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Spatial Distribution, Morphological Descriptors and Seed Biometry of *Syagrus oleracea* (Mart.) Becc. (Arecaceae): An Important Brazilian Cerrado Palm

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Abstract

The *Syagrus oleracea* is adapted for dry regions, has used for food, ornamental palm and development of cosmetic. It occurs in impacted areas of Cerrado. The management of the species is important for traditional communities. Morphological descriptors, biometric pyrenes and spatial distribution of individuals are important for the species distinction, conservation, forest management and implantation of breeding programs. Thus, our objectives were to determine and correlate the main morphological characters of the palm tree, to evaluate the biometric of the pyrenes and the spatial distribution of the species. Neighbourhood Density Function (NDF) evaluated the spatial distribution in georeferenced individuals in four populations (Mirabela, Mato Verde, Rio Pardo de Minas and Novorizonte). The Novorizonte population showed an aggregate pattern in the first distance classes. The other populations had a random pattern. We evaluated 13 morphological descriptors in six populations (Mirabela, Mato Verde, Rio Pardo de Minas, Novorizonte, Varzelandia and São João da Ponte). The cluster analysis corroborates the results obtained by the multivariate analysis, which shows a greater distance of the SJP3 and SJP5 samples from the other accessions. The evaluated characteristics of the pyrenes biometry were: longitudinal diameter, equatorial diameter and the mass of the pyrenes. The highest mean longitudinal (22.17 mm) and equatorial diameter (38.89 mm) in addition to the mean mass (9.29 g) were observed in the Novorizonte population. The fruits of *S. oleracea* present an elongated shape. The study generated important information about the species that is still little studied, and has economic potential for product development.

Keywords: Neighbourhood Density Function (NDF), PCA, pyrenes biometrics, sustainable exploitation

1. Introduction

The Arecaceae family is present in tropical regions, and in Brazil, 39 genus and 119 palm species are found, distributed from humid environments, such as the Amazon rainforest, to xeric environments, such as the Caatinga and Cerrado (Cappelatti & Schmitt, 2015). Among the species of Brazilian, palm trees, *Syagrus oleracea* (Mart.) Becc. stands out for its ecological and economic importance. The species is popularly known as Gueroba, Guairoba, Jaguaroba, Catolé, Pati and Pati-Amargoso, has a solitary stem, superficially ringed, with an average height of 5 to 20 meters of 15 to 30 cm in diameter, and 15 to 20 sheets arranged spirally in the canopy. It has small flowers, established in clusters that emerge predominantly from May to August and fruits that ripen in the period from October to December (Lorenzi et al., 2010).

The fruits are elliptical, ovoid or round, yellowish green. They are smooth with 4.0 to 5.5 cm in length with thick mesocarp, meaty, sweet and fibrous. The average annual production is 2,000 kg/ha of fruit and can reach 4,000 kg/ha. The almond is rich in vegetable oil with contents of 35 to 38% (Lorenzi, 1998). The fruits are about 5 cm in length, have a sweet taste, and are consumed in nature by the communities (Lorenzi et al., 2004).

Coconut pulp is used for the production of liqueurs and syrups and oil extracted from the almond for hair, skin and for cooking nutrition (Amorim et al., 2005).

It is exploited in a disorderly way (palm heart extraction and fruit collection), and populations are declining mainly by extractivism, habitat loss and fragmentation (Batista et al., 2011). These factors may contribute to decreased fitness of the populations, compromise future generations of the species (Begon et al., 2006), and changes in the pattern of spatial distribution of individuals within populations (Wiegand et al., 2007).

Biometrics provide tools that differentiate species of the same genus in the field (Cruz et al., 2001; Freitas et al., 2009). The size and other characteristics that can be obtained through the study of biometrics contribute to a better understanding of seed dispersal and seedling establishment (Fenner, 1993). Biometry is also used for differentiation of pioneer and non-pioneer species in tropical forests (C. C. Baskin & J. M. Baskin, 1998). The biometry of fruits of the species *S. oleracea* is also an important instrument for the detection of genetic variability within populations of the same species and a relation with the environment and with genetic improvement (Macedo et al., 2009; Gonçalves et al., 2000).

Seeds grow until they reach the characteristic size of the species (Carvalho & Nakagawa, 2000), with the presence of individual variations within the same species due to genetic variability and environmental influence during development (Turnbull, 1997). Another important factor in the biometry of fruits and seeds is related to the selection of seeds for the use of the edible parts for sustainable use of the species (Chuba et al., 2008). Complementary to the biometry studies, the evaluation of morphological characters of the palm are important for research of genetic variance as subsidies for conservation and better of the species in the future.

Characteristics as a proportion of the pulp, endocarp and seed are basic information on the productive and economic potential of the fruits for use as a food resource or as raw material in the industry in general.

Other important ecological factors to be studied are the distribution patterns of individuals in space. Spatial patterns of species distribution are results of ecological processes and biotic and abiotic factors. The analysis of spatial distribution is an important tool for the understanding of ecological and genetic processes in populations and communities, in forest environments, and as strategies for the conservation and sustainable management of species (Silva et al., 2014).

Thus, we sought to investigate the species *Syagrus oleracea* on the spatial distribution of individuals in natural populations, evaluation of the morphological characters of palm trees and the pyrenes biometry as preliminary subsidies for commercial planting and breeding programs.

2. Method

2.1 Spatial Distribution

The spatial distribution analyze pattern of the *S. oleracea* palm were performed using the SpPack program 1.38, using the second-order neighbors density function (NDF) (Condit et al., 2000) spatial distribution pattern of the species, including all individuals. Sixty-two individuals were sampled in four locations in the Cerrado of Northern Minas Gerais, Brazil (Novorizonte, Mirabela, Mato Verde and Rio Pardo de Minas - Note 1).

Simulations were performed by distance classes (t) between 1 and 50 m, with intervals of 5 m for the total population to avoid the occurrence of jagged plot or dentin pattern (Wiegand and Moloney, 2004). Correction of edge effect was calculated, according to Goreaud and Pelissier (1999). Using the values obtained in the NDF (t) statistic, correlograms were constructed as a function of distance t and compared to confidence intervals (upper and lower), obtained from 499 Monte Carlo random simulations (alpha = 0.01).

Three statistical hypotheses were tested: (1) Complete spatial randomness (null hypothesis): NDF values within the range of confidence intervals; (2) Aggregate standard (alternative hypothesis 1): NDF values above the upper confidence interval; (3) Segregated spatial pattern (alternative hypothesis 2): NDF values below the lower confidence interval.

The individuals of *S. oleracea* were mapped on position in the x and y-axes, with the help of a compass and GPS device.

2.2 Morphological Characteristics

We selected 13 morphological descriptors to *S. oleracea* (Table 1) in 25 accessions (palm trees with 15 to 20 meters in height) of 5 populations (Novorizonte, Rio Pardo de Minas, Mirabela, Varzelandia and São João da Ponte), in the northern Cerrado of the State of Minas Gerais, Brazil - Note 1).

Table 1. Morphological descriptors used in the characterization of the morphology of catolé plants (*S. oleracea*)

Abbreviation	Morphological Descriptor	Description
NLL	Number of live leaves	Count all sheets completely open without considering the closed ones
SL	Sheet length	Measurement of the beginning of the leaf, until the last leaflet
NLRSL	Number of leaflets on right side of leaf	Leaflet count
NLLSL	Number of leaflets on left side of leaf	Leaflet count
CLD	Central leaf diameter	Evaluation in the average position of the sheet
LCP	Length of center pin	Measurement of the leaflet from the base to the right side of the leaf
DCL	Diameter of the central leaflet	Measure done in the central position of the leaflet on the right side of the leaf
DCH	Diameter of chest height	Measurement of stem circumference
FDS	Final diameter of the leaf sheath	Measurement of the final diameter of the leaf sheath
DCP	Diameter of center pin	Measurement of central pin diameter
SD0	Stem diameter at ground level	Measurement of soil-level stipe
H7A	Height of seventh ring	Height measurement of the seventh ring
TKB7180	Thickness of the knot below the 7th ring at 180° of its smallest thickness	Measurement Thickness of the node inferior to the 7th ring at 180° of its lowest soil level thickness

Analysis of variance and estimation of the average squares of each morphological characteristic evaluated was performed. Significance was verified by the F test. For the quantification of the phenotypic divergence between the different provenances, multivariate analyzes were performed and the distances of Mahalanobis as a measure of genetic similarity were estimated. Also analyzed were canonic variables and grouping of provenances by the Tocher optimization algorithm. The Euclidean distance was obtained by paired group UPGMA from the means of the accesses of the different origins for the morphological descriptors and the matrix of variances and residual covariance (Cruz, 2006). Consistency of nodes was obtained with 10,000 bootstraps (Jolliffe, 1973).

The multivariate analysis of variance averaged and dispersion matrices relative to provenances was obtained. The associations between the morphological descriptors were analyzed by means of estimates of the coefficients of simple linear correlation between the accesses studied, using the Pearson method. The level of significance of the aforementioned values was calculated by the t-test (Steel & Torrie, 1960). All analyzes were performed using the PAST 3.21 software application (Hammer et al., 2018).

2.3 Pyrenes Biometrics Evaluation

The pyrenes were collected within a radius of 6 meters of the plant *S. oleracea*, after natural baroque dispersion, which were randomly collected 30 samples of the 30 plants in three different areas (Novorizonte, Mato Verde and Mirabela - Note 2).

The pyrenes were forwarded to the Laboratory of Bioprospecting and Genetic Resources of the University of Montes Claros, UNIMONTES. Measurements of the longitudinal length (CLF) and equatorial diameter (DEF) of the fruits were obtained using a digital caliper, and the weight with analytical balance. For all values obtained, the mean, minimum and maximum values, standard deviation and coefficient of variation were determined. In addition, the data were submitted to correlation analysis, calculating the Pearson correlation coefficient (r) and testing its significance with the t test, with the support of the Bioestat 5.3 program (Ayres et al., 2007).

3. Results and Discussion

3.1 Spatial Distribution

The NDF analysis showed a random distribution pattern for the *S. oleracea* species for most populations, except for the Novorizonte population, which showed an aggregate pattern in the first distance classes (Figure 1).

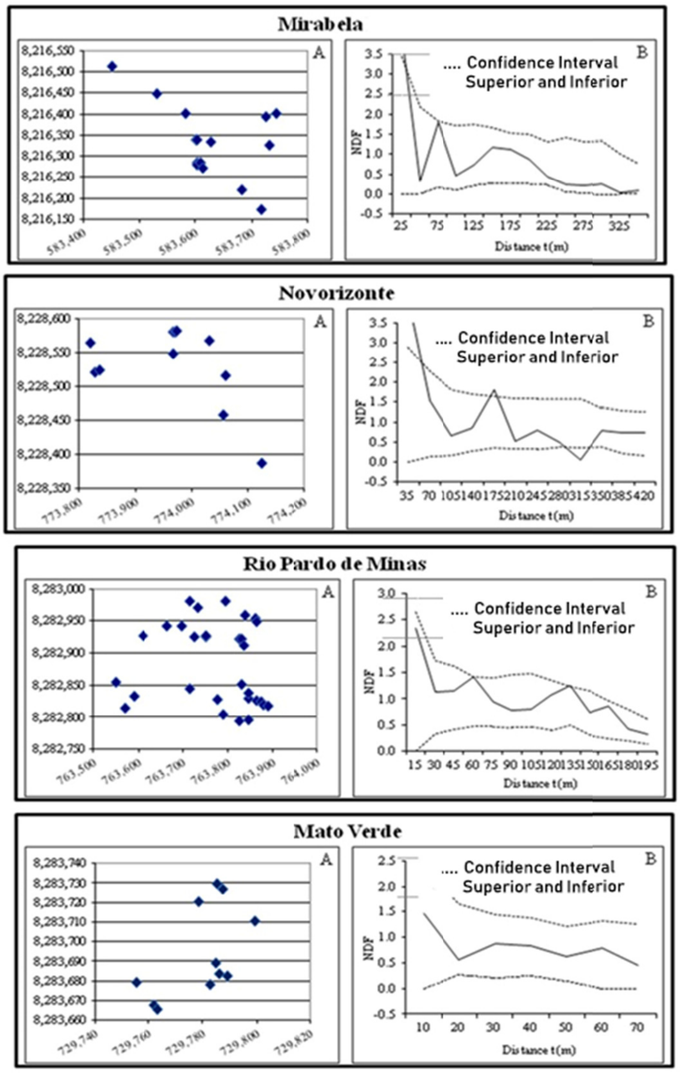

Figure 1. (A) Mapping of *S. oleracea* individuals in Universal Transverse Mercator (UTM) coordinates and (B) analysis of the NDF spatial pattern by means of univariate density analysis

The random pattern may be associated with ecological processes such as, for example, interaction with the dispersers, or by the environmental heterogeneity of the areas. Homogeneous environments and specific ecological interactions can lead to aggregate patterns of individuals, as observed in Farjado et al. (2015). On the other hand, the absence of dispersers and environments with different degrees of disturbance may reflect the distribution pattern. In fact, in all evaluated areas no juvenile or regenerating *S. oleracea* individuals were found, which may hinder their survival over the generations and may be an indicator of inefficiency in the natural restoration of these environments (Lima et al., 2016).

Mainly birds and small mammals (Oliveira et al., 2014) carry out the dispersal of *S. oleracea*. These animals carry the fruits away from the parent plant, which may favor the random dispersion pattern. The aggregate distribution observed in population of Novorizonte may be associated to the restriction of seed dispersal. The sampled site is close to the urban agglomerate and the highway. Impacts such as suppression of vegetation and burning can interfere, over the generations, with the possibility of seed dispersal.

3.2 Analysis of Morphological Characteristics

When analyzing the estimates of the eigenvalues associated to the main components and their respective relative and accumulated variances, we can notice that the first two components managed to explain 65.6% of the total variation, since much of it was diluted until the sixth main component, responding by 96.0% of all the variation available in the germplasm collection (Table 2).

Table 2. Estimates of the eigenvalues associated to the main components and their relative and accumulated variances obtained from the 28 characters evaluated in 87 accessions of *S. oleracea*

PC	Eigenvalue	% variance	Cumulative variance
1	1145.89	49.217	49.22
2	382.745	16.439	65.66
3	302.862	13.008	78.66
4	205.084	8.808	87.47
5	128.334	5.512	92.98
6	71.9439	3.090	96.07
7	48.8672	2.098	98.17
8	27.3346	1.174	99.35
9	14.1388	0.607	99.96
10	0.557064	0.023	99.98
11	0.319091	0.013	99.99
12	0.136489	0.005	99.99
13	0.0097511	0.000	100.00

These values were higher than those found in *Euterpe oleracea* (Oliveira et al., 2006) and close to the values observed in the *Bactris gasipaes* (Martel et al., 2003). The distribution of variance is associated with the nature and number of characters used in the analysis, which concentrates on the first components when the biometric characters are few (Barros, 1991; Perreira et al., 1992).

The results of the morphological characters of *S. oleracea* in each population were ordered by main component analysis (PCA) (Figure 2), in which the main components 1 and 2 (PCA-1 and PCA-2) explained 65.6%, with PCA-1 explaining close to 50% of the total variability of the data. The scores of principal component 1 (PCA-1) were positively correlated with DO (r = 0.63), NFLEF (r = 0.48), A7A (r = 0.42), CAP (r = 0.29), NFLDF (r = 0.23) and ENI7180 (r = 0.18). The most prominent component was positively correlated with A7A (r = 0.77). The data obtained were not sufficient to generate solid clusters. However, there is a tendency of grouping between populations of Rio Pardo de Minas and Novorizonte, and another group between Varzelândia, Mirabela and São João da Ponte. The inclusion of this last group in the lower right quadrant in the PCA chart was strongly influenced by the values of the characters DO, EN7180, NFLEF and NFLDF.

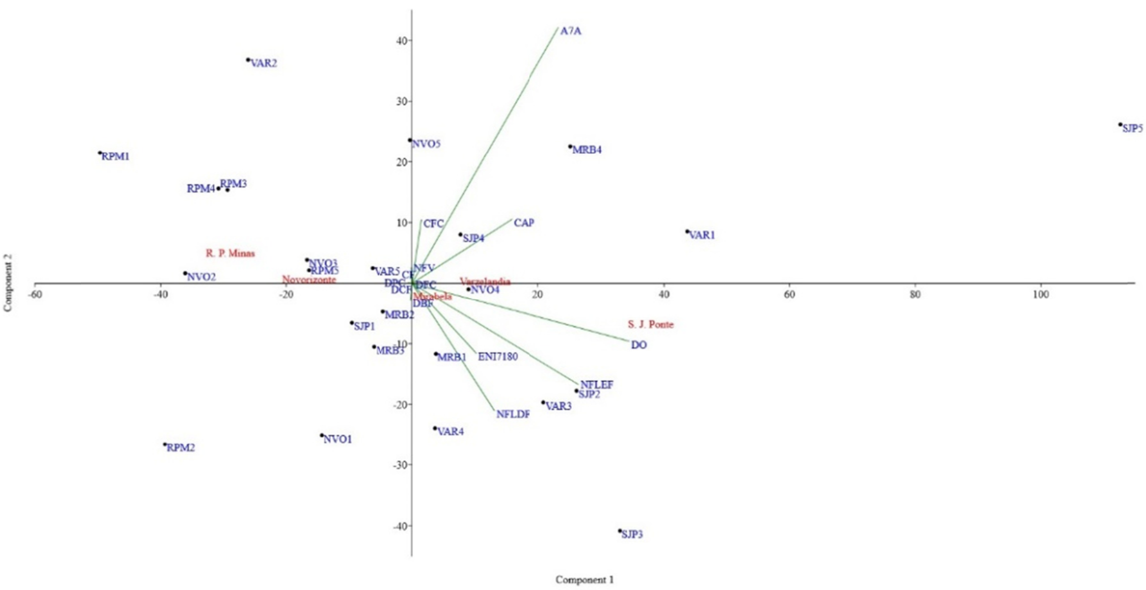

Figure 2. Graph of the main components (PCA-1 and PCA-2) of the samples and the morphological characters of each analyzed population of *S. oleracea*

Note. number opposite the abbreviation represents the sample number. VAR-Varzelândia, MRB-Mirabela, RPM-Rio Pardo de Minas, NOV-Novorizonte, SJP-São João da Ponte.

The clustering analysis corroborates the results obtained by the multivariate analysis, which shows a greater distance of the SJP3 and SJP5 samples from the other accessions (Figure 3). These outliers should be better evaluated, which may be representative of morphogenetic characters of interest for the implantation of a breeding program of the species. It is important to highlight the need to implement studies on the genetic diversity of the species, since the lack of natural regenerants compromises the conservation of the species in the long term.

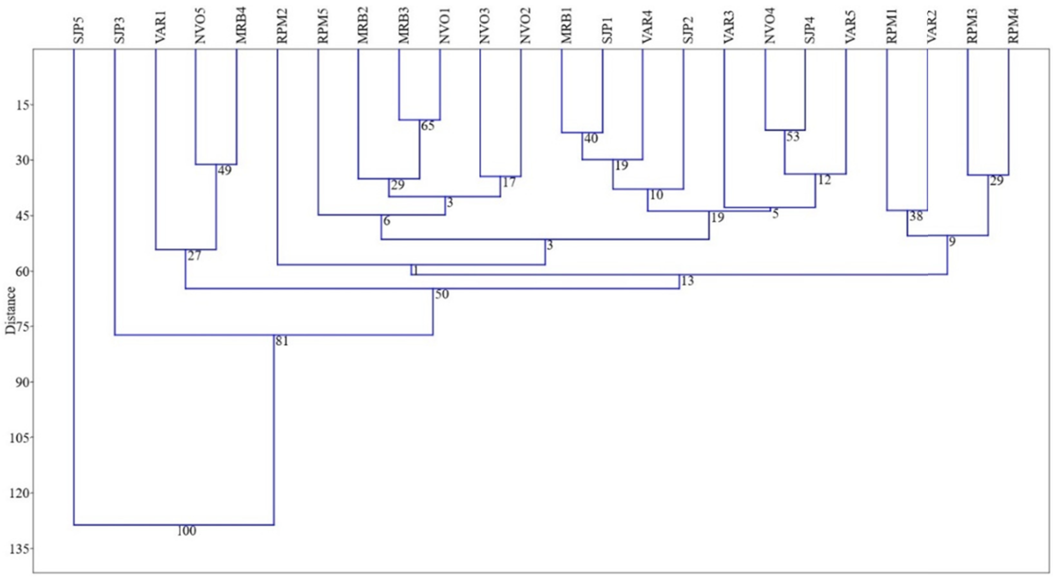

Figure 3. Dendrogram obtained by UPGMA method from the similarity between *S. oleracea* accessions, based on Euclidean distance. Consistency of nodes was obtained with 10,000 bootstraps

The thirteen selected morphological descriptors are important in the characterization of *S. oleracea* germplasm, providing information of great importance for breeding programs. These elements should be complemented by qualitative characteristics, such as the morphological characters of the fruits, precocity of fruit production, quantity of fruits produced, among others.

3.3 Biometrics Analysis

The biometry of the *S. oleracea* pyrenes showed that the population of Novorizonte showed a greater mean of longitudinal (DLP) and equatorial (DEP) diameter: 22.17 mm (±2.82) and 38.89 mm (±4.94), respectively, followed by Mirabela with 20.87 mm (±2.15) and 32.13 mm (±4.41) and Mato Verde 17.28 mm (±2.22) and 27.16 mm (±2.80) (Figure 4). Regarding the shape of the perennial, these have the DLP greater than the DEP, presenting on average a DLF/DEF ratio of 1,379 (±0.226), having an aspect of elongated fruit, similar to the data found for another important Cerrado species, *Butia capitata* (Rivas & Barilani, 2004; Pedron et al., 2004; Moura et al., 2010).

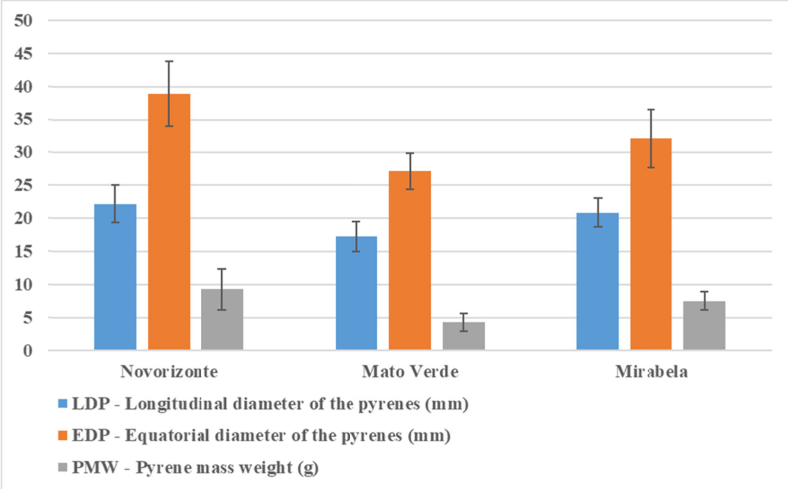

Figure 4. Mean values and standard deviation (σ) characteristics of longitudinal diameter (LDP), equatorial diameter (EDP) and pyrene mass weight (PMW) in three populations of *S. oleracea*

The diameters correlate positively and significantly with the mass evaluated, which indicates that the larger the fruit size, the greater the mass, in order Novorizonte (9.29±3.09 g), Mirabela (7.5±1.4 g) and Mato Verde (4.27±1.37 g) (Table 3).

Table 3. Pearson correlation (rP) among the biometric variables of the *S. oleracea* pyrenes

Variables	Novorizonte	Mato Verde	Mirabela
LDP × EDP	0.467^{*}	0.522^{*}	0.056^{*}
LDP × PMW	0.897^{*}	0.311^{*}	0.101^{ns}
EDP × PMW	0.683^{*}	0.512^{*}	0.476^{*}
(LDP/EDP) × PMW	0.929^{*}	0.481^{*}	0.354^{*}

Note. * = P < 0.05; ns = not statistically significant. Longitudinal diameter (LDP), equatorial diameter (EDP) and pyrene mass weight (PMW).

According to Pearson's correlations, only the values among the LDP × PMW variables of the population of Mirabela were not significant. The correlations between the variables were positive and significant, demonstrating that larger pyrenes also have greater mass. In addition, it was found that pyrenes with greater length have bigger diameter.

The mean pyrenes mass weight (Figure 4) presented approximately 46% difference between the pyrenes of Novorizonte (9.29±3.09 g) and Mato Verde (4.27±1.37 g), which may be related to the soil-environmental conditions and genetic origin of the studied material, as mentioned in Barbosa et al. (2010).

The coefficients of variation of the measurements (logitudinal and equatorial) varied little among populations (between 10 and 13%). On the other hand, the mass of the pyrene had a greater oscillation in the coefficient of variation, and the populations of Mato Verde and Novorizonte had close values (CV 32.1% and 33.32% respectively) and higher than observed in Mirabela (CV 18.7%). The values found in the analyzed populations indicate potential for conservation and genetic improvement of the species, since the coefficient of variation of the pyrene mass is considerable, representing intra-population variability (Freitas et al., 2012).

4. Conclusions

In the studied populations, the species *S. oleracea* presented, predominantly, the pattern of random distribution, except for the population of Novorizonte. The difference in the pattern of distribution in this locality may be associated with the greater degree of disturbance of the area, in comparison to the others.

The cluster analysis corroborates the results obtained by the multivariate analysis, in which SJP3 and SJP5 are outliers that should be better evaluated, which may be representative of morphogenetic characters of interest for the implementation of a breeding program of the species. There is a tendency of grouping between populations of Rio Pardo de Minas and Novorizonte, and another group between Varzelândia, Mirabela and São João da Ponte.

In the biometrics analysis, the correlations between the variables were positive and significant, demonstrating that larger pyrenes also have greater mass. In addition, it was found that pyrenes with greater length have bigger diameter.

In view of these results, further studies should be developed to assess the impacts of anthropogenic processes on species and genetic consequences in these populations. In addition to studies aimed at genetic improvement of the species and sustainable exploitation.

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Notes

Note 1. For the analysis of the spatial distribution of the individuals, four areas (populations) were mapped. In the morphological study, the same four populations, plus two other populations, were evaluated. These two additional populations have very low *N* population, which did not result in consistent NDF statistical values.

Note 2. For the analysis of the biometrics of the pyrenes, only three localities had pyrenes in the period of collection (Nov.-Dec. 2017 and Jan.-Feb. 2018).

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