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REGULAR ARTICLE

Germination of morphology and evaluation of emergency of cambucá (*Myrciaria floribunda* (H. West ex Willd) O Berg) in substrates

Maria Klécia das Neves Tavares[1]; Maria Cristina Barbosa da Silva[1]; Karla da Fonseca Silva[1], Luis Gonzaga Pinheiro Neto[1], Francisco José Carvalho Moreira[1*]

[1] Instituto Federal do Ceará (IFCE) *Campus* Sobral, Sobral-CE

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Abstract

The germinative aspects of native species plants are important, as they provide useful information for the production and control of forest seedlings, management, as well as taxonomic identification in the field. With the aim of studying the morphology of germination and emergence of cambucá (*Myrciaria floribunda*) depending on the types of substrates, the experiment was carried out, conducted in Greenhouse at IFCE - *campus* Sobral, during the period from August 2019 to March 2020. The trial was developed in a completely randomized design (DIC), with six treatments, consisting of the types of substrates, namely (sand, sand + cattle manure, sand + goat manure, cattle manure, goat manure, cattle manure + manure goat), with four replications of 15 seeds each. At 192 days after sowing, the final evaluation of the trial was carried out, measuring: emergence (%), speed index (IVE) and average emergence time (TME), plant height, number of leaves, stem diameter stem, root growth, shoot fresh and dry weight, root fresh and dry weight and the Dickson quality index (DQI). The data were tabulated and analysis of variance was carried out using the F test ($p<0.05$), using the Assistat Beta 7.7 statistical program, with the treatment means compared using the Tukey test ($p<0.05$). With the results, it is concluded that cambucá (*Myrciaria floribunda*) seeds present slow and uneven emergence; The sand substrate is the most suitable for its germination, cambucá seedlings do not develop well in high concentrations of organic matter in the substrate.

Keywords

Fertilization; Germination; *Myrciaria floribunda*.

Introduction

The Myrtaceae family includes several species that produce edible fruits with pleasant flavors, such as guava, jaboticaba, araçá, guabiroba, cagaita, and cambuci. Many of these species also possess characteristics suitable for urban greening and are used as ornamental plants (Silva et al., 2001). In addition, they produce fruits that have attracted significant attention from the scientific community due to their nutritional and functional properties, which offer potential human health benefits (Seraglio et al., 2018).

Several species from this family, especially those from the genus *Myrciaria*, hold potential for environmental restoration programs, as they contribute to the recovery not only of flora but also fauna by attracting birds and other animals (Maluf et al., 2003; Tavares, 2015). Species from this genus are also known for their commercial value, nutritional richness, and pharmacological potential (Silva et al., 2003; Nascimento et al., 2020; Santos et al., 2020).

Cambucá (*Myrciaria floribunda* (H. West ex Willd.) O. Berg) is a plant from the Myrtaceae family that grows as a shrub, reaching slightly over 5.0 meters in height, with numerous branches measuring between 1.30 and 1.95 meters, averaging 1.63 meters. It is native to the Ibiapaba mountain range and can be found in the municipalities of Ipueiras, Guaraciaba do Norte, Carnaubal, and São Benedito, in the state of Ceará, Brazil. It flowers from December to February and bears fruit between March and April, however, recent climate changes have altered its flowering and fruit ripening periods, thus significantly impacting harvesting. The plant is still relatively unknown, and studies on this species remain scarce (Tavares, 2015). Its fruits, besides being consumed fresh, are also used by local residents in the form of pulps, juices, and liqueurs (Tavares, 2015). They can be eaten raw or processed for the production of juices, jams, or fermented products. The fruits are rich in vitamin C (129.43 mg of ascorbic acid/100 g) (Nascimento et al., 2020) and contain high concentrations of phenolic compounds such as flavonoids (Santos et al., 2020).

Several studies have been conducted with the aim of improving the germination process of native species. These studies are extremely important, as they provide useful information for the production and quality control of forest seedlings, management practices, and even taxonomic identification in the field. According to Barbosa et al. (2000), some reforestation techniques may be ineffective due to the limited understanding of the biological behavior of native species. Souza et al. (2001) emphasize that producing native seedlings is essential for preserving genetic diversity and preventing biodiversity loss.

*Corresponding authors
E-mail address: franze.moreira@ifce.edu.br

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According to Freitas (2004), the production of forest seedlings plays an important environmental role, including improving quality of life, combating global warming, enhancing local microclimates and air quality, restoring degraded areas, and reducing pressure on native forests.

Germination can be perceived as the initial phase of plant development and directly influences plant distribution (Honório et al., 2011). It is defined as the emergence and development of essential embryonic structures, demonstrating the seed's ability to produce a normal plant under favorable field conditions (Brasil, 2009). Understanding the early stages of development, along with other factors, is key to grasping the regenerative processes of plant formations (Ávila, 2010).

Various approaches to the germination process have been reported, involving morphological, physiological, or biochemical criteria. According to Bewley and Black (1994), the main stages of germination include reactivation (imbibition), growth induction (resting phase), and actual growth (protrusion of the primary root). For Cardoso (2004), germination involves physiological criteria, beginning with seed imbibition and concluding with radicle expansion and seedling emergence. Imbibition is a physical process typically divided into three stages and involves colloidal properties and potential differences between the seed and its environment.

Available information on the germination process is still insufficient for a comprehensive understanding. Despite progress made in studying various species, a complete and definitive description of this phenomenon for any plant species is still lacking due to its complexity (Marcos Filho, 2005).

During seed germination, a sequence of physiological events occurs, influenced by both internal and external factors. External factors include light, temperature, water availability, and substrate, while internal factors involve dormancy, physiological immaturity, and genotype. Each factor affects germination differently, either independently or in combination; however, the sensitivity of each species must be taken into consideration (Cardoso, 2004).

The substrate plays a fundamental role in seed germination, maintaining suitable conditions for both seed germination and seedling development (Figliolia et al., 1993). Substrate characteristics such as structure, aeration, water retention capacity, and pathogen infestation levels can vary depending on the material used (Wagner Júnior et al., 2006). The substrate should maintain a proper balance between water content and aeration. Excessive moisture should be avoided, as a continuous water film around the seed can restrict oxygen absorption. Therefore, substrate selection should take into account seed size, water requirements, light sensitivity, and ease of seedling assessment and counting (Brasil, 2009; Honório et al., 2011). According to Fossati (2007), substrates serve primarily to support seeds both physically and chemically, and are composed of three fractions: physical, chemical, and biological. The physical and chemical fractions consist of mineral and organic particles, with pores that can hold air and/or water, while the biological fraction comprises organic matter.

The mechanical properties of soil can limit seed germination, root expansion, and seedling emergence. Furthermore, soil texture affects water retention, organic matter content, and drainage. Therefore, soil permeability is directly related to seedling emergence, and well-structured soils are necessary for good root penetration (Benvenuti, 2003).

Given the above, this study aimed to morphologically characterize the germination process and evaluate the emergence of cambucá (*Myrciaria floribunda*) in different substrates.

Materials and methods

Place and date of the experiment: This study was conducted at the Agricultural Shade House and the Laboratory of Plant Health and Seeds, under the Technological Axis of Natural Resources, at the Federal Institute of Education, Science and Technology of Ceará (IFCE), Sobral Campus, from August 2019 to March 2020. The campus is located at the geographical coordinates of 3°41’03” South latitude and 40°20’24” West longitude, at an altitude of 70 meters. The climate of the region is classified as Aw’ (tropical savanna climate with dry winters), characterized by high temperatures and summer rains, with peak precipitation in autumn. Maximum temperatures range from 36 °C in October to 31.2 °C in May, while minimum temperatures vary between 23.2 °C in December and 21 °C in July. The annual average rainfall is approximately 833 mm, occurring predominantly from January to June. The average relative humidity is 68.42%, and annual sunshine duration totals 2,556.0 hours (Brasil, 1990).

Seed Collection Site: For this study, fruits were harvested from native plants located in Nova Fátima, situated in the Ibiapaba mountain range, a district belonging to the municipality of Ipueiras, Ceará. This municipality is located in the northwestern mesoregion of Ceará, at the geographical coordinates of 4°32’30” S and 40°43'08" W. According to the Köppen-Geiger climate classification, the region has a BSh climate, characterized as a hot, semi-arid tropical climate with mild conditions. The average annual rainfall is 933 mm, concentrated between January and April, with average temperatures ranging from 24 to 26 °C and an altitude of 231.34 meters (IPECE, 2012).

After harvesting, the fruits were stored in plastic containers and transported to the Laboratory of Plant Health and Seeds at IFCE – Sobral Campus, where they were kept in a refrigerator at 16 °C for two days until the seeds were extracted. Once removed, the seeds were left to dry on newspaper at room temperature for 24 hours and then stored in glass containers in a refrigerator until the beginning of the experiment.

Analyzed Variables: Germination type, root system, hypocotyl, epicotyl, and leaf were evaluated. Assessments were performed both visually and using equipment such as a centimeter-graduated ruler and a millimeter-graduated digital caliper. The following variables were assessed:

a. Emergence Percentage (%E): After 192 days, the number of intact emerged seedlings was counted. Results were expressed as a percentage;

b. Emergence Speed Index (ESI): Daily counts of emerged seeds were performed. The index was calculated using Equation 1.

$$\text{ESI} = \frac{E1}{N1} + \frac{E2}{N2} + \cdots + \frac{En}{Nn} \quad \text{Equation 1}$$

where E_1, E_2, En = number of seeds emerged on the first, second, and last count; N_1, N_2, N_n = number of days after sowing on the first, second, and last count day;

c. Mean Emergence Time (MET): Obtained through daily counts of emerged seeds. Data were calculated using Equation 2.

$$\mathrm{MET} = \frac{\mathrm{E1.T1+E2.T2+\cdots+En.Tn}}{\mathrm{E1+E2+Em}} \qquad \text{Equation 2}$$

where E_1, E_2, En = number of seeds emerged on the first, second, and last count; T_1, T_2, Tn = number of days after sowing on the first, second, and last count day. Results were expressed in days;

d. Seedling height Measured at the end of the germination test using a centimeter-graduated ruler. Height was measured from the collar (root-shoot junction) to the plant apex. Results were expressed in centimeters;

e. Number of leaves: Counted after the germination test ended. Leaves present on each seedling were counted individually, considering only fully developed leaves. Cotyledonary leaves were not considered. Results were expressed as leaves per plant;

f. Stem diameter: Measured at the end of the germination test using a DIGIMESS ® brand caliper, placed at the stem collar of each plant. Results were expressed in millimeters;

g. Root length: After the germination test, seedlings were measured for root length. Using a centimeter-graduated ruler, the root of each seedling was measured from the collar to the root tip. Results were expressed in centimeters;

h. Fresh shoot weight: Performed after the germination test. Plants were separated from the root system using pruning shears. After separation, seedling shoots were weighed and grouped by replicate to obtain an average weight per replicate. Each replicate was then placed in a paper bag and dried in a forced-air oven at 85 °C for 24 hours;

i. Fresh root weight: same as item h;

j. Dry shoot weight: After the drying period, each replicate was weighed on a Bel Engineering® Kern model digital balance with 0.001 g precision;

k. Dry root weight: same as item j; After the oven period, bags containing roots were removed, placed in a desiccator, and then weighed. Roots were weighed grouped by replicate to obtain an average weight per replicate. Results were expressed in grams per seedling root system;

l. Dickson Quality Index (DQI): Calculated based on evaluated morphological parameters (Dickson et al., 1960) using Equation 3.

$$DQI = \frac{TDM}{\left[\left(\frac{H}{DC}\right)+\left(\frac{SDW}{RDW}\right)\right]} \qquad \text{Equation 3}$$

where: TDM is the Total Dry Mass (DSW+DRW) (g), SDW is the Shoot Dry Weight (g), RDW is the Root Dry Weight (g), H is the Plant Height (cm), DC is the Collar Diameter (mm).

Experimental Design: The seedling emergence experiment was conducted using a completely randomized design (CRD), with six treatments corresponding to six types of substrates (sand, sand + cattle manure, sand + goat manure, cattle manure, goat manure, and cattle manure + goat manure), with four replicates of 15 seeds each.

The seeds were sown in 11 x 22 cm polyethylene plastic bags filled with the appropriate substrate for each treatment and irrigated twice daily. Throughout the entire experimental period, the number of germinated seeds was recorded daily; the germination process began 54 days after sowing. The experiment lasted a total of 192 days.

After the experiment concluded, the collected data were entered into a Microsoft Excel® spreadsheet and subjected to analysis of variance (ANOVA) using the F-test in the Assistat Beta 7.7® software. When significant differences among treatments were detected, means were compared using Tukey's test ($p<0.05$), and the results were presented in tables.

Results and discussion

The germination process began fifty-four days after sowing and was classified as epigeal and phanerocotylar. Germination occurred through the emergence of the radicle, which broke through the seed coat at the base of the seed, near the hilum region. The radicle was short, cylindrical, smooth, with a pointed apex and a light color that quickly turned darker. The primary root was axial in type and developed rapidly, initially thick and gradually tapering toward the tip. It was cylindrical, vigorous, dark brown in color, and semi-woody (Figure 1).

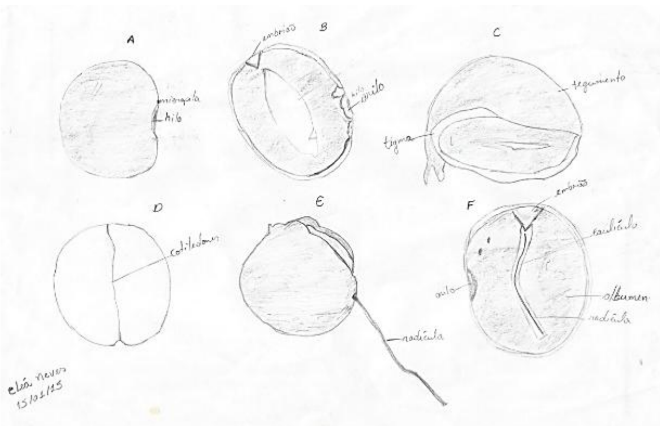

Figure 1. Germination process of cambucá seeds (*Myrciaria floribunda* (H.West ex Willd.) O. Berg) from seed swelling (A), radicle emergence (E) to plumule emergence (C). IFCE - *campus* Sobral, Sobral-CE, 2024.

As elongation occurs, the root cap differentiates and becomes tapered, displaying a yellowish coloration. Secondary roots emerge simultaneously with the shedding of the seed coat, appearing very thin with few branches, irregularly distributed along the primary root. The green cotyledons emerge from the seed remnants and function as photosynthetic leaves. The hypocotyl is cylindrical and greenish in color, elevating the persistent cotyledons. The embryo is of the cotyledonary type, with the hypocotyl-radicle axis and cotyledons easily distinguishable; it is axial, invaginated, fleshy, and dark green in color. Throughout the germination process, the green cotyledons gradually expand until they fully open, revealing the apical bud between them. This bud, green in color, is responsible for the vertical growth of the seedling, which by this stage already shows good development. After this phase, the seedling presents a well-defined epicotyl, hypocotyl, root system, and protophylls.

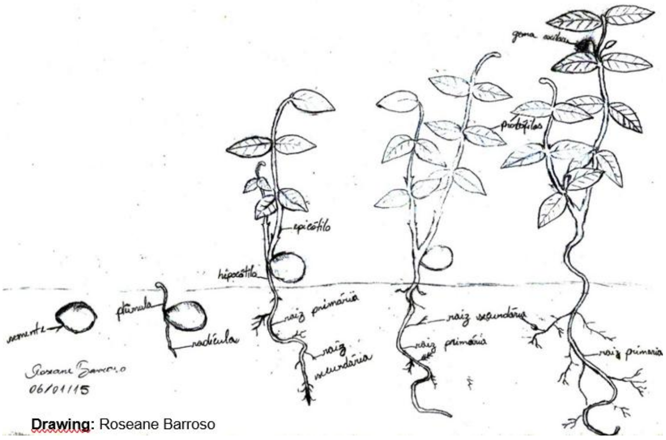

Figure 2. Germination process of cambucá seeds (*Myrciaria floribunda* (H. West ex Willd.) O. Berg) from the seed swelling to the emergence of the radicle and plumule to the details of the iniTial development of the seedlings. IFCE - *campus* Sobral, Sobral-CE, 2024.

Cambucá seeds (*Myrciaria floribunda*) began to emerge 54 days after sowing (DAS), with initial germination occurring in treatments 1, 2, 3, 5, and 6, respectively. The highest germination rates were observed at 105 DAS, with germination ceasing at 180 DAS.

Table 1 presents the mean values for the variables related to emergence, emergence speed index (ESI), and mean emergence time (MET). Regarding emergence, it is observed that the sand substrate provided suitable conditions for cambucá seed germination, offering ideal moisture and aeration levels that allowed the seeds to express their full germinative potential, reaching 100%. The substrates composed of sand + bovine manure and sand + caprine manure also showed good results for this variable. According to the literature, germination rates above 60% can be considered satisfactory for native plant species.

Masetto et al. (2009) report findings that support these results, indicating that the sand substrate produced the highest absolute germination values and the best outcomes 90 days after the test was set up. Similar results were also reported by Lopes and Pereira (2005), who found that sand was the best substrate for the germination of cubiu (*Solanum sessiliflorum*).

Table 1. Means of emergence (%), emergence speed index (ESI), and mean emergence time (MET) of cambucá seeds as a function of the substrates: sand (SM), sand + bovine manure (SM + BM), sand + caprine manure (SM + CM), bovine manure (BM), caprine manure (CM), and bovine manure + caprine manure (BM + CM). IFCE, Sobral-CE, Brazil, 2024.

Variables Analyzed	Tested Substrates					
	Sand	SM + BM	SM+ CM	BM	CM	BM+CM
Emergence (%)	100% a	75%a	66%ab	11%d	41%bc	26%cd
ESI	0,79a	0,61ab	0,48b	0,04c	0,22c	0,1c
MET	126a	126a	133a	136a	138a	146a

* Means followed by the same lowercase letter within a column do not differ significantly by Tukey's test (p<0,05).

According to Abreu et al. (2005), sand substrate is recommended for all seed types, including species more sensitive to desiccation and those requiring extended germination periods. Sand has been widely used to assess emergence and initial growth of various species. Regardless of particle size, it significantly improves soil structure. Its physical properties enhance conditioning, which determines soil aeration and permeability (Tibau, 1983).

Regarding substrates commonly recommended for tree species, sand is employed for large seeds or those requiring prolonged germination (ISTA, 1991). Seeds of some tree species need extended germination periods, often due to dormancy. Cambucá seeds (*Myrciaria floribunda*) fall into this category, requiring approximately 60 days for germination, as observed in this experiment.

After 192 days (test conclusion), several seeds had not germinated. However, some seeds remained viable and slightly swollen, indicating dormancy. Per Brasil (2009), dormant seeds are viable but fail to germinate under species-specific optimal conditions. Some absorb water and swell yet neither germinate nor decompose by test end. Not all dormant seeds post-germination test remain viable; some may be dead.

Substrates of bovine manure, caprine manure, and bovine+caprine manure yielded unsatisfactory germination for cambucá, showing low emergence percentages – negligible compared to sand-amended treatments. Despite their rich organic nutrients, these substrates unexpectedly underperformed. Scalon et al. (1993) note substrates critically influence germination through factors like aeration, structure, and water retention. Piña-Rodrigues et al. (2004) add that substrate and water requirements relate to species-specific ecological traits.

The Emergence Speed Index (ESI) performed best in sand-containing treatments (Table 1), confirming sand accelerated emergence. Favorable results for sand substrates were also reported by Lopes & Pereira (2005) for *Solanum sessiliflorum* and Lima et al. (2006) for *Caesalpinia ferrea*. Faster emergence in sand across treatments is attributed to lower organic matter content, reducing microbial contamination and improving oxygen availability. Lowest ESI values occurred in bovine/caprine manure substrates.

Mean Emergence Time (MET) results indicate bovine manure, caprine manure, and bovine+caprine manure substrates had the longest germination periods (the latter showing the highest MET value; Table 1). The shortest MET occurred with pure sand, followed by 50% sand + 50% bovine manure and 50% sand + 50% caprine manure. These results confirm cambucá seeds require extended periods to initiate and stabilize germination.

For seedling height (Table 2), the lowest value occurred in the Sand treatment. Contrasting results were reported by Cavalcanti (2010), who found greater heights (14.5 cm) in sand for *Syzygium cumini* seedlings. Santos et al. (1994) also observed superior seedling height in sand for *Mimosa caesalpiniaefolia*. unlike this study's findings.

Sandy soils exhibit higher porosity and lower water retention, along with improved drainage and aeration. However, they also have low CEC (Cation Exchange Capacity), low cohesion, higher leaching potential, and low organic matter content, which likely caused stunted seedling growth in sand-based treatments. The use of sand as a substrate has shown positive results; due to its very low ionic exchange capacity, sand is considered an easy-to-manage substrate (Burés, 1997; Abad et al., 2004).

Table 2. Means of growth variables: plant height (H), number of leaves (NL), collar diameter (DC), root length (RL), fresh shoot weight (FSW), dry shoot weight (DSW), fresh root weight (FRW), dry root weight (DRW), and Dickson Quality Index (DQI) of cambucá plants across substrates: sand (SM), sand + bovine manure (SM+BM), sand + caprine manure (SM+CM), bovine manure (BM), caprine manure (CM), and bovine + caprine manure (BM+CM). IFCE Sobral, Ceará, Brazil, 2024.

Variables Analyzed	Tested Substrates					
	Sand	SM + BM	SM + CM	BM	CM	BM+CM
Plant height (cm)	8,63a	9,57a	9,14a	9,83a	9,86a	9,04a
Number of Leaves	13,60a	14,14a	13,87a	11,33a	13,05a	10,27a
Stem diameter (mm)	1,15a	1,23a	1,20a	0,93a	1,01a	0,94a
Root Length (cm)	11,39a	11,78a	12,40a	9,30a	10,36a	8,53a
FSW (g)	2,84a	2,75a	2,31ab	0,77c	1,25bc	0,69c
DSW (g)	1,41a	1,28a	1,07ab	0,16c	0,57bc	0,30c
FRW (g)	1,34a	1,11a	1,13a	0,10b	0,33b	0,19b
DRW (g)	0,73a	0,60a	0,63a	0,05b	0,18b	0,10b
DQI	0,67a	0,58b	0,55b	0,08c	0,18c	0,10c

* Means followed by the same lowercase letter within a column do not differ significantly by Tukey's test (p<0,05).

The highest seedling height values occurred in bovine and caprine manure treatments. Organic substrates promoted better seedling height development compared to the Sand treatment, which yielded inferior results. Organic fertilization with animal waste is viable for maintaining fertility (especially nitrogen supply), increasing productivity, improving soil properties, reducing pollution, and enhancing nutrient use efficiency (Menezes & Salcedo, 2007). It also supplies essential nutrients like N, P, S, and micronutrients (Pires & Junqueira, 2001), though statistical analysis showed no significant differences.

According to analysis of variance, the mean values for leaf number in cambucá seedlings did not differ statistically. However, it can be observed that these means showed higher values when sand-based substrate was used. Through the presented stem diameter values, it is possible to verify that the lowest value was attributed to bovine manure, while the highest value occurred in the Sand + Bovine Manure treatment. However, the presented data showed no statistical differences according to analysis of variance.

Regarding the root system, the greatest root length of cambucá seedlings was provided by the substrate composed of sand and caprine manure, where roots showed average length growth. This same trend occurred in Sand and Sand + Bovine Manure treatments. In treatments containing bovine manure, caprine manure, and bovine + caprine manure, the lowest root length values were recorded. This is likely due to the nutrient action provided by manure, a condition not present in other substrates where roots developed more extensively due to searching for absent nutrients. These results corroborate Marschner et al. (2004).

Lima et al. (2007), studying jambolão cutting rooting, obtained best results with medium-grain sand substrate. Santos et al. (1994) also verified in *Mimosa caesalpiniaefolia* that sand substrate provided the best results for root length. These results show similarity to findings in this experiment, where sand-composed substrates promoted greater root system length in cambucá. Cambucá was observed to possess dark, extensive taproots composed of capillary roots. Regarding root length, the obtained means showed no significant differences between substrates according to analysis of variance; these observations were explained by the presented results.

According to results in Table 2, the highest fresh biomass weight of cambucá plants was obtained in Sand treatment, followed by Sand + Bovine Manure and Sand + Caprine Manure treatments. Meanwhile, the lowest value was observed in Bovine + Caprine Manure treatment. Similar results were found by Santos et al. (1994) who verified that for shoot fresh weight, sand substrate provided higher values than topsoil and rice husk substrates. Analysis of variance demonstrated significant differences between seedlings of evaluated treatments for shoot fresh weight.

For dry matter production, greatest increase occurred in Sand and Sand + Caprine Manure treatments. Similar results were found by Santos et al. (1994) where sand substrate provided higher values than topsoil and rice husk substrates for shoot dry weight. The lowest mean values were found in Bovine Manure and Bovine + Caprine Manure treatments. Analysis of variance demonstrated no significant difference between organic matter treatments for dry weight.

According to sampled data for root fresh and dry weight, Sand, Sand + Bovine Manure and Sand + Caprine Manure treatments provided the highest values and differed from other treatments. Bovine Manure treatment showed unsatisfactory data with worst effect. According to results evaluated in this experiment, cambucá seeds require a long period for radicle protrusion to occur. Native species generally show slow growth; therefore, defining a substrate that promotes emergence speed and uniformity is highly important, along with high physiological quality (Carrijo, 2011).

Among studied substrates, sand contributed most favorably to germination variables and fresh/dry biomass of shoot and root. This was followed by substrates composed of 50% sand + 50% bovine manure and 50% sand + 50% caprine manure, respectively. For seedling height, bovine and caprine manure substrates were most favorable for development, likely due to abundant release of nutrients such as nitrogen (N), phosphorus (P) and potassium (K), enabling optimal growth. In sand substrate, seedlings could not find equivalent nutrition since sand lacks nutrients, requiring mixture with organic substrates to meet plant needs.

It should be emphasized that despite disadvantages such as rapid water infiltration, difficulty maintaining moisture, uneven water retention/distribution, and nutrient poverty, sand substrate was the only one that adequately favored cambucá seed needs, providing favorable conditions for germinative development including: temperature, moisture and oxygen. This suggests cambucá does not adapt to high organic matter concentrations, preferring sandier, nutrient-poor substrates – possibly a species characteristic due to deep roots, as deep-rooted plants generally adapt better to sandy soils. Cambucá possesses taproots featuring a main root penetrating vertically into soil, typically thicker and longer than secondary roots branching from it. This root type absorbs water from deeper soil layers.

For Dickson Quality Index (DQI) presented in Table 2, sand substrate stood out with index 0.67, statistically superior to others, followed by Sand + Bovine Manure and Sand + Caprine Manure substrates with values 0.58 and 0.55, respectively. Thus, substrates with greater porosity facilitating drainage provide better plant development, as evidenced by root length measurements and fresh/dry root weights observed in these three substrates (Table 2).

According to Abreu et al. (2019), DQI is considered one of the most complete indexes for forest seedling quality evaluation, as its calculation includes relationships between morphological parameters (height, diameter, shoot dry weight, root dry weight) plus total biomass. It therefore represents good information regarding seedling quality since its calculation considers robustness and biomass distribution balance. Higher index values indicate greater seedling quality within the batch (José et al., 2009).

This study characterized cambucá (*M. floribunda*) germination type, seed germination rate, time required to complete germination, substrates enabling germination exceeding fifty percent, and initial growth behavior of this species. These are essential contributions for native species literature, supporting forest recovery studies, native species preservation, silviculture, and other applications.

Conclusions

Cambucá seeds exhibit epigeal and phanerocotylar germination. The radicle is short, cylindrical, smooth, with a pointed apex and a light color that quickly darkens. The primary root is axial, develops rapidly, initially thickening and tapering towards the tip; it is cylindrical, vigorous, dark brown in color, and semi-woody. Regarding its germination, cambucá seeds show slow and uneven emergence. Sand is the most suitable substrate for seed emergence, as well as for the development of shoot and root biomass, thus producing the best quality seedlings. Cambucá seeds did not emerge in substrates with a high concentration of organic matter and low porosity.

References

Abad, M. B., Noguera, P. M., & Carrión, C. B. (2004). *Los substratos en los cultivos sinsuelo*. In: URRESTARAZU MG. (Ed.). Tratado de cultivo sinsuelo. Madrid: Mundi-Prensa, 113-158.

Abreu, A. H. M.; Leles, P. S. S.; Melo, L. A.; Ferreira, D. H. A. A., & Monteiro, F. A. S. (2015). Produção de mudas e crescimento inicial em campo de *Enterolobium contortisiliquum* produzidas em diferentes recipientes. *Revista Floresta*, *45*(1): 141-150. https://doi.org/10.5380/rf.v45i1.28931

Abreu, D. C. A. Nogueira, A. C., & Medeiros, A. C. S. (2005). Efeito do substrato e da temperatura na germinação de sementes de cataia (*Drimys brasiliensis* Miers. Winteraceae). *Revista Brasileira de Sementes*, *27*(1):149-157. https://doi.org/10.1590/S0101-31222005000100019

Avila, A. L. (2010). *Mecanismos de regeneração natural e estrutura populacional de três espécies arbóreas em remanescente de Floresta Ombrófila Mista, Rio Grande do Sul*. 150f. Dissertação de Mestrado – Universidade Federal de Santa Maria. Santa Maria-RS.

Barbosa, F. R. Moreira, A. N. Alencar, J. A. Haji, F. N. P., & Medina, V. D. (2000). *Metodologia de amostragem e nível de ação para as principais pragas da mangueira, no Vale do São Francisco*. Embrapa Semiárido, Petrolina, (Embrapa Semiárido. Circular Técnica, 50). 23p.

Benvenuti, S. (2003). Soil texture involvement in germination and emergence of buried seeds. *Agron. Jour., 95*: 191-198. https://doi.org/10.2134/agronj2003.1910

Bewley, J. D., & Black, M. (1994). *Seeds*: physiology of development and germination. New York and London: Plenum Press, 445p.

Brasil. (1990). Ministério da Agricultura. *Plano Estadual dos Recursos Hídricos do Ceará*: dados climatológicos de Sobral – CE (1961 – 1988). Brasília.

Brasil. (2009). Ministério da Agricultura, Pecuária e Abastecimento. *Regras para Análise de Sementes*. Ministério da Agricultura, Pecuária e Abastecimento. Secretaria de Defesa Agropecuária. – Brasília: Mapa/ACS, 399p.

Burés, S. (1997). *Sustratos*. Madrid: Agrotécnicas, 342p.

Cardoso, V. J. M. (2004). *Germinação*. In: Kerbauy, G. B. Fisiologia vegetal. 1. ed. São Paulo: Guanabara Koogan S. A, Cap.17, p. 386-408.

Carrijo, N. S. (2011). *Germinação e caracterização física e morfológica de frutos e sementes de* Syagrus oleracaea *Becc.* 81f. Dissertação (Mestrado) – Universidade Federal de Goiás, Campus Jataí. URL: < www.fcav.unesp.br/Home/download/pgtrabs/pv/m/78295.pdf>

Cavalcanti, N. B. (2010). Influência de Diferentes Substratos na Emergência e Crescimento de Plântulas de Jambolão. *Engenharia Ambiental*, *7*(2): 241-251.

Dickson, A.; Leaf, A. L. & Hosner, J. F. (1960). Quality appraisal of white spruce and white pine seedling stock in nurseries. *Forest Chronicle*, *36*(1): 10-13.

Figliolia, M. B.; Oliveira, E. C., & Pinã-rodrigues, F. C. M. (1993). *Análise de sementes*. In: Aguiar, I. B.; Pinã-Rodrigues, F. C. M.; Figliolia, M. B. Sementes florestais tropicais, Brasília: ABRATES, 137-174.

Fossati, L. C. (2007). *Ecofisiologia da germinação das sementes em populações de* Ocotea pu*berula (Rich.) Ness,* Prunus Sellowii *Koehne e* Piptocarpha angustifolia *Dusén Ex Malme*. 193f. Tese (Doutorado em Ciências Florestais) – Universidade Federal do Paraná, Curitiba-PR.

Freitas, L. C. (2004). *Avaliação quantitativa de impactos ambientais da colheita florestal em plantios equiêneos de eucalipto*. 101f. Dissertação (Mestrado em Ciência Florestal) - Universidade Federal de Viçosa., Viçosa-MG.

Honório, I. C. G.; Pinto, V. B.; Gomes, J. A. O., & Martins, E. R. (2011). Influência de diferentes substratos na germinação de jambu (*Spilanthes oleracea* L. – Asteraceae). *Biotemas*, *24*(2): 21-25. https://doi.org/10.5007/2175-7925.2011v24n2p21

International Rules for Seed Testing – ISTA. (1991). *Tree and shrub seed handbook*. Zurich, Switzerland, 97p.

Ipece. (2012). *Perfil básico municipal*: Ipueiras. Fortaleza, Governo do Estado do Ceará, Secretaria de Planejamento e Coordenação. 2012.

José, A. C.; Davide, A. C., & Oliveira, S. L. (2009). Efeito do volume do tubete, tipo e dosagem de adubo na produção de mudas de aroeira (*Schinus terebinthifolia* Raddi). *Agrarian*, *2*(3): 73-86. URL: < https://ojs.ufgd.edu.br/index.php/agrarian/article/view/420>.

Lima, J. D.; Almeida, C. C.; Dantas, V. A. V.; Silva, B. M. S., & Moraes, W. (2006). Efeito da temperatura e do substrato na germinação de sementes de *Caesalpinia ferrea* Mart. ExTul. (Leguminosae, Caesalpinoideae). *Revista Árvore*, *30*(4): 513-518. https://doi.org/10.1590/S0100-67622006000400003

Lima, Y. O. U.; Ritter, M.; Alcântara, G. B.; Lima, D. M.; Fogaça, L. A.; Quoirin, M.; Cuquel, F. L. & Biasi, L. A. (2007). Tipos de estacas e substratos no enraizamento de jambolão. *Scientia Agraria*, *8*(4): 449-453.

Lopes, J. C., & Pereira, M. D. (2005). Germinação de sementes de Cubiu em diferentes substratos e temperaturas. *Revista Brasileira de Sementes*, *27*(2): 146-150. https://doi.org/10.1590/S0101-31222005000200021

Maluf, A. M.; Camargo-Bilia, A. D., & Barbedo, C. J. (2003). Drying and storage of *Eugenia involucrata* DC. Seeds. *Scientia Agrícola*, *60*(3): 471-475. https://doi.org/10.1590/S0103-90162003000300009

Marcos Filho, J. (2005). *Fisiologia de sementes de plantas cultivadas*. Piracicaba: Fealq, 495p.

Marschner, H.; Kirkby, E. A., & Cakmak, I. (2004). Effect of mineral nutritional status on shoot-root formação de porta-enxerto de gravioleira (*Annona muricata* L.). *Ciência e Agrotecnologia*. *28*(3): 530-536. https://doi.org/10.1093/jxb/47.Special_Issue.1255

Masetto. T. E.; Davide. A. C; Faria. J. M. R.; Silva. E. A. A.; Rezende. R. K. S. (2009). Avaliação da qualidade de sementes de *Eugenia pleurantha* (Myrtaceae) pelos testes de germinação e tetrazólio. *Agrarian*, *2*(5). https://doi.org/10.14295/oh.v13i0.1757

Menezes, R. S. C., & Salcedo. I. H. (2007). Mineralização de N após incorporação de adubos orgânicos em um Neossolo Regolítico cultivado com milho. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *11*: 361-367. https://doi.org/10.1590/S1415-43662007000400003

Nascimento, A. L. S.; Muniz, E. N., & Cruz Silva, A. V. (2020). Fruiting and quality attributes of cambui (*Myrciaria floribunda* (West ex Willd.) O. Berg in the Atlantic Forest of northeast Brazil. *Revista Agro@Mbiente on-Line*, *14*: 1-13. http://dx.doi.org/10.18227/1982-8470ragro.v14i0.5861

Piña-Rodrigues, F. C. M.; Figliolia, M. B., & Peixoto, M. C. (2004). *Tecnologia de sementes*: Testes de qualidade. In: Ferreira, A.G.; Borghetti, F. Germinação – do básico ao aplicado. Porto Alegre: Artmed, p. 265-282.

Pires, J. F., & Junqueira, A. M. R. (2001). Impacto da adubação orgânica na produtividade e qualidade das hortaliças. *Horticultura Brasileira*, *19*(2): 195-207.

Santos, D. S. B.; Santos-Filho, B. G.; Torres, S. B.; Firmino, J. L., & Smiderle, O. J. (1994). Efeito do substrato e profundidade de semeadura na emergência e desenvolvimento de plântulas de sabiá. *Revista Brasileira de Sementes*, *16*(1): http://dx.doi.org/50-53.10.17801/0101-3122/rbs.v16n1p50-53

Santos, I. B. D. S., et al. (2020). Antioxidant action and *in vivo* anti-inflammatory and antinociceptive activities of *Myrciaria floribunda* fruit peels: possible involvement of opioidergic system. *Advances in Pharmacological and Pharmaceutical Sciences*, 1–11. http://dx.doi.org/10.1155/2020/1258707

Scalon, S. P. Q.; Alvarenga, A. A., & Davide, A. C. (1993). Influência do substrato, temperatura, umidade e armazenamento sobre a germinação de sementes de pau pereira (*Platycya musregnelli* Benth). *Revista Brasileira de Sementes, 15*(1):143-146.

Seraglio, S. K. T.; Schulz, M.; Nehring, P.; Betta, F. Della; Valese, A. C.; Daguer, H.; GONZAGA, L. V.; Fett, R., & Costa, A. C. O. (2018). Nutritional and bioactive potential of Myrtaceae fruits during ripening. *Food Chemistry*, *239*: 649–656. https://doi.org/10.1016/j.foodchem.2017.06.118

Silva, G. M. C.; Silva, H.; Almeida, M. V. A.; Cavalcanti, M. L. F., & Martins, P. L. (2003). Morfologia do fruto, semente e plântula de mororó *Bauhinia forficata*. *Revista de Biologia e Ciências da Terra*, *3*(2), 36-45.

Silva, R. S. M. Chaves, L. J., & Naves, R. V. (2001). Caracterização de Frutos e árvores de cagaita *Eugenia dysenterica* DC, no sudeste de Goiás, Brasil. Jaboticabal. *Revista Brasileira de Fruticultura*. *23*(2): 330-334. https://doi.org/10.1590/S0100-29452001000200026

Souza, E. R.; Carneiro, I. F.; Naves, R. V.; Borges, J. D.; Leandro, W. M., & Chaves, L. J. (2001). Emergência e crescimento de cagaita em função do tipo e do volume de substratos. *Pesquisa Agropecuária Tropical*, *31*(2): 89-95. https://doi.org/10.5216/pat.v31i2.2467

Tavares, M. K. N. (2015). *Caracterização físico-química, rendimento de polpa e produção de mudas de cambucá (*Myrciaria cuspidata *O. Berg.) - (Myrtaceae)*. 129f. (Monografia - Curso de Tecnologia em Irrigação e Drenagem). Instituto Federal de Educação, Ciência e Tecnologia do Ceará, IFCE – *campus* Sobral. Sobral-CE.

Tibau, A. O. (1983). *Matéria orgânica e fertilidade do solo*. São Paulo: Nobel, 218p.

Wagner Júnior, A.; Alexandre, R. S.; Negreiros, J. R. S.; Pimentel, L. D.; Costa e Silva, J. O., & Bruckner, C. H. (2006). Influência do substrato na germinação e no desenvolvimento inicial de plantas de maracujazeiro amarelo (*Passiflora edulis* Sim s*f. flavicarpa* Deg.). *Ciência Agrotécnica*, *30*(4): 643-647. https://doi.org/10.1590/S1413-70542006000400008