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Evaluation of biometric parameters in the selection of substrates for buriti seedlings (*Mauritia flexuosa* L. f.)

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***Abstract*— *The buriti (Mauritia flexuosa L.f.) is a tree species native of the Cerrado with food and medicinal importance in several places as well as for the population of western Bahia. In the west of Bahia, buriti oil is sold in open markets and the fruits are important in the region's culinary and medicinal uses and for that reason it is important to select substrates that guarantee the development of healthy seedlings, aiming at a high survival rate in the field. The objective of this work was to identify suitable substrates for the development of buriti seedlings. The experimental design was a randomized block with ten treatments and four replications. The substrates used were sand, wood shavings, sugarcane bagasse, soil, cattle manure and footpath soil. The conclusion was that the footpath soil was the one (100%) that provided the best development of the buriti seedlings, which is the most recommended for a quick nursery production. However, given the difficulty of obtaining this material, sand (80%) + soil (20%) can be used to replace footpath soil with similar results.*

I. INTRODUCTION

The species *Mauritia flexuosa* L.f. popularly known as buriti, belongs to the family Arecaceae. The buriti palm occurs in flooded areas, forming dense populations in areas of footpaths (Martins, 2012). It is a palm tree that deserves to be highlighted for its abundance in Brazilian flora (Rossi *et al.*, 2014).

In Brazil, it is found in the region of the Cerrado biome, mainly in the states of the Amazonas, Minas Gerais and Goiás (Martins, 2012) with dense populations in humid areas, gallery forests and footpaths. It is considered like a key species in the footh paths environment (Resende *et al.*, 2012) defined by CONAMA Resolution nº 303/2002 (Brazil, 2002), as a swampy or flooded space, containing springs or headwaters of water courses, where occurs hydromorphic soils with predominance of rows of marsh buritis and other forms of typical vegetation.

This palm is widely distributed in South America (Virapongse *et al.*, 2017). buriti fruits are harvested throughout the Peruvian Amazon for subsistence and commercial purposes. Recent estimates suggest that residents of Iquitos, the largest city in the region, consume approximately 148.8 metric tons per month, the vast majority of which are harvested by felling and killing adult trees (Gilmore, Endress & Horn, 2013).

In the city of Barreiras and throughout the region that covers western Bahia, buriti is of great economic importance both for the riverside populations and for people who live in the urban area. They take advantage of the harvest season of the species to make a profit both on the sale by-products of the fruit (production of ice cream, popsicles, sweets, jams, cocadas, oil extraction, production of medicines, etc.) as well as in the extraction of the palm tree for handicrafts (manufacture of baskets, tables, chairs, among others). For this reason, the university has a socio-environmental commitment to guarantee the conservation of this species.

The native seed nursery at the State University of Bahia - UNEB located in Barreiras, since its creation has as its main function the production of native seedlings to restore areas impacted by agricultural exploration in the region. For this purpose, seedlings of different species are produced annually, giving preference to the production and perpetuation of species that are in constant threat of extinction and that have regional importance and species that have dormant seeds since this characteristic slows down the perpetuation. This is a way of guaranteeing the conservation and preservation of Cerrado species.

Most Arecaceae species have difficulties in germinating, even under suitable conditions, making seedling production difficult (Seleguini *et al.*, 2012). Martins Filho *et al.* (2007) evaluated different substrates in the development of palm seedlings and concluded that the species show different behavior in relation to the evaluated substrates. The development of seedlings inside the nursery has to occur in an accelerated way due to the limited space and resources. Therefore, knowing the ideal substrate for each species, creates a protocol of agility of this work for nurseries because of the possibility of using substrates that guarantee the development of healthy seedlings with a high survival rate in the field.

Andrade *et al.* (2013) found that the use of sieved wood bark along with sugarcane bagasse with bovine manure are efficient to develop seedlings of native trees from the cerrado and favored the initial growth of aroeira seedlings (*Myracrodruon urundeuva* Allemão) in western Bahia, becoming a viable alternative for seedling production. Bovine manure, both with sand and in a mixture with commercial substrate Bioplant®, were also the best substrates for growth in height and diameter of the collection and production of total dry mass in açaí seedlings (*Euterpe oleracea* Mart.), according to Sousa *et al.* (2018).

The aim of this work was to identify suitable substrates for the development of buriti seedlings.

II. MATERIAL AND METHODS

Experimental area

The experiment took place in the nursery for the production of native seedlings in the Cerrado Biome, located at the State University of Bahia, Department of Human Sciences, *Campus* IX, Barreiras, Bahia, Brazil.

Fruit harvesting and seed processing

The fruits were collected on the soil surface under the matrices in an area of footpath located in the community of Perdizes, in the municipality of São Desidério - Bahia at coordinates 12 ° 26 '43.7 ”S and 45 ° 22' 05.3” W. The fruits were processed and removed from the pulp to obtain the seeds. They were washed with water and neutral detergent and then placed in a 1% sodium hypochlorite solution for 5 minutes, then placed to dry the shade for 2 hours. Finally, the seeds were subjected to mechanical scarification in sandpaper on the opposite side to the embryonic axis.

Sowing took place in white trays with a capacity of 20 liters of substrate and was suspended in masonry and wood structure, thus avoiding direct contact with the nursery soil. Forty-five seeds were sown by trays with a spacing of 4.5 cm between them and an approximate depth of 3.0 cm.

Substrates

The substrate used was sand from a river. Wood shavings were purchased from lumber companies in the city of Barreiras – BA. The material used was from random trees of unknown origin with no type of wood shavings being selected.

The sugarcane bagasse was collected in local stores, distributed in the city of Barreiras, taken to the laboratory, dried in an oven at 70 ° C for 72 hours, then, crushed in the machine into pieces of approximately 9.5 mm in diameter.

The soil used was horizon B of the dystrophic red-yellow Latosol, from the property of *Campus* IX of UNEB. The soil was sieved in a grain sieve with a 5.5 mm mesh. The cattle manure used was previously tanned and then sieved through a 5.5 mm mesh grain sieve.

The footpath soil came from the same area where the fruits were collected. The soil was collected in the superficial layer, taking care to remove the first 5 cm and collecting it up to 20 cm deep. Still in place, the soil was sieved in a grain sieve with a 5.5 mm mesh. The substrates (treatments) were sterilized in an autoclave for 2 hours at 120°C and were composed according to Table 1.

Table 1: Treatments composition. Barreiras–BA, UNEB 2020.

TREATMENTS		Composition				
		Sand	**Wood shav.**	**Soil**	**Sugarcane bag.**	**Manure**
T1	Sand	100%				
T2	Sand +Wood shavings	20%	80%			
T3	Sand + Soil	80%		20%		
T4	Footpathsoil	100%				
T5	Sand+ Manure	75%				25%
T6	Soil			100%		
T7	Soil + Wood shavings		80%	20%		
T8	Soil + Sand	80%		20%		
T9	Soil + Sugarcane bagasse			20%	80%	
T10	Soil + Manure			75%		25%

The experiment was irrigated in the morning and in the afternoon for 10 minutes in each period, by a micro-sprinkler system installed in the nursery with a 50% brightness shade. If it rains, the trays will be covered to avoid external interference with irrigation.

Biometric parameters

The emergency speed index (IVE) was calculated using the methodology proposed by Schwerz *et al.* (2010), using the formula IVE = ΣNi / Di, where Ni is the number of seeds emerged in Di days after planting.

The stem length was measured every 7 days after emergence at 7, 14 and 21 days with a millimeter ruler (cm), as well as the stem diameter was measured using a digital caliper (mm). At 21 days, the experiment ended, and the root size was measured with a millimeter rule (cm) and the fresh and dry masses of the aerial part and the root were obtained.

The Dickson Quality Index IQD = MST / (H / DC) + MSPA / MSR) (Dickson, Leaf & Hosner, 1960) was used to evaluate the seedling quality standard. Where MST = Total dry mass; H = length of the aerial part; DC = stem diameter; MSPA = Dry mass of the aerial part and MSR = Dry mass of the root. The relationship between shoot length and stem diameter and the dry mass of the aerial part and dry mass of the root were also analyzed.

Chemical analysis of substrates

The substrates were sent for chemical analysis and results were obtained according to Table 2.

Table 2: Chemical analysis of the substrates: Calcium (Ca), Magnesium (Mg), Potassium (K), Phosphorus (P), Organic matter (O.M.), Cation exchange capacity (CEC) and Saturation by Base (S Base).

Substratos (%)	Ca	Mg	K	P	Al	O.M.	CEC	S Base
	mg^3	mg^3	mg^3	mg^3	mg^3	$g\ kg^{-1}$	Cmol	Cmol
Sand (100)	1,00	0,50	12,44	4,80	0,00	0,70	3,03	50,52
Sand(20)+Wood shavings (80)	2,80	0,80	84,00	14,60	0,00	6,20	8,72	43,78
Sand (80) + Soil (20)	2,40	0,60	35,80	2,30	0,00	0,80	4,59	67,33
Footpathsoil (100)	0,60	0,30	17,10	4,60	0,50	5,30	7,74	12,19
Sand (75) + Manure(25)	3,20	0,80	988,00	84,60	0,00	5,40	7,33	89,09
Soil (100)	2,00	0,90	118.00	6,90	0,00	2,64	5,60	57,16
Soil (80) +Wood shavings (20)	1,80	1,20	138,60	5,60	0,00	8,80	7,96	42,18
Soil (80) + Sand (20)	2,70	0,70	74,00	3,90	0,00	2,80	5,89	49,06
Soil (20) + Sugarcane bag. (80)	0,50	0,40	600,2	28,80	0,70	6,20	10,24	23,82
Soil (75) + Manure (25)	3,00	0,20	770,80	43,90	0,00	3,60	7,68	80,46

Statistical analysis

The experimental design was randomized blocks with 10 treatments and four repetitions. The results obtained were subjected to analysis of variance and the treatment averages compared by the Duncan test at 5% probability, using the Software SAS (Statistical Analysis System), version 9.1 (SAS Institute, 2003).

III. RESULTS AND DISCUSSION

The results of the analysis of variance were significant at 5% significance for the Emergency Speed Index - IVE, indicating that the treatments are different. The Duncan average test was performed for this purpose and it was possible to observe that the substrate composed of sand was statistically superior to the other substrates, and should therefore be indicated to obtain a greater emergence in the culture under study (Table 3). Although the sand has a low amount of nutrients and retains little water, the embryo needs little of the substrate in the first days, as it contains a significant amount of endosperm. Carvalho (2012) evaluated the buriti on different substrates and according to the authors the species has slow germination and is characterized as being of an adjacent ligulated type, which shows the dependence of the endosperm for its nutrition.

In this experiment, buriti seeds began to emerge from 30 days to 121 days, however, dormancy was overcome, which facilitated germination. According to Sousa *et al.* (2005) buriti seeds have slow germination with marked unevenness, starting seedling emergence 40 days after sowing and stabilizing at 260 days. The germination percentage was higher in the substrate containing sand (75%) + manure (25%) and did not differ from the other substrates.

Table3: Emergency speed index – IVE, Percentage of Germinated Seeds - PG%, buriti seedling Stem Length depending on the substrate used. UNEB, Barreiras, BA, 2020.

Substrates (%)	**IVE**	**PG%**	**Steem lenght (cm)**		
			7 days	**14 days**	**21 days**
Sand (100)	62,9 a	0,69 ab	20,11 bcd	22,95 bc	25,61 bcd
Sand (20) +Wood shavings (80)	24,5 b	0,67 ab	17,98 cd	20,52 cd	23,68 de
Sand(80) + Soil (20)	35,9 b	0,70 ab	24,26 b	27,21 b	30,08 ab
Foothpathsoil (100)	26,2 b	0,73 ab	29,92 a	31,99 a	34,11 a
Sand (75) + Manure (25)	37,1 b	0,80 a	21,57 bc	24,52 bc	27,82 bcd
Soil (100)	37,2 b	0,73 ab	21,25 bc	24,58 bc	17,38 bcd
Soil (80) + Wood shavings (20)	28,3 b	0,71 ab	19,54 bcd	21,81 cd	24,31 cde
Soil (80) + Sand (20)	21,3 b	0,58 ab	24,15 b	26,85 b	28,84 bc
Soil (20) +Sugarcane bagasse (80)	23,0 b	0,62 ab	16,18 d	18,13 d	20,41 e
Soil (75) + Manure (25)	29,2 b	0,55 b	21,77 bc	23,82 bc	27,39 bcd

Means followed by the same letters do not differ by Duncan's test at 5% significance.

The Table 3 shows the stem length data for the buriti seedlings, at 7, 14 and 21 days after germination, depending on the substrate. It is observed in this table that the substrate with only footpath soil presented the longest length in the three dates when it was measured, which was significantly longer than the others, except for the 21 days that it was not superior to the substrate with 80% sand plus 20% of soil.

Sousa *et al.* (2011) studied the footpath soils of the cerrado biome and according to the authors, the footpaths are humid ecosystems, generally associated with hydromorphic soils and the outcrop of the water table, frequently occurring near the springs and water courses in the Cerrado region. Through the chemical analysis of the substrates it was possible to verify that the substrate containing only footpath soil presented low levels of potassium (K) phosphorus (P), magnesium (Mg), as well as the other nutrients that are described in the literature as essential for the good plant development. However, this did not influence the development of buriti seedlings, since the diameter was also significantly larger in seedlings containing only footpath soil at 7, 14 and 21 days.

According to Passos *et al.* (2015), the Cerrado area close to the footpath had very low natural fertility, especially low concentrations of phosphorus and organic matter (M.O.). In relation to the latter, it corroborates with the results presented in the studies by Nunes *et al.* (2019) in which native Cerrado soils showed about 2.43% of

O.M. While Silva Junior (2019), studying this parameter in soil samples from agricultural areas and native areas of 10 micro-regions in western Bahia, found even lower values for soils from the native Cerrado that reached 1.52% of O.M in the region's average, which is considered low, according to the classification suggested by Ribeiro, Guimarães e Alvarez (1999). Even so, because it is a native species, buriti is adapted to these conditions, managing to establish itself in these areas.

It was also possible to observe aluminum levels only in the soil and footpath treatments and in the Soil (20) + sugarcane bagasse (80) treatments. Aluminum is a toxic element for plants. In the work by Passos *et al.* (2015), when assessing footpath soils, high levels of aluminum were also identified, which is a characteristic of the cerrado soil.

The Table 4 shows that the stem diameter of buriti seedlings in footpath soils (100%) tends to be larger, however, there is no statistical difference for substrates with sand (80%) + soil (20%), soil (100%), soil (80%) + sand (20%) and soil (75%) + manure (25%). In general, the stem diameter of buriti seedlings was influenced by the substrate.

Table 4: Diameter of buriti seedling stem according to the substrate used. UNEB, Barreiras, BA, 2020.

Substrates (%)	**Stem diameter (mm)**		
	7 days	**14 days**	**21 days**
Sand (100)	8,43 b	8,62c	8,62c
Sand (20)+ (80)	8,66b	8,66c	8,66c
Sand (80) + Soil (20)	9,43ab	9,68 abc	9,68abc
Foothpathsoil (100)	10,06[a]	10,5 a	10,5a
Sand (75) + Manure (25)	8,81b	9,12bc	9,18bc
Soil (100)	9,22ab	9,68 abc	9,81ab
Soil (80) +Wood shavings (20)	8,62b	8,93bc	8,93bc
Soil (80) + Sand (20)	9,37ab	9,75 ab	9,81ab
Solo (20) + Sugarcane bagasse (80)	8,31b	8,75 bc	8,81bc
Soil (75) + Manure (25)	9,18ab	9,56abc	9,62abc

Means followed by the same letters do not differ by Duncan's test at 5% significance.

Regarding the fresh and dry mass, the footpath soil showed the best results, however the fresh mass did not show any significant difference for the substrate in which 80% sand was used plus 20% soil, while the dry mass was significantly different from all the others (Table 5). Regarding the root length, the soil, footpath soil (80) + wood shavings (20) and sand (80) + soil (20) treatment did not differ statistically, which are the most recommended to obtain a good root growth of buriti.

The fresh and dry root mass was superior in the treatment containing sand (80)+ soil (20), and it was also possible to observe satisfactory results in the soil (80) and footpath soil (20) + wood shavings (20) treatments (Table 5). These substrates, when compared to nutritional contents, have totally different characteristics, however both guaranteed satisfactory root growth, as well as for dry matter. According to Haridasan (2008), the concepts of plant nutrition and toxicity that are well established in agriculture, should not be extended to native plants in natural ecosystems, indiscriminately. The great number of species of native plants that occur in the biome are resistant or tolerant to edaphic conditions considered unfavorable to cultivated plants. Perhaps the differences in nutrient concentration observed had a radical influence on cultivated plants, which does not occur in this experiment, where the presence of aluminum and the low concentrations of essential nutrients did not negatively influence the development of buriti seedlings.

Table 5: Fresh and dry mass of the aerial part, Length, fresh and dry weight of buriti seedling roots depending on the substrate. UNEB, Barreiras, BA, 2020.

Substrates (%)	**FAPM (g)**	**ADM (g)**	**RL (cm)**	**FRW (g)**	**DRW (g)**
Sand (100)	5,33 bcd	1,26 bcd	20,30 bc	2,47 bc	0,63 b

Sand (20)+Wood shav. (80)	5,76 bcd	1,30 bc	18,91 c	2,92 abc	0,75 ab
Sand (80) + soil (20)	6,91 ab	1,57 b	24,59 ab	3,73 a	0,95 a
Foothpathsoil (100)	8,24 a	1,91 a	26,01 a	3,42 ab	0,76 ab
Sand (75) + Manure (25)	5,74 bcd	1,34 bc	19,62 c	2,57 bc	0,66 b
Soil (100)	6,25 bc	1,36 bc	17,48 c	2,36 c	0,62 b
Soil (80)+Wood shav. (20)	4,93 cd	1,14 cd	25,38 a	2,70 bc	0,72 b
Soil(80)+Sand (20)	6,34 bc	1,40 bc	20,40 bc	3,07 abc	0,73 b
Soil (20)+Sugarcane bag. (80)	4,33 d	0,94 d	21,72 abc	2,33 c	0,60 b
Soil (75)+Manure (25)	5,98 bc	1,32 bc	21,50 abc	3,21abc	0,73 b

Means followed by the same letters do not differ by Duncan's test at 5% significance.FAPM: Fresh aerial part mass; ADM: Aerial dry mass; RL: Root length; FRW: Fresh rooth weight; DRW: Dry rooth weight.

When assessing the Dickson Quality Index (DQI), significant differences were observed between the substrates, indicating that the substrate containing sand (80%) + soil (20%) showed better quality seedlings (Table 6). The higher the value of this index, the better the seedling quality standard (Gomes & Paiva, 2012). The DQI is used in studies that deal with morphological parameters related to seedling quality (Rosa *et al.*, 2009; Caione, Lange & Schoninger, 2012; Garcia & Souza, 2015; Sousa *et al.*, 2018), being important for considering the vigor and balance of the distribution of biomass in the seedling which involves the results of several important parameters used to assess quality.

Table 6: DQI - Dickson Quality Index and relationship between Dry Mass of the Aerial Part and Dry Mass of the root, Stem Length (cm)/Diameter (mm) ratio of buriti seedlings. UNEB, Barreiras, BA, 2020.

Substrates (%)	**DQI**	**DMAP/ DMR**	Stem length (cm)/ Diameter ratio(mm) ratio		
			7 days	**14 days**	**21 days**
Sand (100)	0,37 b	2,05bc	2,37 bc	2,65 ab	2,96 ab
Sand (20)+Wood shavings (80)	0,45 ab	1,76 cd	2,10 bc	2,39 bc	2,76 abc
Sand (80) + Soil (20)	0,52 a	1,70cd	2,56 ab	2,80 ab	3,10 ab
Foothpathsoil (100)	0,46 ab	2,50a	2,98 a	3,06 a	3,24 a
Sand (75) + Manure (25)	0,39 b	2,04bc	2,44 bc	2,68 ab	3,03 ab
Soil (100)	0,39 b	2,26ab	2,31 bc	2,54 bc	2,80 ab
Soil (80) + Wood shavings (20)	0,43 ab	1,57d	2,28 bc	2,44 bc	2,73 bc
Soil (80) + Sand (20)	0,43 ab	1,93bcd	2,59 ab	2,76 ab	2,95 ab
Soil (20) + Sugarcane bagasse (80)	0,39 b	1,61	1,95 c	2,07 c	2,32 c
Solo (75) + Manure (25)	0,44 ab	1,81cd	2,36 bc	2,50 bc	2,84 ab

Means followed by the same letters do not differ by Duncan's test at 5% significance.

The DMAP/ DMR ratio was also higher in the soil substrate (100%) (Table 6). This result indicates a balance between the aerial part and the root. This balance avoids future tipping, as well as seedlings with a well-developed root system are more likely to survive in the field, especially if you are in an environment with water limitations (Lima *et al.*, 2008).

There was a greater stem length/stem diameter relationship for the soil substrate (100%) at 7, 14 and 21 days (Table 6).This corroborates with the studies by Souza et al (2018) in which the substrates presented the best growths in height and diameter of the collection and increased the production of total dry mass in seedlings of Euterpe oleracea Mart. over a period of 60, 90, and 120 days using sand and cattle manure. According to Araújo *et al.* (2017), this non-destructive evaluation method represents the plant's growth balance. The stem diameter is one of the best indicators of the seedling quality standard and is correlated with the initial survival at the time of planting, and there must be a diameter compatible with the height (Frigotto *et al.*, 2015).

IV. CONCLUSION

The conclusion was that the footpath soil provides better development of the buriti seedlings (100%), which is the most recommended for a quick nursery production. However, due to the difficulty in obtaining this material, sand (80%) + soil (20%) can be used to replace the footpath soil with similar results.

The deepening of studies related to the production of seedlings of species of socio-economic cultural interest are fundamental to corroborate the conservation actions of the native flora of the different Brazilian biomes.

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