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ARTICLE

Analysis of the physical properties of the seeds of the ubim palm (*Geonoma deversa* (Poit.) Kunth): an Amazonian species with ornamental potential

Análise das propriedades físicas das sementes da palmeira ubim (*Geonoma deversa* (Poit.) Kunth): uma espécie amazônica com potencial ornamental

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Abstract: The study of the physical properties of seeds is essential to determine the specific approach in the manufacture of equipment intended for seed processing. The objective of this work was to determine the physical properties of ubim seeds. For this purpose, measurements of length, width, and thickness were taken using a caliper, and the mass was determined with a precision balance. The results were calculated using equations that allowed the characterization of the physical properties of these seeds. Among the estimated parameters, sphericity, with a standard deviation of 3.21%, stood out for presenting low variation and ensuring the similarity of the spherical shape of the seeds. The analysis showed that the seeds have a rounded shape and uniform size within the studied batch.
Keywords: Arecaceae, biometrics, physical quality, post-harvest process.

Resumo: O estudo das propriedades físicas das sementes é essencial para determinar a abordagem específica na fabricação de equipamentos destinados ao processamento de sementes. O objetivo deste trabalho foi determinar as propriedades físicas de sementes de ubim. Para tanto, foram realizadas medidas de comprimento, largura e espessura com paquímetro e a massa determinada em balança de precisão. Os resultados foram calculados por meio de equações que permitiram a caracterização das propriedades físicas dessas sementes. Dentre os parâmetros calculados, a esfericidade, com desvio padrão de 3,21%, destacou-se por apresentar baixa variação e garantir a similaridade do formato esférico das sementes. A análise mostrou que as sementes apresentam formato arredondado e tamanho uniforme dentro do lote estudado.
Palavras-chave: Arecaceae, biometria, processo de pós-colheita, qualidade física.

Introduction

The Amazon is a tropical region home to biological diversity made up of various elements, including fauna, flora, water resources, and plant extracts used for medicinal and cosmetic purposes. Also noteworthy is the presence of species with great potential for urban afforestation and ornamental use. In this context, *Geonoma deversa* (Poit.) Kunth, a palm popularly known as "ubim" stands out as a valuable option for ornamentation and landscaping in parks and urban afforestation in cities.

Despite this, the unavailability of native species on the Brazilian market and the lack of publicity about their ornamental potential, such as *G. deversa*, has limited their use and marketing among landscapers who, out of ignorance, favor the use of exotic palm species that are more easily found in nurseries across the country (Junqueira and Peetz, 2018). Thus, the search for new ornamental plants based on native species represents great production and marketing potential for both the domestic and export markets (Heiden et al., 2006).

Geonoma deversa (Arecaceae) is a small palm tree that can reach a maximum height of about 4 m. Its leaves are usually pinnate, but sometimes have entire leaves, with the youngest ones having a reddish hue. Its mature infructescences are also striking, displaying an orange color contrasting with black, spherical fruits. It is a widely distributed species in primary terra firme or occasionally flooded forests from Central America to the northern region of South America, including the Amazon biome and adjacent premontane regions up to altitudes of 1,200 m (Henderson, 1995).

Although many native palm species have proven economic potential, in many cases studies addressing the morphological and germination attributes of their seeds and fruits still need to be carried out and represent obstacles to their eventual cultivation (Pinheiro et al., 2015; Pinheiro et al., 2017; Pinheiro and Ferreira, 2018). In this context, it is important not only to deepen our understanding of seed physiology and the initial development of seedlings but also to assess the genetic variability of species in natural populations, since this information is indispensable for proposing conservation strategies and genetic improvements (Silva et al., 2022).

The characteristics of the physical properties of seeds are essential to determining appropriate methods in the postharvest stages, such as drying and processing. Furthermore, progeny variability can be observed through morphometric analyses (Araújo et al., 2022; Pinheiro et al., 2023; Souza et al., 2023).

To move from the stage of a species with potential for use to one of broad commercial acceptance, more comprehensive information on the morphometric and germination aspects of *G. deversa* seeds must be known, as they are crucial for understanding their dissemination characteristics. Therefore, the present study aimed to characterize the physical properties of *G. deversa* seeds, as they are essential for the development of efficient propagation techniques that enable their widespread cultivation for ornamental purposes.

Materials and methods

The *G. deversa* palms from which the fruits used in this study were extracted grew spontaneously in an area of primary tropical forest in the Seringal Porongaba (10°48'15"S; 68°46'10"W), which is part of the Chico Mendes Extractive Reserve, located in the municipality of Epitaciolândia, in the eastern region of Acre, Brazil. Freshly harvested fruit bunches were packed in plastic bags and promptly transported in a polystyrene cooler (to avoid damage) to the forest seed analysis laboratory in Rio Branco, Acre,

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approximately 283 km away from the collection area. For the study, four bunches of ripe *G. deversa* fruits were harvested, from which 100 healthy, undamaged units were randomly selected.

All measurements and weighings were made on an analytical balance with a sensitivity of 0.001 g and a King Tools 150BL digital caliper with a sensitivity of 0.01 mm.

After weighing and measuring the fruits, their seeds were extracted by manually rubbing them on a stainless-steel sieve mesh to separate the epicarp and endocarp. The extracted seeds were then left to dry in a natural laboratory environment (average temperature of 30 °C; average relative humidity of 65%) for 24 hours.

After these procedures, the degree of humidity, the weight of the thousand seeds and the fresh mass were determined, and three-dimensional measurements of each seed were taken.

Determination of moisture content

The standard oven method at 105 ºC was used, following the methodology established in the Brazilian Rules for Seed Analysis (Brasil, 2009). This method consists of exposing the seeds to a temperature of 105 ± 3 °C for 24 hours, with four repetitions > 5 g of seeds each. The results, expressed as a percentage (%) of wet basis (b.u.), represent the ratio between the mass of water present in the seed and the total mass of the seed.

Mass of one thousand seeds

Determining the mass of a thousand seeds provides an idea of the size of the seeds, as well as their state of maturity and health. The methodology used in this study, established by the Rules for Seed Analysis (Brasil, 2009), consisted of eight replicates of 100 seeds randomly counted by hand. Each replicate was weighed on a precision analytical balance (in grams).

The variance, standard deviation and coefficient of variation of the values obtained in the weighings were calculated using the following formula: √= n (∑ x2) – (∑ x)2 /n (n – 1); Where: x = mass of each replicate; n = number of replicates; Standard Deviation (S) = √variance; Coefficient of Variation (CV) = S/X x 100; Where: X = average mass of 100 seeds. The variance, standard deviation and coefficient of variation of the values obtained in the weighings were calculated using the following formula: √= n (∑ x2) – (∑ x)2 /n (n – 1); Where: x = mass of each replicate; n = number of replicates; Standard Deviation (S) = √variance; Coefficient of Variation (CV) = S/X x 100; Where: X = average mass of 100 seeds.

Fresh mass and three-dimensional dimensions of the seeds

A heterogeneous sample was used to determine the individual fresh mass of each of the 100 units evaluated. The three-dimensional dimensions of the seeds were measured as previously established by Pinheiro et al. (2019), with the length measured between the hilum and the opposite base of the seeds, the width on the sides of the median region with the greatest amplitude of the seeds, and the thickness on the side that appeared to be the thinnest (Fig. 1).

The seeds' fresh mass and three-dimensional dimensions were carried out using the aforementioned digital caliper and scale.

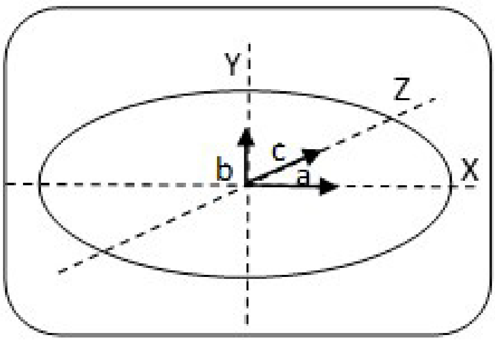

Fig. 1. Three-dimensional geometric dimensions of *Geonoma deversa* seeds from Porongaba Seringal, Chico Mendes Extractive Reserve, Epitaciolândia, Acre: (a) = length; (b) = width; (c) = thickness. Seed size: length mm x width mm x thickness mm.

Physical properties

After determining the dimensions, the results of the physical properties were obtained through mathematical calculations. The SVI - Seed Volume Index (Araújo et al., 2022), GMD - Geometric Mean Diameter, EMD - Equivalent Mean Diameter, AMD - Arithmetic Mean Diameter (Sahay and Singh, 1994), As - Surface Area (McCabe et al., 2005), Ø - Seed Sphericity; V - Seed Volume (Mohsenin, 1986) and Ra - Aspect Ratio (Varnamkhasti et al., 2008). These properties were calculated using mathematical equations (Eq. 1; Eq. 2; Eq. 3; Eq. 4; Eq. 5; Eq. 6; Eq. 7 and Eq. 8).

$$SVI = length \ x \ width \ x \ thickness \qquad (Eq.1)$$

$$GMD = SVI^{1/3} \qquad (Eq.2)$$

$$EMD = \left[length \ \frac{(width \ x \ thickness)}{4}\right]^{1/3} \qquad (Eq.3)$$

$$AMD = \frac{length + width + thickness}{3} \qquad (Eq.4)$$

$$As = \pi GMD^2 \qquad (Eq.5)$$

$$\emptyset = \left[\frac{GMD}{length}\right] 100 \qquad (Eq.6)$$

$$Ar = \left[\frac{width}{length}\right] 100 \qquad (Eq.7)$$

$$V = \frac{SVI}{6} \qquad (Eq.8)$$

Frequency distribution calculations were carried out based on pre-established classes. Relative frequency, an analysis tool that compares data by determining the percentage of a piece of data about the total collected, was explicitly used for seed data. This relative frequency was defined by the following equation (Eq. 9).

$$Fr = \frac{fi}{n} \ x \ 100 \qquad (Eq.9)$$

Fr = relative frequency; fi = absolute frequency; n= total elements.

Data analysis

Biostat software version 5.0 (Ayres, 2007) was used for all statistical analyses, including the definition of classes. Data relating to biometric characteristics was explored using the mean and range (maximum and minimum), coefficient of variation (CV), relative frequency, arithmetic mean, standard deviation, and confidence interval to determine possible associations between phenotypic variation and the variables analyzed.

The data was assessed for normality using the Lilieforts test to determine whether a normal distribution model random variable data sets well.

Results

Geonoma deversa presents distinct characteristics in its reproductive phase and in the natural forest environment that reflect important aspects of its ecology. It can have cespitose or solitary, erect, and non-scandescent stems. Its bunches present variations in color in the peduncle, rachis, and rachillae, which at the beginning of development present a light green tone, changing to a striking orange when the fruits ripen. Its fruits are rounded, with an epicarp with a bright greenish color when immature and a matte black color when the fruits are ripe. The seeds have an endocarp with a color that varies from light brown to dark gray (Fig. 2).

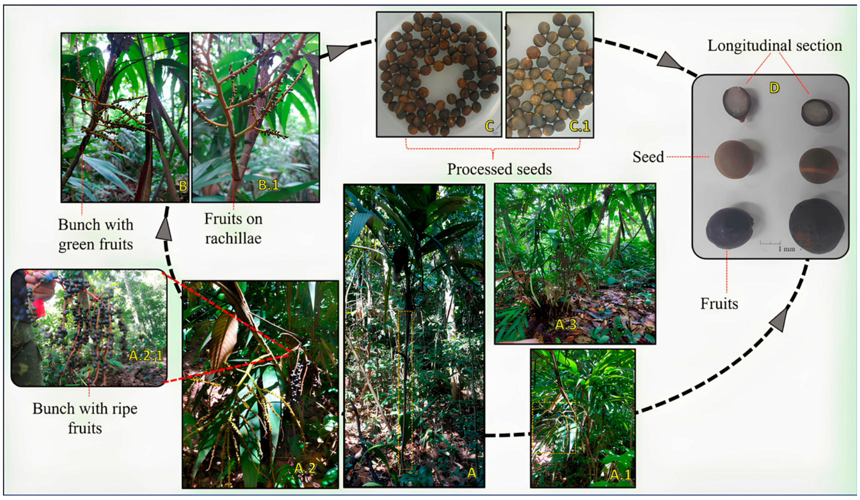

Fig. 2. Characteristics of a small mother plant of *Geonoma deversa* in reproductive phase from the Porongaba Seringal, Chico Mendes Extractive Reserve, Epitaciolândia, Acre. A - Plant with solitary habit; A.1 - Details of pinnate leaves; A.2 - Plant with bunch containing ripe fruits; A.2.1- Detail of black fruits, denoting physiological maturity; A.3 - Plant with caespitose habit; B - Detail of bunch with immature fruits; B.1- Detail of developing fruits in rachillae; C and C.1 - Intact and processed seeds; D - Shape of fruits and seeds.

Table 1 shows that the seeds have a high degree of humidity (27.28%), indicating that a sharp reduction in their mass could occur during the phase of water content reduction that precedes both storage and drying. Seeds with a high moisture content tend to deteriorate more quickly. Thus, knowing the variation in these seed characteristics may be essential not only for the survival of propagated seedlings but also to ensure the success of their propagation in different environments.

Table 1. Moisture content and thousand-seed mass of a batch of *Geonoma deversa* palm from the Porongaba Seringal, Chico Mendes Extractive Reserve, Epitaciolândia, Acre.

Variables	Sample size	Mean	DP	CV (%)
Degree of Moisture (%)	4	27.58	2.53	9.05
Thousand Seed Mass (g)	8	96.98	0.10	3.89

The characterization of the physical properties of different aspects of *G. deversa* seeds can be seen in (Table 2). Of the 12 aspects evaluated, only three showed higher coefficients of variation (CV): Mass (16.92%), and Seed Volume Index and Volume (14.97% each). The others showed CVs of less than 6.20%, indicating strong uniformity in the batch of seeds evaluated. The averages for width (W) and thickness (T) are very close (4.79 ± 0.26 x 4.63 ± 0.29 mm), while the length is slightly greater (5.41 ± 0.30 mm), indicating that the fruits have a slightly elongated spherical shape.

Figure 3 shows the relative frequency values of the three-dimensional classes (length, width, thickness, and mass), with the frequency graphs showing the ranges at which the intervals are repeated for each variable.

Table 2. Characterization of physical properties of *Geonoma deversa* seeds from the Porongaba Seringal, Chico Mendes Extractive Reserve, Epitaciolândia, Acre. Three-dimensional data: length = L, width = W, thickness= T and mass = M; Volume Index = IVS, Geometric Mean Diamete = GMD, Equivalent Mean Diamete = EMD, Arithmetic Mean Diameter = AMD, Surface Area = SA, Seed Sphericity = Ø; Volume of Seeds = V, Aspect Ratio = Ar

Variables	Minimum	Mean ± SD	Maximum	CV (%)	± 95% CI	p-Value
L (mm)	4.40	5.41 ± 0.30	6.10	5.61	5.35–5.47	*
W (mm)	4.10	4.79 ± 0.26	5.40	5.38	4.73–4.84	*
T (mm)	3.70	4.63 ± 0.29	5.30	6.20	4.56–4.68	*
M (g)	0.05	0.08 ± 0.01	0.11	16.92	0.07–0.08	ns
SVI	75.85	120.72 ± 18.07	163.13	14.97	117.16–124.28	ns
GMD (mm)	4.23	4.93 ± 0.25	5.46	5.15	4.87–4.97	ns
EMD (mm)	2.10	2.33 ± 0.08	2.48	3.40	2.31–2.34	ns
AMD (mm)	4.27	4.94 ± 0.25	5.47	5.11	4.89–4.99	ns
SA (mm²)	56.29	76.54 ± 7.75	93.79	10.13	75.01–78.06	ns
V (mm³)	39.71	63.21 ± 9.46	85.42	14.97	61.34–65.07	ns
Ø (%)	83.20	91.17 ± 2.92	99.34	3.21	90.59–91.74	ns
Ar	76.79	88.63 ± 4.19	100.00	4.73	87.80–89.45	ns

Legend: *significant $p < 0.05$, ns = no significant; CV= coefficient of variation; CI=confidence interval; SD= standard deviation.

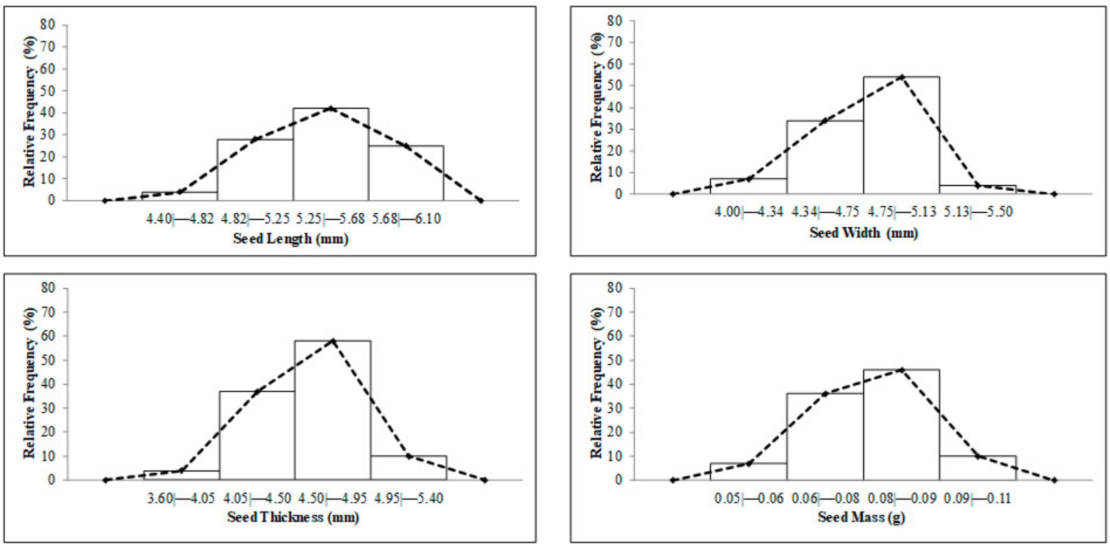

Fig. 3. Graphs showing the relative frequency of the length, width, thickness and mass of *Geonoma deversa* seeds from the Porongaba Seringal, Chico Mendes Extractive Reserve, Epitaciolândia, Acre.

In the length graph (Fig. 3A), the seeds included in the 4.82|—5.25, 5.25|—5.6 mm and 5.68|—6.10 millimeter length classes accounted for 98.9% of all seeds, each class individually representing 31.3%, 42.4% and 25.2%. With regard to width (Fig. 3B), 88.8% of all the seeds were included in the 4.34|—4.75 mm and 4.75|—5.13 millimeter width classes, each individually representing 34.3% and 54.5%. The thickness graph (Fig. 3C) concentrated 95.9% of the total seeds measured in the 4.05|—4.50 and 4.50|—4.95 mm classes, with each class representing 37.3% and 58.5% respectively. About mass (Fig. 3D), the 0.06|—0.08 g and 0.08|—0.09 g classes accounted for 82.8% of the total seeds weighed, with each class representing 36.3% and 46.4% of the seeds respectively.

Discussion

The highest coefficients of variation values observed among the evaluated variables were, respectively, 16.92% for seed mass (M) and 14.97% for the seed volume index (SVI) and seed volume (V). The fact that the SVI and V values were equal reflects the close

interconnection between them, since the first is obtained by the simple ratio between the length, width, and thickness of the seeds (see equation 1 in the physical properties section in material and methods), while the second requires, in its calculation formula, the value of the first (see equation 8 in the physical properties section in material and methods).

The high coefficient of variation of seed mass can be partially explained by the fact that *G. deversa* is a native species not subjected to breeding and/or selection processes, a condition in which it tends to present high morphological variability in the seeds (Pontes et al., 2018). In addition, this variability may be related to the great hygroscopic capacity of the seeds and is possible that sorption (absorption of air moisture by the seeds) and desorption (loss of seed moisture to the air) of *G. deversa* seeds occur relatively easily. Pinheiro et al. (2019) and Araújo et al. (2022) found that the fresh mass of *Pueraria phaseoloide* seeds showed the highest coefficients of variation (CV = 19.51% and CV = 18.37%, respectively) and credited this condition in part to the high hygroscopicity of the seeds.

The high and related CVs of the variables SVI, V and M may be because *G. deversa* fruits tend to be spherical in shape. As such, variations in their mass (weight) necessarily lead to variations in their length, width and thickness. Thus, a high coefficient of variation of their mass (M) indicates that high coefficients of variation will be observed for the seed volume index (SVI) and seed volume (V).

Seed sphericity (Ø), a variable that shows the spherical appearance of the seed, showed an average value of 91.17% (CV = 3.21%). The closer the Ø values are to 1.0 (100%), the closer the seeds are to a spherical shape (Pontes et al., 2018). In the present study, the results do not indicate this condition, because even though the width and thickness showed very similar results (4.79 ± 0.26 and 4.63 ± 0.29 mm, respectively), the length of the fruit is much greater (5.41 ± 0.30 mm), and this gives it an oval appearance. This condition was observed by Pinheiro et al. (2023) in their study on the characteristics and physical properties of guarana seeds (*Paullinia stellata*).

Information on the weight of a thousand seeds is important not only for characterizing and managing seed stocks of tropical species but also indicates their uniformity and quality. Although controversial, some authors classify seeds according to this variable. Cavalcante et al. (2018) considered a weight of 202.2 g/1000 moringa seeds (*Moringa oleifera* Lam.) as light. Araújo et al. (2022), in turn, found a weight of 75 mg/1000 seeds in *Pueraria phaseoloides* and considered them extremely light. Thus, if the above criteria are considered and considering that the average weight of the mass of a thousand seeds of *G. deversa* was 96.98 ± 0.10 g, its possible classification should be between light and extremely light.

The geometric mean diameter (GMD) and arithmetic mean diameter (AMD) presented very similar coefficients of variation (CV) (5.15% and 5.11%, respectively). The equivalent mean diameter (EMD), in turn, presented the second smallest CV (3.40%) among all the variables evaluated. According to Araújo et al. (2022) and Pinheiro et al. (2024a), variations in these characteristics show the frequency with which unevenness occurs in the morphological shape and the aspect relative to the mass of the seeds. Pontes et al. (2018), in turn, suggest that such variations may be a result of the way of life and the habitat where the plants occur, perhaps reflecting the relationship of the plants with factors such as seed predation, dispersal, and recruitment.

The seed surface area (SA) showed a relatively high coefficient of variation of 10.13% (Table 1), possibly reflecting the large amplitude (37.5 mm²) between the smallest and largest areas observed among all the seeds evaluated (56.29 mm² x 93.79 mm²). Gomes et al. (2018), when performing the colorimetric and biometric characterization of fava seeds (*Phaselous lunatus*), state that the water content of the seeds can influence the physical parameters related to the seed area. According to them, since the ideal water content for storing fava seeds varies between 11% and 13% (b.u.), this causes an interaction between the water, carbohydrates, and proteins present in the seeds that alter their original structure, especially the processes of adsorption or desorption of moisture from the seeds that leads to changes in the dimensions of the grains via their volumetric contraction or expansion.

In this sense, as the degree of humidity of *G. deversa* seeds was 27.58%, a high value, it can be inferred that the wide range of variation in seed area (SA) of the species is possibly due to the ease with which the processes of adsorption or desorption of moisture from the seeds occur, as this causes changes in the dimensions of the seeds via volumetric contraction or expansion.

The shape of the seed may be the result of the development or adaptation of survival mechanisms in adverse situations. This possibly explains, for example, the longevity of the soil seed bank (Pereira et al., 2023) and the fire or heat tolerance of the seeds of some species during burning events (Ruprecht et al., 2015). In addition, the shape of the seeds can be a directional selection step by plants aiming to attract a specific disperser to select their fruits and seeds (Palácio et al., 2020).

The aspect ratio (R_a) involves the distribution of the three linear dimensions of the seeds and allows the visualization of variations in size outside the usual standards. In the case of forest species, it is useful in the selection of seeds that result in the production of more vigorous seedlings, since it allows the inference, based on knowledge of the relationships between the size and the amount of seed reserve, of this possibility in advance (Dresch et al., 2013; Pontes et al., 2018; Anandakumar et al., 2022). Graphs discriminating the fluctuation of the distribution of the dimensions that make up the calculation of the aspect ratio (R_a) of a given batch of seeds can take the form of a sharp zigzag when the peaks of variations in the minimum and maximum values are far from the average, as in the case of the study of *Annona reticulata* seeds by Pontes et al. (2018). In the case of *G. deversa*, an object of the present study, the peaks of variations of the minimum and maximum values are close to the average, indicating low magnitude oscillations of the data and, consequently, a low coefficient of variation (4.73%).

However, if the degree of heterogeneity is high, vigor tests will better assess the performance of seed lots at the field level (Shinohara et al., 2021). Thus, studies to determine variations in seed size and mass help, on the one hand, in decision-making regarding the segregation of large and small seeds, and on the other hand, they can highlight the importance of using larger seeds, since these tend to have better speed, germination percentage, and vigor (Azevedo et al., 2023; Adji et al., 2021). However, for many native forest species, studies are needed to confirm this assumption.

In view of the above, we can suggest that the determination of physical and morphometric properties of *G. deversa* seeds facilitates actions for seedling production and, in the future if it becomes relevant in the market, the eventual development of equipment for sowing, processing and drying. This statement was also recommended by Pinheiro et al. (2024b) regarding Brazil nut seeds. However, it is equally important to consider that for the development of technologies aimed at forest seeds, as is the case of *G. deversa*, sanitary, storage and harvesting aspects must be taken into account (Pires and Baute, 2023).

Conclusions

The physical properties of the seeds indicated uniformity in size and spherical shape, essential characteristics for the development of machines intended for their handling. The homogeneity and rounded shape of the seeds facilitate the use of specific equipment, optimizing processing and handling, while also simplifying the selection of these seeds for propagation in the ornamental sector.

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Author Contribution

HPC: Conceptualization, Methodology, Validation, Investigation, Writing. **RMP**: Conceptualization, Methodology, Validation, Investigation, Writing - Original Draft, Supervision. **EJLF**: Conceptualization, Methodology, Validation, Investigation, Writing - Original Draft, Supervision. **QSB**: Conceptualization, Methodology, Validation, Writing - Original Draft. **GIG**: Conceptualization, Methodology, Validation, Investigation, Writing - Original Draft. **EKBO:** Conceptualization, Investigation, Writing. **FAFS:** Methodology, Investigation. **AAR:** Writing - Review & Editing, Visualization.

Conflict of interest

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

Data Availability Statement

All the research data is contained in the manuscript.

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