**Scientific Article**

# GERMINATION AND POST-SEMINAL DEVELOPMENT OF *Astrocaryum murumuru* MART. PROGENIES

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ABSTRACT – *Astrocaryum murumuru* is a palm tree whose seeds have been exploited in an extractive way by traditional populations in the Amazon, providing raw material to the cosmetic industry, with lack of information about its propagation. Thus, the aim of this study was to characterize seeds, germination, and seedling development of different *A. murumuru* progenies. Seeds from six racemes from different plants were used, which were physically characterized and sown in a completely randomized design, with six treatments (progenies) and four replicates. Description, illustration, and quantification of the mean time of the different seedling stages were performed. On average, the diameter, length, and mass of soaked seeds were 17.1 ± 1.2 mm, 28.4 ± 5.8 mm, and 3.3 ± 0.6 g, respectively. *A. murumuru* germination is of adjacent type, with the cotyledon sheath developing next to the seed. Seedling development took an average of 46 ± 28 days to reach the germinative bud stage and 225 ± 38 days to reach the third expanded eophyll stage. The emergence of the first cataphyll (normal seedling) ranged from 12 to 73% among progenies, which occurred in an average time of 73 ± 29 days. There is a need to improve the processing of *A. murumuru* seeds aiming to reduce seed loss during this process, as well as studies on seed dormancy. Progenies showed variation regarding the physical and physiological characteristics of seeds and seedlings. Germination and seedling development can be considered slow, with variable times among progenies.

Keywords: Arecaceae; Seed; Seedling.

# *GERMINAÇÃO E DESENVOLVIMENTO PÓS-SEMINAL DE PROGÊNIES DE* Astrocaryum murumuru *MART.*

*RESUMO –* ***Astrocaryum murumuru*** *é uma palmeira cujas sementes têm sido exploradas extrativamente por populações tradicionais da Amazônia, fornecendo matéria prima à indústria de cosméticos, com carência de informações sobre a sua propagação. Assim, objetivou-se caracterizar a semente, a germinação e o desenvolvimento da plântula de diferentes progênies de* ***A. murumuru****. Foram utilizadas sementes de seis racemos de plantas distintas. Essas foram caracterizadas fisicamente e semeadas em delineamento inteiramente ao acaso, com seis tratamentos (progênies) e quatro repetições. Foram feitas a descrição, a ilustração e a quantificação do tempo médio dos diferentes estádios da plântula. Em média, o diâmetro, o comprimento e a massa de sementes embebidas foram 17,1 ± 1,2 mm, 28,4 ± 5,8 mm e 3,3 ± 0,6 g, respectivamente. A germinação de* ***A. murumuru*** *é do tipo adjacente, com a bainha cotiledonar se desenvolvendo junto à semente. O desenvolvimento da plântula levou em média 46 ± 28 dias para atingir o estádio de botão germinativo e 225 ± 38 dias para alcançar a fase de terceiro eofilo expandido. A emergência do primeiro catafilo (plântula normal) variou de 12 a 73% entre as progênies, com tempo de médio de 73 ± 29 dias. Observou-se a necessidade de aperfeiçoamento do beneficiamento das sementes de* ***A. murumuru****, visando diminuir as perdas de sementes durante o processo, bem como de estudos sobre a dormência das sementes. As progênies apresentaram variação quanto às características fisicas e fisiológicas das sementes e plântulas. A germinação e o desenvolvimento da plântula podem ser considerados lentos, com tempo variável entre as progênies.*

*Palavras-Chave: Arecaceae; Semente; Plântula.*

## 1. INTRODUCTION

In the Amazon, palm trees (Arecaceae family) constitute a group of species of great importance for traditional populations, as well as for wild fauna. In addition to serving as food sources for both humans and animals, they are used in building houses, for making handicrafts and as a source of raw material for the industrial sector (Henderson et al., 1995). Among these species, *Astrocaryum murumuru* Mart. stands out, being widely distributed in the region, usually found along riverbanks or in periodically flooded areas, although occasionally occurring at 900 m altitude, on slopes of the eastern Andes (Henderson et al., 1995). Frequently, it has hyperdominance, reaching 325 plants per hectare (Steege et al., 2013), which favors extractivism due to the logistical ease for fruit collection (Cruz et al., 2017). Its seeds have great potential for use in the cosmetic, food, emulsifier, soap, surfactant, and biodiesel industries, due to their high content of fatty acids, especially lauric (55%) and myristic (31%) acids (Almeida et al., 2008).

*A. murumuru* seeds have been exploited in an extractive way by some communities in the Amazon, mainly aiming to meet the demands of the cosmetic industry (Costa and Simões, 2013; Vidal et al., 2021). This activity has been considered important for being a complementary alternative to income for these communities, in addition to favoring the conservation of the species and/or local biodiversity (Costa and Simões, 2013). Although extracted products are well accepted in the market, it is necessary to improve processing techniques to reduce losses that occur during the oil extraction process (Cruz et al., 2017). In addition, the production seasonality and the high cost of distribution logistics make it difficult to estimate the amounts of oil to be produced and, therefore, the meeting of demands (Vidal et al., 2021).

The continuous exploitation of certain plant species allows the accumulation of knowledge about them, making extractors to have specific management practices for each species under exploitation (Silva and Miguel, 2014). In addition, scientific research can contribute to increasing the degree of domestication of species through the development of sustainable agricultural practices, with the cultural appreciation of local communities, maintenance of current markets and the possibility of the emergence of new ones (Chaves et al. al., 2021).

Amazonian palms, with the exception, for example, of *Euterpe oleracea* Mart. (Chaves et al., 2021), have received little attention regarding management, selection, and breeding, which could boost the cultivation of these species. Most of the time, studies have addressed botanical aspects such as systematics, reproductive biology, economic uses, and biogeography (Henderson, 2006).

The germination of palm seeds has peculiar morphological and physiological characteristics, varying extremely among species (Henderson, 2006). Normally, in species of the genus *Astrocaryum*, germination is delayed and may take more than a year, as observed in *Astrocaryum aculeatum* G. Mey. and *Astrocaryum vulgare* Mart. seeds (Koebernik, 1971). In *Astrocaryum acaule* Mart., germinative bud formation occurs, on average, at 113 days, with minimum and maximum time of 14 and 250 days, respectively (Corrêa et al., 2019). The removal of the endocarp, followed by imbibition and stratification at alternating temperature (26-40 ºC), favors the germination of *A. aculeatum* seeds (Ferreira et al., 2021). Baskin and Baskin (2014) observed that the seeds of most palm trees have morphophysiological type dormancy or are morphologically dormant, something that needs to be proven for Amazonian species.

Knowledge about seedling development can support the determination of laboratory analysis protocols for evaluating the physiological quality of seeds (Brasil, 2009), as well as the definition of techniques for the cultivation of seedlings for planting. The different development stages of palm seedlings can contribute to the identification of species in ecological studies on natural regeneration (Latifah et al., 2016). In some species of the genus *Astrocaryum*, seedling development has already been described, as in *A. aculeatum* (Gentil and Ferreira, 2005) and in *A. acaule* (Corrêa et al., 2019). It is important to emphasize that for *A. murumuru*, there is lack of information about germination, seedling development and seedling production, and growth and establishment of adult plants (productive phase) in the field. Thus, the investigation of these processes can help a better understanding of this species.

Given the above, this work aimed to characterize seeds and germination, as well as the development of seedlings of different *A. murumuru* progenies.

## 2. MATERIAL AND METHODS

### 2.1. Seed origin and research location

*A. murumuru* seeds were obtained from ripe fruits (at the beginning of natural dispersion) from six racemes of different plants, chosen at random, collected at the Várzea Forest (Gleysoil), Butija Island (3º57'16.45"S and 62º53'37.64"W), municipality of Coari, Amazonas, Brazil. The climate of the region is Am type – no dry season. The research was carried out at the Laboratory of Seeds and greenhouse of the Biodiversity Coordination (COBIO), National Institute for Amazon Research (INPA), Campus III, Manaus, state of Amazonas, Brazil.

### 2.2. Seed processing and soaking

Initially, fruits of the different racemes and plants, henceforth considered progenies (P1, P2, P3, P4, P5 and P6), were soaked in water for three days. During this period, water was daily changed to facilitate the removal of part of the pericarp (epicarp and mesocarp). After manual squashing and discard of this portion, the cleaning of diaspores (seed with endocarp) was completed by scraping the endocarp with a knife, rubbing in sand, and washing in running water. Then, diaspores were placed in "net type" plastic bags and placed to dry in room with natural air circulation (temperature varying between 26 and 29 ºC and average relative humidity of 80%) for 30 days, during which, seeds detached from the endocarp. Subsequently, diaspore mass was determined, and the endocarp was broken for seed extraction, adopting procedures like those used in *A. aculeatum* seeds (Ferreira and Gentil, 2006).

The seeds of each progeny that suffered any apparent mechanical damage during extraction were recorded and discarded. Before sowing, seeds were soaked in water for nine days, with daily water change, as recommended for *A. aculeatum* seeds (Ferreira and Gentil, 2006). The moisture content of seeds (Brasil, 2009) was determined before and after soaking, using two replicates of five seeds each, per progeny. Subsequently, the diameter, length, and mass of 25 soaked seeds of each progeny were measured, and the number of seeds per kilogram (kg) was determined.

### 2.3. Seedling emergence

Using soaked seeds, the experiment was installed in a completely randomized design, with six treatments (progenies) and four replicates, each containing 25 seeds. Sowing was carried out in drained plastic boxes (40 x 60 x 20 cm), containing medium texture vermiculite, and kept in greenhouse (minimum and maximum average temperatures of 25.2 and 40.8 ºC, respectively).

Emergence was evaluated every five days for 195 days, considering the appearance of the first cataphyll as a criterion for normal seedling. From these data, in percentage, the emergence speed index and the mean time of emergence were calculated (Ranal and Santana, 2006). At the end of the experiment (195 days after sowing), through the cut test (Brasil, 2009), dead seeds (fully rotten or with only rotten embryo) and dormant seeds (without rotting and firm embryo with white-milky color) were identified. In addition, seeds that had germinated, although without reaching the first cataphyll stage, were recorded at the germinative bud stage.

Prior to the analysis of variance of data, values in percentages were transformed into arcsine $\sqrt{(x/100)}$, or $\sqrt{[(x+0.5)/100]}$, when there was zero between values. Treatment averages were compared using the Tukey test at 5% probability level. Data referring to the physical characteristics of seeds were analyzed using descriptive statistics.

### 2.4. Seedling development

Seedling development was evaluated using a replicate of 25 seeds from each progeny of the test described above, resulting in 150 seeds. Every five days, the following seedling stages were observed: germinative bud (gb); first cataphyll (1c); second cataphyll (2c); emission of the first eophyll (e1); first expanded eophyll (1e); emission of the second eophyll (e2); second expanded eophyll (2e); emission of the third eophyll (e3); and third expanded eophyll (3e). For these variables, boxplots showing average, median, quartiles, extremes and outliers were constructed.

A mixture of 80 seeds from different progenies was sown separately to assist in the morphological description of developing seedlings. As the different development stages were reached, seedlings were separated, fixed in FAA 50 (formaldehyde, glacial acetic acid, and ethanol) and maintained in 70% alcohol. The manual illustration of seedlings was

**Table 1 –** Seeds damaged in the extraction process (SDE), dry seed mass/diaspore mass ratio (SDR), moisture content of dry seeds (MCDS), moisture content of soaked seeds (MCSS), diameter of soaked seeds (DSS), length of soaked seeds (LSS), mass of soaked seeds (MSS) and number per kilogram of soaked seeds (NKSS), referring to *Astrocaryum murumuru* progenies from Coari, AM, Brazil.
***Tabela 1** – Sementes danificadas no processo de extração (SDE), razão entre as massas da semente e do diásporo secos (SDR), grau de umidade das sementes secas (MCDS), grau de umidade das sementes embebidas (MCSS), diâmetro (DSS), comprimento (LSS), massa (MSS) e número por quilograma de sementes embebidas (NKSS), referentes a progênies de **Astrocaryum murumuru**, provenientes de Coari, AM, Brasil.*

| Progeny | SDE(%) | SDR | MCDS(%) | MCSS(%) | DSS(mm) | LSS(mm) | MSS(g) | NKSS |
|---|---|---|---|---|---|---|---|---|
| P1 | 1.1 | 0.50 | 14.8 | 24.4 | 18.0 | 28.3 | 3.9 | 256 |
| P2 | 15.7 | 0.32 | 16.1 | 31.5 | 16.8 | 39.0 | 3.9 | 271 |
| P3 | 2.5 | 0.31 | 11.9 | 25.7 | 15.2 | 27.3 | 2.5 | 415 |
| P4 | 1.7 | 0.32 | 16.0 | 26.8 | 18.2 | 22.5 | 3.4 | 429 |
| P5 | 7.9 | 0.38 | 17.1 | 27.0 | 17.9 | 29.1 | 3.5 | 275 |
| P6 | 2.2 | 0.37 | 13.6 | 25.3 | 16.4 | 24.3 | 2.8 | 377 |
| Average | 5.2 | 0.37 | 14.9 | 26.8 | 17.1 | 28.4 | 3.3 | 337 |
| SD | 5.7 | 0.07 | 1.9 | 2.5 | 1.2 | 5.8 | 0.6 | 79 |

SD – standard deviation.
*SD – desvio padrão.*

performed with the aid of a stereoscopic microscope and with the naked eye.

## 3. RESULTS

During the extraction process, seed loss (SDE) was variable among *A. murumuru* progenies (Table 1), with average of 5.2 ± 5.7%, being lower in progeny P1 (1.1%), and higher in progeny P2 (15.7%).

Progenies showed variation regarding the physical characteristics of seeds (Table 1). The seed mass/diaspore mass ratio (SDR) was on average 0.37 ± 0.07, which means that 63% of the diaspore mass corresponds to the endocarp mass, which serve as protection for the seed. Among progenies, this ratio ranged from 0.31 (P3) to 0.50 (P1), which may be associated with the variation in endocarp thickness, visually observed during seed extraction.

The moisture content of seeds from progenies, soon after extraction (MCDS), was on average 14.9 ± 1.9%, ranging from 11.9 (P3) to 17.1% (P5). Nine days after soaking, the moisture content of seeds (MCSS) from progenies increased by about 80% (26.8 ± 2.5%), with the highest value reached by progeny P2 (31.5%).

The diameter (DSS), length (LSS) and mass of soaked seeds (MSS) varied among progenies, with averages of 17.1 ± 1.2 mm, 28.4 ± 5.8 mm and 3.3 ± 0.6 g, respectively. Seeds differed more in length than

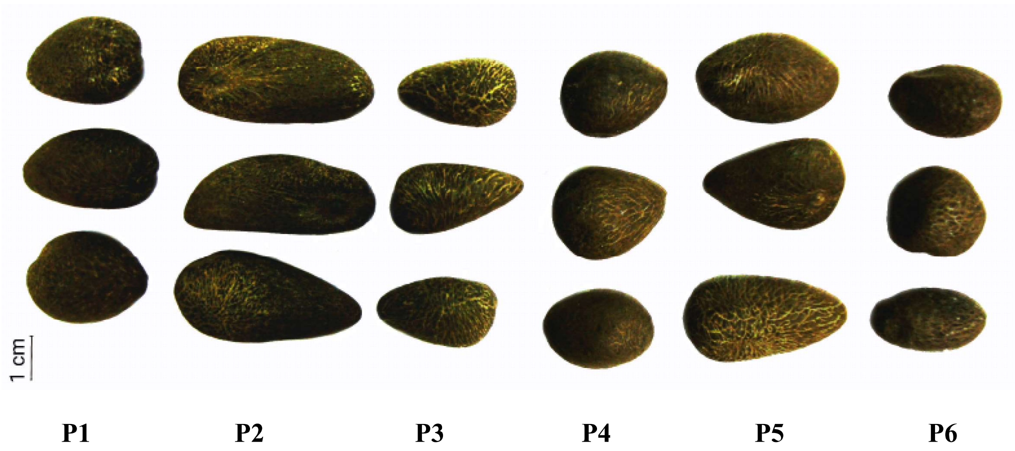


**Figure 1 –** Seeds of different *Astrocaryum murumuru* progenies (P1, P2, P3, P4, P5 and P6) from Coari, AM, Brazil.
***Figura 1** – Sementes de diferentes progênies (P1, P2, P3, P4, P5 e P6) de **Astrocaryum murumuru**, provenientes de Coari, AM, Brasil.*

**Table 2 –** Emergence, emergence speed index (ESI), mean emergence time (MET) of the first cataphyll (normal seedling), germinative bud stage (GB), dormant and dead seeds, referring to *Astrocaryum murumuru* progenies from Coari, AM, Brazil.
***Tabela 2*** *– Emergência, índice de velocidade de emergência (ESI), tempo médio de emergência (MET) do primeiro catafilo (plântula normal), estádio de botão germinativo (GB), sementes dormentes e mortas, referentes a progênies de* ***Astrocaryum murumuru****, provenientes de Coari, AM, Brasil.*

| Progeny | Emergence (%) | ESI (%.day$^{-1}$) | MET(day) | GB(%) | Dormant(%) | Dead(%) |
|---|---|---|---|---|---|---|
| P1 | 73a | 1.349a | 63.5c | 6a | 12b | 9c |
| P2 | 12c | 0.162d | 78.7c | 18a | 10b | 60a |
| P3 | 31b | 0.355d | 103.9ab | 23a | 9b | 37ab |
| P4 | 43b | 0.629c | 80.2bc | 18a | 11b | 28bc |
| P5 | 26bc | 0.267d | 105.8a | 12a | 43a | 19bc |
| P6 | 68a | 0.980b | 74.6c | 12a | 11b | 9c |
| F test | 30.4$^{**}$ | 61.2$^{**}$ | 9.8$^{**}$ | 1.5$^{ns}$ | 7.2$^{**}$ | 13.0$^{**}$ |
| CV (%) | 13.7 | 18.9 | 12.7 | 39.7 | 30.6 | 25.5 |

$^{**}$ Significant at 1% level by the F test; ns – not significant at 5% level by the F test.
CV – coefficient of variation.
Means followed by the same letter in each column do not differ significantly by the Tukey test, at 5% probability level.
*$^{**}$ Significativo em nível de 1% pelo teste F; ns – não significativo em nível de 5% pelo teste F.*
*CV – coeficiente de variação.*
*Médias seguidas da mesma letra em cada coluna não diferem significativamente pelo teste de Tukey, em nível de 5% de probabilidade.*

in diameter, and seeds from progeny P2 showed more elongated shape, evidenced by the greater length/diameter ratio (2.32), while seeds from progeny P4 showed lower length/diameter ratio (1 ,24) and, therefore, more rounded shape (Figure 1).

The number per kilogram of soaked seeds (NKSS), on average 337 ± 79 units, also varied among progenies. Progenies P1 and P2 showed lower number of seeds per kilogram (256 and 271 units, respectively), probably related to the higher masses of soaked seeds observed in these progenies.

The different progenies had different behaviors regarding emergence, emergence speed index and mean emergence time (Table 2). Progenies P1 and

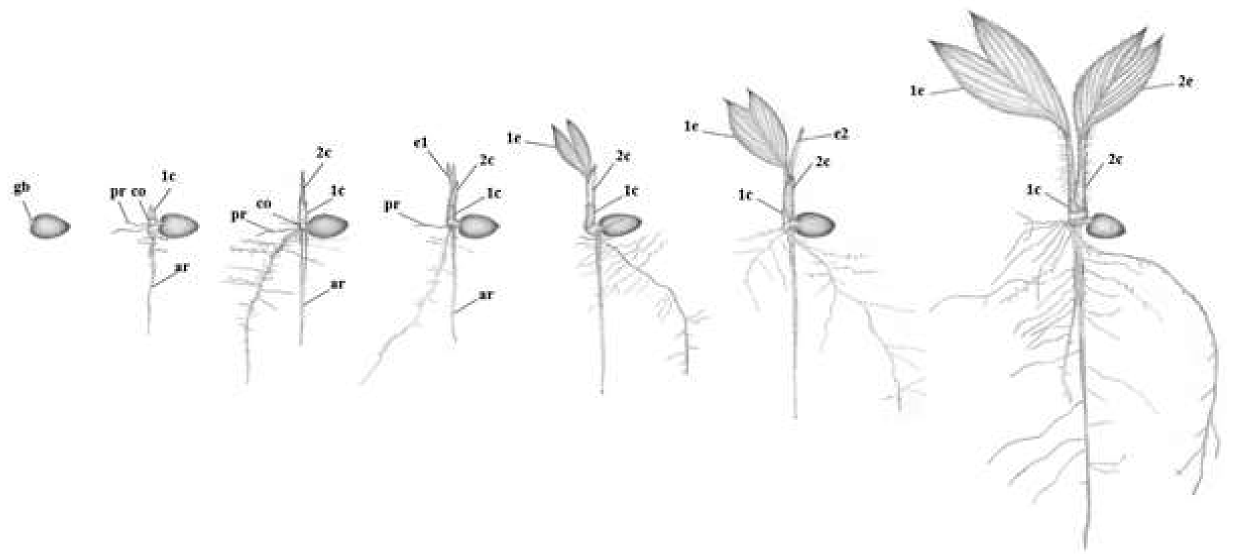


**Figure 2 –** *Astrocaryum murumuru* seedling stages: gb - germinative bud; co - coleoptile; 1c - first cataphyll; 2c - second cataphyll; e1- emission of the first eophyll; 1e - first expanded eophyll; e2 - emission of the second eophyll; 2e - second expanded eophyll; pr - primary root; ar - first adventitious root.
***Figura 2*** *– Estádios da plântula de* ***Astrocaryum murumuru****: gb - botão germinativo; co – coleóptilo; 1c - primeiro catafilo; 2c - segundo catafilo; e1- emissão do primeiro eofilo; 1e - primeiro eofilo expandido; e2 - emissão do segundo eofilo; 2e - segundo eofilo expandido; pr - raiz primária; ar - primeira raiz adventícia.*

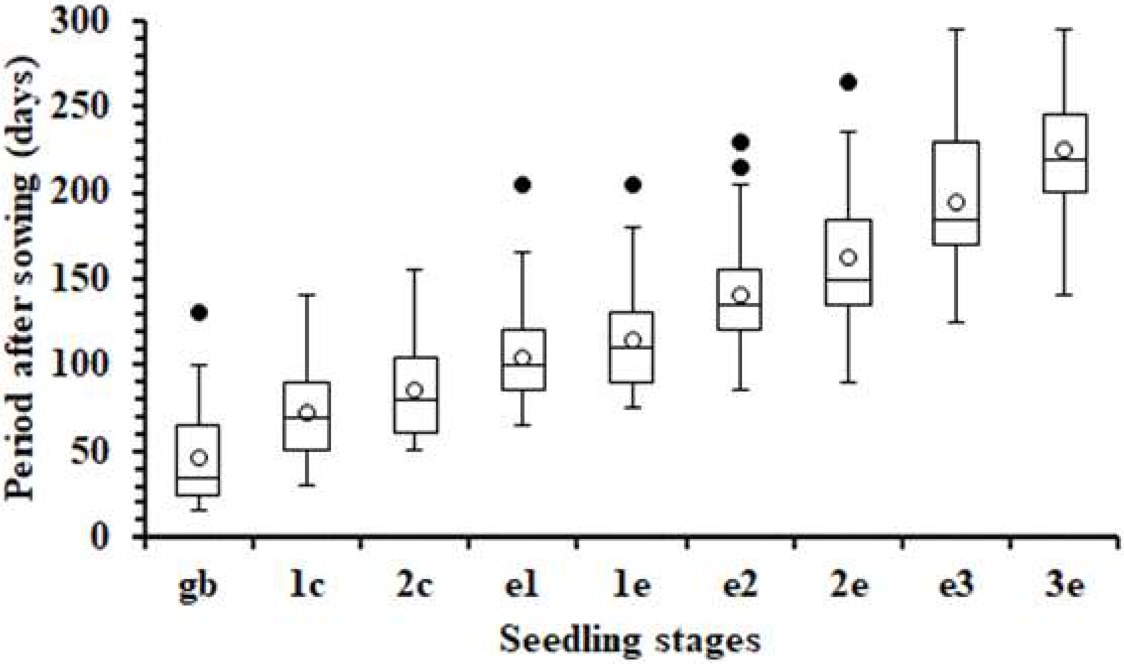


**Figure 3 –** Boxplot for the variation of the time of occurrence of the different seedling development stages obtained from seeds of six *Astrocaryum murumuru* progenies: gb - germinative bud; 1c - first cataphyll; 2c - second cataphyll; e1 - emission of the first eophyll; 1e - first expanded eophyll; e2 - emission of the second eophyll; 2e - second expanded eophyll; e3 - emission of the third eophyll; 3e - third expanded eophyll; empty circle – average; full circle – outlier value.

***Figura 3*** *– Boxplot da variação do tempo de ocorrência dos diferentes estádios de desenvolvimento de plântula, obtidos a partir de sementes de seis progênies de* ***Astrocaryum murumuru****: gb - botão germinativo; 1c - primeiro catafilo; 2c - segundo catafilo; e1 - emissão do primeiro eofilo; 1e - primeiro eofilo expandido; e2 - emissão do segundo eofilo; 2e - segundo eofilo expandido; e3 - emissão do terceiro eofilo; 3e - terceiro eofilo expandido; círculo vazio – média; círculo cheio – valor discrepante (outlier).*

P6 had the highest emergence values (73 and 68%, respectively), while P2 and P5 had the lowest values (12 and 26%, respectively). Regarding the physiological quality of seeds from each progeny, the occurrence of latent damage resulting from the extraction process cannot be ruled out, since samples from progenies P2 and P5 showed the highest percentages of damaged seeds (SDE) (Table 1).

In general, progenies with the highest emergence percentages had the highest emergence speed indices (ESI) and the lowest mean emergence times (MET), evidencing differences in the degree of seed dormancy among progenies, with mean emergence time varying between 63.5 (P1) and 105.8 days (P5).

At the end of the experiment, different conditions were verified in the remaining seeds from progenies, in which seedlings did not emerge above the substrate level (Table 2). Seeds that had germinated, although without reaching the first cataphyll stage, were included in the germinative bud stage (GB) (15%), even though the majority (80%) showed signs of rotting. After the application of the cut test (Brasil, 2009), seeds that had not germinated and without signs of rotting were considered dormant, whose percentages varied between 9 (P3) and 43% (P5) and reinforced the evidence of differences in the degree of seed dormancy among progenies. Finally, partially, or totally rotten seeds that had not germinated were considered dead, being discarded during the conduction or at the end of the experiment. Progeny P2, which had the highest percentage of damaged seeds during extraction (15.7%, Table 1) and the lowest emergence value (12%), was the one with the highest percentage of dead seeds (60%) (Table 2).

*A. murumuru* germination is of adjacent type, with cotyledon sheath developing next to the seed (Figure 2). The first visible sign of germination was the detachment of the opercular tegument, below which the protrusion of the cotyledon sheath was observed, which dilated, giving rise to what is conventionally called the germinative bud. From the germinative bud, the coleoptile developed, and, in its lower portion, the primary root emerged. Subsequently, the upper portion of the coleoptile acquired a conical shape, through which the first cataphyll emerged, which became tubular. The primary root is ephemeral, and when the second cataphyll began to develop, the first adventitious root appeared, which came to play the role of main root. The first and second cataphylls, in addition to eophyll sheaths, are densely covered by spines. In the case of eophylls, spines are also present on the rachis, on the ribs of the adaxial surface and on the margins of the leaf blade.

Among progenies, the mean times to reach each of the different stages of seedling development were different (Figure 3). The formation of the germinative bud presented average time of 46 days, with 50% of occurrences taking between 25 and 65 days. Subsequently, the first and second cataphylls, and the first, second and third expanded eophylls, presented mean time of 73, 86, 115, 162 and 225 days, respectively. In the case of the third expanded eophyll, 100% of seedlings reached this stage between 140 and 295 days, while 50% of these reached this stage between 200 and 245 days.

## 4. DISCUSSION

The loss of *A. murumuru* seeds during the extraction process was on average low (5.2%), compared to results obtained with *A. aculeatum*. In this species, Ferreira and Gentil (2006) found loss of 20.4% of seeds, while Nazário and Ferreira (2010) found higher loss (30%).

It is possible that the low emergence in progeny P2 is due to the physical characteristics of diaspores and seeds (such as endocarp size and thickness), which impaired the extraction of fully intact seeds without immediate (apparent) and latent (manifested after sowing) mechanical damage. Like what Nazário and Ferreira (2010) reported about *A. aculeatum* seeds, it is likely that losses in the extraction of *A. murumuru* seeds are related to the origin of fruits, which express variation in diaspore size, endocarp thickness and moisture content of seeds. Furthermore, similarly to what was suggested by Ferreira and Gentil (2006) for *A. aculeatum* seeds, it would be advisable to evaluate the drying of *A. murumuru* diaspores in environment with lower relative humidity and/or forced ventilation in future studies. Such a situation would aim to reduce the drying period for extraction and increase the percentage of seeds extracted without mechanical injuries.

*A. murumuru* seeds showed variations in terms of size and shape, which somehow may have influenced germination and vigor. According to Rodrigues et al. (2015), the biometric characteristics can provide information necessary for the selection of seeds of greater size and mass since these parameters have contributed to greater success in germination and vigor tests of some palm tree species. Ferraz et al. (2021) found that morphophysiological characteristics of seeds, germination and seedlings are useful to detect genetic variability among *Phytelephas macrocarpa* Ruíz & Pavón progenies.

From the seed mass/diaspore mass ratio, it was deduced that endocarp thickness is variable among *A. murumuru* progenies. In *Elaeis guineensis* Jacq. accessions of the tenera type, Camillo et al. (2014) found differences associated with endocarp thickness and seed shape, which can guide the development of breeding strategies for the species.

Differences in the moisture content of *A. murumuru* seeds were possibly caused by uneven maturation between racemes and endocarp thickness, similar to that observed in *A. aculeatum* (Ramos et al., 2011) and *Archontophoenix cunninghamiana* (H.Wendl) .) H.Wendl. & Drude (Martins et al., 2013).

The germination process of *A. murumuru* seeds is slow and uneven, probably due to their different degrees of dormancy, similarly to that observed in other species of the genus *Astrocaryum* (Koebernik, 1971; Ferreira and Gentil, 2006; Corrêa et al., 2019). Germination speed and seedling vigor are selection criteria recommended to produce *Cocos nucifera* L. seedlings (Lédo et al., 2019). In *A. cunninghamiana*, selection is important because it enables efficient seedling production, reducing the mean germination time and increasing emergence uniformity and seedling size (Martins et al., 2013).

Martins et al. (2013) consider that, under favorable environmental conditions, the performance differences in *A. cunninghamiana* seeds are expressions of the genotype inherited from mother plants, influencing emergence speed and uniformity. This, in part, can also be attributed to *A. murumuru* seeds. In *Euterpe edulis* Mart., the existence of genetic variability in germination percentage and speed between genotypes indicated the possibility of selection for these characteristics (Soler-Guilhen et al., 2020).

Differences in germination performance among *A. murumuru* progenies are probably related to the incipient stage of domestication of the species. Rivas et al. (2012) highlight that most palm species have not yet undergone breeding and, therefore, seeds and seedlings have high genetic and phenotypic variability.

In seeds with adjacent germination, common among palm trees, only a small portion of the cotyledon emerges from the seed (Costa and Marchi, 2008). In general, this type of germination can also be classified as cryptocotyledonary, due to the permanence of the cotyledon inside the seed, and hypogeal, because cotyledons remain in the soil or on its surface. Similar germination has been described for other palms of the same genus, such as *A. aculeatum* (Gentil and Ferreira, 2005), *Astrocaryum alatum* Loomis (Henderson, 2006) and *A. acaule* (Corrêa et al., 2019).

According to Henderson (2006), the number of cataphylls for each palm species varies according to the tribe and is related to the eophyll morphology; for example, species with single cataphyll have entire eophyll, while in species with more than one cataphyll, eophylls can be bifid or pinnate. *A. murumuru* seedlings have two cataphylls and bifid eophyll, with parallel veins. Similarly, *A. aculeatum* (Gentil and Ferreira, 2005), *A. alatum* (Henderson, 2006) and *A. acaule* (Corrêa et al., 2019) seedlings also have two cataphylls and bifid eophyll.

The primary root of *A. murumuru* seedlings was like that observed in *A. aculeatum* (Gentil and Ferreira, 2005) and *A. alatum* (Henderson, 2006). Costa and Marchi (2008) reported that in species with adjacent type germination, the primary root is usually small and quickly replaced by roots formed from the embryonic axis (adventitious roots). What was called “primary root” in the present study (*A. murumuru*), Corrêa et al. (2019) considered as “lateral root”, as well as for “first adventitious root”, they called “primary root” in *A. acaule*. Thus, there is no doubt about the need for more in-depth studies on the initial development of the root system of *A. murumuru* to corroborate or not results obtained by Corrêa et al. (2019).

Compared with other species of the same genus, *A. murumuru* presented shorter period for germination and seedling development: 46 days to reach germinative bud formation and 115 days to reach the first expanded eophyll stage. These stages in *A. aculeatum* were reached at 107 and 253 days, respectively (Gentil and Ferreira, 2005), while for *A. acaule*, periods were 113 and 234 days, respectively (Corrêa et al., 2019).

In summary, the results obtained in this study showed the need for improvement in processing and for investigations on the dormancy of *A. murumuru* seeds. It is also necessary to expand the number of sampled individuals, as well as the inclusion of different populations. Advances in knowledge of the species can support breeding programs and projects for the implementation of commercial plantations of this palm tree of sociocultural and economic importance in the Amazon.

## 5. CONCLUSIONS

*A. murumuru* progenies show differences in the physical and physiological characteristics of seeds and seedlings. Germination and seedling development can be considered slow, with variable times among progenies.

## AUTHOR CONTRIBUTIONS

Jucimara G. dos Santos: installed, evaluated, analyzed, and wrote the first draft of the work. Sidney A. N. Ferreira: conceived the research idea, reviewed data analysis, and wrote the work. Daniel Felipe de O. Gentil: helped in interpreting results and wrote the work.

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