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RESEARCH ARTICLE

Collection, *ex situ* conservation and characterization of mangaba (*Hancornia speciose* Gomes) germplasm in coastal lowland of Northeastern Brazil

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Abstract This study aimed to evaluate the Mangaba Genebank of Embrapa Tabuleiros Costeiros, Brazil, since its implementation in 2006 and characterize the accessions in the reproductive stage. We used 21 descriptors (botanical, morphological, growth, biometric, and physicochemical) to assess mangaba germplasm, as well as the data of enrichment and survival since the genebank implementation. There was a success in the enrichment, maintenance, and diversity of the germplasm evaluated. The results showed a significant difference between the accessions for most descriptors. The fruits presented good quality characteristics both for fresh consumption and processing. Moreover, these results supported the publication of the minimum descriptors for this species by Bioversity International and Embrapa. The knowledge of mangaba variability will subsidize conservation strategies and should encourage future researches on breeding.

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Introduction

Mangaba (*Hancornia speciosa* Gomes—Apocynaceae) is a native fruit tree from Brazil, Bolivia, Paraguay and Peru. In Brazil, it naturally occurs from Amapá, in the north, to Paraná, in the south, in many biomes, especially in different phytophysiognomies associated with *Cerrado*, a Neotropical savannah, and Atlantic Rain Forest, a coastal forest. The genus is monotypic and six botanical varieties are described: *H. speciosa* var. *speciosa* Gomes; *H. speciosa* var. *cuyabensis* Malme, *H. speciosa* var. *pubescens* (Nees. and Martius) Muell. Arg., *H. speciosa* var. *gardneri* (A. DC.) Muell. Arg., *H. speciosa* var. *maximiliani* A. DC., and *H. speciosa* var. *lundii* A. DC. (Monachino 1945). However, the recent phylogenic study undertaken by Santana (2018) in his thesis, suggests the existence of only three varieties (*speciosa, cuyabensis* and *pubescens*), supported by Colevatti et al. (2016) and Flores et al. (2018). It is a medium-sized tree, and is 4–7 m in height, reaching up to 15 m (Fig. 1). It has slow growth with a wide canopy that is sometimes more branched than high (Silva Júnior et al. 2018).

Although mangaba has a potential for wide spreading, its exploitation is carried out mainly in an

Fig. 1 *Hancornia speciosa* Gomes (tree and fruits). *Photos* Josué Francisco da Silva Júnior

extractive system. In addition, mangaba is a species under domestication and genetic erosion process due to the real estate expansion and the increase of agricultural activities in its native areas (Soares et al. 2015).

The extractive activity of mangaba is conducted by traditional communities of women known as "mangaba pickers" ("catadoras de mangaba", in portuguese). They are responsible for the conservation of natural areas where the species occurs, as well as the collection and supply of the fruit market on the coast of Northeast Brazil. As a result, mangaba an important source of food and income for these women (Mota et al. 2011).

Given the social, economic, environmental, and cultural importance of mangaba, as well as, its natural habitat reduction, Embrapa Tabuleiros Costeiros, a research center of Brazilian Agricultural Research Corporation (Embrapa), has developed conservation strategies for this species. Therefore, in 2006, Mangaba Genebank was implemented in Itaporanga Experimental Field, located on the municipality of Itaporanga d'Ajuda, in Sergipe State (SE), Brazil (11°06′40″S and 37°11′15″N and 9 m). The genebank is also the Loyal Depositary for Subsamples of the Genetic Heritage Component of the species in Brazil since 2014. Currently, the genebank comprises of 27 accessions represented by 299 plants collected in a wide geographical distribuition. The collecting expeditions prioritize the coastal tablelands and coastal lowland areas of the Northeast Region of Brazil.

In 2011, the first molecular characterization of the Mangaba Genebank was performed, whose results showed a large genetic variability among the accessions (Silva et al. 2011). Microsatellite primers specific for mangaba were tested in the genebank by Amorim et al. (2015) and confirmed the germplasm diversity. In 2018, the publication of the descriptors manual of mangaba by Bioversity International and Embrapa was considered an important step to characterize and evaluate this species (Silva Júnior et al. 2018). Thereby it can provide standardization for using descriptors to differentiate genotypes of genebanks and collections.

The aim of this study was to evaluate the enrichment, conservation, characterization, and documentation of Mangaba Genebank accessions developed by Embrapa Tabuleiros Costeiros, from 2006 to 2017.

Material and methods

The Mangaba Genebank (Fig. 2) is located in a coastal lowlands ecosystem known as *Restinga* and the soil is classified as humiluvic spodosol. Mangaba Genebank also includes an area of 4.7 ha in the Private Natural Heritage Reserve of Caju, located in this experimental field that is destined to the in situ conservation of mangaba population.

The first accessions were collected and planted in 2006 (Table 1), and as time passes by collecting expeditions were undertaken in natural populations of several Brazilian regions (Fig. 3).

The accessions were named according to the location in which population samples were collected. Since 2009, all accessions were evaluated annually to characterize morphological and botanical parameters related to plant growth (Table 2).

From 2013, when plants were already in the fruiting stage, 12 fruits of each individual were collected and their biometric characteristics (total weight, number of seeds, length, width, and shape) and seeds (length,

Fig. 2 Mangaba Genebank of Embrapa Tabuleiros Costeiros, Itaporanga d'Ajuda, SE, Brazil, 2018. *Photos* Ana Veruska Cruz da Silva

width, thickness, and volume) were evaluated. The following physicochemical attributes were also evaluated: (a) pulp pH, performed with an electronic potentiometer using five grams of pulp diluted in 50 mL of distilled water; (b) Titratable Total Acidity (TTA), determined by titration with 0.1 N NaOH solution and 1% phenolphthalein as indicator, and the values expressed as a citric acid percentage; (c) soluble solids content (SS), using a digital refractometer, PAL-1 Atago®, according to AOAC (1992), and the contents expressed as °Brix; (d) SS / TTA, soluble solids / Titratable Total Acidity ratio; (e) Vitamin C (Muniz et al. 2019).

The data for each parameter from all accessions were analyzed using the analysis of variance (ANOVA). Tukey test at 5% significance level was applied when the model showed significant difference ($P < 0.05$), using the SAS® program.

Results and discussion

Since the Mangaba Genebank implantation, one of the criteria established by curators was to collect and conserve individuals from natural and endangered populations. In 2006, collecting expeditions resulted in germplasm enrichment, initially with six accessions, represented by 36 plants. In 2018, there were 27 accessions and 299 plants. In 2010, the highest number of new accessions introduced was observed (seven) (Fig. 4). Thenceforth, each accession was represented by 18 plants, since it better represents a population of an allogamous species. This change of strategy occurred in 2009. Until then, they were represented by six plants.

A large decrease in the survival percentage of accessions was observed in 2013 (Fig. 5). The main reason for that could be probably due to a prolonged drought and the highest temperatures that contributed to the increase of the individuals' mortality.

In addition to accessions established in the genebank, some new introductions were not successful due to the high seedlings mortality in the field caused by root rot, one of the main phytosanitary problems of mangaba seedlings. In the period between 2013 and 2015, seven accessions were introduced, with 100% mortality (Table 3). This fact was recorded in all accessions collected in the states of Maranhão, Tocantins and Ceará. In the latter, only four Jacarecoara accessions from the Municipality of Cascavel survived, and none collected in the Municipality of Iguape survived. Currently, the original population located in Jacarecoara, a village in Cascavel, has been destroyed, which reinforces the importance of the ex situ conservation of genetic resources.

Regarding the morphological characteristics evaluated, the results indicate the existence of diversity in several aspects (Table 4). The canopy shape (Fig. 6) in evidence was oblong (63.63% of individuals); 72% of BAG plants showed strong vigor and erect growth habit (56.46%).

In this study, the predominant fruit shape observed in the accessions was spheroid (Table 4). Muniz et al. (2019) and Oliveira, Silva and Chagas (2018) reported

Table 1 Origin, accession/ local code, date of introduction and number of plants from mangaba genebank accessions of Embrapa Tabuleiros Costeiros, Itaporanga d'Ajuda, SE, Brazil

Accession/local code	Origin (municipality and state)	Date of introduction	Number of plants per accesion
Costa Azul—CA	Jandaíra, Bahia	11/08/2006	5
Barra de Itariri—BI	Conde, Bahia	11/08/2006	6
Lagoa Grande—LG	Mata de São João, Bahia	11/08/2006	6
Terra Caída—TC	Indiaroba, Sergipe	11/08/2006	6
Preguiça—PR	Indiaroba, Sergipe	11/08/2006	6
Pontal—PT	Indiaroba, Sergipe	11/08/2006	6
Água Boa—AB	Salvaterra, Pará	03/06/2007	6
Ipiranguinha—IP	Conde, Paraíba	03/17/2007	5
Alhandra/Mata Redonda—AD	Alhandra, Paraíba	03/17/2007	6
Guaxinduba—GX	Conde, Paraíba	03/17/2007	5
Paratibe—PA	João Pessoa, Paraíba	03/17/2007	5
Capuã—CP	Barra dos Coqueiros, Sergipe	09/17/2009	17
Casas Velhas—CV	Palmeiras, Bahia	09/17/2009	18
Chapada do Areião—CH	Rio Pardo de Minas, Minas Gerais	06/16/2010	17
Tabúa—TA	Montes Claros, Minas Gerais	06/16/2010	10
Couto Magalhães de Minas—CM	Couto Magalhães de Minas, Minas Gerais	09/01/2010	13
Guaiamum—GU	Sirinhaém, Pernambuco	09/02/2010	15
Oiteiro—OI	Ipojuca, Pernambuco	09/01/2010	17
Japaratinga—JA	Japaratinga, Alagoas	09/01/2010	18
Ponta de Mangue—PM	Maragogi, Alagoas	11/18/2010	13
Tamandaré—TM	Tamandaré, Pernambuco	07/21/2011	17
Carneiros—CN	Tamandaré, Pernambuco	07/21/2011	12
Jacarecoara—JC	Cascavel, Ceará	05/10/2013	4
Aeroporto—AE	Aracaju, Sergipe	08/10/2016	16
Mamucabinhas—MM	Tamandaré, Pernambuco	08/10/2016	16
Touro—TO	Barra dos Coqueiros, Sergipe	09/14/2017	16
Ilha da Prainha—PH	Indiaroba, Sergipe	09/18/2017	18
	Total		299

mean values of fruit longitudinal diameter (LD) similar to those obtained in this study (35.89 mm). However, Oliveira, Silva and Chagas (2018) observed the mean fruit weight of 31.94 g, values above those found in fruits from Embrapa Tabuleiros Costeiros Mangaba Genebank (19.38 g). Regarding seed physical attributes, Muniz et al. (2019) reported similar values to those found in this study for the number of seed, however, the weight of seeds was higher. In the *Cerrado*, Pinheiro et al. (2018) observed higher number (13.15) and weight (4.74 g) of seeds.

Studies of the seeds biometry can indicate whether there is variability within the species, being used for different native species of Brazil (Menegatti et al. 2019). In certain species, the seeds classification by size or weight could be a strategy adopted to standardize the seedlings emergence and to obtain uniform and vigorous seedlings. In Brazilian native fruit species, there are still several gaps to be filled. There are reports of seed biometry for species such as *Syagrus romanzoffiana (*Goudel et al. 2013*);* cambuí (*Myrciaria tenella* O. Berg) (Silva et al. 2012a); bacuri (*Platonia insignis* Mart.) (Santos et al. 2019); gabiroba

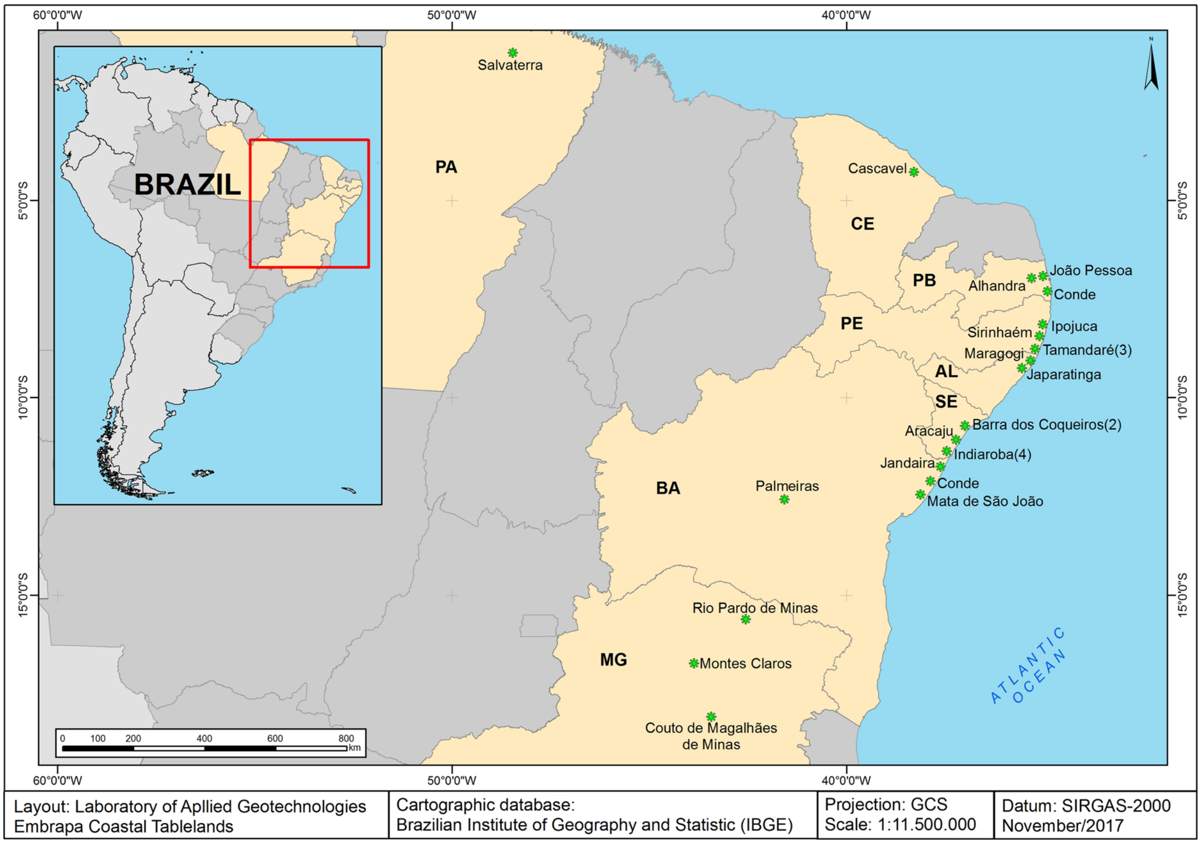

Fig. 3 Natural occurrence and collecting areas of mangaba (*Hancornia speciosa* Gomes) in Brazil

(*Campomanesia lineatifolia* Ruiz e Pav.) (Lima et al. 2016), and mangaba (Oliveira et al. 2018). However, significant basic knowledge of seed biometry remains to be known and published.

There were significant differences in characteristics such as fruit width and seed length. For the others, there was no variation among accessions (Table 5). For fruit length, there was no significant difference and the mean value was 36.19 mm. However, the BI accession produced fruits with the highest width (34.85 mm). When evaluating the seeds, the physical attributes showed a difference between the accessions only for the seed length, in which PT accession had the lowest value (7.62 mm).

The first fruiting of mangaba individuals from the genebank occurred in 2013. The quality attributes of these fruits were reported by Silva et al. (2015). The first accessions to show fructification were CA, BI, LG, TC, PR, PT, and AB, with a mean age of six years. In 2016, new accessions also showed fructification—AB, IP, AD, GX, and PA. There was a significant difference among accessions for the characteristics related to the quality attributes of mangaba fruits (Table 6).

The pH results (Table 6) were similar to those found by Muniz et al. (2019), who obtained values between 3.48 and 3.52. Soluble solids (SS) values were lower than those reported by Santos et al. (2017) −18.47° Brix, but higher than those obtained by Muniz et al. (2019), which reported a mean of 12.41° Brix. The sweetness of fruits is due to the presence of soluble sugars and can be influenced by climatic conditions (Silva et al. 2019). The TTA results were similar to those of Muniz et al. (2019) and Santos et al. (2017).

The best SS / TTA ratio was found in AB accession (20.71) (Table 6). The values found for this ratio evaluated in this work are high and indicate the potential use of mangaba in the food industry. The vitamin C contents were high for the most of accessions evaluated, except for TC accession that obtained the lowest mean (333.85 mg 100 g^{-1}). The highest SS / TTA ratio found—20.71 in this study

Table 2 Parameters evaluated in Mangaba Genebank accessions, Itaporanga d'Ajuda, SE, Brazil

Morphological and botanical	Types
Canopy shape	Pyramidal, oblong, spherical, semicircular, elliptic, irregular
Vigor	Weak, intermediate, strong
Growth habit	Erect, irregular, semi-erect, horizontal, pendent
Branch type	Little branched, intermediate, highly branched
Trunk surface	Smooth, rough, very rough
Leaf shape	Ovate, rounded, lanceolate, oblong, oblong-lanceolate
Leaf texture	Coriaceous, semi-coriaceous, malleable
Inflorescence position	Terminal, subterminal, axillary, terminal and subterminal, terminal and axillary
Fruiting habit	Solitary, bunches, solitary + bunches
Fruit shape	Oblong, spheroid, ovoid
Growth characteristics	
Plant height (h)	determined with the use of clinometer in higher plants or wooden tape measure in lower plants, expressed in meters
Height of crown insertion point (CI)	from the soil at the height of the first canopy insertion
Canopy length (CL)	determined by the difference between total height and canopy insertion (h—CI)
Canopy diameter (CD)	determined by the canopy length measurements in the (N-S) + ((E-W) / 2 directions
Canopy area (CA)	determined by $CD^2 * \pi/4$
Stem diameter at height of the canopy bifurcation (SDC)	measured with tape below the first canopy bifurcation, expressed in meters. This variable was an adaptation to DBH (diameter at breast height), considering the specific morphological characteristics of mangaba tree with presence of stem branches
Morphometric indexes	
Canopy proportion (CP)	Vitality indicator, which corresponds to the canopy length (L)/ total tree height ratio, expressed by CP = L/h
Slenderness degree (SD)	Expressed by the h/SDC ratio, which is a variable that characterizes tree stability
Salience index (SI)	Expressed by the ratio between canopy diameter and SCD: IS = CD/SDC
Cover Index (CI)	Calculated by the ratio between canopy diameter to total tree height: CI = CD/h
Canopy shape (CS)	Calculated by the ratio between canopy diameter to canopy length: CS = CD/L

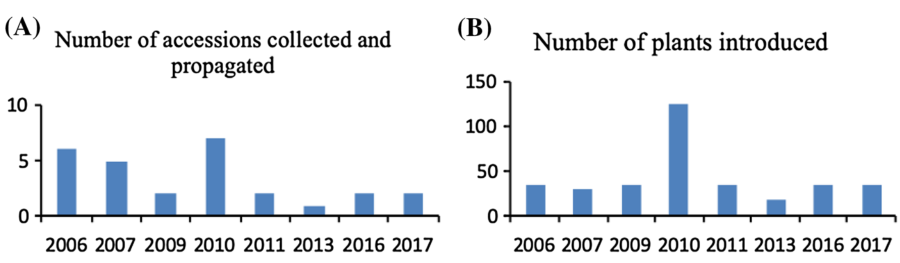

Fig. 4 Enrichment of Mangaba Genebank from 2006 to 2017: (**A**) Number of accessions collected and propagated; (**B**) Number of plants per accession introduced. Itaporanga d'Ajuda, SE, Brazil

(Table 6) was higher than the values found by Muniz et al. (2019)—18.8. This ratio is essential for taste assessment and is considered more representative than individual measurements of sugars and acidity. Higher soluble solids values and lower acidity characterize higher SS/TTA ratio, which is preferred by consumers.

In this study, the vitamin C values (Table 6) were similar to those of Silva et al. (2012b) and Santos et al. (2017), but much higher than 188.33 mg 100 g^{-1}

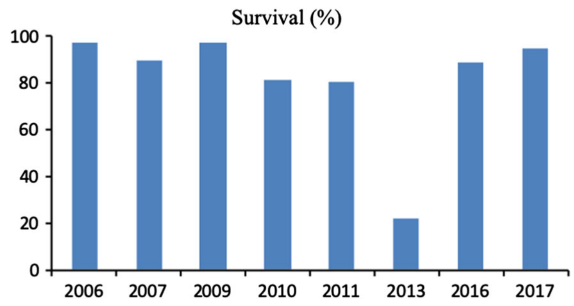

Fig. 5 Survival percentage of accessions from Mangaba Genebank of Embrapa Tabuleiros Costeiros over the years, Itaporanga d'Ajuda, SE, Brazil

Table 3 Accession/ local code, origin, date of introduction, number of individuals introduced, survival percentage at 6 and 12 months of Mangaba Genebank accessions did not establish in the field of Embrapa Tabuleiros Costeiros, Itaporanga d'Ajuda, SE, Brazil

Accession/ Local Code	Origin (municipality and state)	Date of introduction	N° of plants per accession	Survival % (6 months)	Survival % (12 months)
Santa Helena—SH	Morros, Maranhão	04/27/2015	18	44.44	0
Lagoa Grande—LR	Morros, Maranhão	04/27/2015	18	27.77	0
Pequi dos Bois—PB	Morros, Maranhão	04/27/015	18	11.11	0
Campo do Morro—CM	Morros, Maranhão	04/27/2015	18	27.77	0
Flor da Serra—FS	Colmeia, Tocantins	04/27/2015	18	33.33	0
Tapera—TP	Iguape, Ceará	12/05/2013	18	11.11	0

Table 4 Percentages of morphological characteristics observed in the Mangaba Genebank accessions. Itaporanga d'Ajuda, SE, Brazil

Characteristics	Types (%)
Canopy shape	Oblong (63.63%); spherical (15.78%); irregular (12.91%); elliptic (6.7%) and pyramidal (0.95%)
Vigor	Strong (72%); intermediate (28%)
Growth habit	Erect (56.46%), semi-erect (20.40%), irregular (9.03%), horizontal (0.67%), pendent (0.48%)
Branching type	Very branched (45.53%); intermediate (39.88%); slightly branched (14.58%)
Trunk surface	Rough (77.67%); very rough (19.04%); smooth (0.29%)
Leaf shape	Lanceolate (76.19%); oblong (22.91%); rounded (0.89%)
Leaf texture	Semi-coriaceous (100%)
Leaf pilosity	Smooth (100%)
Inflorescence position	Terminal (60.71%); axillary (39.28%)
Fruiting habit	Solitary (89.19%); bunches (10.81%)
Fruit shape	Spheroid (78.37%); oblong (21.62%)

reported by Plácido et al. (2016). These values indicate that mangaba is a fruit rich in vitamin C, reaching values higher than some fruits such as guava (78.2 to 268.7), mango (13.2 to 92.8 mg 100 g^{-1}), and papaya (21.2 mg 100 g^{-1}) (Rojas-Barquera and Narvaez-Cuenca 2009; USDA 2018; Wall 2006, respectively). This feature can be used to select promising genotypes for later uses in breeding programs. Ascorbic acid is a water-soluble vitamin that has high nutritional value and acts in physiological processes, as antioxidant. Fruits evaluated have excellent quality and nutritional value and can be used in the food industry as a valuable raw material for the production of frozen pulp, ice cream, and more recently, for blends with juices of other fruits, with great potential to conquer intern and extern market (Silva Júnior et al. 2018).

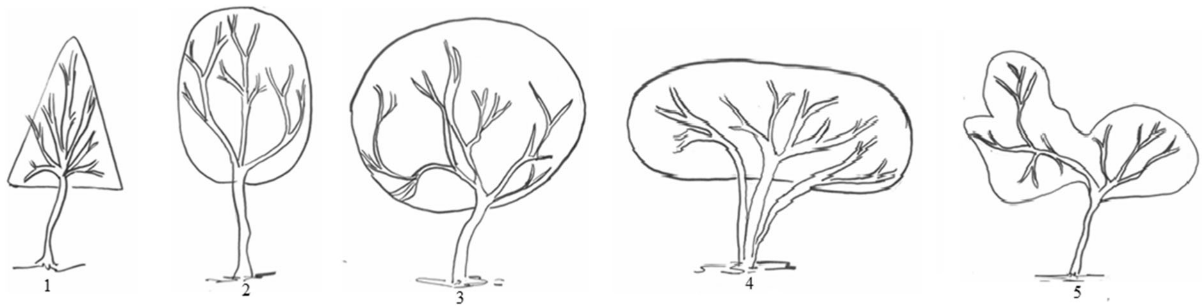

Fig. 6 Canopy shapes observed in mangaba genebank accessions. Itaporanga d'Ajuda, SE, Brazil. 1. Pyramidal; 2. Oblong; 3. Spherical; 4. Elliptical; 5. Irregular. *Source* Silva Júnior et al. (2018)

Table 5 Mean values of biometric characteristics for fruits and seeds from eight Mangaba Genebank accessions. Itaporanga d'Ajuda, SE, Brazil

Accession	Fruits				Seeds			
	Weight (g)	Number of seeds	Lenght (mm)	Width (mm)*	Weight (g)	Lenght (mm)*	Width (mm)	Thickness (mm)
CA	19.65	9.40	35.08	31.76abc	0.14	8.90a	6.77	2.86
AB	16.40	5.60	38.98	28.77cd	0.07	7.85ab	6.41	2.79
PT	17.70	10.20	37.02	29.79bcd	0.11	7.62b	6.03	2.50
PR	19.53	7.85	36.42	30.95abcd	0.14	8.74a	6.51	2.59
TC	24.22	12.75	36.75	34.52ab	0.09	8.00ab	6.37	2.84
PA	12.40	5.00	33.96	26.63d	0.08	8.51ab	6.50	2.51
LG	18.71	10.40	34.82	31.72abc	0.10	8.15ab	6.45	2.64
BI	26.46	10.50	36.52	34.85a	0.13	8.76a	6.81	2.91

CA Costa Azul; *AB* Água Boa; *PT* Pontal; *PR* Preguiça; *TC* Terra Caída; *PA* Paratibe; *LG* Lagoa grande; *BI* Barra do Itariri

Mangaba is also used for artisanal sweet, jam, and liquor fabrication.

The results of quality attributes indicated that fruits are in accordance with the Brazilian legislation standards, composed of the Quality Identity Standard, which requires that the mangaba pulp should present 8° Brix; pH 2.80, and TTA expressed as citric acid from 0.7 to 100 g pulp (Brazil 2016).

Among the morphological characteristics of accessions that are in the adult phase, there was a significant difference for all characteristics evaluated (Table 7). The AB accession had the highest total height and canopy length, diameter, and area. On the other hand, the GX accession showed the lowest mean values for all parameters evaluated, reaching only 1.24 m of total height.

Regarding morphometric indexes, there was a significant difference among accessions for the slenderness degree and salience index. The results for the salience index were better for AB, PR, TC, PA, IP, and AD accessions. The cover index had a mean value of 0.54, and there was no significant difference among accessions. However, the AD accession stood out, reaching respectively values of slenderness degree and salience index of 18.04 and 10.42 (Table 8).

The mean height value (4,57 m) was greater than that observed in natural populations in Sergipe by Silva et al. (2017) (3,84 m). For canopy insertion, values ranged from 0.18 m to 0.68 m, with a mean value of 0.45 m, similar to 0.41 m observed by Freitas et al. (2012). This parameter is crucial to elaborate on growth models after periodic analyses. In addition to influencing the harvest process, which is manual and facilitated by small trees, it also reduces the distance from fruits at higher branches to the soil, reducing

Table 6 Mean values of quality attributes (pH, soluble solids—SS, Total Titratable Acidity—TTA, SS / TTA ratio, and vitamin C content) of 11 Mangaba Genebank accessions evaluated from 2013 to 2017. Itaporanga d'Ajuda, SE, Brazil

Accession	pH	SS (°Brix)	TTA (% citric acid)	SS/TTA	C Vit (mg 100 g^{-1})
CA	3.67ab	16.11a	1.37abc	12.71bc	406.50ab
AB	3.67ab	14.14bc	0.85e	20.71a	367.81ab
PT	3.59ab	16.35a	1.16bcd	14.85b	352.49ab
PR	3.51b	15.14ab	1.34abc	11.60bc	400.97ab
TC	3.77a	16.60a	1.28abc	13.64bc	333.85b
PA	3.48b	13.30c	1.10cde	12.29bc	383.00ab
LG	3.71a	16.26a	1.30abc	14.31bc	378.86ab
BI	3.65ab	16.62a	1.40ab	12.74bc	417.64a
IP	3.52b	14.25bc	1.11cde	12.81bc	382.30ab
AD	3.51b	12.83c	0.90de	14.18bc	395.81ab
GX	3.49b	14.23bc	1.49a	9.52c	395.06ab

CA Costa Azul; *AB* Água Boa; *PT* Pontal; *PR* Preguiça; *TC* Terra Caída; *PA* Paratibe; *LG* Lagoa Grande; *BI* Barra do Itariri; *IP* Ipiranguinha; *AD* Alhandra/Mata Redonda; *GX* Guaxinduba

Table 7 Morphological characteristics of 11 Mangaba Genebank accessions in the adult phase evaluated in 2017. Itaporanga d'Ajuda, SE, Brazil

Accessions	Total Heigh (m)	Canopy insertion height (m)	Canopy Lenght (m)	Canopy diameter (m)	Canopy area (m)	Stem diameter below 1st stem bifurcation DCBC (m)
CA	4.76b	0.43ab	4.34bc	2.59abc	5.36bc	0.54bc
AB	6.46a	0.46ab	6.00a	3.46a	9.55a	0.62b
PT	4.95ab	0.35ab	4.60abc	2.65abc	5.63bc	0.61b
PR	5.08ab	0.55ab	4.55abc	2.81ab	6.31b	0.49bc
TC	5.35ab	0.40ab	4.93abc	2.87ab	6.63b	0.51bc
PA	4.21bc	0.68a	3.52cd	2.45bc	5.34bc	0.39bc
LG	5.60ab	0.46ab	5.15ab	3.03ab	7.41ab	0.89a
BI	5.41ab	0.55ab	4.85abc	2.98ab	7.03ab	0.60bc
IP	4.12bc	0.41ab	3.73bcd	2.27bc	4.71bc	0.37bc
AD	3.18c	0.37ab	2.81d	1.78c	3.061cd	0.32bc
GX	1.24d	0.18b	1.04e	0.71d	1.29d	0.43bc

CA Costa Azul; *AB* Água Boa; *PT* Pontal; *PR* Preguiça; *TC* Terra Caída; *PA* Paratibe; *LG* Lagoa Grande; *BI* Barra do Itariri; *IP* Ipiranguinha; *AD* Alhandra/Mata Redonda; *GX* Guaxinduba

damage. The canopy diameter varied from 0.71 to 3.46, lower than that found by Freitas et al. (2012).

The slenderness degree tends to decrease as increasing the age until reaching the stability. This happens due to the smallest diameter at breast height and total tree height, and presents height growth relatively smaller than diameter growth. The canopy cover index had a mean value of 0.54 (Table 8), and there was no significant difference among accessions. Freitas et al. (2012) obtained higher mean values, from 0.7 to 1.3. This measure indicates canopy symmetry, and the closer to 1, the more symmetrical is. Values higher than 1, the canopy is thinner and lower than 1, is more spread.

The analysis of similarity dendrogram grouped the closest accessions according to the growth

Table 8 Morphometric indexes of Mangaba Genebank accessions evaluated in 2017. Itaporanga d'Ajuda, SE, Brazil

Accessions	Canopy proportion	Degree of slenderness	Salience index	Canopy cover index	Canopy shape index
CA	90.86a	9.00b	4.91b	0.54a	0.60a
AB	93.03a	10.52ab	5.65ab	0.53a	0.57a
PT	92.91a	8.06b	4.32b	0.53a	0.58a
PR	89.01a	10.78ab	6.03ab	0.55a	0.62a
TC	92.58a	10.57ab	5.69ab	0.53a	0.58a
PA	84.52a	13.45ab	7.94ab	0.57a	0.68a
LG	90.75a	7.83b	4.21b	0.54a	0.60a
BI	89.61a	9.15b	5.06b	0.55a	0.61a
IP	90.56a	14.60ab	7.93ab	0.54a	0.60a
AD	86.96a	18.04a	10.42a	0.56a	0.65a
GX	91.54a	6.16b	3.61b	0.54a	0.60a

CA Costa Azul; *AB* Água Boa; *PT* Pontal; *PR* Preguiça; *TC* Terra Caída; *PA* Paratibe; *LG* Lagoa Grande; *BI* Barra do Itariri; *IP* Ipiranguinha; *AD* Alhandra/Mata Redonda; *GX* Guaxinduba

characteristics, morphometric indexes and phisico-chemical atributes analyzed, and two groups were formed, one consisting of CA, PR, BI, and PA accessions, and the other consisting of LG, TC, PT, and AB accessions. It was observed that the harvest site was not a determining factor for the group's formation (Fig. 7).

The 299 individuals that currently compose Mangaba Genebank were evaluated annually. The mean values of the descriptive features of agronomic importance are presented, and they are considered relevant for the production and management of all accessions (Table 9). These parameters are important to measure growth and vigor of accessions from genebank. Some accessions were not evaluated due to the size (young plants) not allowing the measurement. In general, the results indicate the existence of variability based on the descriptors evaluated. Therefore, those results can be used to making conservation strategies for the species and in future breeding programs.

Concerning the height of plants (Table 10), the values found were similar to those described by Monachino (1945). Accessions with lower values are explained by the date of introduction. The canopy introduction has values close to those observed by

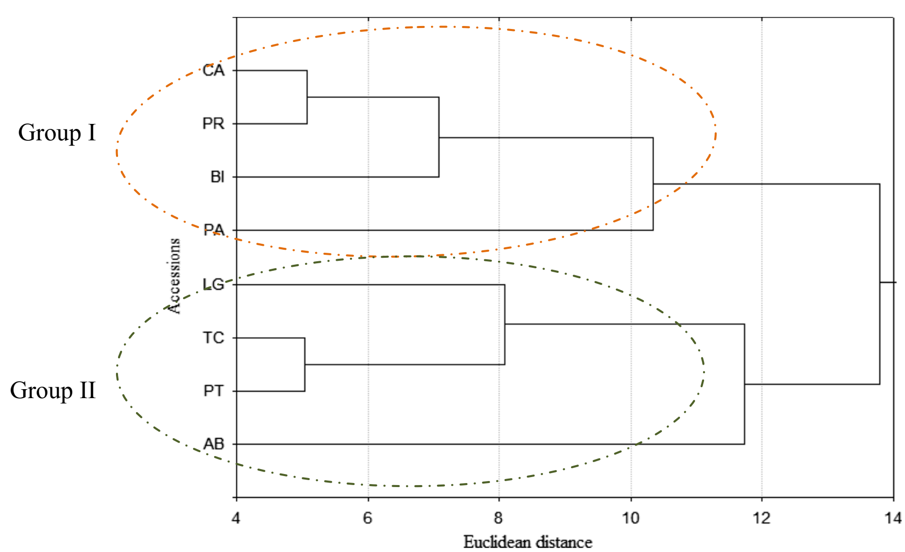

Fig. 7 Similarity dendrogram based on the characteristics evaluated in Mangaba Genebank accessions in the adult phase using the Euclidean distance. Itaporanga d'Ajuda, SE, Brazil

Table 9 Descriptive analysis of the morphological characteristics of all Mangaba Genebank accessions. Itaporanga d'Ajuda, SE, Brazil, 2017

Accessions	Age (year)	Height (m)	Diameter of stem (m)	Canopy area (m)	Insert of the canopy (m)	Petiole length (mm)
CA	11	4.76	0.16	21.28	0.43	8.56
BI	11	5.41	0.15	23.24	0.56	8.04
LG	11	5.60	0.16	28.18	0.47	7.83
TC	11	5.35	0.16	26.26	0.40	8.92
PR	11	5.08	0.15	22.80	0.56	8,13
PT	11	4.95	0.16	27.70	0.36	9.09
AB	10	6.47	0.18	25.57	0.47	8.30
IP	10	4.13	0.09	17.14	0.41	7.86
AD	10	3.18	0.08	15.19	0.38	9.05
GX	10	1.25	0.03	4.78	0.18	5.67
PA	10	4.21	0.10	15.37	0.69	7.09
CP	8	4.22	0.11	15.35	0.50	8.15
CV	8	4.99	0.11	12.27	0.61	8.17
CH	7	3.74	0.08	9.23	0.79	6.48
TA	7	2.19	0.05	5.84	0.87	4.42
CM	7	3.20	0.06	4.96	0.88	3.93
GU	7	3.71	0.11	12.01	0.44	8.79
OI	7	3.72	0.11	15.69	0.37	8.71
JA	7	3.80	0.09	14.14	0.37	8.45
PM	7	3.39	0.09	8.96	0.39	8.24
CN	6	2.96	0.06	6.26	0.02	4.51
JC	4	0.45	0.00	0.09	0.22	6.89
TM	6	0.57	0.08	1.10	NE	4.30
TO	1	0.27	NE	0.20	NE	4.75
AE	1	0.37	NE	0.12	NE	4.43
MM	1	0.37	NE	0.05	NE	4.14
PH	1	0.19	NE	0.01	NE	3.35

NE not evaluated

Freitas et al. (2012) and higher than those found by Muniz et al. (2019) and Freitas et al. (2012), except when they are young. For stem diameter, the values found were lower than those found by Muniz et al. (2019) and Silva et al. (2012b). In the present study, two mangaba botanical varieties were studied (*speciosa* and *gardneri*), but no variation was observed for the petiole analysis. As described by Monachino (1945), the petiole is a morphological criterion for the differentiation of botanical varieties.

Conclusions

The success of collection and enrichment actions in several regions of Brazil resulted in the existence of high variability in the Mangaba Genebank of Embrapa Tabuleiros Costeiros. The AB accession stood out in almost all characteristics evaluated. Fruits of all accessions evaluated have quality attributes for both fresh consumption and processing. The results of this work contributed to the elaboration of mangaba descriptors published in 2018 by Bioversity International and Embrapa. The genetic variability in the genebank will subsidize conservation strategies and direct research on breeding.

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Data Availability All relevant data generated during this study are included in this manuscript.

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