Acta Scientiarum

http://www.uem.br/acta
ISSN printed: 1679-9275
ISSN on-line: 1807-8621
Doi: 10.4025/actasciagron.v36i1.13220

Dormancy breaking in macaw palm [*Acrocomia aculeata* (Jacq.) Loddiges ex Mart.] seeds

Aurélio Rubio Neto[1], Fabiano Guimarães Silva[2*], Juliana de Fátima Sales[2], Edésio Fialho dos Reis[3], Lailla Queiroz Silva[2] and Rafael Cândido Campos[2]

*[1]Cooperativa Mista dos Produtores Rurais do Sudoeste de Goiás Ltda., Rio Verde, Goiás, Brazil. [2]Instituto Federal Goiano, Rod. Sul Goiana, Km 1, Cx. Postal 66, 75901-970, Rio Verde, Goiás, Brazil. [3]Universidade Federal de Goiás, Jataí, Goiás, Brazil. *Author for correspondence. E-mail: fabianocefetrv@yahoo.com.br*

ABSTRACT. This study was performed to improve the speed of and standardize the process for the germination of macaw palm seeds. The effect of mechanical scarification (removal of the tegument in the hilum region), thermal scarification (imbibition of seeds in water at approximately 100°C for two or four minutes) and chemical scarification (98% sulfuric acid treatment for two or four minutes) were compared to a control (no scarification) in both a germination chamber and a greenhouse, representing trials one and two, respectively. The effect of imbibition speed (fast or slow) and different concentrations of gibberellic acid (0, 100 or 200 mg L^{-1}) on the germination percentage and index of germination velocity were evaluated during a third trial. Mechanical scarification to remove the seed tegument in the hilum region enhanced the germination of the seeds in the germination chamber and seedling emergence in the greenhouse, and this type of scarification should be recommended for breaking dormancy in this species. Not obtained increase in seed germination with gibberellic acid, regardless of the application form in the seeds.

Keywords: Arecaceae, germination, gibberellic acid.

Superação da dormência em sementes de macaúba [*Acrocomia aculeata* (Jacq.) Loddiges ex Mart.]

RESUMO. O trabalho foi realizado no Laboratório de Sementes do Instituto Federal Goiano Câmpus de Rio Verde, Estado de Goiás, visando acelerar e homogeneizar a germinação de sementes de macaúba. Para isso foi avaliado o efeito da escarificação física (remoção do tegumento na região do hilo), térmica (embebição das sementes em água aquecida a aproximadamente 100°C, por dois e quatro minutos) e química (ácido sulfúrico 98%, por dois e quatro minutos), comparadas ao controle (ausência de escarificação), bem como o efeito da forma de embebição (rápida e lenta) e diferentes concentrações do ácido giberélico (0, 100 e 200 mg L^{-1}) na porcentagem e velocidade de germinação. A mortalidade das sementes escarificadas e mantidas em germinador ocorrem em baixas porcentagens, porém em casa de vegetação esse número foi acima de 50% quando se utilizou a escarificação térmica em água quente e em ácido sulfúrico. A escarificação física, removendo o tegumento das sementes na região do hilo, favoreceu a germinação das sementes e a emergência das plântulas, sendo este o tipo de escarificação mais indicado para a superação da dormência nessa espécie. Não se obteve acréscimo na germinação das sementes com o ácido giberélico, independente da forma de aplicação nas sementes.

Palavras-chave: Arecaceae, germinação, ácido giberélico.

Introduction

The macaw palm [*Acrocomia aculeata* (Jacq.) Loddiges ex Mart.], which is also known as bocaiúva, coco de espinha, macaúva, marcová and mucajá, is a native palm tree in tropical forests. This plant can reach 10 to 15 meters in height and three to four meters in canopy diameter. Its leaves are pinnate with thorns in the rib and reach lengths of four to five meters. Its fruits are spherical or slightly flattened, having a globose drupes morphology that measure two to five cm in diameter and contain one to three seeds. The darkened endocarp is tightly adhered to the mesocarp. The nut is oily, edible and covered by a thin tegument layer (LORENZI, 1996; SILVA et al., 2001).

The stem of the plant can be used for poles and fences. The fleshy part of the fruit, which has a high vitamin content, can be used *in natura* or for medicinal and cosmetic purposes or edible oil extraction, which is a very common practice in tribes of native peoples. However, the most promising characteristics of the plant are related to the use of the oil extracted from its seeds and from the endocarp as charcoal for energy generation (ALMEIDA et al., 1998; LORENZI, 1996; NASCIMENTO et al., 2009).

The development of the basic structures involved in the germination process is highly unique in Arecaceae and can differ among species belonging to this family, as well as among other families (MARTINS-CORDER; SALDANHA, 2006). One of the major characteristics of palm trees is the variation in the number of days required to initiate the germination process; for example, the process requires 68 days in royal palm (*Archontophoenix alexandrae* H. Wendl. and Drude) seeds, 90 days in guariroba (*Syagrus oleracea* Becc.), 97 days in palm (*Euterpe edulis* Mart.) and 50 days in seeds of phoenix palm (*Phoenix roebelenii* O'Brien) (BOVI, 1990; CHARLO et al., 2006; IOSSI et al., 2007; NASCENTE et al., 2000).

In addition to genetic variability, other variables affect germination in this family, such as temperature, substrate and maturation stage. In general, temperature and substrate are analyzed jointly, and the best germination results for these species are obtained when seeds or diaspores are placed in a porous substrate, such as sand or vermiculite, at constant temperature of 25 to 30°C (IOSSI et al., 2003; PIVETTA et al., 2005, 2008; SILVA e SILVA et al., 2006). The maturation stage is usually evaluated based on the color of the epicarp, and positive results regarding the germination percentage have been produced when fruits are harvested in more advanced maturation stages (IOSSI et al., 2007).

Another characteristic of this family is related to the dormancy mechanism of several species, which causes germination to occur slowly and unevenly, as is seen for macaw palm. One of the most frequent dormancy types is associated with impermeability of the tegument (IOSSI et al., 2003; LORENZI; NEGRELLE, 2006; LUZ et al., 2008; PÉREZ et al., 2008). According to Ferreira and Gentil (2006), physical dormancy of seeds can be overcome by scarification, i.e., the use of treatments that improve water absorption.

Water absorption is essential for triggering the germination process. However, not only hydration but also the subsequent processes are restricted in some species for which the endocarp acts as a mechanical barrier and, consequently, affects seedling emergence, as has been observed for inaja (*Maximiliana regia* Mart.), *Butia capitata* (Mart.) and tucuma (*Astrocaryum aculeatum* Meyer) (FERREIRA; GENTIL, 2006; LOPES et al., 2011; MARTINS et al., 1996). Based on this premise, Ferreira and Gentil (2006) evaluated different periods of imbibition in water to improve the hydration of tucuma (*Astrocaryum aculeatum* Meyer) seeds. These authors obtained a significant increase in the germination percentage (70%) when seeds were imbibed for nine days, at which time they exhibited the greatest water content (30%). After this period, germination decreased until 15 days of imbibition, and the index of germination velocity behaved similarly to the trend for germination.

It is not only the physical dormancy imposed by the seed coat that increases the time required for the beginning of germination in this family but also the physiological dormancy, which is related to delayed germination due to physiological factors inherent in the embryo. Therefore, in addition to scarification treatments, methods such as soaking in water or even using chemical growth regulators may be effective for overcoming this type of dormancy and increasing germination in many species, as reported by Nagao et al. (1980), Odetola (1987) and Mora-Aguilar et al. (2003).

The use of chemical growth regulators are effective for overcoming dormancy because these growth regulators, such as gibberellic acid (GA_3), can increase seed germination due to impacts on hydrolysis control in the reserve tissues supplying energy for the embryo (TAIZ; ZEIGER, 2004). Cytokinin regulates the level of active inhibitors present in seeds under physiological dormancy, allowing them to become more sensitive to the action of GA_3 (PICOLOTTO et al., 2007). However, no increase in *Rhapis excelsa* (Thunberg) Henry ex. Rehder seed germination was observed after imbibition in cytokinins such as BAP (6-benzylaminopurine) at concentrations of 0 to 100 mg L^{-1} and gibberellic acid at concentrations of 0 to 300 mg L^{-1} (LUZ et al., 2008). The effects of chemical treatments vary depending on the concentration and duration of the treatment, as observed in seeds of *Areca triandra* (Roxb.) Ex Buch-Ham (YANG et al., 2007).

To our knowledge, no information regarding methods for increasing the speed of and standardizing the process for the germination of macaw palm seeds is available. Therefore, this study evaluated the effect of different types of scarification methods and the use of gibberellic acid to overcome seed dormancy in the macaw palm.

Material and methods

This study was performed using ripe fruits of macaw palm that were hand harvested in December 2009 in the county of Montes Claros de Goiás, Goiás

State, located at – 16º06'20" latitude, – 51º17'11" longitude and 459 meters above sea level (Figure 1A).

After manual collection, the water content in the seeds was evaluated according to Brasil (2009). The evaluation included employing the greenhouse method at 105 ± 3°C but using the constant mass of the seeds to calculate humidity, and four repetitions of 20 seeds was performed.

Based on previous studies, the remaining fruits were dried in a forced air oven at 37°C for six days (Figure 1B) to improve seed extraction. Subsequently, the moisture content of the seeds was determined again. The fruits were broken open with a 1.5-kg hammer on a concrete block. The extraction yield (number of seeds extracted.hour.man^{-1}) and the state of the extracted seeds were determined, classifying them as physically intact, visibly mechanically damaged, completely broken or adhered to the endocarp.

Trial 1. Germination of scarified seeds.

Physically intact seeds were used to determine the effects of mechanical, thermal and chemical scarification compared to the control (no scarification). Mechanical scarification was performed with a scalpel, removing the tegument in the hilum region (Figure 1C-1). Thermal scarification was carried out by imbibing the seeds in hot or cold water. For scarification in hot water, water preheated to 98°C was used. Scarification in cold water was performed at an initial temperature of 1.5°C for two or four minutes (Figure 1C-3). The thermal scarification temperature was monitored, but it was not held constant. Chemical scarification was carried out using treatment with concentrated (98%) sulfuric acid for two or four minutes, followed by rinsing the seeds three times for one minute each in distilled water (Figure 1C-2).

Figure 1. The harvesting, extraction, scarification and germination of macaw palm [*Acrocomia aculeata* (Jacq.) Loddiges ex Mart.] seeds and seeds that died. A) Manual harvesting; bar=0.5 m. B) Drying in oven at 37°C for 6 days; bar=30 cm. C) Mechanical scarification to remove the tegument in the hilum region (1), chemical scarification with concentrated sulfuric acid (2) and thermal scarification (3); bar=2 cm and beakers=600 mL. D) Germination and development of basic structures, such as shoots and primary roots, in seeds maintained in a germinator at 30ºC; bar=1.5 cm. E) Emergence of seedlings; bar=5 cm. F) Microorganism damage to seeds maintained in the greenhouse (1) and seeds maintained in a germinator at 30ºC (2); bar = 1 cm.

After these treatments, the seeds were germinated in rolls of germitest® paper pre-moistened with distilled water at 2.5 times the weight of the dry substrate and kept in a germinator at 30 ± 2°C. The index of germination velocity (IGV) and the germination percentage were evaluated daily until the germination process stabilized. Protrusion of the tip of the radicle was used as the criterion for germination. The IGV was calculated based on a daily count of the number of germinated seeds, applying the methodology described by Maguire (1962) (Figure 1D). In some seeds, the entire endosperm was consumed by microorganisms, and they became visibly hollow and brittle. In this case, the seeds were removed immediately, and the percentage of dead seeds was accounted for at the end the experiment.

Trial 2. Emergence of seedlings

This test was carried out in a greenhouse with an average daily temperature of 21.98°C in 300-cm^3 plastic containers filled with a substrate composed of vermiculite and carbonized rice hulls in a 1:1 proportion to evaluate the effects of the previously described treatments (scarifications) on the emergence and index of emergence velocity (IEV) of the seeds (Figure 1E). The emergence criterion adopted was development of the first leaf. The IEV was calculated using the formula proposed by Maguire (1962). During the 150 days of incubation, seeds in which the endosperm was consumed by microorganisms were considered to be dead and were removed from the substrate with tweezers (Figure 1F).

Trial 3. Effect of imbibition mode and gibberellic acid concentration on germination

Fruits and seeds were processed as previously described for seed removal to evaluate the effect of the imbibition mode (i.e., seeds submerged in gibberellic acid solution: quick imbibition, or seeds over germitest® paper: slow imbibition) and the concentration of gibberellic acid (0, 100 or 200 mg L^{-1}) applied.

The imbibition curve was produced using four samples of 15 seeds maintained under the same conditions as all other seeds. Samples were weighed every two hours during the first 24 hours, then every 12 hours until 48 hours of imbibition were completed. Samples were weighed after removal of excess water by blotting in paper towels, according to Pivetta et al. (2005).

The seeds were treated with fungicide [Active Ingredient (carboxin + thiram): 200 + 200 g L^{-1}] at a dose of 500 mL product per 100 kg of seeds or with 500 mL distilled water per 100 kg of seeds before sowing.

At the end of the first and second trials, non-germinated seeds were classified as dormant, and the experimental design was completely randomized.

A total of 8 treatments were employed, consisting of no scarification, chemical scarification, thermal scarification in hot and cold water for two or four minutes and mechanical scarification with four replications of 20 seeds being used for each treatment.

In the third trial, a completely randomized factorial experimental design was used with 2 imbibition modes (quick and slow) x 3 gibberellic acid concentrations (0, 100 and 200 mg L^{-1}) and four replications of 20 seeds being used for each treatment.

All data (trials one, two and three) were subjected to analysis of variance and an F-test using the SISVAR® software (FERREIRA, 2003), and the averages were compared by the Fisher test at a 5% probability.

Results and discussion

Trial 1. Germination of scarified seeds

Drying the harvested fruits for six days in a forced air oven at 37°C reduced the seed water contents from to 26.8 to 25.7%, making seed extraction easier. In general, the seed water content in palm trees is high at the time of harvesting, as reported by Charlo et al. (2006) for royal palm [*Archontophoenix alexandrae* (f. Mueller) h. Wendl. E Drude], with a water content as high as 36.8%; Martins-Corder and Saldanha (2006) in edible palm (*Euterpe edulis* Mart.), with a 42.0% water content; and Yang et al. (2007) for areca palm [*Areca tiandra* (Roxb.) ex Buch-Ham] with a 40.6% water content. However, moisture cannot be reduced below certain levels because of the negative correlation between drying and the germination of palm seeds. There is no available information in the literature regarding the physiological behavior of macaw palm when subjected to critical levels of moisture (PIVETTA et al., 2005).

After breaking the endocarp, 49.0% of the seeds were extracted with no visible damage (physically whole), 22.6% of the seeds were extracted with some visible damage and 12.2% of the seeds were broken, while 16.2% of the seeds remained adhered to the endocarp. The yield of intact seeds was 584 seeds extracted/hour/man. According to Ferreira and Gentil (2006), removal of the rigid endocarp from palm seeds is always associated with the risk of damaging the endosperm and the embryo; therefore, this process should be studied for each species.

Tegument removal in the hilum region resulted in higher values germination (64%) and vigor (IGV) (1.92) (Table 1), and the results of this treatment differed from those of all other types of scarification.

The obtained germination percentages were 20 and 23% for two and four minutes of chemical scarification, respectively. These values were similar to those for the untreated control and lower than the values associated with tegument removal (Table 1). Dewir et al. (2011) observed the highest percentages of germination in seeds of *Sabal palmetto* following chemical scarification using sulfuric acid for seeds with an intact tegument and using 500 ppm gibberellic acid for seeds without a tegument.

It was observed that the results of thermal scarification in either cold or hot water did not differ from those of the untreated control, and these treatments resulted in the lowest percentages and speed of germination in comparison with mechanical scarification (tegument removal in the hilum region). Similar findings were obtained for Bamboo palm seeds (*Rhapis excelsa* (Thunberg) Henry ex. Rehder), in which thermal scarification did not improve seed germination (LUZ et al., 2008).

Table 1. Percentages of germination, dormant seeds and dead seeds and the IGV for macaw palm [*Acrocomia aculeata* (Jacq.) Loddiges ex Mart.] subjected to different types of scarification.

Treatment	(%) Seed germination	Dormant seeds (%)	Dead seeds (%)	IGV
Tegument removal	63.8 A[1] ± 5.91[2]	33.8 A ± 6.57	2.5 AB ± 1.44	1.92 A ± 0.18
Water (98-57.6ºC) 2'	0.0 D ± 1.44	95.0 D ± 2.04	5.0 AB ± 2.04	0.01 C ± 0.01
Water (98-56.0ºC) 4'	2.5 D ± 2.04	76.2 BCD ± 5.15	21.2 B ± 4.27	0.04 C ± 0.01
Water (1.5-3.0ºC) 2'	1.5 D ± 1.44	91.2 CD ± 4.27	7.5 AB ± 3.23	0.03 C ± 0.02
Water (1.5-3.0ºC) 4'	5.0 CD ± 2.09	90.0 CD ± 3.53	5.0 AB ± 0.81	0.07 BC ± 0.02
Sulfuric ac. 2'	20.0 BC ± 7.36	71.2 BC ± 4.27	8.8 AB ± 4.27	0.41 B ± 0.10
Sulfuric ac. 4'	22.5 B ± 0.35	65.0 B ± 7.90	12.5 AB ± 8.29	0.40 B ± 0.06
Control (no scarification)	7.5 BCD ± 3.75	92.5 CD ± 3.28	0.0 A ± 0.00	0.09 BC ± 0.04

[1]Averages followed by the same letter in a column do not differ by the Tukey test at a 5% probability. [2]± standard error of the mean.

The lowest percentage of dormant seeds was associated with the tegument removal treatment (34%), followed by chemical scarification in sulfuric acid for two (71.2%) or four minutes (65%) and, finally, by thermal scarification in hot water for four minutes (76.2%).

Scarification in hot water for two or four minutes resulted in low germination velocity indices (0.01 and 0.04, respectively) and germination percentages (0.0 and 2.5%, respectively), with no differences between the two treatments. Similar results were observed for thermal scarification in cold water for the same time periods, after which the germination rates were 1.5 and 5.0% and the germination velocity indices were 0.03 and 0.07, respectively. There was no difference between these variables for the times and temperatures evaluated.

Dead seeds were observed in all of the treatments, except for the control, and hot water scarification for four minutes resulted in the highest percentage of dead seeds (21.2%). This mortality can be explained by the fact that all of the treatments caused damage to the seed tegument to different degrees, thus favoring attacks by microorganisms.

Trial 2. Emergence of seedlings

Results similar to those obtained for germination speed and percentage were found for emergence percentage and speed (IEV), but in lower proportions for all scarification processes. Higher values for speed and emergence percentage were obtained following seed tegument removal in the hilum region, with values of 1.92 and 45.0% being observed for these parameters, respectively, which differed from all other scarification treatments, as has been seen in Bamboo palm [*Rhapis excels* (Thunberg) Henry ex. Rehder] and Pindo palm seeds [*Butia capitata* (Mart.) Becc.] (LUZ et al., 2008; FIOR et al., 2011) (Table 2).

The lowest percentages of dormant seeds were obtained following removal of the tegument in the hilum region (45.0%), scarification in hot water for two minutes (42.5%) and chemical scarification for four minutes (36.2%), which differed from other forms of scarification. With respect to the percentage of dead seeds, the highest values were found after thermal scarification in hot water for two minutes (57.5%) and chemical scarification for four minutes (61.2%), which differed from the other scarification methods. In accord with what was reported by Ferreira and Gentil (2006), we observed high percentages of dead seeds in the this study; this finding may be related to the seed extraction process, which results in damage to the tegument and favors attacks from microorganisms.

Although tegument removal was associated with the highest emergence percentage and velocity and the lowest percentage of dead seeds, the resultant percentage of dormant seeds was also high, indicating that another type of dormancy was likely occurring.

Seedling emergence from seeds scarified by tegument removal occurred at approximately 55 days after sowing, while those scarified in sulfuric acid for two or four minutes or in cold water for two or four minutes occurred at approximately 63 days (Figure 2A).

Table 2. Seedling emergence, dormant seeds, dead seeds and IEV of macaw palm [*Acrocomia aculeata* (Jacq.) Loddiges ex Mart.] subjected to different types of scarification.

Treatment	Seedling emergence (%)	Dormant seeds (%)	Dead seeds (%)	IEV
Tegument removal	45.0 A[1] ± 9.78[2]	45.0 A ± 6.12	10.0 A ± 0.82	0.16 A ± 0.04
Water (98-56°C) 2'	0.0 B ± 0.00	42.5 A ± 11.09	57.5 B ± 2.22	0.00 B ± 0.00
Water (98-54.5°C)4'	0.0 B ± 0.00	82.5 B ± 5.95	17.5 A ± 1.19	0.00 B ± 0.00
Water (1.5-5.0°C) 2'	3.8 B ± 2.40	86.2 B ± 2.39	10.0 A ± 0.41	0.01 B ± 0.01
Water (1.5-5.5°C) 4'	5.0 B ± 3.53	87.5 B ± 4.33	7.50 A ± 0.29	0.07 B ± 0.01
Sulfuric ac. for 2'	7.5 B ± 1.44	76.2 B ± 4.27	16.2 A ± 0.75	0.02 B ± 0.01
Sulfuric ac. for 4'	2.5 B ± 1.44	36.2 A ± 4.46	61.2 B ± 1.65	0.01 B ± 0.01
Control (no scarification)	10.0 B ± 5.00	86.2 B ± 5.54	3.8 A ± 0.25	0.03 B ± 0.02

[1]Averages followed by the same letter in a column do not differ by the Tukey test at a 5% probability. [2]± standard error of the mean.

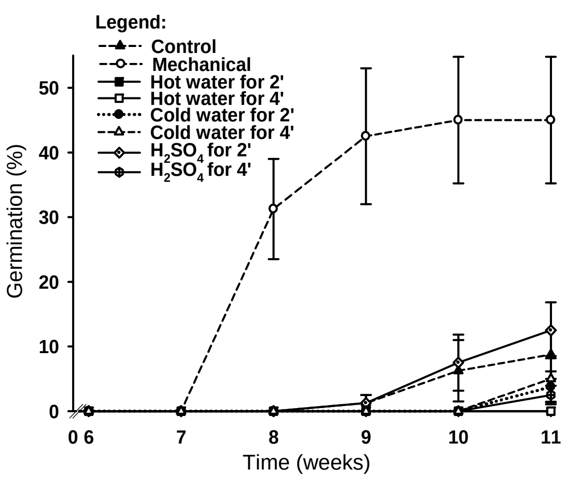

Figure 2. Cumulative emergence of macaw palm [*Acrocomia aculeata* (Jacq.) Loddiges ex Mart.] seedlings obtained from seeds subjected to different types of scarification. Legend: control - no scarification; mechanical - tegument removal in the hilum region; hot water for 2 and 4' - thermal scarification in hot water (98°C) for two and four minutes; cold water for 2 and 4' - scarification in cold water (1.5°C) for two and four minutes; H_2SO_4 for 2 and 4' - chemical scarification in concentrated sulfuric acid for two and four minutes. Error bars = standard error of the mean.

In accord with the findings of this study, the removal of the tegument also produced satisfactory results with respect to the emergence of Bamboo palm seedlings [*Rapis excelsa* (Thunberg) Henry ex. Rehder], with this treatment producing better results than seed imbibition and chemical scarification for two minutes (LUZ et al., 2008). Similar results were reported by Yang et al. (2007), who found that mechanical scarification favored the germination of seeds of *Areca triandra* (Roxb) ex Buch-Ham. and was superior to chemical scarification with sulfuric acid, which had a deleterious effect on germination percentage and speed.

In contrast to the findings of this study, mechanical and chemical scarification were not found to influence germination for the Inaja palm (*Maximiliana regia* Mart.), (MARTINS et al., 1996) indicating that the scarification methods that are effective for breaking dormancy in this family vary among the species that exhibit dormancy. However, a positive effect of mechanical scarification is commonly observed with the seeds of different species in this taxonomic group.

Trial 3. Effect of imbibition mode and gibberellic acid concentration on germination.

No interaction between the different modes of application and times of imbibition with gibberellic acid was observed, and thus, these factors were treated separately. Seeds that imbibed quickly took in 4.93 g of water in only four hours of imbibition, with their weight gains subsequently stabilizing at 48 hours. In contrast, for the slow imbibition process, the total observed weight gain was only 0.9 g. Although there was a difference of 2 g between the initial average masses of the samples of 20 seeds used to evaluate slow versus quick imbibition, this did not affect the evaluation of the imbibition curve because weight gain was measured based on water absorption and the length of time, with the initial mass of the seeds being subtracted from the final mass (Figure 3).

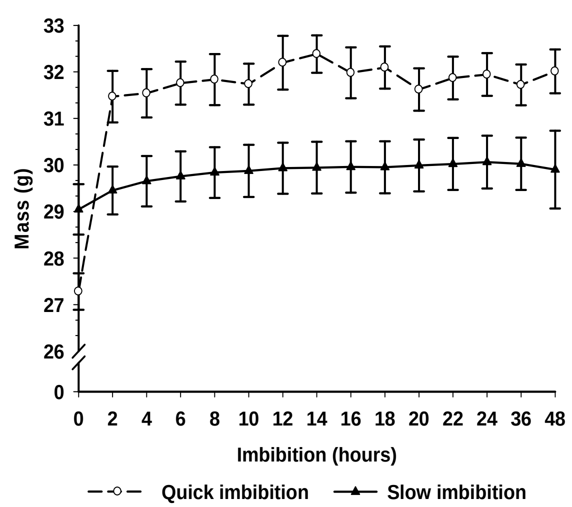

Figure 3. Imbibition curve for macaw palm [*Acrocomia aculeata* (Jacq.) Loddiges ex Mart.] seeds subjected to different imbibition modes and times. Error bar = standard error of the mean.

The germination percentage varied between 2.50 and 17.50%, and the IGV varied between 0.01 and 0.19. Higher values were observed in seeds that imbibed slowly in 100 mg L-1 gibberellic acid, which also presented the lowest percentage of dormant seeds (48.75%). In contrast, seeds that imbibed quickly showed no differences between the concentrations analyzed for any of the investigated characteristics. Germination began 13 days after the initiation of the experiments, and a maximum value of 17.50% germination was observed in the treatment employing slow imbibition in 100 mg L^{-1} gibberellic acid after 90 days (Table 3). The percentage of dead seeds varied from 12.5 to 50.0%; thus, this value was high for this entire experiment, as there was no significant difference between imbibition modes and gibberellic acid concentrations for this parameter.

Table 3. Percentages of germination, dormant seeds and dead seeds and the IGV for macaw palm [*Acrocomia aculeata* (Jacq.) Loddiges ex Mart.] seeds subjected to different imbibition modes and concentrations of gibberellic acid.

	Types of imbibition		
	Quick	Slow	Average
Gibberellic ac. (mg L^{-1})	Germination (%)		
0	6.25 ± 2.39[1]	2.50 ± 1.44	4.38 B[2]
100	6.25 ± 2.39	17.50 ± 3.23	11.9 A
200	6.25 ± 2.40	5.00 ± 2.04	5.62 B
Average	6.25 a	8.33 a	
	Dormant (%)		
0	62.50 ± 5.54	85.00 ± 5.15	73.75 B
100	43.75 ± 3.22	53.75 ± 2.04	48.75 A
200	63.75 ± 4.27	78.75 ± 3.75	71.25 B
Average	56.67 a	72.50 b	
	Dead (%)		
0	31.25 ± 5.54	12.50 ± 1.44	21.88 A
100	50.00 ± 2.04	28.75 ± 3.53	23.12 A
200	30.00 ± 7.35	16.25 ± 5.15	39.38 A
Average	37.08 a	19.17 b	
	IGV		
0	0.05 ± 0.03	0.01 ± 0.02	0.03 B
100	0.05 ± 0.04	0.19 ± 0.01	0.12 A
200	0.06 ± 0.04	0.07± 0.02	0,07 AB
Average	0.056 a	0.088 a	

[1]± Standard error of the mean. [2]Averages followed by the same upper case letter in a column and lowercase letter in a row do not differ by the Tukey test at a 5% probability.

As no substantial difference was found with respect to germination percentage when we separately evaluated seeds exposed to different modes of application and concentrations of gibberellic acid, future studies should address the interaction of gibberellic acid with mechanical scarification. Our result most likely occurred due to the tegument preventing the absorption of gibberellic acid by the embryo, in addition to the positive effect that this type of scarification has on this species. Therefore, higher germination and emergence percentages should be expected if these treatments are combined.

Similar results were obtained by Luz et al. (2008), who found no effect of different concentrations of various growth-regulating substances on the germination percentage obtained for raffia palm (*Rapis excelsa* Thunberg Henry ex. Rehder).

According to the results obtained in this study, future studies should be undertaken to develop more efficient techniques for seed extraction to increase extraction yields and concurrently reduce damage caused to the tegument, including investigation of the germination of scarified seeds treated with gibberellic acid in different concentrations.

Conclusion

To overcome dormancy in macaw palm seeds, mechanical scarification involving removal of the tegument in the hilum region is recommended.

Treatment with gibberellic acid not increased germination in seeds without scarification, independent of the application mode.

References

ALMEIDA, S. P.; PROENÇA C. E. B.; SANO, M.; RIBEIRO, J. F. **Cerrado**: espécies de vegetais úteis. Planaltin: Embrapa/CPAC, 1998.

BOVI, M. L. A. Pré-embebição em água e porcentagem e velocidade de emergência de sementes de palmiteiro. **Bragantia**, v. 49, n. 1, p. 11-22, 1990.

BRASIL. Ministério da Agricultura e Reforma Agrária. **Regras para análise de sementes**. Brasília: MAPA/ACS, 2009.

CHARLO, A. C. O.; MÔRO; F. V.; SILVA, V. L.; SILVA E SILVA, B. M.; BIANCO, S.; MÔRO, J. R. Aspectos morfológicos, germinação e desenvolvimento inicial de plântulas de *Archontophoenix alexandrae* (f. Mueller) h. Wendl. e Drude (Arecaceae) em diferentes substratos. **Revista Árvore**, v. 30, n. 6, p. 933-940, 2006.

DEWIR, Y. H.; EL-MAHROUK, M. E. S.; NAIDOO, Y. Effects of some mechanical and chemical treatments on seed germination of Sabal palmetto and *Thrinax morrisii* palms. **Australian Journal of Crop Science**, v. 5, n. 3, p. 248-253, 2011.

FIOR, C. S.; RODRIGUES, L. R.; LEONHARDT, C.; SCHWARZ, S. F. Superação de dormência em sementes de *Butia capitata*. **Ciência Rural**, v. 41, n. 7, p. 1150-1153, 2011.

FERREIRA, D. F. **Programa de análises estatísticas (Statistical Analysis Software) e planejamento de experimentos**. Lavras: Universidade Federal de Lavras, 2003.

FERREIRA, S. A. N.; GENTIL, D. F. O. Extração, embebição e germinação de sementes de tucumã (*Astrocaryum aculeatum*). **Acta Amazônica**, v. 36, n. 2, p. 141–146, 2006.

IOSSI, E.; SADER, R.; MORO, F. V.; BARBOSA, J. C. Maturação fisiológica de sementes de *Phoenix roebelenii* O'Brien. **Revista Brasileira de Sementes**, v. 29, n. 1, p. 147-154, 2007.

IOSSI, E.; SADER, R.; PIVETTA, K. F. L.; BARBOSA, J. C. Efeitos de substratos e temperaturas na germinação de sementes de tamareira-anã (*Phoenix roebelenii* O'Brien). **Revista Brasileira de Sementes**, v. 25, n. 2, p. 63-69, 2003.

LOPES, P. S. N.; AQUINO, C. F.; MAGALHÃES, H. M.; BRANDÃO JÚNIOR, D. S. Tratamentos físicos e químicos para superação de dormência em sementes de *Butia capitata* (Martius) Beccari. **Pesquisa Agropecuária Tropical**, v. 41, n. 1, p. 120-125, 2011.

LORENZI, H. **Palmeiras no Brasil**: exóticas e nativas. Nova Odessa: Plantarum, 1996.

LORENZI, G. M. A. C.; NEGRELLE, R. R. B. *Acrocomia aculeata* (Jacq.) Lodd. ex Mart.: Aspectos ecológicos, usos e potencialidades. **Visão Acadêmica**, v. 7, n. 2, p. 1-12, 2006.

LUZ, P. B.; TAVARES, A. R.; PAIVA, P. D. O.; AGUIAR, F. F. A.; KANASHIRO, S. Germinação de sementes de palmeira-ráfia: efeito de tratamentos pré-germinativos. **Revista Árvore**, v. 32, n. 5, p. 793-798, 2008.

MAGUIRE, J. D. Speed of germination-aid in selection and evaluation for seedling emergence and vigor. **Crop Science**, v. 2, n. 2, p. 176-177, 1962.

MARTINS-CORDER, M. P.; SALDANHA, C. W. Germinação de sementes e crescimento de plântulas de diferentes progênies de *Euterpe edulis* Mart. **Revista Árvore**, v. 30, n. 5, p. 693-699, 2006.

MARTINS, C. C.; SILVA, W. R.; BOVI, M. L. A. Tratamentos pré-germinativos de sementes da palmeira inajá. **Bragantia**, v. 55, n. 1, p. 123-128, 1996.

MORA-AGUILAR, R.; RODRÍGUEZ-PÉREZ, J. E.; PEÑA-LOMELÍ, A.; RAMÍREZ-LAZO, V. Response of *Chamaedorea elegans* Mart. to pregermination treatments. **Revista Chapingo Serie Horticultura**, v. 9, n. 1, p. 135-149, 2003.

NAGAO, M. A.; KANEGAWA, K.; SAKAI, W. S. Accelerating palm seed germination with gibberelic acid, scarification and bottom heat. **HortScience**, v. 15. n. 2, p. 200-201, 1980.

NASCIMENTO, A. R. T.; SANTOS, A. A.; MARTINS, R. C.; DIAS, T. A. B. Comunidade de palmeiras no território indígena Krahò, Tocantins, Brasil: biodiversidade e aspectos etnobotânicos. **Interciencia**, v. 34, n. 3, p. 182-188, 2009.

NASCENTE, A. S.; PEIXOTO, N.; SANTOS, C. W. F. Peso de sementes e emergência de plântulas de guariroba (*Syagrus oleracea* Becc). **Pesquisa Agropecuária Tropical**, v. 30, n. 2, p. 77-79, 2000.

ODETOLA, J. A. Studies on seed dormancy, viability and germination in ornamental palms. **Principes**, v. 31, n. 1, p. 24-31, 1987.

PICOLOTTO, L.; BIANCHI, V. J.; FACHINELLO, J. C. Ação de giberelinas e citocininas na germinação de sementes de pessegueiro. **Scientia Agraria**, v. 8, n. 3, p. 225-232, 2007.

PÉREZ, H. E.; CRILEY, R. A.; BASKIN, C. C. Promoting germination in dormant seeds of *Pritchardia remota* (Kuntze) Beck., an endangered palm endemic to Hawaii. **Natural Areas Journal**, v. 28, n. 3, p. 251-260, 2008.

PIVETTA, K. F. L.; CASALI, L. P.; CINTRA, G. S.; PEDRINHO, D. R.; PIZETTA, P. U. C.; PIMENTA, R. S.; PENARIOL, A. P.; MATTIUZ, C. F. M. Efeito da temperatura e do armazenamento na germinação de sementes de *Thrinax parviflora* swartz (Arecaceae). **Científica**, v. 33, n. 2, p. 179-184, 2005.

PIVETTA, K. F. L.; SARZI, I.; ESTELLITA, M.; BECKMANN-CAVALCANTE, M. Z. Tamanho do diásporo, substrato e temperatura na germinação de sementes de *Archontophoenix cunninghamii* (Arecaceae). **Revista de Biologia e Ciências da Terra**, v. 8, n. 1, p. 126-134, 2008.

SILVA E SILVA, B. M.; CESARINO, F.; LIMA, J. D.; PANTOJA, T. F.; MÔRO, F. V. Germinação de sementes e emergência de plântulas de *Oenocarpus minor* Mart. (Arecaceae). **Revista Brasileira de Fruticultura**, v. 28, n. 2, p. 289-292, 2006.

SILVA, D. B.; SILVA, A. S.; JUNQUEIRA, N. T. V.; ANDREADE, L. R. M. **Frutas do cerrado**. Brasília: Embrapa Informação Tecnológica, 2001.

TAIZ, L.; ZEIGER, E. **Fisiologia vegetal**. 3. ed. Porto Alegre: Artmed, 2004.

YANG, Q. H.; YE, W. H.; YIN, X. J. Dormancy and germination of *Areca triandra* seeds. **Scientia Horticulturae**, v. 113, n. 1, p. 107-111, 2007.

Received on April 22, 2011.
Accepted on October 21, 2011.