Population structure, diametric distribution and use of *Commiphora leptopholoeos* (Mart.) JB Gillett in arboreal Caatinga[1]

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ABSTRACT

The objective of this work was to characterize the population structure, analyze the spatial distribution pattern and identify the potential use of the *Commiphora leptopholoeos* in the Contendas do Sincorá National Forest, BA. Thus, three disjoint transects of 40 x 160 m were installed for the phytosociological study and spatial distribution and subdivided into 64 plots of 10 x 10 m, for which the density and frequency values of regenerating individuals (dbh < 5 cm), and the density, frequency and basal area of arboreal size were calculated (dbh ≥ 5 cm). The spatial distribution pattern was calculated by the Morisita index, Payandeh's dispersion index and the Chi-squared test for the different populations. The diametric distribution was in the form of a reverse J-shaped, usually indicate full regeneration with constant seed production, germination and recruitment. The stems of the species were mostly healthy, but with a large tillering percentage and tortuosity below the commercial height, constituting characteristics which favor uses for firewood, stakes and poles. The spatial distribution pattern values of the species for tree size and regeneration point to an aggregate spatial distribution or to a tendency to aggregation.

Keywords: Contendas do Sincorá National Forest; natural regeneration; vitality class; stem quality; dispersion index.

INTRODUCTION

Commiphora lepthophloeos (Mart.) J.B. Gillet (Burseraceae) is one of the most representative species of the Caatinga biome, which it can be observed for its high density and importance values (Marangon *et al*., 2013; Carvalho, 2009; Silva & Scariot, 2004).

It is popularly known as *Imburana-de-cambão*, *Imburaninha* or *Imburana-de-Espinho*. It presents deciduousness with heliophile, pioneer and xerophilic behavior. Its height varies between three and four meters as an adult, but its largest individuals can reach dimensions of approximately 12 m in height and 60 cm in diameter (Carvalho, 2009).

It has proven uses such as for animal feed, energy, medicine, handicrafts, landscaping, carpentry and construction. It provides pollen and nectar, in addition to harboring native bees in their hollow trunks, demonstrating a potential apiculture. In projects for the recovery of degraded areas and enrichment of *capoeira* (secondary forest) and devastated forests, it has been indicated for the first phase to act as an initial colonizer (Maia, 2012; Carvalho, 2009). It is worth mentioning that this species is not endemic to the caatinga and has a wide and discontinuous distribution throughout Brazil, also it being found in the Atlantic Forest and Cerrado biomes (Carvalho, 2009).

Despite the potentials already identified, the species needs more scientific investigation that allows its use to propose a management more appropriate to its characteristics. As an example, we can mention the fact that it has mostly non-profiled shafts, which it shows a wide possibility of more noble uses of its wood.

The study of diametric distributions has several applications in forest science, as it can be used as an indicator of the growing stock (Machado *et al*., 2009), of the forest structure and in the distinction of forest types, in addition to providing subsidies for identifying the intensity of natural regeneration of the forest or species (Machado *et al*., 2010). For Orellana *et al*. (2014), the diameter distribution knowledge can be used to assess natural regeneration and define extraction/exploitation criteria, aiming toward sustainable management of the forest and individual species.

In addition to the diametric distribution, studies related to the spatial distribution have been essential in understanding the behavior of a given species and its environment in terms of landscape ecology and occupation forms (Gurevitch *et al*., 2009). Such studies facilitate understanding the influence on the forest structure, understanding colonization forms, propagule spread and ways of managing a particular species (Martins, 2009; Gurevitch *et al.,* 2009).

C. leptopholoeos is a species which stands out in terms of its various uses in the Northeast region of Brazil. Despite being a species potentially used in several categories, scientific studies are still incipient as to its ecology. Scientific investigations point to problems regarding natural regeneration, showing that the wood supply of this species may be reduced in the future. It is worth noting that the species is allogamous (cross-pollination) and it has zoocoria (avifauna) as its main dispersion syndrome (Carvalho, 2009). In this sense, Affonso *et al*. (2014) concluded that the species is not capable of forming a permanent seed bank in Caatinga soils, as germination is drastically reduced after 12 months of storage under natural or artificial conditions.

Thus, this study aimed to characterize the population structure, analyze the spatial distribution pattern and identify the potential use of the *Commiphora leptopholoeos* (Mart.) J.B. Gillett species in the Contendas do Sincorá National Forest, BA.

MATERIAL AND METHODS

The study was carried out in the Contendas do Sincorá National Forest which it has its headquarters located on the BA-026 highway, km 20, in the municipality of Contendas do Sincorá, state of Bahia, Brazil. It is located at 13° 55' 21'' South latitude and 41° 06' 57'' West longitude and has an area of 11,034 hectares. It was created in 1999 as part of environmental compensation. Before its creation as a Conservation Unit, the property was used for coal mining which subsidized the activities of the Magnesita SA company from 1990 to 1994, and was later sold to the Siderúrgica Itaminas SA company, which operated until 1997, ceding the property after that

period as a means of acquiring Forestry Recovery Credits (MMA, 2006).

The predominant vegetation formation in Contendas do Sincorá National Forest is the Caatinga tree species, according to IBGE (2012) classified as Forested Steppe-Savanna. This formation subgroup is fundamentally structured in two strata: an upper one with a predominance of periodically deciduous nanophanerophytes and relatively dense by thick, carved and spiny or accented trunks and a lower grassy-woody layer, generally discontinuous and with little physiognomic expression.

The region's climate according to the Köeppen classification is warm. Irregular rains, low intensity, concentrated in the summer (BSwh). The rainiest period runs from November to April, with an annual rainfall range between 596 and 679 mm, average temperature of 23 ºC, and relative humidity of 20 to 40%. According Barreto-Garcia *et al*. (2020), the soil is Ultisol (Soil Survey Staff, 2014).

Three disjointed transects of 40 m x 160 m distant 260 m were installed for the phytosociological and spatial distribution studies, it being subdivided into 64 plots of 10 x 10 m (Figure 1). Regenerating and arboreal individuals of the *C. leptophloeos* species were sampled in the plots.

Individuals with height greater than or equal to 0.5 m and dbh less than 5 cm were considered as natural regeneration according to a methodology adapted from the protocol of the Scientific Technical Committee of the Caatinga Forest Management Network (CTCRMFC, 2005). The individuals were qualified by height class, being: CI = height from 0.5 to 1.0 m; and CII = height above 1.0 m and dbh > 5 cm.

For arboreal size, all individuals who presented stems with dbh $\geq$ 5.0 cm were considered and the following were recorded: the diameter at breast height (dbh) and the base diameter (BD) measured at ground level with caliper, the total height with electronic clinometer, the vitality class (H = healthy; S = sick and D = dead), stem quality (1 = totally straight, no defects, no bifurcations up to 2.50 m; 2 = slightly askew or with few defects, no bifurcations up to 2.50 m; and 3 = very crooked, with serious defects or with bifurcations up to 2.50 m), and the canopy position (D = Dominant, if it belongs to the top 10% of the trees in the plot; I = Intermediate, if located at the average height level of trees in the plot; or O = Oppressed, if located under crowns of the other trees in the plot) (CTCRMFC, 2005).

In order to evaluate the influence of the forest structure as a whole on *C. leptophloeos*, individuals with dbh $\geq$ 5.0 cm from other species present in the transects were also sampled.

Density and absolute frequency were the parameters used to analyze the horizontal natural regeneration structure of the specie (Souza & Soares, 2013), in addition

to the basal area. The vertical structure was analyzed according to the limits of each stratum, and the canopy position of each individual was calculated.

Regarding the diametric distribution of individuals of arboreal size, a class width of 5 cm was used according to the methodology suggested by Soares *et al.* (2007) for unequal stands.

Parametric assumptions were performed for statistical analysis, observing that the data distribution was devoid of normality (Shapiro-Wilk test) and homogeneity (Levene test). Although there was an attempt to parameterize the variables with the Box-Cox technique (Osborne, 2010), the data were not converted to the normal distribution. The Kruskal-Wallis non-parametric test was used in view of the lack of normality, followed by the Dunn test ($\alpha = 0.05$). In a complementary way, data on the number of individuals in the dominant stratum and natural regeneration were subjected to multivariate principal component analysis (PCA), to condense the multidimensional variation in a diagram, ordering the transects in the components according to their similarities (Ter Braak, 1986), and to evaluate the influence of the number of dominant individuals on the natural regeneration of the studied specie. All analyzes were performed using the Past 4.02 program (Hammer *et al.*, 2001).

The Payandeh Dispersion Index (PDI) (Payandeh, 1970) and the Morisita Dispersion Index (MDI) (Morisita, 1962) were used to detect the spatial pattern. The PDI determines the degree of aggregation of the specie through the relationship between the variance in the number of individuals per plot, and the average number of individuals (Calegário *et al.*, 1993). When PDI <1.0, there is no grouping or random; when 1.0 to 1.5 indicates a tendency to cluster, and when PDI ≥ 1.5, it indicates cluster or aggregation. Based on the MDI, values found less than 1.0 indicate uniform distribution, values equal to 1.0 indicate random distribution, and values greater than 1.0 indicate aggregate distribution.

The x^2 test (chi-squared) was used to statistically examine patterns in relation to randomness at p-1 degrees of freedom. The X^2 value was verified with a significance of 5%. The interpretation of the chi-squared value was based on the following criterion: if the calculated value is less than the tabulated value, the MDI does not differ significantly from 1 and the species will show a random distribution pattern. On the other hand, if the calculated chi-squared value is greater than the tabulated one, the species will tend to an aggregate distribution pattern (Brower & Zar, 1997). The occurrence of individuals in the plots was compared with the Poisson distribution.
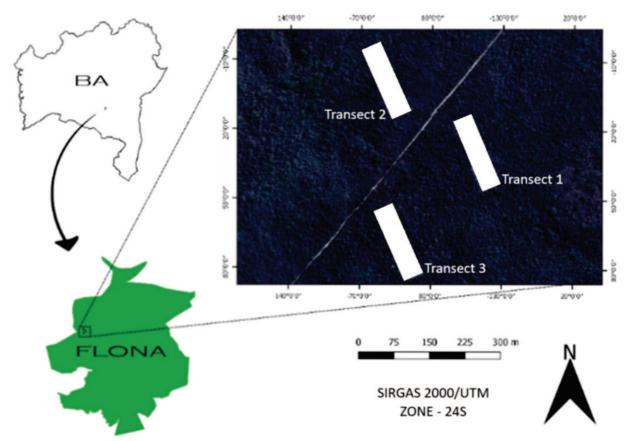

Figure 1: Location and distribution map of the experimental units, Contendas do Sincorá National Forest, Bahia. Author: Adriano Castro de Brito.

RESULTS AND DISCUSSION

Natural regeneration structure

A total of 102 individuals were sampled, distributed in the three transects. The highest values were found in transects I (43.1%) and II (47.1%), although with significant distinction in relation to transect III only in the CII and when considering the total number of individuals (Table 1). Statistical differences were observed in transects I and II when comparing the height classes in each of the transects, and the number of individuals was higher in CII (Table 1).

Additionally, data on the number of individuals explained 94% of the variation between treatments when submitted to PCA using two components (Figure 2). It is possible to verify a similar natural regeneration pattern in

Table 1: Number of regenerating individuals of the *Commiphora leptophloeos* (Mart.) J.B. Gillett in three transects in the Contendas do Sincorá National Forest - BA, Brazil, 2017, where: CI = height from 0.5 to 1.0 m; CII = height above 1.0 m and dbh > 5 cm; and NI = total number of individuals. Means followed by the same capital letter in the column and lower case in the line do not differ by Dunn's test at 5% probability

Transect	CI	CII	NI
I	1 bA	43 aA	44 A
II	2 bA	46 aA	48 A
III	1 aA	9 aB	10 B
Average	1.3	32.7	34.0

the three transects. However, it is noticed that the number of dominant individuals showed a different behavior among transect III and transects I and II. It was observed that the natural regeneration of transects I and II was negatively influenced by the number of dominant individuals, it being different from what occurred for transect III.

The average number of individuals sampled in this study was high when compared to other studies (Table 1). Farias *et al*. (2016), in Serra Talhada (PE), found 11 regenerating *C. leptophloeos* individuals in a study on the physiognomy and structure of the Caatinga vegetation in different environments.

Alves *et al*. (2010) and Alves Jr. *et al*. (2013) reported that the specie has establishment problems due to low regeneration values. However, the result found was different, as well as that by Farias *et al*. (2016) in which *C. leptophloeos* was among the most abundant species.

The predominance of individuals in the CII (Table 1) is attributed to the amplitude of the class. Souza *et al*. (2016) obtained the same result in a study of Caatinga area.

Structure of arboreal individuals

The total number of individuals from Transect I (57.8%) differed statistically from Transects II (20.8%) and III (21.4%). When we observed the vertical distribution, it is clear that this pattern is only repeated for individuals in the intermediate stratum. In relation to the oppressed class, the significance was only verified in transect III. Transect
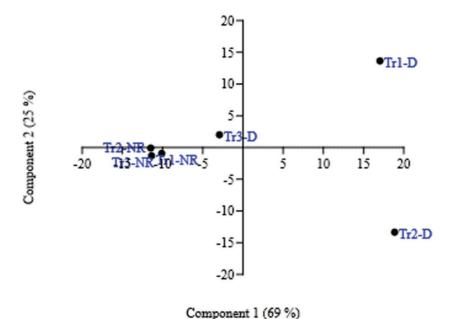

Figure 2: Principal Component Analysis relating the number of canopy individuals in the forest with the natural regeneration of *Commiphora leptophloeos* (Mart.) JB Gillett in Transect III, in the Contendas do Sincorá National Forest - BA, Brazil, 2017, in which: Tr1-D = number of individuals from the dominant stratum in transect 1; Tr2-D = number of individuals from the dominant stratum in transect 2; Tr3-D = number of individuals from the dominant stratum in transect 3; Tr1-NR = number of individuals from natural regeneration in transect 1; Tr2-NR = number of individuals from natural regeneration in transect 2; and Tr3-NR = number of individuals from natural regeneration in the transect 3.

I also differed from transects II and III for the basal area (Table 2).

Water availability has been identified as one of the main factors affecting plant communities in areas subjected to strong climatic seasonality (Trejo & Dirzo, 2002; Segura *et al.*, 2003), as occurs in vegetation environments in Caatinga (Andrade *et al.*, 2009).

Regarding the canopy position, the pattern found in this study differs from that found by Souza *et al.* (2016) with a Caatinga fragment. They observed that the oppressed class had a greater number of individuals with a percentage of 65.17% of the stems, the intermediate class had 19.84% of the stems, and the dominant class had 14.99% of the stems.

In a study carried out in the same location, Lima & Lima (1998) found a much higher value than that of the present study (4.717 m²ha⁻¹). It is worth mentioning that it was still called *Fazenda Extrema-Lapinha* in this period, and it was used to extract wood for charcoal production through a Management Plan.

Diameter class

The distribution of individuals by diameter classes showed a high concentration of stems in the smaller diameter classes. The largest diameter observed was 51.6 cm. The distribution of individuals by diameter classes followed the reverse J-shaped trend, with classes 7.5 and 12.5 being the most frequent, with 29.7% and 39.1%, respectively (Figure 3).

The distribution of the total number of individuals by diameter class following the reverse J-shaped pattern indicated that the specie is in full regeneration with constant seed production, germination and recruitment (Dalla Lana *et al.*, 2013). Other studies carried out in the Caatinga biome also found a greater concentration of individuals in the smallest diameter classes (Almeida Neto *et al.*, 2009; Dantas *et al.*, 2010; Marangon *et al.*, 2013; Farias *et al.*, 2016). This pattern confirms what has been reported in native forests in general, and tropical forests in particular are generally designated as having the reverse J-shaped, indicating a decreasing number of trees as the diameter increases (Lima & Leão, 2013).

Qualitative analysis

Most of the stems were classified as healthy in both the general average and by transect, which corresponded to 87% of the individuals (Table 3). The number of diseased stems evaluated was 24, making a total of 12.5% of the individuals.

The individuals sampled in this study were mostly healthy. In studying a Caatinga fragment, Souza *et al.* (2016) registered 71.73% of healthy stems. This indicates that the specie exhibits the standard behavior of a community in the Caatinga biome, meaning there are many healthy individuals and low mortality.

In the analysis of stem quality, it was observed that most of the stems were classified as very crooked with serious defects (hollow, cracked, rotten) or with bifurcations, making a total of 62.5% (Table 4). Only 8.3% of the individuals had straight stems and no bifurcations.

A low quality of *C. leptopholoeos* individuals was also observed by Souza *et al.* (2016), who found 71.73% of the healthy stems and 89.40% classified as class III stem quality in the Caatinga area, considering this pattern as being typical of Caatinga vegetation. The results obtained show low potential for using the specie for purposes such as sawn wood and furniture.
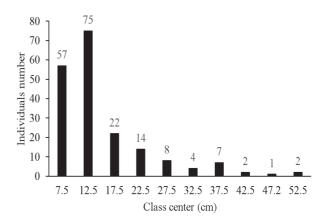

Figure 3: Distribution *Commiphora leptophloeos* (Mart.) J.B. Gillett individuals in diameter classes of 5 cm in the Contendas National Forest of Sincorá – BA, Brazil, 2017.

Table 2: Number of the arboreal individuals, canopy position and basal area (BA) of *Commiphora leptophloeos* (Mart.) J.B. Gillett in three transects in the Contendas do Sincorá National Forest – BA, Brazil, 2017, where: NI = total number of individuals, D = dominant; I = intermediate; and O = oppressed. Means followed by the same capital letter in the column and lower case in the line do not differ by Dunn's test at 5% probability

Transect	NI	D	I	O	BA (m²/ha⁻¹)
I	111 A	14 cA	51 aA	46 bA	1.8916 A
II	40 B	3 bA	11 abB	26 aA	0.8819 B
III	41 B	12 abA	26 aB	3 bB	1.1816 B
Average	64	9.7	29.3	25.0	1.3184

Spatial pattern

The PDI showed values greater than 1.0 in all transects, indicating an aggregate spatial distribution or with a tendency to aggregate the specie (Table 5). In addition, the MDI indicated an aggregate distribution pattern for all transects for both tree size and for regeneration, with values ranging from 1.42 to 4.60.

The χ^2 values calculated for both tree size and for regeneration in all transects were higher than the χ^2 tabulated value, resulting in an aggregate distribution.

For arboreal size, most plots in all transects had between one and three individuals. The same pattern was found for regeneration where most plots had one or two individuals (Table 6).

It was possible to verify the existence of more plots with a larger number of individuals than expected in the tree size (Table 6), which it demonstrated an aggregate pattern. This pattern occurred in plots with five, six, nine and 11 individuals in Transect I, while it occurred in plots with four individuals in Transect II, and in plots with four and five individuals in Transect III.

The "aggregate" type pattern observed by PDI, MDI and χ^2 for the tree size of the specie was also found by Santana *et al*. (2016). In studying the tree size of this species in a Caatinga area, Marangon *et al*. (2013) found that it had a "tendency to aggregate". Bruzinga *et al*. (2013) reported that the aggregate distribution pattern may indicate that the species has a limited dispersion in relation to the propagule source or is demanding under specific microenvironmental conditions.

It is worth highlighting the fact that *C. leptophloeos* has wide and discontinuous dispersion (Carvalho, 2009), and the aggregation can be considered common in species with this characteristic. This specie is reputed as a pioneer and indicated for the first phase of recovery of degraded areas (Carvalho, 2009). According to Nasi (1993), species which inhabit altered locations tend to aggregate. The author still characterizes these species as aggressive, adapted to varied ecological conditions which applies to the species studied. Another important characteristic is its zoochoric dispersion, mainly by avifauna (Carvalho, 2009), which according to Antonini & Nunes-Freitas (2004), generate an aggregate spatial distribution pattern.

Dispersing animals have a great influence on the spatial patterns of seeds and consequently of seedlings (Crawley, 1986). As an example, we can mention the behavior of rodents and birds, which feed by taking fruits to their shelters and natural perches, respectively (Pottker *et al*., 2016). The degree of influence of seed dispersal also depends on the way the mother plants are distributed (Crawley, 1986).

The presence of clearings is a factor which favors aggregation of young individuals due to the increase in light intensity (Capretz *et al*., 2012). This fact mainly has an influence on the species under study as it shows

Table 3: Vitality classes and canopy position of *Commiphora leptophloeos* (Mart.) J.B. Gillett in the Contendas do Sincorá National Forest – BA, Brazil, 2017

Transect	Vitality			
	H	**S**	**D**	**Total**
I	93	17	1	111
II	38	2	-	40
III	36	5	-	41
Total	167	24	1	192
Total (%)	87.0	12.5	0.5	100

In which: Vitality – H = Healthy stem; S = Sick stem; D = Dead stem.

Table 4: Stem quality of *Commiphora leptophloeos* (Mart.) J.B. Gillett in the Contendas do Sincorá National Forest – BA, Brazil, 2017

Transect	Stem quality			
	C1	**C2**	**C3**	**Total**
I	4	34	73	111
II	1	13	26	40
III	11	9	21	41
Total	16	56	120	192
Total (%)	8.33	29.17	62.5	100

In which: C1 = totally straight, no defects, no bifurcations up to 2.50 m; C2 = slightly crooked or with few defects, no bifurcations up to 2.50 m; and C3 = very crooked, with serious defects or bifurcations up to 2.50 mm.

Table 5: Spatial distribution pattern of the *Commiphora leptopholoeos* (Mart.) J.B. Gillett species in a stand at Contendas do Sincorá National Forest - BA, 2017

Transect	Arboreal size				Regeneration			
	N	**PDI**	**MDI**	x^2	**N**	**PDI**	**MDI**	x^2
I	111	2.66	1.95	167.49	44	1.29	1.42	81.09
II	40	1.45	1.72	91.20	48	3.68	4.60	232.00
III	41	1.90	2.42	119.78	10	1.47	4.27	92.40

In which: N: number of individuals; PDI: Payandeh Dispersion Index; MDI: Morisita Index; x^2: calculated chi-squared value.

Table 6: Percentage of plots per number of individuals of *Commiphora leptophloeos* (Mart.) J.B. Gillett at a stand in Contendas do Sincorá National Forest - BA, 2017

NInd	Transect I Frequency				Transect II Frequency				Transect III Frequency			
	AS		R		AS		R		AS		R	
	OF	EF	OF	EF	OF	EF	OF	EF	OF	EF	OF	EF
0	28.13	17.65	89.06	50.28	59.38	53.53	67.19	47.24	60.94	52.70	59.38	85.53
1	34.38	30.61	6.25	34.57	26.56	33.45	18.75	35.43	26.56	33.76	26.56	13.36
2	17.19	26.55	4.69	11.88	9.38	10.45	3.13	13.29	7.81	10.81	9.38	1.04
3	6.25	15.35	0.00	2.72	1.56	2.18	7.81	3.32	0.00	2.31	1.56	0.05
4	3.13	6.65	0.00	0.47	3.13	0.34	0.00	0.62	1.56	0.37	3.13	0.00
5	4.69	2.31	0.00	0.06	0.00	0.04	0.00	0.09	3.13	0.05		
6	3.13	0.67	0.00	0.01			0.00	0.01	0.00	0.01		
7	0.00	0.17					0.00	0.00				
8	0.00	0.04					1.56	0.00				
9	1.56	0.01					1.56	0.00				
10	0.00	0.00										
11	1.56	0.00										

In which: NInd - number of individuals; AS - arboreal size; R - regeneration; OF - observed frequency; EF - expected frequency.

heliophile behavior. The different levels of light intensity provided by the canopy and clearings can increase the survival of seedlings in specific places.

CONCLUSIONS

The natural regeneration behavior was not impacted by shading.

The diametric distribution was in the reverse J-shaped form, indicating that the species is in full regeneration with constant seed production, germination and recruitment.

The stems of the specie were mostly healthy, but with a high percentage of tillering and tortuosity below the commercial height, constituting characteristics which favor its uses as firewood, stakes and poles.

The spatial distribution pattern values of the specie for tree size and regeneration point to an aggregate spatial distribution or with a tendency to aggregation. This confirms the characteristic of the specie to form clusters.

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