Original Research Article

Potential of Artificial Bird Perches for Recovery Different Areas in Brazilian Semiarid

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ABSTRACT

To evaluate the potential of artificial bird perch for recovering areas on the Brazilian semiarid through seed dispersion and the establishment of regeneration. We tested the treatments: PC= perches in area with preserved surroundings; CC = absence o perches in area with preserved surroundings (Control 1); PP= disturbed area with perches and CP= disturbed area without perches (Control 2). The experiment has a complete randomized design with four replications.The study was performed in the municipalities of Ibaretama and Quixaba, State of Ceará, Brazil. We used one perturbed (Area 1) and one conserved area (Area 2) in each municipality. The experiment was conducted from April 2014 to May 2016, a total of 24 months. Twenty four (24) perches were used in each area. Seed rain and natural regeneration were evaluated. Collectors were installed at the perch bases and the seeds sampled monthly, quantified and identified. Every twelve months, the natural regeneration was verified under the perches, quantifying and identifying the regenerates. We found 1031 seeds of shrub-tree species dispersed. The treatment with perches in environment with conserved surroundings had the higher number of seeds. The main dispersed species were *Commiphora leptophloeos* (28.3 sem.m^{-2}), *Lantana camara* (7.3 sem.m^{-2}) and *Cynophalla flexuosa* (2.6 sem.m^{-2}). We observed the higher value of regeneration in the treatments with artificial perches with conserved surroundings, 2.7 individuals.m^{-2}. The dispersal syndrome of natural regeneration consisted of 50% of zoochoric species. Artificial perches exert a recuperative function on Brazilian semiarid areas, increasing the rain of zoochoric seeds and the recruitment of the species. We recommend artifitial perches for the attraction of dispersers in different disturbed areas.

Keywords: forest restoration, dry forest, seed dispersal.

1. INTRODUCTION

Caatinga is typical vegetation of Brazilian semiarid, drastically reduced due to unsustainable use by human actions, resulting in large devastated areas [1, 2]. The risk of desertification, inherent of dry regions [3], makes the scenario worrying and requires urgent actions of restoration.

Environmental restoration, foreseen by law [4], emerges as a contemporary need facing the disturbances suffered by natural ecosystems. Restoration facilitates the entry of species characteristic of an area, driving the natural processes to the return of stability and biological integrity. However, there are numerous biotic and abiotic factors limiting the entry of species naturally into an environment, especially in systems with high levels of degradation. Among these factors, the absence of dispersers and the low seed rain, especially the zoochorous ones, limit the floristic recomposition of the environment [5].

The nucleating techniques provide the formation of diversity nuclei that naturally radiate, respecting the successional processes and gene flow between the disturbed area and the fragments of the environment [6]. Artificial perches have been considered as a nucleator method of easy application and low cost for the restoration [7, 8].

Despite the advantages of perches in the regeneration activation of disturbed ecosystems, its use for restoration of areas is scarce in tropical forests and semiarid regions of Brazil, with few studies with these techniques. Therefore, this work aimed to evaluate the seed rain and the establishment of regenerants under artificial perches for recovering areas in Caatinga.

2. MATERIAL AND METHODS

The study was carried out in the municipalities of Quixadá and Ibaretama, Ceará, Brazil, under areas destined to research by the Biomas - Caatinga Biome Project.

The experiment was settled into two rural properties. The first, Area 1, coordinates 4º44’23.62’’S and 38º45’05.25’’W, have a total area of 700 ha, marginal to Pirangi River, in the area of Vertisol Hydromorphic sodium saline. Area 1 was quite disturbed by successive anthropic processes of agricultural exploitation, including successive fires. The second property, called Area 2, coordinates 4°49'34" S, 38°58'9" W, has a total area of 928 ha. Area 2 had a good condition, located at a Private Reserve of Natural Heritage (RPPN ‘Não Me Deixes’) of 300 ha of arboreal Caatinga, installed in the area of eutrophic Arenic Hapludult soil.

The rainy period occurs between the months of January and June with a historical annual average of 863.4 mm; mean temperature of 27.7°C and evapotranspiration of 1893.5 mm [9]. However, during the study period, the average annual rainfall was 500 mm. The experiment started in April 2014 and lasted 24 months. Parameters of seed rain and natural regeneration were evaluated using nucleating techniques with artificial perches.

We used 48 perches of 10 x 15 mm each, consisting of 24 perches in Area 1, area of a perturbed environment, and 24 in Area 2, area of a conserved environment. The two properties distanced themselves 20 km in a straight line. Eight plots were used in each area: four with perches and four without. The plots were spaced five meters from each other. We installed three perches per plot assign to have a perch.

The distribution of plots and perches resulted in four treatments Tratamento PC = Area of conserved surround with perch; Treatment CC = Area of conserved surround without perch; Treatment PP = Area of perturbed surround with perch; and CP = Area of perturbed surround without perch. We used a randomized block design with four replicates and three perches per replicate.

Seed rain and natural regeneration were evaluated in each treatment. We installed seed collectors to verify seed dispersal. In the perches that were not installed collectors, we evaluate the regenerants, respecting the area of influence.

The perch structure was composed of two wooden stick with one meter long each. The wooden rods were fixed in a cross shape under a wooden picket of two meters high and made of branches of native species of the area. The seed collectors were built using sticks with a height of 0.30 m fixed in nylon screens of 0.01 mm of mesh.

The seed rain was monitored monthly for 24 months. All the diaspores were quantified, identified, separated by morphotype and quantified all the sampled seeds. However, we limited the identification to the diaspores of shrub-tree species. Identification was performed by comparison with fertile botanicals materials with fruits *in vivo* collected in the area, and by expert and specialized bibliographies. When it was not possible to identify the seeds from the previous procedures, the seeds were sown in trays containing vermiculite for possible identification after the emergence of seedlings, in a greenhouse.

The species were classified according to the characteristics of the dispersion vehicle of each seed [10]: seeds dispersed by wind (anemochory); dispersed by animals (zoochory); species with their own mechanisms of dispersion (autochory), and the last group, which had as mechanisms of dispersion both autochory and zoochory (auto-zoochory). Seeds found inside the feces were classified as zoochorous. Total seed deposition densities ($seeds.m^{-2}$) was calculated dividing the number of seeds by the total sampled area.

Regeneration was evaluated after one year of perch installation. Subplots of 1 m^2 were plotted in the area of influence of the collectors (total of 12 per plot) and in the control plots, which did not have perches, subplots were allocated among the collectors, also a total of 12 per plot. All species of the shrub-arboreal stratum, from the seedling stage, were counted, and the height and diameter of the colon were identified and recorded. The species were further classified according to the dispersion, life form, and origin (native or exotic), all parameters compared by treatment.

The similarity index was used to compare the floristic composition between seed rain and natural regeneration of the different areas under perches. Sorensen Similarity Index (SI) was used, $SI = (2a / b + c) \times 100$, a = number of species common to both areas; and b and c = total number of species in the two compared areas. Data were also analyzed using the non-parametric statistic, Kruskal-Wallis test ($p<0.05$), using the Assistat software.

3. RESULTS

3.1 Seed rain

We found a total of 13,863 seeds dispersed in the areas during the study period. Shrub-tree species accounted for 1,031 seeds. Wood species presented the highest density (27.6 seeds.m^{-2}.year^{-1}) at the areas with conserved surroundings and artificial perches. The treatment with artificial perches in a disturbed surrounding had a shrub-tree species density of 11.2 seeds.m^{-2}.year^{-1}.

Seed rain was higher in treatments with perches, both in conserved and disturbed areas. All treatments were statistically different ($p<0.05$), and perches in a conserved surrounding showed the highest values for seed rain (Figure 1).

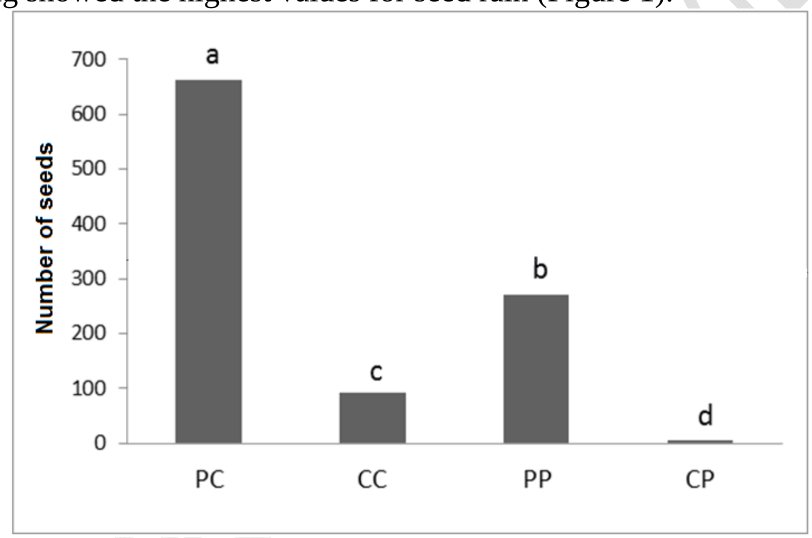

Fig. 1. Number of seeds of tree-shrub species found under artificial perches and control areas (without perches) on Ibaretama and Quixadá, CE. Treatment PC = Area of conserved surround with perch; Treatment CC = Area of conserved surround without perch; Treatment PP = Area of perturbed surround with perch; and CP = Area of perturbed surround without perch. The same letter in columns do not differ among themselves by the Kruskal-Wallis test ($p<0.05$).

We found 29 species of shrub-tree by the seed rain measure (Table 1). The species belonged to 14 families, but the families Fabaceae and Euphorbiaceae have the larger number of species, 7 and 3 respectively. We found seven undetermined species. Approximately half of the species presented zoochorous dispersion.

Table 1. Tree-shrub species found in seed rain in treatments with and without perches on Ibaretama and Quixadá, CE

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Family - Species	Dispersion	PC	CC	PP	CP
Anacardiaceae					
Myracrodruon urundeuva Allemão	ane	x		x	x

Apocynaceae					
Cryptostegia madagascariensis Bojer ex Decne	ane			x	x
Arecaceae					
Copernicia prunifera (Mill.) H.e.Moore	zoo	x			
Boraginaceae					
Cordia trichotoma (Vell.) Arrab. ex Steud.	ane	x	x		
Burseraceae					
Commiphora leptophloeos (Mart.) J.B. Gillett	zoo	x		x	
Cactaceae					
Cereus jamacaru DC.	zoo	x		x	
Capparaceae					
Crateva tapia L.	zoo	x			
Combretaceae					
Combretum leprosum Mart	ane	x			
Euphorbiaceae					
Croton heliotropiifolius Kunth	auto-zoo	x	x		
Croton sonderianus Müll. Arg	auto-zoo	x	x		
Jatropha mollissima (Pohl) Baill.	auto-zoo			x	
Fabaceae					
Anadenanthera colubrina (Vell.) Brenan	aut	x	x		
Cynophalla flexuosa (L.) J.Presl	zoo	x		x	
Mimosa caesalpiniifolia Benth.	aut	x	x		
Mimosa tenuiflora (Willd.) Poir	aut	x	x	x	x
Mimosa sp.	aut	x			
Pityrocarpa moniliformis (Benth.) Luckow & R.W.Jobson	aut	x			
Poincianella bracteosa (Tul.) L.P.Queiroz	aut	x			
Nyctaginaceae					
Guapira graciliflora (Mart. ex J.A. Schmidt) Lundell	zoo	x			
Olacaceae					
Ximenia americana L.	zoo	x			
Sapindaceae					
Cardiospermum sp.	ane	x	x		
Verbenaceae					
Lantana camara L.	zoo	x			
Indeterminada					
Morphospecies 1	zoo	x			
Morphospecies 2	zoo	x		x	
Morphospecies 3	aut	x			
Morphospecies 4	zoo	x			
Morphospecies 5	zoo	x			
Morphospecies 6	zoo			x	
Morphospecies 7	zoo			x	

PC = Area of conserved surround with perch; CC = Area of conserved surround without perch; PP = Area of perturbed surround with perch; and CP = Area of perturbed surround without perch. Ane = anemochorous; zoo = zoochorous; aut = autochorous; auto-zoo = autochorous and zoochorous.

All treatments presented a similar temporal tendency during the two years of sampling. The larger amount of seeds were dispersed soon after the rainfall peaks and extending throughout the dry period, with a gradual decrease with increasing drought.

There was a trend of greater dispersion of seeds under the perches in years of higher rainfall. Thus, seed dispersion on disturbed environments with perches was higher in 2015 (2025 seeds), year of greater rainfall than during 2014 and 2016 (408 seeds).

3.2 Natural regeneration

The higher density of shrub-tree regenerants occurred in treatments with perches (Figure 2). However, perches with conserved surroundings showed greater regeneration, with 2.7 individuals.m^{-2} and the absence of perches in conserved environment resulted in the lowest amount of regenerants, 0.2 individuals.m^{-2}, differing statistically from each other ($p < 0.05$). CC and CP did not differ.

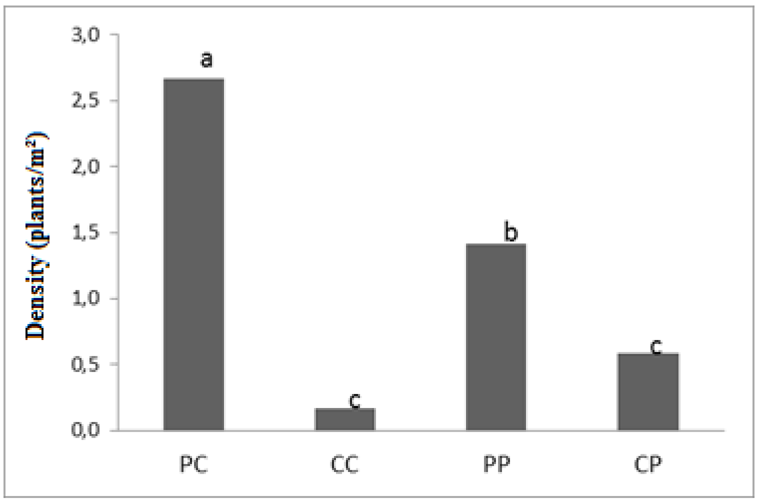

Fig. 2. Density of tree species at the evaluation of natural regeneration under different treatments in Ibaretama and Quixadá, CE. PC = Area of conserved surround with perch; CC = Area of conserved surround without perch; PP = Area of perturbed surround with perch; and CP = Area of perturbed surround without perch. Same letter in column do not differ among themselves by the Kruskal-Wallis test ($p<0.05$).

Evaluating the natural regeneration, we found 12 shrub-tree species and 09 families. The species of highest densities of individuals by area were *Cynophalla flexuosa* (2.92 ind.m^{-2}), *Cryptostegia madagascariensis* (1.92 ind.m^{-2}), *Jatropha mollissima* (1.83 ind.m^{-2}), *Croton sonderianus* (1.17 ind.m^{-2}) and *Commiphora leptophloeos* (1.08 ind.m^{-2}). The other species accounted less than 1 ind.m^{-2}. Table 2 shows the floristic list of species found in the regeneration under the different treatments.

Table 2. Tree-shrub species found at the natural regeneration evaluation in different treatments on Ibaretama and Quixadá, CE

Family - Species	Dispersion	PC	CC	PP	CP
Apocynaceae					
Allamanda blanchetii A.DC.	ane		x		

Family - Species	Dispersion	PC	CC	PP	CP
Cryptostegia madagascariensis Bojer ex Decne	ane				x
Burseraceae					
Commiphora leptophloeos (Mart.) J.B.Gillett	zoo	x		x	
Capparaceae					
Cynophalla flexuosa (L.) J.Presl	zoo	x			
Combretaceae					
Combretum leprosum Mart.	ane		x		
Euphorbiaceae					
Croton sonderianus Müll.Arg.	auto-zoo	x			
Jatropha mollissima (Pohl) Baill.	auto-zoo			x	x
Fabaceae					
Libidibia ferrea Mart. ex Tul. var. ferrea	auto-zoo	x			
Mimosa caesalpiniifolia Benth.	auto	x			
Nyctaginaceae					
Guapira graciliflora (Mart. ex J.A. Schmidt) Lundell	zoo	x			
Olacaceae					
Ximenia americana L.	zoo	x			
Rhamnaceae					
Ziziphus joazeiro Mart.	zoo	x			

**PC = Area of conserved surround with perch; CC = Area of conserved surround without perch; PP = Area of perturbed surround with perch; and CP = Area of perturbed surround without perch. Ane = anemochorous; zoo = zoochorous; aut = autochorous; auto-zoo = autochorous and zoochorous.*

Disturbed environments with perches showed the highest floristic similarity between the seed rain and regeneration (Table 3). We found the lowest floristic similarity between the floristic regeneration of conserved and disturbed environments both with perches (Regeneration PC x PP) (Table 3).

Table 3. Comparison of the floristic similarity of seed rain and regeneration under different treatments on Ibaretama and Quixadá, CE

Comparison	Index of Similarity (%)
Seed rain PC x PP	34.29
Regeneration PC x PP	18.18
Seed rain PC X Regeneration PC	35.29
Seed rain PP X Regeneration PP	50.00

**PC= perches in preserved area; PP= perches in disturbed area.*

4. DISCUSSION

4.1 Seed rain

Seed rain density is an important indicator of the potential of regeneration of plant populations. We found a significant increase of seed rain with the inclusion of perches under conserved and disturbed areas. A previous study of seed rain in a well-conserved area of Caatinga [11], reported a density of 75.6 seeds.m^{-2}.year^{-1}, including herbaceous species. In our study, we found 429 seeds.m-^{2}.year^{-1} at the most favorable treatment (PC) when we include herbaceous species, showing the importance of seed rain for the beginning of succession in semi-arid environments.

The use of perches provided an increase in seed rain in conserved environments and in the disturbed environments, compared to treatments with no perches. Despite the increase in seed rain with the presence of perches, the disturbed area still showed 60% lower seed density than the conserved area. The disturbed area, besides being grazed and burned, was colonized by a problematic invasive species, Cryptostegia madagascariensis Bojer ex Decne, that can modify the relations between fauna and flora of the region.

Using dry perches in the recovery of areas of Caatinga, another study [8] obtained a seed rain density of 10.41 seeds.m^{-2}.year^{-1} in one year of study. In semiarid, resources supply is limited by the climatic fluctuations, mainly regarding greater or less precipitation [12], which may have influenced the results.

The climatic variability may drive the seed rain density in semiarid regions because seed production and dispersal vary with the occurrence of normal rainfall or severe scarcity, common in the Brazilian semiarid. Thus, even in similar environments, seed rain values can be quite variable, reflecting the intrinsic differences in the community studied, or even methodological aspects [8].

Despite the highest number of seeds found in areas of conserved surroundings with perches, we found the greatest differences between treatments with and without perches in the disturbed area. In the disturbed area with perches, we found 45 times more seeds than the control area (without perches), demonstrating that the regeneration could occur slowly without the perches and the effective contribution of perches for recovering disturbed areas. Disturbed areas have a shortage of natural landing structures, such as trees and shrubs; thus, the addition of structures for bird landing increase the potential for use, and may be the only alternative as a springboard during movement of animals in severely degraded areas.

The use of perches to recover areas was also efficient in other dry forest ecosystems of Brazil, such as Cerrado [13]. The researches [13] found five times higher deposition of seeds using perches than without perches (control), which corroborate and confirms the importance of perch implantation for recover degraded dry forest by a greater supply of propagules to be recruited in natural regeneration.

The species of greatest dispersion in the treatments of artificial perches in conserved areas were *Commiphora leptophloeos* (28.3 seeds.m^{-2}), *Lantana camara* (7.3 seeds.m^{-2}) and *Cynophalla flexuosa* (2.6 cm.m^{-2}). In disturbed areas with perches, the most representative species were *Commiphora leptophloeos* (14.6 seeds.m^{-2}), *Cereus* *jamacaru* (3.3 seeds.m^{-2}) and *Cynophalla flexuosa* (2.3 seeds.m^{-2}). Those are zoochorous species, attractive to the avifauna.

The zoochory accounted for 58% of species found in the seeds rain. The treatment of perches in a conserved surrounding had the highest species richness, 25 species (12 zoochorous), and the perturbed area without perches showed the lowest richness, only 3 species (abiotic syndromes). The abiotic dispersion was dominant in the absence of perches, both in disturbed and conserved areas since these seeds not require fauna and structure of perches to reach different environments.

Other studies found abiotic dispersion (anemochory and autochory) as the dominant way of dispersion in Caatinga fragments or close to Caatinga fragments [11,14]. But, zoochory is also reported as the main dispersion syndrome in some caatinga environments and especially when considering species such as Cactaceae [15]. Species with fruits dispersed by the fauna, such as cactus, are also important and indispensable components in the balance of ecosystems, therefore, the use of perch structures in an important tool to increase their entrance.

The input of shrubby-tree species was three-fold higher in conserved areas using perches than in perturbed areas with perches. Artificial perches have a greater potential for formation of a diversity core of shrub-tree species when inserted in areas of caatinga with surroundings conserved. The amount of dispersed diaspores, as well as diversity, is significantly lower when the artificial perches are inserted in areas with surroundings disturbed, such as found here.

Seed rain can indicate the resilience of a community, expressing the speed of the natural dynamics of the vegetation. Thus, the use of perches as a nucleation process seems one of the best methods to initiate a process of succession in the recovery of areas, where the dynamic of species recruitment occurs according to local characteristics [7]. Artificial perches have been prominent in bird attractiveness, resulting in a higher frequency of seed dispersers, increasing the complexity of the study area, is a method with excellent potential for the recovery of the degraded regions [16].

Seed dispersions occurred soon after the rainy peaks and early dry season. Herbaceous species were the main representatives in this period. The highest number of seeds, cumulatively, was observed throughout the dry season months. It has been observed in other studies of seed dispersal in the Caatinga, greater seed increases during dry season, such as [11], that verified a greater range of seed deposition in the dry period, about 65.8% of seeds obtained.

Twice as high seed rain density during dry season was also found by [12] concerning rainy season. The largest dispersions during dry seasons are mainly represented by abiotic dispersion syndromes, which is more favorable climatically. Species of biotic dispersion are usually dispersed shortly before the rains and during the rainy season, soon recruited to compose natural regeneration.

4.2 Natural regeneration

Perches increased the density of natural regeneration considerably, endorsing the efficiency of these structures for the recruitment of shrub-arboreal individuals in Caatinga, regardless of the level of conservation. However, the greater diversity of species found using perches in areas with surroundings conserved (eight species) concerning the use of perches in areas of disturbed surroundings (two species), demonstrate the greater efficiency in the restoration of resilience in the first one, recovering its ecological functions faster.

In treatments with perches, the highest amount of seeds dispersed and regenerants were of the species *C. leptophloeos*, showing great attractiveness and importance to the local avifauna. Artificial perches in areas of Caatinga with the occurrence of *C. leptophloeos* can guarantee greater efficiency in the formation of regenerating nuclei, especially considering their spatial distribution pattern with the tendency to cluster [17], facilitating the formation of more nuclei in the restoration landscape.

The similarity in the relationships between seed rain of the different areas and the regenerating was expected, since the areas, previously to the perches installation, experienced intense disturbance with crops and successive fires, therefore, having little possibility of sheltering propagules of shrub-tree species in its seed bank. Thus, we expected that the species dispersed in the seed rain during the study period would be similar to the species recruited in the regeneration. As the two areas with perches are geographically close, although one has a more conserved environment than the other, they share floristics species, justifying the similarity found in the analysis of the seed rain.

The absence of floristic similarity of the regenerating between conserved and perturbed surrounds with perches, even with the similarity of seed rain, can be related to the different soil of the areas. The first area has Yellow Red Argissolo Tb eutrophic and the second Salmon Sodium Hydromorphic Vertisol, the latter have characteristics that may limit the germination of some species more sensitive to the salinity condition and still lose some diaspores within their deep cracks, occurring during the dry season, decreasing the chances of recruitment of the dispersed seeds and resulting in different floristic growth.

Regardless of the type of soil, we observed low recruitment to the seedling phase and to colonize the environment in both areas, despite the intense dispersion of seeds of zoochorous species under the perches. For example, at the conserved area we found 340 seeds of *C. leptophloeos* but the recruitment of only 11 individuals during the studied period. Moreover, at the perturbed area, we found 176 seeds and just one recruitment of *C. leptophloeos*.

Seed predation, low humidity of the soil to maintain all stages of germination, or even dormancy that would help to compose the diversity of the soil seed bank are limiting factors to germination [18] and may be responsible by the low recruitment. However, for *C. leptophloeos*, dormancy could not be a justification for low germination, since according to [19], this species, after dispersion is rapidly recruited to the seedling stage in the Caatinga with the arrival of the rainy season, thus not remaining in the seed bank. Moisture may be the limiting factor for germination and seedling formation of C. *leptophloeos*.

The combination of the use of perches and deposition of vegetable residues under the perches may guarantee greater humidity and germination success in areas of low recruitment of regenerants due to incipient soil moisture, a common condition in semiarid environments. Studies using perches and rest of vegetal material [8], such as branches, in an area of Caatinga showed that the technique led not only to the occurrence of native seedlings under the clusters but also the use of these structures by the local fauna, enhancing the processes of succession in the area.

Half of the woody species found in the regeneration, in the treatments with perches, were zoochorous. In control treatments, we found only species of abiotic dispersion (anemochory and autochory). The results highlight the contribution of the artificial perches for the biological diversity in the Caatinga area, whether the area has a surrounding preserved or disturbed since in the absence of perches there was no entry of zoochorous species during the two years of observation. A review of ecological succession in dry forests in the world [20], recommend the use of artificial perches considering as one of the most promising techniques in the acceleration of natural regeneration and ecological succession.

The recovery of the diversity of species in semiarid areas using artificial perches can be potentiated in areas with an initial existence of shrub species, even if sparse since shrub species are efficient both in the attraction of biotic dispersers and in the maintenance of anemochorous diaspores in the environment.

4. CONCLUSION

The use of artificial perches increases the arrival of larger amounts of shrubby-trees species, identified both in seed rain and in the recruitment of regenerants, in quantitative and in species diversity terms. We found a predominant contribution of zoochorous species to recover the Caatinga area, with greater efficiency in the recovery of areas with surrounding environment conserved. Therefore, we recommend using this technique in Caatinga restoration projects. However, more researches are still needed to investigate the limitations to the establishment of species dispersed through this nucleating technique.

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