to its oil, rich in vitamin A (Spera et al., 2001; Seleguini et al., 2012). This species has also importance as an ornamental and in fauna preservation, since its fruits are source of food for several birds, mammals and traditional human populations (Almeida and Silva, 1994; Lorenzi et al., 2010; Martins et al., 2012; Koolen et al., 2013).

Nowadays, there is worldwide concern regarding environmental quality, generating a growing demand for services and forest products, especially in seedlings production for reforestation for economic purposes and urban afforestation (Antoniazzi et al., 2013). In Brazil, with the approval of the new Forest Code in 2012, farmers have been required to regularize their farms, carrying out the demarcation, registration and restoration of legal reserves and permanent preservation areas.

Considering that the current legislation allows the exploitation of non-timber forest species, the restoration of degraded areas (mainly swamps) with swamp palms or its exploitation in an agroforestry system represent activities that may increase the demand for its seedlings, besides to be an efficient instrument for the conservation of this species.

Most palm species have not developed natural mechanisms of vegetative propagation, so their multiplication occurs exclusively through seed germination. Swamp palm seeds have a rare association between recalcitrance and dormancy (Silva et al., 2014), which makes their germination slow (45 to 260 days), irregular and often low (Spera et al., 2001; Seleguini et al., 2012). Operculum removal and imbibition in water promoted a significant advance in the germination rate, but the information about germination speed is imprecise (Silva et al., 2014). Furthermore, the use of growth regulators, such as gibberellins, to overcome the dormancy and accelerate and standardize the germination process is well documented in the literature for other species (Buchanan et al., 2015; Bewley et al., 2013); but as far as we know it was never used for swamp palm.

Beyond the challenges of swamp palm seed germination (Spera et al., 2001; Seleguini et al., 2012; Silva et al., 2014), even less is known about the seedling development of this species. The role that containers and substrate types have played on post-planting development has been well documented for several species such as: coffee (Vallone et al., 2010); *Eucalyptus* (Gomes et al., 2003; Pereira and Pinto, 2013); cedar (Antoniazzi et al., 2013); japanese pine (Santos et al., 2000); indian neem (Novaes et al., 2014) and some species of palm trees such as peach palm (Silva et al., 2006); macaw palm (Pimentel et al., 2016); oil palm (Akpo et al., 2014); açaí palm (Almeida et al., 2018); coconut palm (Lédo et al., 2019); jussara palm (Souza et al., 2023). All these studies have contributed to find out the most efficient process to produce seedlings of these species.

The Cerrado biome and mainly its swamp areas, the main environment for swamp palms, have suffered a huge anthropic impact over the last few decades. Considering that swamp palm has economic and environmental importance and the processes to germinate its seeds may be improved and information on the best method for seedling production is scarce, studies looking for propagating this plant will contribute to its conservation and future economic exploitation. Therefore, this research aimed to develop a protocol for seed germination under semi-aseptic conditions using a growth regulator and evaluate the seedling development of swamp palm (*Mauritia flexuosa* L.f.) in different production systems.

2. MATERIAL AND METHODS

2.1. Plant material and collection area

The fruits were collected from natural populations in Uberaba and Água Comprida, located in Minas Gerais state, Brazil. The collections were carried out from December 2016 to March 2017. The fruits were kept in a plastic container covered by canvas for 72 h to complete maturation and pulp softening. Then they were washed in running water and its pulps were removed manually. Four samples of 5 whole seeds were used to determine the water content by the oven method for 24 hours at 105 ºC (Brasil, 2009). Another part of the newly extracted seeds was washed and submitted to disinfestation, immersion in 2% sodium hypochlorite solution for 20 minutes, and washed again with distilled water. These seeds were then used for experiments of dormancy overcoming and seed germination in 2016. The experiment for seedling production took place in 2017, with material obtained in new collections, in the same locations. The fruits and seeds were processed in the same way as described above, using the best treatment from the germination experiment.

2.2. Methodology for overcome dormancy and seed germination

In order to overcome dormancy, standardize and accelerate germination, pre-germination treatments were carried out. The factors studied were: (1) seed imbibition time in aerated water with 2 ml L^{-1} hydrogen peroxide (H_2O_2) solution, (2) immersion for 6 hours in 500 mg L^{-1} gibberellic acid (GA3) solution (plant growth regulator) and (3) mechanical scarification using scalpel for operculum removal. The experiment design was a completely randomized in a 4×2×2 factorial arrangement, with four levels of imbibition in hydrogen peroxide solution (0, 2, 4 and 6 days), with and without mechanical scarification and with and without gibberellic acid application. The control consisted of seeds without pre-germination treatment submitted only to disinfestation. It was adopted experimental units of 20 seeds and five replications (total of 1600 seeds).

After the pre-germination treatments a fungicide Maxim® (0.3%) was applied to the seeds. The fungicide was diluted in water and sprayed over the seeds covering their surfaces. The seeds were arranged in polyethylene trays and were distributed in germination paper (Germitest) moistened with deionized water with a volume equivalent to 2.5 times the weight of the paper and kept in germination chamber (BOD-type) at 28 ºC and 12/12h photoperiod (pre-tests were carried out to determine temperature, photoperiod and adapted to swamp palm seeds). Seed moisture during the germination period was maintained by applying deionized water as needed. The following variables were evaluated: percentage of germination (G) at 30 days (pre-tests were carried to determine period), the first germination count (FGC) at 15 days, the number of dead seeds (M), the mean time to germination (MTG) according to Edwards (1934) and the germination speed index (GSI) according to Maguire (1962).

Seeds were considered to be germinated when they emitted the cotyledonary petiole and root. In pre-tests it was found that some seeds emitted healthy cotyledonary petiole (germination concept for some palm trees) but they did not always develop roots (crucial structure for the establishment of the plant). Seeds with cotyledonary petiole but without root or ligule were considered abnormal. Seeds were considered to be hard when they did not germinate and dead those seeds that were damaged by fungi or bacteria. The terminologies proposed by Henderson (2006) were adopted.

2.3. Methodology for seedlings production

The experiment was carried out in a greenhouse covered with agricultural plastic and shading screen on the sides, at the IFTM, Campus Uberaba, from January to July 2017. The seedlings used in this stage were obtained following the methodology described in the previous experiment, applying the treatment with the highest germination rate.

A completely randomized design was adopted with five treatments (seedling production methods), four replications and experimental units of 10 plants. It was studied two types of containers: conical plastic tube (180 cm^3) or conventional plastic bag (20×30 cm), two types of substrates: composted pine bark (Bioplant®) or a mixture of soil and tanned bovine manure, and two methods of establishment: with or without transplanting (Table 1).

Table 1 – Treatments studied for swamp palm seedling production in Uberaba, MG, Brazil.
Tabela 1 *– Tratamentos estudados para produção de mudas de buriti em Uberaba, MG, Brasil.*

Treatment	Materials
BSoNT	Bag, 2/3 soil and 1/3 manure, not transplanting, six months
TSuNT	Tube, substrate, not transplanting, six months
TSoNT	Tube, 2/3 soil and 1/3 manure, not transplanting, six months
TSoBSoT	Tube, 2/3 soil and 1/3 manure, 2 months, transplanting to bag, 2/3 soil and 1/3 manure, four months
TSuBSoT	Tube, substrate, 2 months, transplanting to bag, 2/3 soil and 1/3 manure, four months

Bag (B, plastic bag, 20×30 cm), Tube (T, conical plastic tube, 180 cm^3), Substrate (Su, composted pine bark, Bioplant®), Soil (So), No transplant (NT), Transplant (T).
Sacola (B, sacola plástica, 20×30 cm), Tubete (T, tubete cônico plástico, 180 cm^3), Substrato (Su, casca de pinus compostada, Bioplant®), Solo (So), Não transplantado (NT), Transplantado (T).

The commercial substrate used was Bioplant Gold (Bioplant®), composed of composted pine bark, coconut fiber, *Sphagnum* peat, vermiculite and carbonized rice husk. The containers were irrigated daily until drainage. No sprays or fertilizations were done.

After 180 days the following variables were evaluated and calculated: shoot length (H, cm), root length (RL, cm), collar diameter (CD, mm), shoot, root and total dry mass (SM, RM, TM, g), shoot and root dry mass ratio (SM:RM), height collar diameter ratio (H:CD) and leaf area (LA, cm^2). With these variables Dickson quality index (DQI) was also calculated using the equation:

$$IQD = \frac{TM}{\frac{H}{CD} + \frac{SM}{RM}} \quad \text{Eq. 1}$$

2.4. Statistical analysis

The data were submitted to *Bartlett* homogeneity test, *Shapiro-Wilk* normality test, analysis of variance (ANOVA) and the means compared by the Tukey test ($p < 0.05$) using R software. The percentage of germination accumulated until 30 DAS (days after sowing) was also performed and this variable of all treatments was submitted to ANOVA and Scott-Knott mean cluster test ($p < 0.05$).

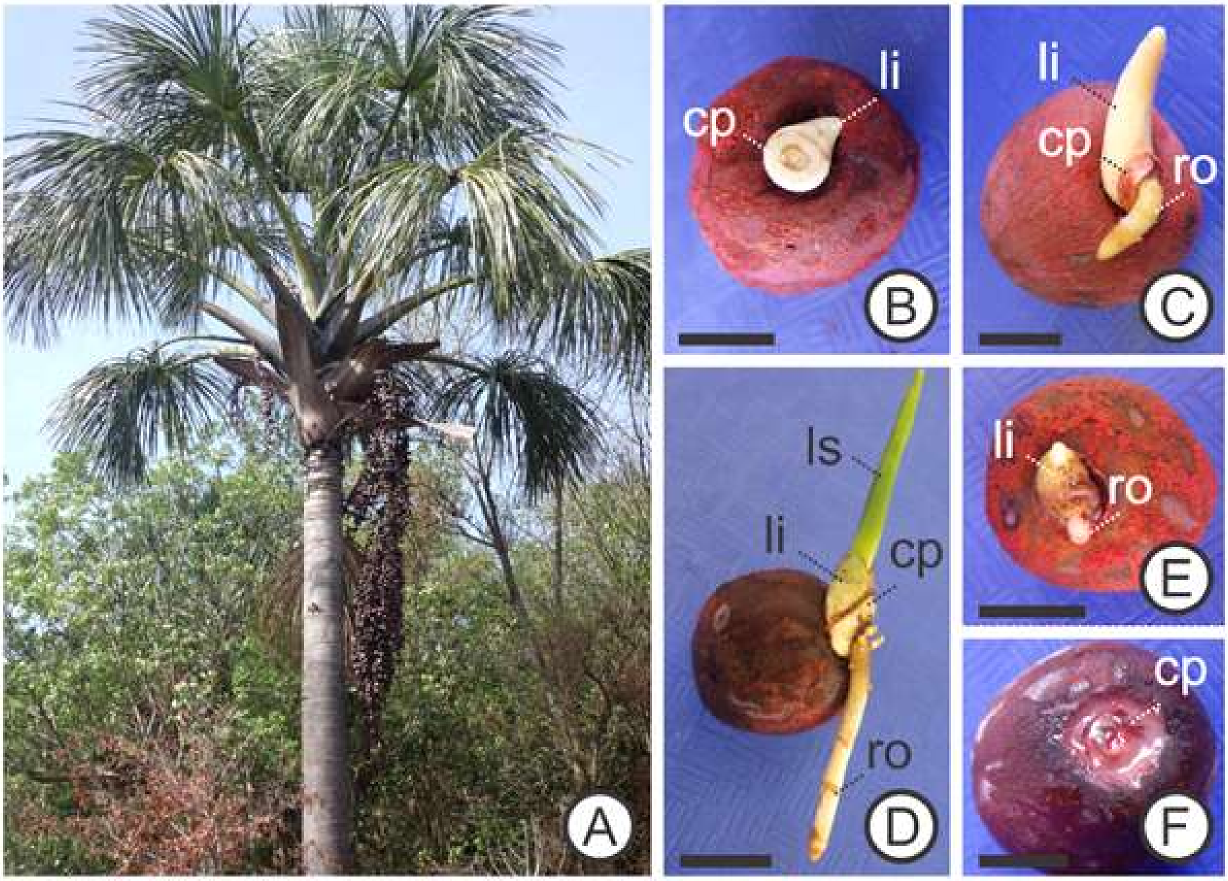

Figure 1 – Swamp palm tree in natural environment and seed germination. A. Swamp palm tree. B. Seed with the presence of cotyledonary petiole (cp) and ligule (li) (5-10 days after sowing, DAS). C. Germinated seed with cotyledonary petiole, ligule and root (ro) (15 DAS). D. Seed in advanced stage of development with normal seedling with presence of cotyledonary petiole, ligule, root and leaf sheath (ls) (30 DAS). E. Seed with abnormal seedling development (30 DAS). F. Dead seed by bacterial infection (30 DAS). Black bar represents 2 cm.

Figura 1 *– Planta de buriti em ambiente natural e germinação das sementes. A. Planta de buriti. B. Semente com presença de pecíolo cotiledonar (cp) e lígula (li) (5-10 dias após semeadura, DAS). C. Semente germinada com presença de pecíolo cotiledonar, lígula e raiz (ro) (15 DAS). D. Semente em estágio avançado de desenvolvimento com plântula normal com presença de pecíolo cotiledonar, lígula, raiz e bainha da folha (ls) (30 DAS). E. Semente com desenvolvimento da plântula anormal (30 DAS). F. Semente morta por ataque de bactérias (30 DAS). Barra corresponde a 2 cm.*

Table 2 – Swamp palm seed germination with (H1) and without (H0) gibberellic acid and different time of imbibition in aerated water: zero days (T0), two days (T2), four days (T4) and six days (T6). Variables: germination (G), first germination count (FGC), mortality (M), abnormal seedlings (AS), mean time to germination (MTG) and germination speed index (GSI).
Tabela 2 *– Germinação de sementes de buriti com (H1) e sem (H0) ácido giberélico e diferentes tempos de embebição em água aerada: zero dias (T0), dois dias (T2), quatro dias (T4) e seis dias (T6). Variáveis: germinação (G), primeira contagem (FCG), mortalidade (M), plântulas anormais (AS), tempo médio para germinação (MTG) e índice de velocidade de germinação (GSI).*

	Treat.	G (%)	FCG (%)	M (%)	AS (%)	MTG (days)	GSI
mean±se	H1	81.7±2.4a	24.2±2.5a	14.0±2.0b	4.2±1.2a	19.3±0.5a	1.01±0.0a
	H0	67.5±2.4b	9.5±2.5b	30.7±2.0a	1.7±1.2a	19.7±0.5a	0.74±0.0b
	p value	<0.001	<0.001	<0.001	0.181	0.437	<0.001
	T0	82.0±3.4ab	36.0±3.5a	10.0±2.8b	5.0±1.8a	18.6±0.7a	1.06±0.0a
	T2	85.0±3.4a	20.0±3.5b	13.0±2.8b	5.0±1.8a	20.4±0.7a	1.01±0.0a
	T4	70.0±3.4bc	9.5±3.5bc	28.5±2.8a	1.5±1.8a	19.6±0.7a	0.77±0.0b
	T6	61.5±3.4c	2.0±3.5c	38.0±2.8a	0.5±1.8a	19.5±0.7a	0.66±0.0b
	p value	<0.001	<0.001	<0.001	0.198	0.664	<0.001
H*T	*F* value	0.414	0.116	0.787	0.254	0.150	0.171
CV (%)	-	14.66	66.25	40.52	192.7	12.10	15.21

Means followed by the same letter within a column and factor are not different by Tukey's test (n=5). Standard error (se), coefficient of variation (CV).
Médias seguidas da mesma letra na coluna e fator não diferem pelo teste de Tukey (n=5). Erro padrão (se), coeficiente de variação (CV).

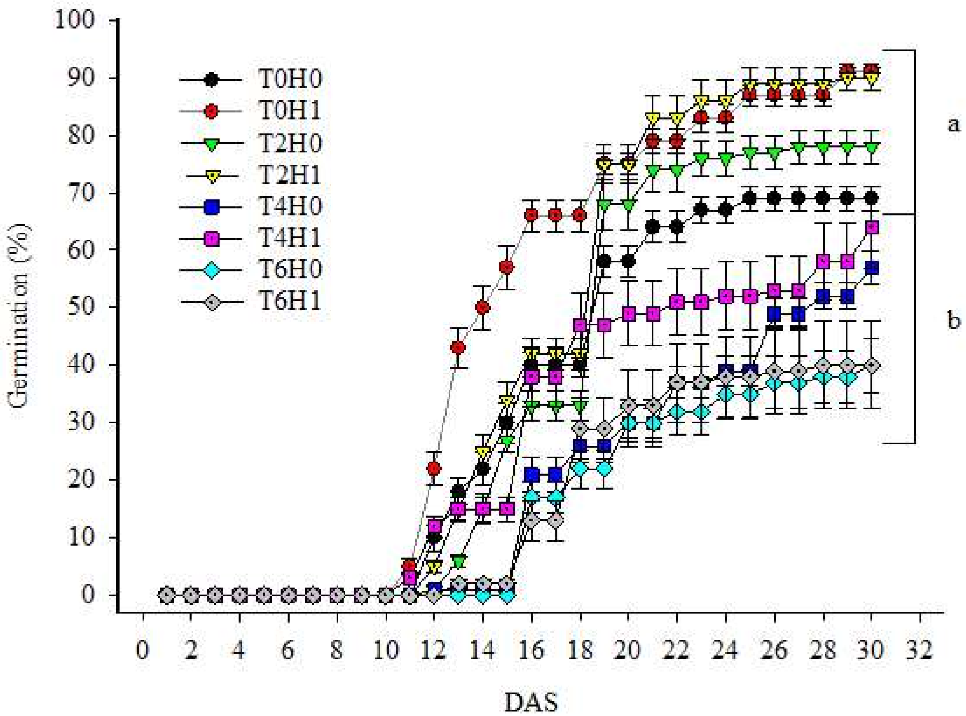

Figure 2 – Percentage of germination accumulated as a function of days after sowing of swamp palm seeds treated with gibberellic acid (H1) and without (H0) and submitted to different time of imbibition in aerated water: without imbibition (T0), two days of imbibition (T2), four days of imbibition (T4) and six days of imbibition (T6). Brackets indicate clusters of equal means by Scott-knott test ($p = 0.003$) at 30 days after sowing. Standard error (bars).
Figura 2 *– Porcentagem de germinação acumulada em função dos dias após a semeadura de sementes de buriti tratadas com ácido giberélico (H1) e sem (H0) giberelina e submetidas a diferentes tempos de embebição em água aerada: sem embebição (T0), dois dias de embebição (T2), 4 dias de embebição (T4) e seis dias de embebição (T6). Os colchetes indicam agrupamentos de médias iguais pelo Scott-knott (**p** = 0.003) aos 30 dias após semeadura. Erro padrão (barras).*

3. RESULTS

3.1. Dormancy overcoming and seed germination

Swamp palm is a lush palm tree with characteristic fan-shaped leaves, 15-30 meters high and clusters with many fruits (Figure 1A). In this study, the seeds were extracted from fruits of freshly collected bunches presented moisture above 30%. The sequence of swamp palm seed germination occurred according to Henderson (2006): first, the cotyledonary petiole protrudes; then the ligule or the root comes and, finally, the leaf sheath (Figure 1B-D). In the figure 1 are images that represent the concepts of germinated seed (Figure 1C), normally developing seedling (Figure 1D), abnormally developing seedling (Figure 1E) and dead seed (Figure 1F).

No germination was observed in treatments without scarification, all 800 seeds were considered hard seeds. Thus, the analysis of variance and the comparison of means were performed only for scarified seeds (the other 800 seeds). There was no interaction between the factors studied, so the factors with and without gibberellic acid and days of imbibition were presented separately (Table 2).

The seeds treated with gibberellic acid showed an increase of 14.5% in germination, 15% in FCG and 0.27 in GSI. They also had 17% less dead seeds. The increase in the time of imbibition in water with H_2O_2, four or six days, impaired seed germination, as it decreased the germination percentage; the percentage of seeds germinated in the first count and the GSI; but also increased the percentage of dead seeds. Seeds with four and six days of imbibition had 12 and 20.5% less germination than those without imbibition. Seeds with four and six days of imbibition had 15 and 23.5% less germination than those with two days of imbibition (Table 2).

Although there was no interaction between the factors studied, the percentage of germination accumulated for all treatments with scarification shows that the seeds treated with gibberellic acid (H1) and with the shortest imbibition times (T0 and T2) presented higher percentage and speed of germination (Figure 2). T0H1, T2H1, T2H0 and T0H0 presented the highest germination rates at 30 DAS, with 91%, 90%, 78% and 69%, respectively. However, until 16 DAS, T0H1 treatment had 24% more germinated seeds than T2H1, but the two treatments were equal

Table 3 – Swamp palm seedlings development in different methods. Variables: height (H), root length (RL), collar diameter (CD), shoot, root and total dry mass (SM, RM, TM), shoot root mass ratio (SM:RM), height diameter collar ratio (H:DC), leaf area (LA) and Dickson's quality index (DQI).

Tabela 3 – *Desenvolvimento de mudas de buriti em diferentes recipientes e substratos. Variáveis: altura (H), comprimento da raiz (RL), diâmetro do coleto (CD), massa seca da parte aérea, da raiz e total (SM, RM, TM), razão parte aérea raiz (SM:RM), razão altura diâmetro do coleto (H:DC), área foliar (LA) e índice de qualidade de Dickson (DQI).*

	Treat.	H (cm)	RL (cm)	CD (mm)	SM (g)	RM (g)
mean	BSoNT	74,9 a	23,8 a	12,33 a	4,29 a	4,88 a
	TSuNT	50,6 b	19,6 b	11,78 a	3,33 ab	5,32 a
	TSoNT	52,8 b	19,4 b	10,76 b	2,36 b	4,71 a
	TSuBSoT	72,2 a	23,9 a	12,65 a	3,55 ab	4,25 a
	TSoBSoT	65,5 a	23,1 ab	12,38 a	4,00 a	4,61 a
	p value	<0,001	0,004	<0,001	0,001	0,794
CV (%)	-	8,60	8,06	3,71	15,35	23,98
	Treat.	**TM (g)**	**SM:RM**	**H:CD**	**LA (cm²)**	**DQI**
mean	BSoNT	9,17 a	0,95 a	6,08 a	152,69 a	1,32 a
	TSuNT	8,65 a	0,63 a	4,29 c	168,35 a	1,75 a
	TSoNT	7,08 a	0,53 a	4,91 bc	134,95 a	1,29 a
	TSuBSoT	7,80 a	0,87 a	5,70 ab	132,17 a	1,21 a
	TSoBSoT	8,62 a	0,86 a	5,30 ac	168,18 a	1,40 a
	p value	0,303	0,043	0,001	0,464	0,078
CV (%)	-	16,99	25,47	9,21	2,77	

Bag (B, plastic bag, 20×30 cm), Tube (T, conical plastic tube, 180 cm³), Substrate (Su, composted pine bark, Bioplant®), Soil (So), No transplant (NT), Transplant (T). Means followed by the same letter within a column are not different by Tukey's test (n=4). Coefficient of variation (CV).

Sacola (B, sacola plástica, 20×30 cm), Tubete (T, tubete cônico plástico, 180 cm³), Substrato (Su, casca de pinus compostada, Bioplant®), Solo (So), Não transplantado (NT), Transplantado (T). Médias seguidas da mesma letra na coluna não diferem pelo teste de Tukey (n=4). Coeficiente de variação (CV).

at 19 DAS, both reaching 75% of germination. Treatments T4H1, T4H0, T6H1 and T6H0 had the lowest germination rates at 30 DAS, with 64%, 57%, 40% and 40%, respectively (Figure 2).

3.2. Seedlings production

There were differences between treatments for the variables: height, root length, collar diameter, shoot dry mass and height collar diameter ratio. Otherwise, there were no differences between treatments for: root dry mass, total dry mass, shoot root mass ratio, leaf area and Dickson quality index (Table 3).

The seedlings from the treatments BSoNT, TSuBSoT and TSoBSoT presented greater H than seedlings grown in TSoNT and TSuNT (Table 3). The greatest height differences were between BSoNT (+ 24.3 cm) and TSuNT and between BSoNT (+ 22.1 cm) and TSoNT. Seedlings grown in BSoNT and TSuBSoT had greater RL ($\geq$ 4.1 cm) than seedlings grown only in tube regardless of the establishment method and substrate (TSoNT and TSuNT) (Table 3).

The seedlings grown in TSoNT had a smaller CD than the other treatments. The biggest differences were between BSoNT, TSuBSoT and TSoBSoT which presented $\geq$ 1.6 mm more DC than TSoNT (Table 3). Seedlings grown in BSoNT and TSuBSoT had higher SM ($\geq$ 1 g) than seedlings grown only in tube regardless of the establishment method and substrate (TSoNT and TSuNT) (Table 3). Seedlings grown only in tubes (TSoNT and TSuNT) had a lower H:CD ratio than seedlings grown in BSoNT (Table 3).

4. DISCUSSION

4.1 Dormancy overcoming and seed germination

Swamp palm seed germination rates vary according to the pre-germination treatment applied, with rates between 20 and 88% (Spera et al., 2001; Seleguini et al., 2012; Silva et al., 2014). Our results outweighed those results obtained by Spera et al. (2001) and Seleguini et al. (2012) for germination rate and speed. As Silva et al. (2014) adopted a different germination approach from our study and they did not accurately describe the germination speed process, it was not possible to compare the results. However, according to Silva et al. (2014), the emission of roots and aerial parts occurred in more than 80% of the seeds at 30 DAS. This development stage is similar in our study for germinated seeds, considering that 91% of germination was obtained at 30 DAS (Figure 2).

In the germination process of palm trees, the emission of the cotyledonary petiole occurs before the emission of the radicle (germination in the strict sense). In swamp palm, the cotyledonary petiole acts in the displacement of the operculum, promoting the protrusion of the embryonic axis (Moura et al., 2019), and although some authors have considered the seed with a cotyledonary petiole as germinated, we adopted root emission as a key feature to consider a germinated seed. Silva et al. (2014) pointed out that seeds with cotyledonary petioles (90%) was higher than seeds with roots and aerial parts (more than 80%). This difference may be due to likely damage to the embryo during the manual removal of the operculum, the process used by those authors. In our research, the embryo damage rate was around 10%.

The type of dormancy found in swamp palm seeds is controversial. Seleguini et al. (2012) stated that the difficulty of seed germination is due to integumentary dormancy or the inability of the embryo to overcome the resistance of adjacent tissues. In contrast, Silva et al. (2014) ensured that the dormancy of this species is physiological, due to the embryo's inability to overcome the resistance imposed by the operculum. Our results confirmed that long imbibition reduces germination (Seleguini et al., 2012) and the high efficiency of operculum removal process (Silva et al., 2014).

Porto et al. (2018) simulated floodplain environments, where *M. flexuosa* naturally occurs, found a reduction in seed viability after imbibition and no germination was observed under these conditions. For palm seeds, the oxygen availability plays an important role for germination (Ribeiro et al., 2012) and it is a key factor for swamp palm.

The efficiency of operculum removal in promoting germination observed for swamp palm seeds and other palm species (Ribeiro et al., 2011; Dias et al., 2018) reinforces the statement by Silva et al. (2014) for the presence of physiological dormancy in swamp palm seeds. However, according to Baskin and Baskin (2014) and Jaganathan (2021), embryos palm trees have required post-maturation development, a morphological dormancy. To observe this type of dormancy it is necessary to consider the size of the embryo at dispersion time and our investigation does not allow us to indicate that swamp palm seeds present only physiological dormancy or morphophysiological dormancy.

Our results evidenced that gibberellic acid application promoted greater rate, uniformity and speed of germination and its use is strongly recommended in the pre-germination for swamp palm species. As far as we know there are no published data about the use of this plant regulator for *M. flexuosa* germination. So, this technique has been being used for the first time for swamp palms. However, the use of gibberellins to overcome dormancy, accelerate and standardize the germination process is well documented in the literature for other species (Dias et al., 2017; Buchanan et al., 2015; Ribeiro et al., 2015; Bewley et al., 2013).

4.2 Seedlings production

The greater growth of swamp palm seedlings occurred in a conventional bag (20×30 cm) with a mixture of soil (2/3) and manure (1/3) and these results corroborate those found in macaúba (*Acrocomia aculeata*), another native palm of economic importance in Brazil (Motoike et al., 2013). The bag is a larger container, providing more space for the seedling to grow and develop. However, it demands more inputs for production and the logistics of transport and planting could be more difficult when compared to tubes or other smaller containers, such as biodegradable paper pots (Robb et al., 1994).

Seedlings grown only in tubes (TSoNT and TSuNT) had a lower H:CD ratio. In this case, having a lower H:CD ratio represents seedlings with a thicker stem. Thicker stem represents a quality factor for seedlings, as they theoretically have a greater amount of vascular tissue and reserve parenchyma between the root system and aerial parts of the plant, which brings advantages of translocation of water, nutrients and photo assimilates between these parts (Lemaire et al., 2019).

The seedlings produced with transplanting method (TSuBSoT and TSoBSoT) had no damage to growth and development when compared to the BSoNT seedlings. The transplant method facilitates the initial management of the seedlings, as the tubes occupy less space in the nursery, are less susceptible to contamination by pathogens and demand less inputs and labor. With this indirect method, only after the initial establishment, the more vigorous and higher quality seedlings are transplanted from the tube to the bags, which would also generate savings. Additionally, the seedlings produced in TSuNT reached a high DQI (average of 1.75) and low values of the SM:RM ratio, but had less biomass and height than other treatments. The use of tubes larger than 180 cm^3 and fertilization would probably increase the biomass and height of TSuNT seedlings, which can lead to the production of high quality seedlings in tubes, without the need for transplanting to bags.

Swamp palm trees have been cited as a typical palm of wetland, such as the Cerrado “veredas” (Almeida and Silva, 1994; Delgado et al., 2007). However, although this has been its natural habitat, its survival only in flooded environments is not a rule. In Brazil this palm has been found in not flooded environments, and in Peru there are reports of groups of two to five swamp palms found in gardens and pastures (Delgado et al., 2007). According to Rodrigues et al. (2021), swamp palm seedlings in its young stage have developed properly with daily irrigation from 50% of the soil’s maximum water retention capacity. Efficient propagation methods and the feasibility of planting swamp palms outside of flooded environments generate a new perspective for its commercial cultivation, with irrigation, fertilization and quality seedlings.

In short, swamp palm seeds only germinate in a short period of time, until 30 days after sowing, if scarified. Among the protocols studied for dormancy overcoming and germination of scarified seeds the best results were obtained with gibberellic acid (0.02%) and shortest time of imbibition in aerated water, zero or two days. The scarification adopted in our study seems to be feasible on a large scale, but people need to be properly trained to remove the operculum. The best treatments in this study (T0H1 and T2H1) outweighed the germination rates and speed previously found in the literature. The production of swamp palm seedlings for reforestation or even for commercial plantations seems to be suitable and may be done with the following treatments: BSoNT, TSuBSoT and TSoBSoT or using only a tube, as long as the tubes are larger than 180 cm^3 and the seedlings are fertilized.

5. CONCLUSION

There was no germination in treatments without scarification. The best germination protocol for swamp palm was scarification with operculum removal in seeds recently extracted from the fruit with the application of gibberellic acid (plant growth regulator), because it increased the rate and accelerated germination. However, imbibition in aerated water (with H_2O_2) proved to be a viable process only when performed up to two days. The best method for seedlings production of swamp palm is the use of conventional bag (20×30 cm) with soil and manure or for producers with greater investment capacity, the use of tubes (180 cm^3) for two months and subsequent transplanting to a conventional bag with soil and manure until completing six months.

AUTHOR CONTRIBUTIONS

Conceptualization: Paim MS, Carvalho M, Coelho VPM; Analysis of results: Paim MS, Carvalho M, Moreira EFA, Paiva PEB, Bicalho EM, Coelho VPM; Statistical analysis: Moreira EFA; Writing original draft: Paim MS, Carvalho M, Moreira EFA, Paiva PEB, Bicalho EM, Coelho VPM; Writing-review and editing: Paim MS, Carvalho M, Paiva PEB; Supervision and coordination of research: Coelho VPM

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