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Phenotypic variability and agronomic traits of açaí tree matrices in the state of Pará, Brazil

Açaí palm (Euterpe oleracea Mart.) is a native palm tree from the Eastern Amazon, Brazil. It is considered an economically viable source of anthocyanins for the dye and medicine industries. This study aimed to estimate the phenotypic variability and to select genotypes for genetic improvement. Descriptive statistics were used to estimate phenotypic variability. Truncated selection was performed for fruit production per bunch. The collected samples presented the highest fruit yield per cluster of all studied region. Number of fruits per cluster and stem circumference are possibly controlled by few genes. longitudinal fruit diameter may have recessive genes that are decreasing fruit size. Fruit weight, seed weight, pulp weight, number of stem per plant, total cluster length, fruit weight per cluster and pulp yield per fruit presented frequency distribution in favor of heterozygotes. There some characteristics controlled by few genes, with evidence of selection and spontaneous domestication of the matrices.

Keywords: Euterpe Oleracea Mart.; Anthocyanins; Germplasm; Truncated Selection; Genetic Improvement.

Variabilidade fenotípica e traços agronômicos de matrizes de árvore de açaí no estado do Pará, Brasil

Açaí (Euterpe oleracea Mart.) é uma palmeira nativa da Amazônia Oriental, Brasil. É considerada uma fonte economicamente viável de antocianinas para as indústrias de corantes e medicamentos. Este estudo teve como objetivo estimar a variabilidade fenotípica e selecionar genótipos para melhoria genética. Estatística descritiva foi usada para estimar a variabilidade fenotípica. A seleção truncada foi realizada para produção de frutos por cacho. As amostras coletadas apresentaram a maior produção de frutos por cacho de todas as regiões estudadas. O número de frutos por cluster e a circunferência do caule são possivelmente controlados por poucos genes. O diâmetro longitudinal do fruto pode ter genes recessivos que estão diminuindo o tamanho do fruto. Peso de frutos, peso de sementes, peso de polpa, número de caule por planta, comprimento total de cacho, peso de cacho por cacho e produção de polpa por fruto apresentaram distribuição de frequências a favor de heterozigotos. Existem algumas características controladas por poucos genes, com evidências de seleção e domesticação espontânea das matrizes.

Palavras-chave: Euterpe Oleracea Mart.; Antocianinas; Germoplasma; Seleção Truncada; Melhoramento Genético.

Topic: **Organização da Biodiversidade**

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INTRODUCTION

Açaí palm (*Euterpe oleracea* Mart.) is a naturally occurring species in permanently or temporarily flooded areas of the Eastern Amazon, Brazil. The products derived from the extraction of açaí berry - fruit and palm - occupy a prominent place in the economy of the state of Pará, which are of fundamental importance for the subsistence of riverside populations (HOMMA, 2006).

The media dissemination of the nutritional qualities of açaí berry made it popular not only in Brazil but also in other countries, inducing the expansion of the fruit and pulp market. As a result, the area harvested from açaí berry has been increasing intensely, with an average rate of approximately 58% (SANTANA et al., 2008). The increase in exports of frozen pulp and other fruit products has caused the scarcity of açaí juice in Pará, especially in Belém, which is the largest consumer center in the region. As a result, there are serious socioeconomic problems, especially considering that açaí is much appreciated by the population, with high consumption in the capital of Pará (SANTANA et al., 2008).

Açaí is considered an economically viable source for anthocyanin for use in the food and pharmaceutical industries (BOBBIO et al., 2002). Its pulp is reputed as a nutraceutical food due to the high content of anthocyanins, which have anticarcinogenic, anti-inflammatory, antimicrobial properties, act to prevent cardiovascular disease, neurological and the oxidation of low-density proteins (MENEZES et al., 2008). Furthermore, its antioxidant capacity is superior to that of tocopherols (GALLORI, 2004). The analysis of frozen açaí pulp marketed in Brazil revealed antioxidant capacity with values close to those found in pear, strawberry - 132.1 mg/100g and grape - 117.1 mg/100g (KUSKOSKI et al., 2006).

In the state of Pará, extractive exploration presents several problems, such as low productivity - less than 5 t/ha -, low fruit yield per cluster (50%) and pulp per fruit (7%), considering production focused on the second semester (August to November). Moreover, there is irregularity in fruit maturation, variation in shade areas, plants with solitary stem or with variations for tillering, low tolerance to water stress and the difficulty in harvesting, since most trees occur in floodplain areas (OLIVEIRA et al., 2007; SANTANA et al., 2008). On land, the crops that began to emerge due to the increase in demand also present problems. For example, there is no use of selected seeds, generating heterogeneous plantations, with uneven yields, low yield of fruits and pulp, due to the segregation of their productive characteristics, since it is classified as an allogamous species (NOGUEIRA et al., 2005).

Even though there has been developed cultivar with early fruit production for land cultivation (OLIVEIRA et al., 2004), much remains to be done in the domestication and cultivation of açaí, such as the participation of the population and the use of local germplasm. Studies aimed at obtaining varieties or cultivars with desirable agronomic characteristics require the study of natural variability and conservation in germplasm collections. Studies were carried out on phenotypic variation for better fruit production (OLIVEIRA et al., 1998), phenotypic correlations between production traits (OLIVEIRA et al., 2000), genetic parameters for palm heart germ traits (OLIVEIRA et al., 2003), release of cultivar for dry-land planting (OLIVEIRA et al., 2004), selection of descriptors for germplasm characterization (OLIVEIRA et al., 2006) and genetic divergence based on morphoagronomic descriptors (OLIVEIRA et al., 2007).

In the preliminary germplasm evaluation, it is recommended that the used traits should be easily measurable. Studies can be based on descriptive statistics for selection, establishing a minimum value in some standard deviations above average as a reference for selection (QUEROL, 1993; PINTO, 1995). In general, descriptive statistics provide valuable insight on the behavior of traits and, therefore, the number of genes that control them. It can provide signals about the genetic control of such traits, whether by a few (qualitative) genes or by many (quantitative) genes (VIANA et al., 2001).

Therefore, this study aimed to collect açaí tree germplasm and to evaluate it for phenotypic variability, selecting genotypes to be used in breeding programs. We ought to provide the producer with productive materials for economic cultivation, preferably considering participatory breeding with local populations.

MATERIALS AND METHODS

Ten expeditions were collected for the collection of açaí germplasm in different six regions of the state of Pará (Figure 1). The information was obtained based on the farmers' knowledge about the plants and their areas of occurrence, taking plants far from each other, giving preference to plants with good tillering, larger number of clusters, full and healthy and with larger fruits. The sampling location was determined using the Global Positioning System - GPS.

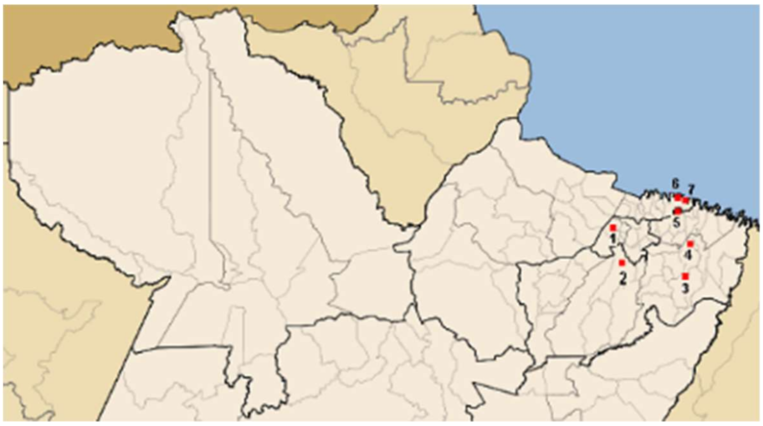

Figure 1: Regions of the state of Pará, where açaí germplasm samples were collected: 1) Belém; 2) Acará; 3) Capitão Poço; 4) Ourém, 5) Santarém Novo; 6) Salinópolis; and 7) São João de Pirabas.

Data were collected from 22 quantitative morphoagronomic characters related to plant (5) and fruits (6), as well as agronomic (11) traits. The plant traits were: (1) Number of stem per plant (NSP), obtained by counting each plant stem; (2) Stem height (SH, m), which corresponds to the length of the oldest stem of the plant from the insertion point of the leaves to the root emission; (3) Number of leaves (NL), obtained by counting all leaves existing in the oldest stem of the plant, except for senesced-leaf; (4) Stem circumference at breast height (CBH, cm), which is the circumference of the oldest stipe of the plant taken at breast height (1.20 m); (5) Length of the internode (LIN, cm), referring to the distance between the nodes (leaf scars) of the oldest stipe of the plant.

The traits related to fruit were evaluated in only one cluster of the plant, and 10 fruits were randomly selected: (6) Longitudinal diameter of the fruit (LDF, mm), measured with digital caliper, from the insertion point of the floral remains (calyx and corolla), up to the trace of stigma; (7) Fruit cross-sectional diameter (FCD, mm), measured with digital caliper; (8) Fruit weight (FW, g), determined by the average weight of 10 fruits; (9) Seed weight (SW, g), obtained by averaging 10 fruits after removal of the edible part (epicarp and mesocarp); (10) Pulp weight (PW, g), calculated by the difference between the traits FW and SW and expressed in grams; (11) Pulp yield per fruit (RPF,%), calculated by the ratio between the traits FW and SW and multiplied by 100.

The agronomic traits were: (12) Cluster weight (CW, kg), obtained by weighing the cluster in production, using a dynamometer-type digital scale; (13) Fruit weight per cluster (FWC, kg), obtained by weighing all the fruits produced in the cluster in production on a dynamometer-type digital scale; (14) Fruit yield per cluster (FYC, %), calculated by the ratio between the traits FWC and PW and multiplied by 100; (15) Number of rachilla per cluster (NRC), obtained by counting all rachilla in the cluster; (16) Number of fruits per rachilla (NFR), calculated as the average fruit per rachilla per cluster; (17) Number of fruits per cluster (NFC), obtained by counting the fruits in the cluster; (18) Number of clusters per plant (NCP), obtained by counting all the clusters of the plant; (19) Weight of one hundred fruits (WHF, g) corresponds to the total weight of 100 fruits taken from the cluster on a dynamometer-type digital scale; (20) Cluster circumference (CC, cm), obtained by the intermediate measurement of the cluster circumference; (21) Total cluster length (TCL, cm), obtained by the longitudinal measurement of the cluster and; (22) Total fruit yield (TFY, kg), obtained by digitally weighing all the fruits per plant in production and expressed in kilograms.

The quantification of the phenotypic variability of the matrices was obtained based on the variation of the morphoagronomic characters, through the estimation of statistical parameters (amplitude of variation, mean, standard deviation and coefficient of variation) and frequency distribution. Data were standardized by the reduced normal transformation ($Z = X - \bar{X}/s$), where X is the trait data, $\bar{X}$ is the average of the data, and s is the standard deviation. The Lilliefors test was used for data normalization.

The agronomic traits were analyzed in standard deviation units by the reduced variable. The probability of obtaining a sample larger than the highest value collected for fruit yield was also estimated, according to the properties of the normal curve cited by Ramalho et al. (2005). Frequency distributions were analyzed considering the expected continuity for quantitative traits, the influence of sample size, the number of genes (if many or few) for each character, and the influence of the environment, using GENES software (CRUZ, 2006).

RESULTS AND DISCUSSION

Table 1 shows the collected matrices and the locations of some collection points with their global positioning. A total of 129 matrices were collected in six municipalities of northeast Pará: Belém (4), Ilha do Mosqueiro (6), Ilha do Combu (76), Guamá (21), Capitão Poço (18), Ourém (3), Bragança (7), Salgado (13), São João de Pirabas (8) and Salinópolis (5). In these locations, the climate is of types Afi, Ami and Awi, according to the Köppen classification (IBGE, 2010). The Belém micro-region is characterized by the climate type Afi, with annual rainfall of 2000 mm and with a few months with monthly rainfall less than 60 mm. The Bragança and Guamá micro-regions are influenced by climate type Ami, a transition climate between Afi and Awi, characterized by dry season, with annual rainfall of up 2000 mm. The climate of the Salgado micro-region is of Awi type, with a clear dry season and annual rainfall less than 2000 mm.

Table 1: Characterization of 129 açaí tree matrices according to micro-region, location, sampling point, geographic coordinate and climate. Northeast Pará, Brazil.

Table 1.	NM	MR[1]	PLACE	COLLECT POINT	FUSO /P[2]	CLIMATE
EO-001	1	BEL	Belém	Tv. Lomas	22/ E = 785321,519/N = 9839863,229	Afi
EO-002 a EO-007	6	BEL	Ilha de Mosqueiro	Baía do Sol	22/ E = 786327,535 / N = 4941319,702	Afi
EO-008 a EO-010	3	BEL	Belém	UFRA	22/ E = 785178,499 / N = 9839169,524	Afi
EO-011 a EO-014	4	RSA	São João de Pirabas	Boa esperança	23/ E = 253649,066 / N = 9991304,549	Awi
EO-015 a EO-021	7	RSA	Salinópolis	Vila de São Bento	23/ E = 240441,851 / N = 9923125,540	Awi
EO-022 a EO-028	7	ZBR	Santarém Novo	Vila de São João de Peri Meri:	23/ E = 240934,783 / N = 9901884,077	Ami
EO-029 a EO-032	4	RSA	São João de Pirabas	Rua Paricá	23/ E = 255961,817 / N = 9910957,315	Awi
EO-033 a EO-040	8	RGU	Capitão Poço	Bairro Timbó	23/ E = 270732,801 / N = 9809916,910	Ami
EO-041 a EO-043	3	RGU	Ourém	Tv. Cipriano Santos	23/ E = 264406,104 / N = 9828590,344	Ami
EO-044 a EO-053	10	RGU	Capitão Poço	Bairro Cotilandia	23/ E = 269593,245 / N = 9805952,361	Ami
EO-054 a EO-094	41	BEL	Ilha do Combu	Beira rio	22/ E = 781177,000 / N = 9834854,000	Afi
EO-095 a EO-107	13	BEL	Ilha do Combu	Furo São Sebastião	22/ E = 779499,000 / N = 9833506,000	Afi
EO-108 a EO-129	22	BEL	Ilha do Combu	Rio Jordão	22/ E = 784013,000 / N = 9832788,000	Afi

R1: Microregion; NM: number of matrices; FUSO/P2: Time zone/Position according to GPS; BEL: Belém; RSA: Salgado region; ZBR: Bragantina zone; RGU: Guamá region. (MR1: Microregion; NM: mother plant number; FUSO/P2: Time zone /Position in the GPS; BEL: Belém; RSA: Salted region; ZBR: Bragantina zone; RGU: Guamá region).

In the municipalities, there were several collection points, and the matrices were sampled in environments such as streets, sleepers, highways, villages, home gardens, small farms, banks of bays and rivers, adopting a single collection point for each interval of matrices (Table 1). The collection point, as well as GPS positioning, refers only to the first matrix of each matrix column interval.

The evaluation of the phenotypic variability of açaí tree for the morphoagronomic characters related to fruit production is shown in Table 2. For number of stems per plant (NSP), the total amplitude was 19, with the highest value recorded in EO- 076 (Acará - Ilha do Combu) and the lowest values in EO-075; EO-128 and EO-165 (Ilha do Combu), which presented average value of 8.17, standard deviation of 3.84 and coefficient of variation of 46.96%. Stem height (SH) had a range of variation of 8.20, with EO-079 showing the highest value (Ilha do Combu), which presented average value of 7.94, standard deviation of 1.81 and coefficient of variation of 22.78%. The number of leaves (NL) had a range of variation of eight, with higher values recorded in the EO-011 (São João de Pirabas) and EO-018 (Salinópolis) matrices, and lower in the EO-019 (Salinópolis) matrix. The average value was 11.21, the standard deviation was 1.11 and the coefficient of variation was 9.95%. The circumference of the stipe at breast height (CBH) presented a range of variation of 36, presenting the highest value in EO-109 (Ilha do Combu) and lowest in EO-038 (Capitão Poço), with an average of 38.50, standard deviation of 6.23 and coefficient of variation of 16.18%. In the internode length (INL), the range of variation was 22, with the highest value observed in matrix EO-033 and the lowest in matrix EO-040, both from Capitão Poço, with average value of 16, estimated standard deviation of 4 and coefficient of variation of 25%.

Table 2: Estimates of statistical parameters and normality test in açaí tree matrices for 22 morphoagronomic characters. Northeast Pará, Brazil.

CHARACTER	**N**	**VMIN^1**	**VMAX^2**	$\bar{X}$	**s^2**	**s**	**CV**	**D (5%P)**	**D (1%P)**
NSP	129	1.00	20.00	8.17	14.72	3.84	46.96	s	ns
SH	129	4.33	12.53	7.94	3.27	1.81	22.78	s	s
NL	129	6	14	11.21	1.24	1.11	9.95	s	s
SC	129	23.00	59.00	38.50	38.83	6.23	16.18	s	ns
INL	129	8	30	15.64	15.63	3.95	25.28	s	s
FCD	129	10.70	15.31	13.22	0.74	0.86	6.50	ns	ns
LFD	129	5.87	14.05	11.30	1.15	1.07	9.48	s	ns
FW	129	1.03	1.78	1.46	0.03	0.16	11.00	s	s
SW	129	0.67	1.54	1.17	0.02	0.14	12.20	s	s
PW	129	0.11	0.51	0.29	0.00	0.07	22.75	ns	ns
CW	129	1.38	8.92	3.53	1.28	1.13	32.02	s	ns
FWC	129	1.00	8.59	2.94	1.30	1.14	38.75	s	s
NRC	129	55.00	155.00	96.73	261.40	16.17	16.71	s	ns
NFR	129	4.00	64.00	21.76	65.54	8.10	37.21	s	ns
TSL	129	129	115	79.21	175.17	13.24	16.71	s	ns
CC	129	84	189	117.33	357.08	18.90	16.11	s	s
WHF	129	103.66	189.52	149.04	314.95	17.75	11.91	ns	ns
NCP	129	1.00	10.00	4.07	3.27	1.81	44.42	s	s
NFC	129	312.00	6464.00	2109.35	738244.26	859.21	40.73	ns	ns
PYF	129	6.93	36.75	20.03	17.12	4.14	20.65	s	s
FYC	129	56.86	97.34	82.01	86.86	9.32	11.36	ns	ns
TFY	129	0.10	60.10	13.13	82.92	9.11	69.34	s	s

N: sample size; VMIN1: minimum value; VMAX2: maximum value; $\bar{X}$: average; s^2: variance; s: standard deviation; CV: coefficient of variation; D: Lilliefors normality test (1%); NSP: number of stem per plant; SH: stem height; NL: number of leaves; SC: stem circumference; INL: internode length; FCD: fruit cross-sectional diameter; LFD: longitudinal fruit diameter; FW: fruit weight; SW: seed weight; PW: pulp weight; CW: cluster weight; FWC: fruit weight per cluster; NRC: number of rachilla per cluster; NFR: number of fruits per rachilla; TCL: total cluster length; CC: cluster circumference; WHF: weight of 100 fruits; NCP: number of clusters per plant; NFC: number of fruits per cluster; PYF: pulp yield per fruit; FYC: fruit yield per cluster; TFY: total fruit yield.

In the fruit cross-sectional diameter (FCD), the range of variation was 4.61, with the highest value presented by the matrix EO-021 (Salinópolis) and the lowest in the matrix EO-095 (Ilha do Combu), with average of 13.22, standard deviation of 0.86 and coefficient of variation of 6.50%. In the longitudinal diameter of the fruit (LDF), the amplitude of variation was 8.18, with the highest value in matrix EO-029 (São João de Pirabas) and the lowest in matrix EO-010 (Belém), presenting an average of 11.30, standard deviation of 1.07 and coefficient of variation of 9.48%. In the fruit weight (FW), the range of variation was 0.75, with the highest value in matrix EO-022 and the lowest in matrix EO-019 (Salinópolis), with average of 11.46, standard deviation of 0.16 and coefficient of variation of 11%. As for seed weight (SW), the range of variation was 0.87, with the highest value in matrix EO-035 (Capitão Poço) and the lowest in matrix EO-014 (São João de Pirabas), with average of 1.17, standard deviation of 0.14 and coefficient of variation of 12.20%. For pulp weight (PW), the range of variation was 0.87 with the highest value in matrix EO-016 (Salinópolis) and the lowest in EO-094 (Ilha do Combu), with average of 0.29, standard deviation of 0.07 and coefficient of variation of 22.75%.

Regarding cluster weight (CW), the range of variation was 7.54, with the highest value observed in matrix EO-0.18 (Salinópolis) and the lowest in EO-014 (São João de Pirabas), presenting an average of 3.53, standard deviation of 1.13 and coefficient of variation of 32.02%. For fruit weight per cluster (PFC), the range of variation was 7.57, with the highest value observed in matrix EO-018 (Salinópolis) and the lowest in EO-010 (Belém), with average of 2.94, standard deviation of 1.14 and coefficient of variation of 38.75%. Considering the number of rachilla per cluster (NRC), the range of variation was 100, with the highest value observed in matrix EO-062 (Ilha do Combu) and the lowest in EO-010 (Belém), with average of 96.73, standard deviation of 16.17 and coefficient of variation of 16.71%. In the number of fruits per rachilla (NFR), the range of variation was 60, with the highest value observed in matrix EO-018 (Salinópolis) and the lowest in EO-124 (Ilha do Combu), with average of 21.76, standard deviation of 8.10 and coefficient of variation of 37.21%.

For total cluster length (TCL), the range of variation was 78, with the highest value observed in matrix EO-018 (Salinópolis) and the lowest in EO-042 (Ourém), with average of 80, standard deviation of 13 and coefficient of variation of 16.55%. For cluster circumference (CC), the range of variation was 1.05, with the highest value observed in matrix EO-017 (Salinópolis) and the lowest in EO-089 (Ilha do Combu), with average of 1.17, standard deviation of 0.19 and coefficient of variation of 16.11%. In the weight of one hundred fruits (FWC), the range of variation was 85.86, with the highest value observed in matrix EO-035 (Capitão Poço) and the lowest in EO-019 (Salinópolis), with average of 149.04, standard deviation of 17.75 and coefficient of variation of 1.81%. In the number of cluster per plant (NCP), the range of variation was 9, with the highest value observed in matrix EO-049 (Capitão Poço) and the lowest in EO-005 (Mosqueiro Island), EO-116, EO-118 and EO-128 (Combu Island), with average of 4.07, standard deviation of 1.81 and coefficient of variation of 44.42%. In the number of fruit per cluster (NFC), the range of variation was 6,152, with the highest value observed in matrix EO-018 (Salinópolis) and the lowest value in EO-124 (Combu Island), with average of 2,109.35, standard deviation of 859 and coefficient of variation of 40.73.

Phenotypic variability was verified in all traits, and significant variations were found for number stem per plant; cluster weight and fruit weight per cluster, number of fruits per rachilla, number of cluster per plant and number of fruits per cluster, which reached coefficients of variation above 30%. The transversal diameter of the fruit and the longitudinal diameter of the fruit had the smallest variation. Total fruit yield stood out among the traits with the highest phenotypic variability.

In Archontophoenix palms, progenies sampled in the state of Santa Catarina and evaluated under experimental conditions in Campinas, São Paulo, had low genetic variation coefficients for number of leaves (7.80), medium for diameter (16.08) and other traits, such as stem height, in which the variation ranged from

23.65 to 33.96 (BOVI et al., 2003). These results are similar to those found for açaí berry, although the species and estimation methods are different. In matrices of pepper (*Piper aduncum* L.) collected and evaluated for phenotypic variability, with the same estimation method used for açaí, the leaf length and width presented the smallest variations. The circumference of the older branch was one of the traits with the highest variations and the height of the plant presented a median variation (GAIA et al., 2010).

Three yield traits were evaluated for standard deviation: pulp yield per fruit (PYF), fruit yield per cluster (FYC) and total fruit yield (TFY). In the pulp yield per fruit (PYF), the range of variation was 29.82%, with the highest value (36.75%) in matrix EO-014 (São João de Pirabas) and the lowest (6.93%) in EO-094 (Ilha do Combu), with average of 20.03%, standard deviation of 4.14% and coefficient of variation of 20.65%, indicating high data variability. Eighty matrices, representing 62% of the evaluated matrices, were below average and 49, corresponding to 38%, were above average.

In the fruit yield per cluster (FYC), the amplitude of variation was 40.48%, with the highest value (97.34%) in matrix EO-033 (Capitão Poço) and the smallest (56.86%) in EO-010 (Belém), with average of 82.01%, standard deviation of 9.32% and coefficient of variation of 11.36, indicating reasonable data variability. Sixty-one matrices, corresponding to 47.29% were below average and 68, representing 52.71%, were above average.

In the total fruit yield (TFY), the range of variation was 60 kg, with the highest value (60.1 kg) in matrix EO-018 (Salinópolis) and the lowest (0.1 kg) in EO-120 (Ilha do Combu), with average of 13.13 kg, standard deviation of 9.11 kg and coefficient of variation of 69.34%, which indicates variability in the data. Eighty-one matrices, representing 62.79% were below average and 48, corresponding to 37.21%, were above average. Thus, the matrices whose values were higher than the average for these traits are those selectable for cultivation and genetic improvement.

The analysis of the standard deviations indicated that the dispersion of the data around the average presented different intervals in the three evaluated traits. Moreover, the fruit yield per cluster presented a larger number of values above the average. However, the dispersion of this trait had low magnitude, which was determinant to reduce the number of standard deviations and lower the coefficient of variation (11.36%), which was much lower when compared to the pulp yield traits. per fruit (20.65%) and total fruit production (69.34%). In the three examined traits, the number of standard deviations of pulp yield per fruit, fruit yield per cluster and total fruit yield per plant were, respectively, 3s (three standard deviations), 2s and 3s higher than of the average. Therefore, it was possible to proceed with the truncated selection. Similarly, it was found that there were three below-average standard deviations in the agronomic traits pulp yield per fruit and fruit yield per cluster. Regarding fruit yield per plant, there were only two standard deviations below the average, which indicates that there was greater selectable phenotypic variability in total fruit yield per plant.

According to the normal distribution (RAMALHO et al., 2005), the probability of collecting a sample with fruit yield per plant higher than the highest value collected, 60.10 kg, in the same localities, is approximately zero, which means that there is very likely selectable phenotypic variability for this character. Thus, the set of the collected samples of the present study agrees with the estimates of the descriptive parameters. The truncated selection for genetic improvement can be made from 49.57 kg corresponding to two standard deviations. A study of 87 accessions of açaí tree, based on 22 morphoagronomic characters, found a significant variation for the trait fruit yield per plant, with values between 0.10 kg and 50.9 kg (OLIVEIRA et al., 2007). Thus, TFY breeding is suggested to be associated with other traits, in which the production ideotype is 25 kg of fruits per plant (OLIVEIRA et al., 2009).

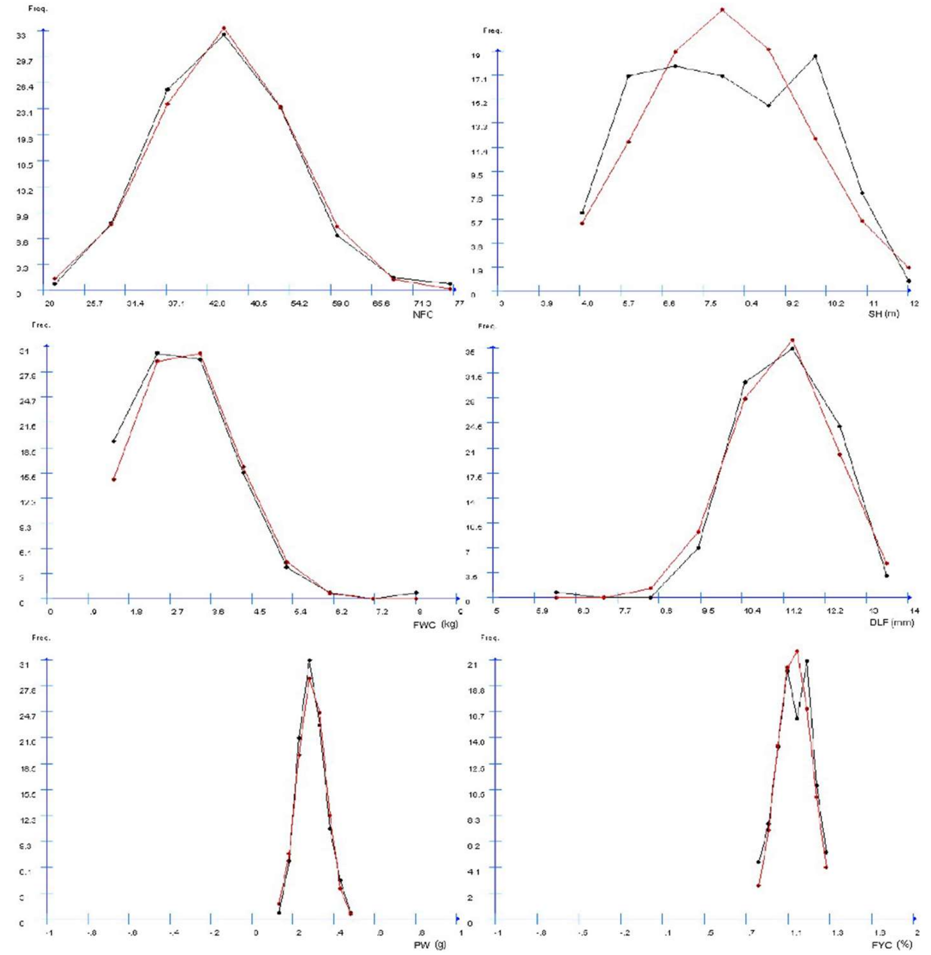

Figure 2: Observed (black line) and expected (red line) frequency distribution of six morphoagronomic traits (NFC, SH, PWC, LDF, PW and FYC) of açaí tree matrices. Northeast Pará, Brazil.

Figure 2 shows the observed (black line) and expected (red line) frequency distributions (FD) in eight variation classes of six of the 22 examined traits. The graphs represent the frequencies on the ordinate axis (y) and the classes or categories of the matrices on the abscissa axis (x). The sample size used for each trait is shown in Tables 2. The traits circumference at breast height (CBH), stem height (SH), weight of one hundred fruits (WHF), fruit cross-sectional diameter (FCD), number of rachilla per cluster (NRC), number of fruits per cluster (NFC), number of clusters per plant (NCP) and number of fruits per rachilla (NFR) showed FD approaching the normal curve, and the NFC and the SC were the ones that closer to a mesocurtic configuration, meaning that these traits can be controlled by a few genes.

Considering the number of sampled matrices (129), the number of genes of these traits, especially

NFC and SH, may possibly be one to three genes. According to Pinto (1995), the probability of selecting contrasting genotypes (end of the normal curve) depends on the size of the sample, which must be related to the proportion of extreme genotypes. In turn, it varies according to the number of genes that control the trait. Thus, one gene has an extreme genotype in four possible individuals; two genes have an extreme genotype in 16 possible individuals; three genes have an extreme genotype for 64 possible individuals and, in general, the probability of extreme genotypes is (1/4)n, where n is the number of genes involved in trait control. The other traits may require a larger number of matrices for a better approximation of the normal curve. Therefore, the numbers of genes that govern these traits may be higher than those possibly controlling NFC and SH.

Ramalho et al. (1993) reported that the number of genes for traits that are governed by a few genes can be obtained by the Mendelian randomization method, followed by non-segregating (F1) and segregating (F2) populations. The number of genes is determined from a frequency distribution in F2, which should be as numerous as possible. The number of genes is determined from the recessive genotype recovered in F2; even though pea, used by Mendel, is self-pollination species.

An important consideration to make in controlling gene inheritance is that there are cases, although rare, in which continuous-distributed quantitative traits can be controlled by a gene (PINTO, 1995). There are cases in which inheritance is polygenic, but has a discontinuous distribution (FALCONER, 1987). Thus, in the present study, there are these possibilities for such traits. The type of distribution defines whether the trait is qualitative or quantitative (PINTO, 1995) and this makes the sample size more important in these studies, especially when oriented to population studies.

Another observation about these traits, particularly NFC and SC, is that if really controlled by a few genes, they may possibly have little environmental influence, which will help to increase the heritability estimate. This may favor selection efficiency, and may also be used for indirect selection of other quantitative traits with a larger number of genes that are correlated by the traits. Correlation between SC and total fruit yield (TFY), at 1% probability level, was detected in açaí trees (OLIVEIRA et al., 2006), meaning that selection for TFY can be made indirectly by SC.

Contrasting this study, stem height is considered by many authors a trait controlled by few genes. Benin et al. (2004) reported that several studies in annual species showed that few genes control the plant height character with great effect on the phenotype. Therefore, palm species, such as the açaí tree, may require a slightly larger number of genes when compared with annual species.

Moreover, quantitative traits controlled by few genes facilitate breeding, unlike those controlled by many genes, particularly in the production of strains, since those controlled by many genes require more generations to achieve complete homozygosity (RAMALHO et al., 1993), as well as making selection against unwanted recessive genotypes more difficult (PINTO, 1995).

The internode length (INL), fruit longitudinal diameter (FLD), fruit weight per cluster (FWC), cluster weight (CW), total fruit yield (TFY) and cluster circumference (CC) presented FD of asymmetrical configuration. The graphs, with the exception of FLD, formed a trailing tail, which could mean that among the sampled matrices, there may be a higher incidence of extreme right genotypes for dominant genes, most likely desirable and; to the left for recessive genes that, in the case of FLD, may be decreasing fruit size. On the other hand, FLD was positively correlated with FWC (OLIVEIRA et al., 2006), indicating that, in the selection of recessive FLD genotypes, an appropriate truncation point must be established in order to not affect FWC.

On the other hand, segmentation of the graph line indicates discontinuity in the data, meaning the need for a larger sample size to express the expected continuity, since these are quantitative traits possibly controlled by many genes. Another factor to consider in this case is that these one-tailed curve traits may be the result of possibly unconscious phenotypic selection of adult plant seeds, since FD points to a concentration of individuals at to the right of the curve, where the dominant homozygotes are probably found for such characteristics.

The traits number of leaves (NL), fruit weight (FW), seed weight (SW), pulp weight (PW), stem number (NSP), total cluster length (TCL), fruit yield per cluster (FYC) and pulp yield per fruit (PYF) presented FD with leptocurtic configuration, which may mean that these traits had a remarkable environmental influence, favoring the heterozygous genotypes, which tend to approach the genotypic values of dominant homozygotes. Thus, it causes an increase in the frequency of the mean and hence narrowing at the base. This may also make it difficult to select against recessive alleles, which appear to be present in NL, as this trait has a small left tail.

The appearance of these traits in leptocurtic configurations may indicate that cultural practices causes more productive plants, especially regarding the quantity and quality of pulp, fruits, seeds and ideal number of tillers. The number of leaves (NL) may be indirectly selected due to a possible correlation with one or more of these traits. However, such correlation was not verified with stem, fruit, seed or fruit yield and yield traits, constituting a trait selected for germplasm characterization (OLIVEIRA et al., 2006). It can also be considered as an indication of selection for small plants, the flatness present in the FD values of stem height (SH), right in the central part of the curve. The fact that FYC also presents a reduction in the central class (Figure 2) suggests a possible correlation with the LA. Nevertheless, it was not verified when analyzing these traits by principal component analysis (OLIVEIRA et al., 2006).

When the study is mainly with data from countries or regions, frequency distribution becomes useful as it allows the verification of the level of variability of phenotypic trait (QUEROL, 1993). In the açaí tree, the phenotypic variations observed in FD may be due to the management of the rural producer carried out in the backyards of his properties, along with the bioclimatic characteristics of the Eastern Amazon. This was particularly observed in the traits that presented leptocurtic FD. In *Byrsonima verbascifolia* Rich. ex A. Juss., a large variation in the trait fresh matter mass in the mesocarp was observed, which could be related to the edaphoclimatic characteristics, among others, at the collection site (GUSMÃO et al., 2006).

An original study applying the gamma distribution to explain the effects of genes affecting quantitative traits in dairy cattle on gene number prediction found values close to 50, 75 and 100 genes for the population sizes of 50, 500 and 5000, respectively. The distribution was moderately leptocurtic, meaning the presence of many small effect genes and few major effect genes (HAYES et al., 2001).

The Lilliefors test indicated that of the 22 traits, FCD, WHF, PW, NFC and FYC were not significant ($P \leq 0.05$), presenting normality, as expected for morphometric traits. However, this depends on a relationship between the sample size, the sampling method and the number of genes that control such traits. The larger the number of genes that govern a given trait, the larger the sample size to express continuity, and the smaller the number of genes, the smaller the sample size required to express continuity in the normal curve (VIANA et al., 2001). Thus, considering these samples, the traits, especially those that were significant with $P \leq 0.01$ (AE, CIC, CEN, NCP, PTF, PFC, RPF, PF, PS and NF), should probably be controlled by a higher number of genes. The traits SC, LDF, NSP, NRC, NFR, CW and TCL presented intermediate condition, significant in $P \leq 0.05$ and not significant in $P \leq 0.01$.

Viana et al. (2001), examining corn phenotypic values for expansion capacity (volume/weight) in 595 plants, considered that the discontinuities present in FD reflect only the sample size. For an infinitely large population and phenotypic classes with amplitudes tending to zero, every value between the minimum and maximum must be observed, regardless of the scale of the values, and the distribution will be continuous. For qualitative traits, the authors consider a sample size for monogenic characteristics of approximately 40 individuals in non-segregating samples and 60 in segregating samples and for digenic 240 in F2. Therefore, four times higher than that used in F2 for monogenic inheritance.

CONCLUSIONS

By analyzing the descriptive parameters and probabilities in the normal curve, it can be concluded that there is selectable phenotypic variability in the collected germplasm, sufficient to be used in a breeding program, especially for total fruit yield (TFY). The evaluation of the three production traits (PYF, FYC and TFY) indicated that it is possible to make truncated selection with two standard deviations. Regarding the other traits, the analysis of frequency distributions indicated that there might be some traits, among those studied, controlled by a few genes (NFC and SC, in particular), which may facilitate the selection of genotypes. There are indications that the Amazonian population from Northeast Pará has been domesticating the studied matrices through management and directed selection of desirable characteristics.

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