ABRATES

Journal of Seed Science

ISSN 2317-1545

www.abrates.org.br/revista

NOTE

Journal of Seed Science, v.43, e202143037, 2021

http://dx.doi.org/10.1590/2317-1545v43251724

Genetic variability among jarina palm (*Phytelephas macrocarpa* Ruíz & Pavón) progenies based on seed, germination and seedling characteristics

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ABSTRACT: Jarina is a palm tree from the western Amazon region, whose seeds have characteristics like those of animal ivory, used for making handicrafts. The aim of this work was to evaluate the genetic variability of jarina palm progenies, from seed morphophysiological characteristics, germination and seedling stages. The experimental design adopted was completely randomized, with 15 treatments (progenies), 3 repetitions, and 15 seeds per experimental unit. Thirty-one morphophysiological characteristics of the seed and seedling were used. With the characteristics that had significant variability, the progenies were grouped using the UPGMA method. The results showed genetic variability among progenies for 24 traits. Considering 50% of dissimilarity, four groups were identified: Group 1 - P05; Group 2 - P04, P11 and P12; Group 3 - P06, P10, P08, P14, P15, P07, P09, P02 and P13; and Group 4 - P01 and P03. Morphophysiological traits of the seed, germination and seedling are useful to detect genetic variability among jarina palm progenies. Three progenies (P04, P11 and P12) stood out for having the highest percentage of germination and the different seedling stages, as well as the highest speed indices and shortest times, in relation to germination and seedling stages.

Index terms: grouping, palm tree, principal component analysis, seed, vegetable ivory.

RESUMO: Jarina é uma palmeira da Amazônia ocidental, cujas sementes possuem características semelhantes ao marfim animal, usadas na confecção de artesanatos. O objetivo deste trabalho foi avaliar a variabilidade genética de progênies de jarina, a partir de características morfofisiológicas da semente, germinação e estádios da plântula. O delineamento experimental adotado foi inteiramente casualizado, com 15 tratamentos (progênies), 3 repetições com 15 sementes por unidade experimental. Foram utilizadas 31 características morfofisiológicas das sementes e plântulas. Com as características que tiveram variabilidade significativa foi feito o agrupamento das progênies pelo método UPGMA. Os resultados mostraram variabilidade genética entre progênies para 24 características. Considerando 50% da dissimilaridade foram identificados quatro grupos: Grupo 1 - P05; Grupo 2 - P04, P11 e P12; Grupo 3 - P06, P10, P08, P14, P15, P07, P09, P02 e P13; e Grupo 4 - P01 e P03. Caracteres morfofisiológicos da semente, germinação e da plântula são uteis para detectar variabilidade genética entre progênies de jarina. Três progénies (P04, P11 e P12) se destacaram por apresentar os maiores percentuais de germinação e dos diferentes estádios da plântula, além de maiores índices de velocidade e menores tempo, em relação à germinação e estádios da plântula.

Termos para indexação: agrupamento, palmeira, componentes principais, semente, marfim vegetal.

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Received: 04/30/2021.
Accepted: 09/23/2021.

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INTRODUCTION

Among palm trees (Arecaceae) native to the Amazon, the genus *Phytelephas* (2n = 36) includes six dioic species (*P. aequatorialis*, *P. macrocarpa*, *P. schottii*, *P. seemannii*, *P. tenuicaulis* and *P. tumacana*), with occurrences in Brazil, Bolivia, Colombia, Ecuador and Peru, in addition to the pacific coast of Ecuador and Colombia, as well as in Venezuela and Panama (Henderson et al., 1995; Dransfield et al., 2008). A common feature of *Phytelephas* species are seeds with white and extremely hard endosperm, which causes them to be known as "vegetable ivory" (Henderson et al., 1995).

Jarina palm (*Phytelephas macrocarpa* Ruiz & Pavón), a medium-sized acaulescent species, is distributed in the understory of forested areas of the western Amazon, in Brazil, Bolivia and Peru (Henderson et al., 1995). Because it is dioic, random cross is favored within a population. The main pollinating agents are beetles, especially species of the families Staphylinidae, Curculionidae and Nitidulidae (Barfod et al., 1987). Its seeds are collected and marketed by traditional extractivist populations and used for making handicrafts and bio-jewelry (Costa et al., 2006).

The pressure resulting from the exploitation of jarina palm seeds represents a threat to the genetic variability of the species. In order to help in its conservation, it is important to better understand the physiology of seeds, initial development of the plant, as well as evaluating the genetic variation in natural populations. These pieces of information are indispensable to propose strategies for conservation and/or genetic improvement of the species.

When dispersed, jarina palm seeds are wrapped by the rigid endocarp, bifacial adaxially, with the abaxial part rounded; round hilum in median to basal position; raphe with numerous branches; homogeneous and hard endosperm, with the embryo in basal or lateral position (Dransfield et al., 2008). Its germination is of the remote type, with the first visible sign of this process observed through the rupture of the endocarp, just above the operculum, through which the proximal part of the embryo emerges; at 114 ± 24 days after sowing, the germination bud is formed, from which the hyperphyll develops; after elongation of the hyperphyll, there is the swelling of the cotyledonary sheath, from which the primary root emerges (149 ± 25 days); the first adventitious roots arise above the primary root, while the secondary ones initially appear in the primary root and, later, in the adventitious roots; the first cataphyll emerges at the top of the cotyledonary sheath, at the same time that the coleoptile is formed; the second cataphyll appears laterally in the distal portion of the first one, and ultimately there may a third cataphyll; the first expanded eophyll (pinnate) appears at 244 ± 57 days after sowing (Ferreira and Gentil, 2017).

Usually, genetic variability of palm trees is evaluated by using morphoagronomic descriptors, as in the case of açai (*Euterpe oleracea* Mart.) (Galate et al., 2014), interspecific hybrids between caiaué [*Elaeis oleifera* (Kunth) Cortés] and oil palm (*E. guineensis* Jacq.) (Gomes-Junior et al., 2014) and macaw palm [*Acrocomia aculeata* (Jacq.) Lodd. ex. Mart.] (Domiciano et al., 2015), which is commonly performed from adult plants. A faster way is by using molecular markers such as in date palm (*Phoenix dactylifera* L.) (Elshibli and Korpelainen, 2008), coconut (*Cocos nucifera* L.) (Ribeiro et al., 2013) and tucumã-do-Pará palm (*Astrocaryum vulgare* Mart.) (Oliveira et al., 2012). However, in poorly studied species the evaluation using morphological and physiological characteristics of seeds and seedlings can be an interesting initial pathway. Oliveira and Farias-Neto (2006) found genetic variability among açai progenies from seedling emergence characteristics, with the time for the beginning of emergence showing greater variation, indicating that this is an important adaptive strategy for the species. Emergence and the mean time of seedling emergence were the variables that best discriminated the progenies of bacabi (*Oenocarpus mapora* Karsten) and bacaba (*Oenocarpus distichus* Mart.), allowing the formation of a larger number of groups (Silva et al., 2009).

In view of the above, the aim of this study was to evaluate the genetic variability of jarina palm (*Phytelephas macrocarpa*), from fifteen progenies, using thirty-one morphophysiological characteristics of seed, germination and seedling stages.

MATERIAL AND METHODS

Collection and processing of seeds

Seeds (diaspores) were collected between December 26, 2014, and January 03, 2015, in three areas of the eastern region of the Acre state (Figure 1). Each progeny was obtained from a plant, by removing one raceme containing from 54 to 105 seeds. At each collection point, the distance between the plants ranged from 10 to 50 m. The vegetation types of the collection areas are: Site 1 – Open Ombrophilous Forest with dominant palm trees and bamboo in the understory (Ultisol); Site 2 – Open Ombrophilous Forest with dominant bamboo and palm trees in the understory (Ultisol); Site 3 – Open Ombrophilous Forest with dominant palm trees and bamboo in the understory (Oxisol) (Acre, 2010). According to Köppen's classification the climate of the region is of Am type, with average precipitation of 2,200 mm and average annual temperature ranging from 24 to 26 °C (Alvares et al., 2013).

Soon after collection, the seeds were manually processed by extracting the epicarp and mesocarp through maceration (pressing), followed by washing in running water on a sieve. When necessary, a pocketknife was used to remove mesocarp residues that remained adhered to the seeds. After washing, they were dried for 24 hours on newspaper, under laboratory conditions with average temperature 24 °C. Then, they were packed in transparent plastic bags and transported in a cardboard box to the Laboratory of Seeds of the Biodiversity Coordination (COBIO) of the National Institute of Amazonian Research (INPA), Campus III (V8) in Manaus/AM.

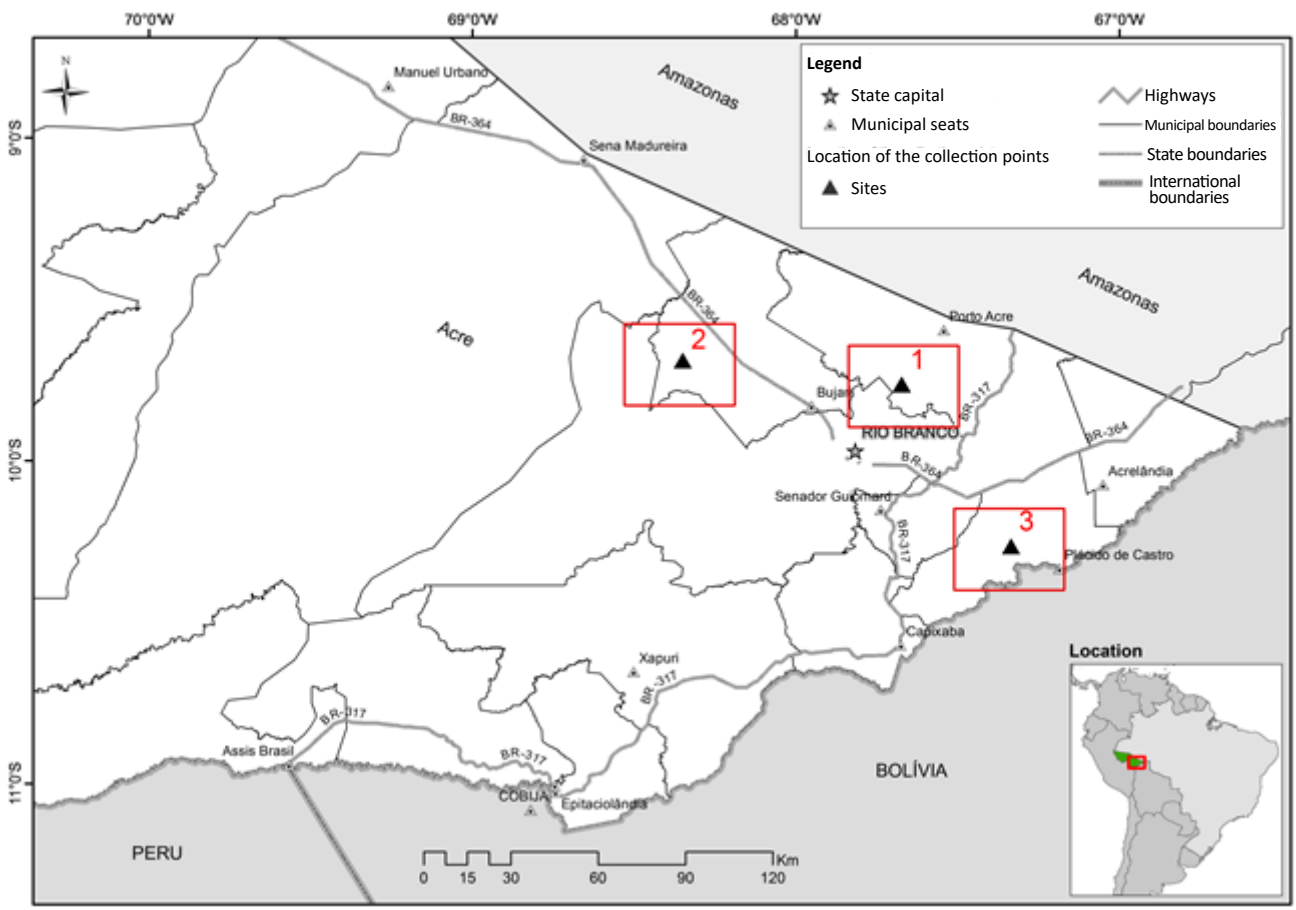

Figure 1. Location of the collection areas of the 15 progenies of jarina palm (*Phytelephas macrocarpa*), in the eastern region of the Acre state, Brazil: Site 1 (9º45'12.6"S and 67º40'30.5" W,181 masl) - progenies P01, P02, P03, P04 and P05; Site 2 (9°42'21.3"S and 68°16'01.2"W, 213 masl) – progenies P06, P07, P08, P09 and P10; Site 3 (10°15'21.3"S and 67°20'13.7"W, 171 masl) – progenies P11, P12, P13, P14 and P15.

Biometrics and moisture content of seeds

Biometric evaluation was carried out using three replications of 15 seeds, per progeny, considering the following characteristics: length (mm) - longitudinal measurement between the extremes, from the base of the seed to the base of the funiculus; fresh mass (g); volume (cm^3) - recording of the force exerted in the water on the scale for the seed to submerge completely, converting the value from gram to cubic centimeters; and specific gravity ($g.cm^{-3}$) - value obtained from the relationship between the mass and the volume of the seed.

The moisture content of the seeds was measured prior to sowing (February 26, 2015) by the oven method at 105 ± 3 °C for 24 hours (Brasil, 2009). Two replications and three units per progeny were used. Before being taken to the oven, the seeds were fractionated into four equivalent parts to facilitate water removal.

Germination and seedling development

Sowing (February 27, 2015) was carried out in plastic boxes (60 x 40 x 20 cm), with drainage holes at the bottom. The substrate used was expanded vermiculite of medium particle size. The boxes were kept on a bench, in a germination nursery, covered with transparent fiberglass tile with minimum and maximum average temperatures of 25.7 ± 0.87 °C and 39.1 ± 1.33 °C, respectively. Irrigation was performed manually, whenever necessary.

Germination and development of seedlings were evaluated every 10 days and consisted of individual removal of each seed to record the stage in which they were, as described by Ferreira and Gentil (2017): emergence of the germination bud; developed cotyledonary sheath; emergence of the first cataphyll; emergence of the second cataphyll; first expanded eophyll; second expanded eophyll; third expanded eophyll.

The data related to the verification of the stages were used to calculate their respective percentages and indices of speed and mean time, according to Ranal and Santana (2006): speed of germination bud; mean time of germination bud; speed of developed cotyledonary sheath; mean time of developed cotyledonary sheath; speed of first cataphyll; mean time of first cataphyll; speed of second cataphyll; mean time of second cataphyll; speed of first eophyll; mean time of first eophyll; speed of second eophyll; mean time of second eophyll; speed of third eophyll; mean time of third eophyll.

At the end of the experiment, after 430 days, the length of the hyperphyll (cm), length of the first cataphyll (cm) and length of the second cataphyll (cm) were also recorded. Through the cutting test (Brasil, 2009), the remaining ungerminated seeds were classified as dormant (with firm, healthy and milky-white embryos) and dead (rotten and/or with deteriorated embryos).

Experimental design and statistical analysis

The experimental design was completely randomized with 15 treatments (progenies) and three replications, with 15 seeds in each experimental unit. In order to evaluate the variability of the progenies, analysis of variance was performed for each characteristic. In the case of significance of the progenies, the Scott-Knott means comparison test was applied at 5% probability level. Analysis of variance and comparison of means were performed in the program Assistat 7.7 (Silva and Azevedo, 2016). Characteristics that showed significant differences were used to construct a dendrogram, which was based on the relative Euclidean distance of standardized data, and grouped by the Unweighted Pair Group Method with Arithmetic Mean (UPGMA), according to Cruz et al. (2014), using the STATISTICA 10.0 program. To determine the number of groups, a cut was made considering 50% of the dissimilarity, and to visualize the efficiency of this cut and the association of groups with the evaluated characteristics, a biplot based on principal component analysis (PCA) was constructed from the standardized data, using the JMP 10 program.

RESULTS AND DISCUSSION

Biometrics and moisture content of the seeds

The variables seed length (SLN), seed fresh mass (SFM), seed volume (SVL) and seed specific gravity (SSG) showed significant differences between progenies (Table 1). The highest mean values of length (43 mm), fresh mass (27 g) and volume (21 cm^3) were reached by the seeds of progeny P01, while the lowest fresh mass (15 g) and volume (11.3 cm^3) were obtained by progeny P15, which also had reduced length (33.7 mm). Regarding the seed specific gravity variable, the highest means were found for the progenies P01, P02, P04, P05, P11, P14 and P15 (1.33 $g.cm^{-3}$) and the lowest one for progeny P10 (1.27 $g.cm^{-3}$).

The biometric variables of fresh mass, length, volume and specific gravity showed low coefficients of variation (CV) (*sensu* Pimentel-Gomes, 2009), between 1.2 and 3.3%, suggesting homogeneity between the seeds of each progeny. The fact that these variables showed significant differences is a good indicator of variability among progenies.

The moisture content of the seeds showed no significant difference between the progenies. This was on average 27.8 ± 1.63%, considering the 15 progenies, with a low coefficient of variation (5.6%), corroborating previous results that indicated great uniformity within each progeny. The mean value found in the present study is above those identified for other palm trees such as maraja palm (*Bactris maraja* Mart.) (about 23%) (Rodrigues et al., 2015) and macaw palm [*Acrocomia aculeata* (Jacq.) Lodd. ex. Mart.] (21%) (Rubio-Neto et al., 2012). The moisture content of the seed in some species can be attributed to the genetic material and maturation stages of the seeds (Martins et al., 2009). Domiciano et al. (2015), when studying macaw palm [*Acrocomia aculeata* (Jacq.) Lodd. ex. Mart.] progenies, found greater variations in morphological parameters than in physiological characteristics of the plant.

Germination and seedling development

Characteristics related to germination, such as the emergence of germination bud (EGB), dormant seeds (DOS), dead seeds (DES), speed of germination bud emergence (SGB) and mean time of germination bud emergence (TGB), showed variability among progenies (Table 2). Those with the highest percentages of EGB were P11 (95.6%) and P12 (91.1%), although they did not differ significantly from P03 (73.3%), P04 (84.4%) and P05 (64.4%); the lowest value was obtained by P08 (6.7%). Some of the results achieved here were similar to those obtained by Ferreira and Gentil (2017), who studied a mixture of jarina palm progenies, using alternating temperatures (26/40 °C), and obtained 88% of germination bud formation. These same authors, in another situation (sowing in a growing house), but also using mixture of progenies, reached EGB of 65%.

Table 1. Biometric characteristics, plus moisture content, of seeds and parts of seedlings of fifteen progenies of jarina palm (*Phytelephas macrocarp*a) collected in the eastern region of Acre state, Brazil.

Characteristic	Progenies															CV (%)	F test
	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15		
SFM (g)	27.4 a	22.8 c	25.1 b	23.7 c	25.1 b	19.9 d	18.1 e	18.3 e	16.5 f	17.0 f	25.5 b	24.9 b	18.9 e	16.9 f	15.0 g	3.1	120.0**
SVL (cm^3)	20.6 a	17.2 c	19.4 b	17.8 c	18.9 b	15.3 d	14.0 e	14.0 e	12.7 f	13.4 e	19.2 b	18.9 b	14.3 e	12.7 f	11.3 g	3.3	97.3 **
SLN (mm)	42.6 a	35.2 e	37.7 d	39.0 c	37.3 d	37.5 d	35.0 e	38.0 d	39.7 b	40.4 b	39.5 b	38.9 c	35.2 e	33.1 f	33.7 f	1.9	42.8 **
SSG ($g\ cm^{-3}$)	1.33 a	1.33 a	1.30 b	1.33 a	1.33 a	1.30 b	1.29 b	1.31 a	1.29 b	1.27 b	1.33 a	1.32 a	1.32 a	1.33 a	1.33 a	1.2	4.4 **
SMC (%)	25.9	28.4	26.5	25.4	27.8	30.1	27.3	29.9	26.1	27.8	30.1	27.3	29.9	26.1	27.8	5.6	2.2 ns
LNH (cm)	8.5	8.6	9.0	9.4	10.0	9.2	8.0	9.1	8.9	9.5	9.5	8.9	8.8	8.1	8.5	9.3	1.2 ns
L1C (cm)	3.5	3.0	3.4	2.7	3.4	3.6	3.5	3.2	3.5	3.5	3.5	2.6	2.9	2.6	3.2	18.6	1.4 ns
L2C (cm)	8.1	7.2	7.9	7.4	9.1	8.7	7.3	8.5	7.6	9.1	9.1	6.2	6.3	5.8	8.1	28.4	0.7 ns

Conventions: SFM - seed fresh mass; SVL - seed volume; SLN - seed length; SSG - seed specific gravity; SMC - seed moisture content; LNH - length of the hyperphyll; L1C - length of the first cataphyll; L2C - length of the second cataphyll. CV - Coefficient of variation. F test: ** - significant at 1% probability level by F test; ns – not significant at 5% probability level by the F test. Means followed by the same letter in the row do not differ significantly by the Scott-Knott test at 5% probability level.

Regarding seed dormancy, jarina palm progenies exhibited wide variation (Table 2), showing an inverse relationship with the results of germination (EGB). Progeny P08 had the highest percentage (82.2%), which justifies, to a great extent, the low germination achieved by this progeny (6.7%). On the other hand, the lowest values of dormancy were obtained by progenies P03 (17.8%), P04 (4.4%), P05 (6.7%), P11 (4.4%) and P12 (4.4%), for which germination percentages were higher. With these results, it is verified that dormancy can be a problem for producers of jarina palm seedlings, depending on the origin of the material used. Ferreira and Gentil (2017) observed that jarina palm seeds, when stratified at 25 °C, did not germinate and/or remained dormant for nine months. After being transferred to the alternating temperature of 26/40 °C, they showed 90% germination, in an additional period of 120 days.

Concerning the speed of germination bud emergence (SGB) and mean time of germination bud emergence (TGB), the progeny P04 had the best indices (0.76% day^{-1} and 152 days, respectively). Ferreira and Gentil (2017) found a mean germination time of 114 ± 24 days for jarina palm under alternating temperature (26/40 °C). The higher coefficients of variation for physiological variables (Table 2) suggest that they showed greater heterogeneity within each progeny compared to those related to morphological aspects of the seeds.

The variables related to seedling stages showed significant differences between progenies, except for those concerning the mean time to reach the first (T1E), second (T2E) and third (T3E) expanded eophyll (Table 3). The highest means for the different seedling stages, associated with the highest velocities, as well as the shorter times to reach each stage, were observed for the progenies P04, P11 and P12, consequently those with the best performance. Also with respect to these variables, the progenies P03 and P05 showed intermediate behavior, while the others (P01, P02, P06, P07, P08, P09, P10, P13, P14 and P15) were less relevant. Silva et al. (2009), from studies with bacabi (*Oenocarpus mapora* Karsten) and bacaba (*Oenocarpus distichus* Mart.) aiming to increase economic productivity through vigorous and healthy seedlings, consider that the progenies with the highest means for emergence and the lowest means for the mean time of emergence can be selected to constitute a group that will result in a greater synchronization of emergence.

Genetic variability among progenies

According to the analysis of variance, 24 characteristics showed significant differences for the effect of progenies (Tables 1, 2 and 3). This indicates that there is genetic variability among progenies and that the morphophysiological characteristics of seeds and seedlings are useful to characterize this species.

The cluster analysis by the UPGMA method, based on the relative Euclidean distances, was able to group the progenies from 25% dissimilarity. Considering the mean value of 50% dissimilarity, four groups were identified (Figure 2): Group 1, P05; Group 2, P04, P11 and P12; Group 3, P06, P10, P08, P14, P15, P07, P09, P02 and P13; and Group 4, P01 and P03.

Table 2. Characteristics related to the germination of fifteen progenies of jarina palm (*Phytelephas macrocarpa*) collected in the eastern region of Acre state, Brazil.

Characteristic	Progenies															CV (%)	F test
	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15		
EGB (%)	48.9 b	26.7 b	73.3 a	84.4 a	64.4 a	37.8 b	33.3 b	6.7 b	24.4 b	33.3 b	95.6 a	91.1 a	42.2 b	20.0 b	22.2 b	30.5	11.6 **
DOS (%)	44.4 a	51.1 a	17.8 b	4.4 b	6.7 b	53.3 a	48.9 a	82.2 a	62.2 a	44.4 a	4.4 b	4.4 b	48.9 a	75.6 a	57.8 a	44.1	6.6 **
DES (%)	6.7 b	22.2 a	8.9 b	11.1 b	28.9 a	8.9 b	17.8 a	11.1 b	13.3 b	22.2 a	0.0 b	6.7 b	8.9 b	4.4 b	20.0 a	68.0	2.5 *
SGB (% d^{-1})	0.28 c	0.13 c	0.34 c	0.76 a	0.43 b	0.21 c	0.19 c	0.03 c	0.17 c	0.18 c	0.59 a	0.67 a	0.21 c	0.10 c	0.11 c	33.2	15.6 **
TGB (days)	225 a	214 a	233 a	152 b	183 b	203 a	231 a	258 a	228 a	202 a	172 b	166 b	257 a	216 a	221 a	15.6	2.7 *

Conventions: EGB - emergence of the germination bud; DOS - dormant seed; DES - dead seed; SGB - speed of germination bud; TGB - mean time of germination bud. CV - Coefficient of variation. F test: * and ** - significant at 5% and 1% probability levels by F test, respectively. Means followed by the same letter in the row do not differ significantly by the Scott-Knott test at 5% probability level.

Table 3. Characteristics of seedlings in different development stages of fifteen progenies of jarina palm (*Phytelephas macrocarp*a) collected in the eastern region of Acre state, Brazil.

Characteristic	Progenies															CV (%)	F test
	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15		
DCS (%)	44.4 b	26.7 b	73.3 a	75.6 a	62.2 a	35.6 b	28.9 b	6.7 b	24.4 b	28.9 b	93.3 a	84.4 a	33.3 b	20.0 b	22.2 b	29.3	12.9 **
SDS (% d^{-1})	0.21 c	0.12 c	0.30 b	0.53 a	0.36 b	0.17 c	0.13 c	0.02 c	0.12 c	0.14 c	0.50 a	0.50 a	0.15 c	0.09 c	0.09 c	30.8	16.7 **
TDS (days)	241 a	241 a	262 a	174 b	198 b	216 b	255 a	290 a	261 a	219 b	199 b	185 b	261 a	234 a	274 a	11.3	5.1 **
E1C (%)	44.4 b	26.7 b	73,3 a	75.6 a	62.2 a	37.8 b	26.7 b	6.7 b	22.2 b	26.7 b	91.1 a	84.4 a	35.6 b	20.0 b	22.2 b	31.0	11.6 **
S1C (% d^{-1})	0.20 c	0.11 c	0.27 b	0.47 a	0.32 b	0.16 c	0.12 c	0.02 c	0.11 c	0.13 c	0.44 a	0.44 a	0.14 c	0.08 c	0.09 c	30.9	15.8 **
T1C (days)	258 b	258 b	282 a	188 c	213 c	243 b	252 b	300 a	249 b	214 c	217 c	209 c	284 a	271 a	291 a	9.2	6.7 **
E2C (%)	42.2 b	24.4 b	73.3 a	73.3 a	62.2 a	33.3 b	26.7 b	4.4 b	22.2 b	26.7 b	91.1 a	84.4 a	28.9 b	20.0 b	17.8 b	29.2	14.9 **
S2C (% d^{-1})	0.17 c	0.09 c	0.26 b	0.40 a	0.29 b	0.14 c	0.10 c	0.02 c	0.10 c	0.11 c	0.39 a	0.39 a	0.11 c	0.07 c	0.07 c	30.1	17.3 **
T2C (days)	269 a	263 a	296 a	201 b	234 b	250 b	281 a	275 a	266 a	237 b	237 b	230 b	270 a	297 a	287 a	10.5	3.0 **
1EE (%)	40.0 b	24.4 b	64.4 a	66.7 a	57.8 a	33.3 b	22.2 b	4.4 b	13.3 b	26.7 b	82.2 a	68.9 a	24.4 b	11.1 b	13.3 b	41.7	7.8 **
S1E (% d^{-1})	0.13 b	0.08 b	0.20 a	0.25 a	0.20 a	0.11 b	0.06 b	0.01 b	0.04 b	0.09 b	0.27 a	0.22 a	0.07 b	0.03 b	0.04 b	42.1	8.4 **
T1E (days)	330	314	333	271	296	317	353	335	295	290	305	316	346	347	313	9.9	1.7 ns
2EE (%)	37.8 b	24.4 b	60.0 a	66.7 a	55.6 a	31.1 b	15.6 b	4.4 b	13.3 b	24.4 b	75.6 a	64.4 a	22.2 b	11.1 b	13.3 b	41.2	8.2 **
S2E (% d^{-1})	0.11 b	0.07 b	0.16 a	0.22 a	0.17 a	0.09 b	0.04 b	0.01 b	0.04 b	0.07 b	0.23 a	0.18 a	0.06 b	0.03 b	0.04 b	43.3	8.3 **
T2E (days)	366	359	368	314	334	357	381	400	340	335	338	361	383	400	361	8.1	2.2 ns
3EE (%)	20.0 c	22.2 c	28.9 c	66.7 a	42.2 b	24.4 c	8.9 c	2.2 c	6.7 c	26.7 c	60.0 a	40.0 b	15.6 c	4.4 c	11.1 c	51.8	6.7 **
S3E (% d^{-1})	0.05 c	0.06 c	0.07 c	0.19 a	0.12 b	0.06 c	0.02 c	0.01 c	0.02 c	0.07 c	0.16 a	0.10 b	0.04 c	0.01 c	0.03 c	53.7	6.8 **
T3E (days)	400	407	378	359	368	393	420	400	377	397	387	395	418	390	405	5.3	2.1 ns

Conventions: DCS - developed cotyledonary sheath; SDS - speed of developed cotyledonary sheath; TDS - mean time of developed cotyledonary sheath; E1C - emergence of the first cataphyll; S1C - speed of the first cataphyll; T1C - mean time of the first cataphyll; E2C - emergence of the second cataphyll; S2C - speed of the second cataphyll; T2C - mean time of the second cataphyll; 1EE - first expanded eophyll; S1E - speed of the first eophyll; T1E - mean time of the first eophyll; 2EE - second expanded eophyll; S2E - speed of the second eophyll; T2E - mean time of the second eophyll; 3EE - third expanded eophyll; S3E - speed of the third eophyll; T3E - mean time of the third eophyll. CV - Coefficient of variation. F test: ** - significant at 1% probability level by F test; ns - not significant at 5% probability level by the F test. Means followed by the same letter in the row do not differ significantly by the Scott-Knott test at 5% probability level.

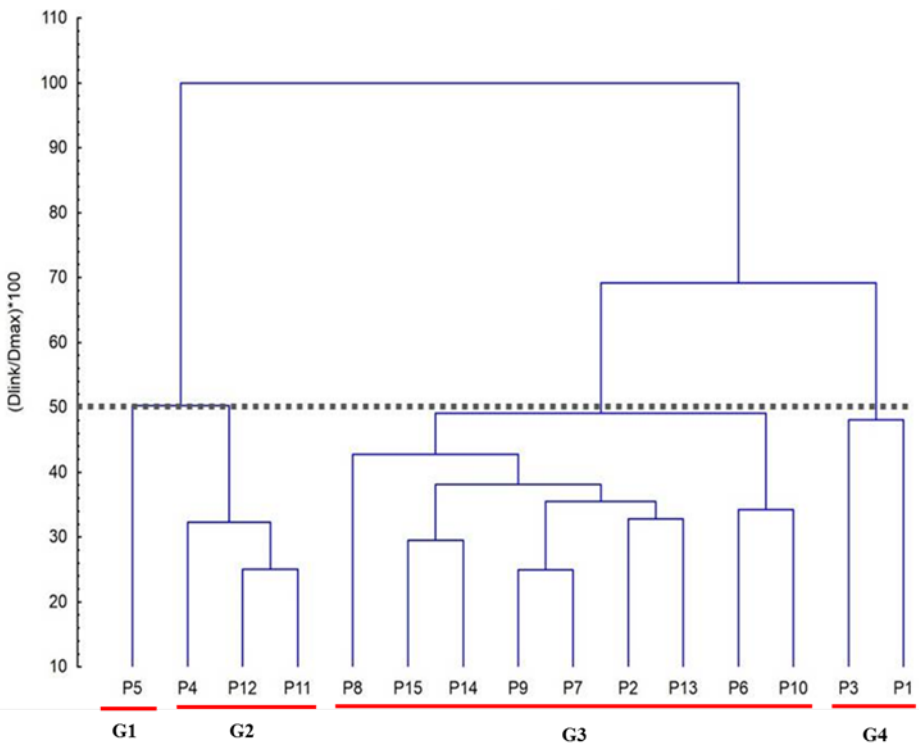

Figure 2. Dendrogram showing the clusters of fifteen progenies of jarina palm (*Phytelephas macrocarpa*) from the eastern region of the Acre state, generated by the UPGMA method from the Euclidean distances calculated based on 24 variables.

In general, it was observed that the groups did not coincide with the geographical origin. For example, Group 2 included progenies from Sites 1 and 3, and Group 3 included progenies from Sites 1, 2 and 3. Only Group 4 had its progenies in Site 1. A study on genetic divergence of açai (*Euterpe oleracea* Mart.) (Galate et al., 2014), as well as studies with juçara palm (*E. edulis* Mart.) (Moraes et al., 2020) and peach palm (*Bactris gasipaes* Kunth) (Negreiros et al., 2013), showed that greater diversity was associated with the site of origin or collection compared to the diversity among populations.

Principal component analysis (PCA) explained 85% of the total variation considering the 24 traits with genetic variability (Figure 3). This analysis showed the four groups previously observed in the dendrogram (Figure 2). Group 1 was mainly associated with intermediate values of SLN. Group 2 was associated with high values of SFM, SVL, DCS, E1C, E2C, 1EE, EGB, 2EE, S2E, S1E, S2C, S1C, SDS, SGB, 3EE and S3E. Group 3 was associated with high values of TDS, TGB, T1C, T2C, DOS and DES. Group 4 was associated with high SSG values.

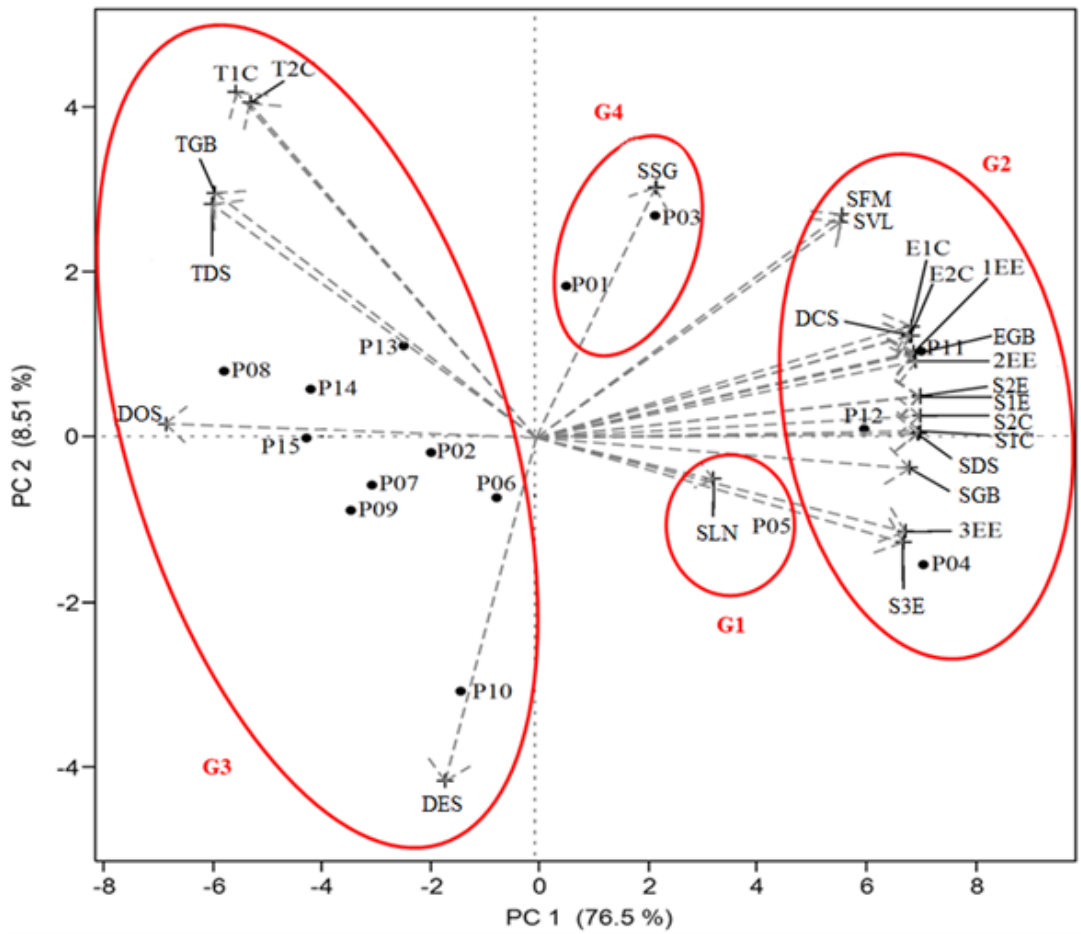

Figure 3. Biplot based on principal component analysis (PCA) using 24 morphophysiological traits of 15 progenies of jarina palm (*Phytelephas macrocarpa*) collected in the eastern region of the Acre state, Brazil. Conventions: SFM - seed fresh mass; SVL - seed volume; SLN - seed length; SSG - seed specific gravity; EGB - emergence of the germination bud; DOS - dormant seed; DES - dead seed; SGB - speed of germination bud; TGB - mean time of the germination bud; DCS - developed cotyledonary sheath; SDS - speed of developed cotyledonary sheath; TDS - mean time of the cotyledonary sheath; E1C - emergence of the first cataphyll; S1C - speed of the first cataphyll; T1C - mean time of the first cataphyll; E2C - emergence of the second cataphyll; S2C - speed of the second cataphyll; T2C - mean time of the second cataphyll; 1EE - first expanded eophyll; S1E - speed of the first eophyll; 2EE - second expanded eophyll; S2E - speed of the second eophyll; 3EE - third expanded eophyll; S3E - speed of the third eophyll.

As jarina palm is a dioic species, it needs pollinating agents and coleopterans play an important role in this process (Barfod et al., 1987). These insects, along with bees, may be spreading pollen in each area of the study (Meléndez and Ponce, 2016), so that each progeny is composed of half siblings. The effective size of a population of half siblings is four (Souza-Junior, 2001), which indicates that a female plant receives pollen from four male plants. Therefore, to start an improvement program with jarina palm, it is recommended to plant at least four plants of each progeny from group 2 (P04, P11 and P12), since these had the most favorable values for most characteristics evaluated. On the other hand, to preserve the variability of the three areas studied, one should increase the sampling size, collecting at least 50 progenies per area (Souza-Junior, 2001).

CONCLUSIONS

Morphophysiological traits of seed, germination and seedling stages are useful to detect genetic variability among progenies of jarina palm half siblings.

From fifteen jarina palm progenies and twenty-four traits related to morphophysiology of seed, germination and seedling, four distinct genetic groups were found.

Three jarina palm progenies (P04, P11 and P12) stood out for having the highest percentages of germination and the different seedling stages, in addition to higher speed indices and shorter time, in relation to germination and seedling stages.

ACKNOWLEDGMENTS

To the *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES), for granting the scholarship to the first author.

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