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Melocactus violaceus Pfeiff. (Cactaceae) growth rate and abundance in a sandy terrace of Atlantic Rain Forest (REBIO Guaribas, Paraíba, Brazil)

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Taxa de crescimento e abundância de *Melocactus violaceus* Pfeiff. (Cactaceae) em um Tabuleiro de Mata Atlântica (REBIO Guaribas, Paraíba, Brasil)

Resumo: Também conhecido como cacto botão, o *Melocactus violaceus* é uma espécie endêmica do Brasil, que ocorre do Rio Grande do Norte ao Rio de Janeiro. Habita florestas úmidas (Mata Atlântica/restinga), campo rupestre ao Norte (cerrado) crescendo diretamente na areia em meio a arbustos na restinga, dunas ribeirinhas e tabuleiros da Mata Atlântica. Apesar de ter ampla distribuição e ocorrer em áreas protegidas, esta espécie é considerada pela *International Union for Conservation of Nature* (IUCN) como vulnerável. O objetivo do presente trabalho é estudar a abundância, distribuição de tamanho, e taxa de crescimento em uma população de *Melocactus violaceus,* que ocorre em tabuleiro numa área de Floresta Estacional Semidecidual, na Reserva Biológica (REBIO) Guaribas, Paraíba. Foram amostradas três fitofisionomias diferentes do tabuleiro, onde uma área é predominantemente fechada, a segunda é aberta, na sua grande parte, e por último em uma área onde predomina *Lagenocarpus* spp., conhecido popularmente como capim azul. Em cada fisionomia marcou-se 10 parcelas de 12.6 m^2, com 20 m de distância entre cada uma, onde indivíduos foram marcados e mensurados. A espécie foi encontrada somente na área aberta, com densidade média de 1.46 $ind.m^{-1}$ com média de crescimento (em diâmetro) anual dos indivíduos que sobreviveram ao longo de todo estudo foi de 1.76 ± 1.12 cm ao ano, com crescimento mínimo de 0.04 cm e crescimento máximo de 4.7 cm.

Palavras chave: Cacto botão, estrutura populacional, taxa de crescimento de cactus.

Abstract: Also known as Turk´s cap cactus or melon thistle, *Melocactus violaceus* is a Brazilian endemic species, occurring from Rio Grande do Norte to Rio de Janeiro states. It inhabits humid forests (Atlantic Rain Forest and associated shoreline sandy vegetation), rocky soils in savannah vegetation (Cerrado) and in sandy terraces. Despite its wide distribution and occurrence in protected areas, it is considered a vulnerable species in International Union for Conservation of Nature (IUCN) Red List. In this paper, we study abundance, size distribution and growth rate in a population of *Melocactus violaceus* in the Guaribas Biological Reserve (REBIO), Paraíba, Brazil. We sampled three vegetation types in a sandy terrace, one with a dense covered area with small trees and shrubs, another area with a very open canopy, where sunlight reaches most of the exposed soil, and a third area densely covered by a grassy vegetation dominated by *Lagenocarpus* spp., locally known as blue grass. In each of these three vegetation types, we made 10 samples of 12.6 m^2, 20 m apart from each other, where individuals were measured and tagged. Individuals from this species were found only in the open area, with an average abundance of 1.46 $ind.m^{-1}$. Average

annual growth rate was 1.76 ± 1.12 cm a^{-1}, with a minimum growth of 0.04 cm a^{-1} and maximum of de 4.7 cm a^{-1}.

Key words: Cactus button, population structure, cactus growth rate.

Introduction

Cactaceae is one of the largest eudicot families, with over 90 genera and around 1500 species (Almeida 2016). Thirty seven (37) genera of the family are native to Brazil, which is about 30% of the total richness known (Zappi *et al.* 2011). Some of the species that constitute the family are characterized by their ability to inhabit areas with low water availability and high solar incidence; their distribution defined by a specific set of conditions, occurring from North to South America (Almeida 2016). In Brazil, it occurs in areas such as river sand banks, riparian forests, the Caatinga, restinga and low plateau formations within the Atlantic Forest, and Cerrado (Gomes *et al.* 2014).

Cactaceae are key to the functioning of their ecosystems as a source of energy for a diversity of pollinators and dispersers (Zappi *et al.* 2011). As an example, *Melocactus zehntneri* Britton & Rose, presents an important role in the ecological succession in the environments they occur, being capable of turning inhospitable environments, such as rock outcrops, in habitable areas for other species (Fabricante *et al.* 2010).

Melocactus is a genus formed by small, globe-shaped cacti, common in the semi-arid regions, with small flowers that blossom in the afternoon and close at dusk. The fruits are small (~ 3 cm) and develop protected inside the cephalium, becoming succulent and varying from white to red when ripe, and carrying small black seeds within the pulp (Zappi *et al.* 2011). Among the species found in Brazil, several are native, such as *Melocactus azureus* Buining & Brederoo*, Melocactus bahiensis* Britton & Rose, *Melocactus conoideus* Buining & Brederoo*, Melocactus ernestii* Vaupel*, Melocactus glaucescens* Buining & Brederoo e *Melocactus violaceus* Pfeiff. (Zappi *et al.* 2011).

Melocactus violaceus Pfeiff. is a small, globe-shaped plant, presenting in its upper part a soft white cephalium, which presents short reddish hairs during the reproductive phase, reaching up to 7 cm in height and 10 cm in diameter (Figueira *et al.* 1994). Its fruit are rose-colored, completely exposed when ripe, allowing for the dispersal by lizards and ants (Colaço *et al.* 2006) which, according to Xavier (2015), *Tropidurus hygomi* Reinhardt & Luetken, is one of the responsible for the dispersion of *Melocactus violaceus* Pfeiff. seeds, where the high nectar concentration would explain the lizard's attraction for the flowers, which themselves have a high carbohydrate budget, being a source of food throughout the year (Gomes *et al.* 2014). Despite the mutualistic relationship found between *Melocactus* and its pollinizer and seed disperser, *Tropidurus* (Gomes *et al.* 2014), it is possible to obtain excellent germination rates even with seeds that had not passed through the lizard's digestive tract (Zamith *et al.* 2013).

Also known as "button cactus", *Melocactus violaceus* Pfeiff. is a species endemic to Brazil, occurring from Northeast to Southeast in altitudes ranging from 0 to 1100 m (Taylor 1991; IUCN 2013). It inhabits ombrophilous forests (Atlantic Forest/restinga), rock fields in the North (cerrado) growing among bushy vegetation in the sand of coastal restinga, riverside dunes, and low plateau formations in Atlantic Forest (CNC Flora 2012).

The coastal Low plateau formation is a landscape structure constituted of small plateaus, ranging from flat to rugged, limited by barriers with altitude between 20 and 50 meters, that extend from Ceará to Bahia, Espírito Santo and Rio de Janeiro (Embrapa 2014), being characterized in the National Action Plan for the Conservation of the Cactaceae as cerrado scrubland, being then defined as savanna areas with low arboreal density, and abundant underbrush (Zappi *et al.* 2011).

According to the National Action Plan for the Cactaceae (Zappi *et al.* 2011), habitat fragmentation, the degradation of environmental quality, mining activities, and the commerce and illegal harvest contribute heavily to the population collapse of species like *Melocactus*

violaceus Pfeiff. Other important driver of population decrease in is its economic importance, its use for cattle and human nutrition, in the fabrication of sweets, and its use on traditional medicine where *Melocactus* is used in the confection of molasses used to treat the flu, bronchitis and cough (Taylor 1991; Zappi *et al.* 2011).

Despite its wide distribution and occurrence within protected areas, this species is considered by the IUCN (2013) as vulnerable due to habitat destruction for urbanization, tourism, road construction, artificial landscaping and agribusiness. Consequently, some populations have already disappeared due to agricultural expansion and de environmental degradation of restinga environments for sand mining. Thus, a population decline of at least 30% is estimated for *M. violaceus* Pfeiff. due to past and present loss of habitat (IUCN 2013).

Due to its vulnerability and the scarce information about the species' ecology, the present study aims to expand our understanding of the species, specifically on its abundance, size distribution, growth rate and to verify if there is a relationship between size and growth of the species in the Guaribas Biological Reserve (REBIO), a federal conservation unit located in the state of Paraíba/BR. From the conservation point of view, including population recovery in cases of local extinction, it is important to estimate the turnover time of a viable population in the region.

Material and Methods

Study area

According to the Operation Plan for the Combat of Forest Fires (Brasil 2006), the Guaribas Biological Reserve was created in 1990 with the main goal of maintaining Atlantic Forest remnants in Paraíba, and thereby protecting endemic and threatened species.

This study was developed in an area of coastal low plateau within the REBIO Guaribas, located in the municipality of Mamanguape – PB, starting in 2014 and ending in 2017. With intense anthropogenic influence, the area is located in the margin of the BR 101 highway, which facilitates the entrance of people, as there are no fences or barriers in place. Another important factor to the large flux of people in the area is the harvest of the Mangaba fruit, *Hancornia speciosa* Gomes (Apocynaceae), very abundant and is a source of income to several families in the region.

Sampling design

Thirty (30) plots were delimited in three phyto physiognomies found in the low plateau: one with predominance of small-sized trees and bushes (in the higher part of the terrain); the second is dominated by herbaceous vegetation with small, spaced islands of trees and bushes (an intermediary position on the terrain's relief); and lastly na area where there is a dense and almost exclusive of *Lagenocarpus* spp. (Cyperaceae) (the lowest part of the terrain, prone to flooding during the rain period) popularly known as "blue grass" (**Figure 1**).

In each physiognomy, 10 circular plots of 12.6 m^2 were installed, 20 m from each other on a transect. The demarcation of the plots was done randomly in a straight line parting from the first plot, with northbound direction. To obtain the abundance data, we accounted for all individuals within 1 m of each side of the central line along the 200 meter long transect. For the description of the size distribution for the population, the same individuals were measured. For each individual, we registered whether it was in the reproductive stage (with the presence of the cephalium, flower or fruit). In total, 52 individuals were initially marked, numbered and tagged, with their diameter measured with the aid of a caliper, to estimate individual growth rate. These measurements occurred on 07/23/2014, 03/04/2016, 07/15/2016, 10/14/2016 and 03/01/2017, with five measurements in total throughout the study. The individuals were differentiated as reproductive when presenting flowers and/or fruit, and immature without flowers or fruit.

The data was organized in a spreadsheet, where the growth rate was calculated following the formula (Silk 1984):

$$T_c = \frac{\Delta D}{\Delta t}$$

Where: T_c is the growth rate; ΔD is the variation in diameter and Δt is the interval of time between measurements.

Abundance was estimated by the mean number of individuals per square meter. Size classes for both diameter and height were created, with the classes plotted in a histogram and a graph relating the height and diameter of the individuals.

We performed a correlation analysis between the initial diameter and the total growth (initial diameter – final diameter / time interval) of all individuals alive throughout the duration of the study. And from this relationship, we performed a regression and correlation between the two variables to verify if there is a significant correlation between them, as to test if the size interferes positively in the growth rate.

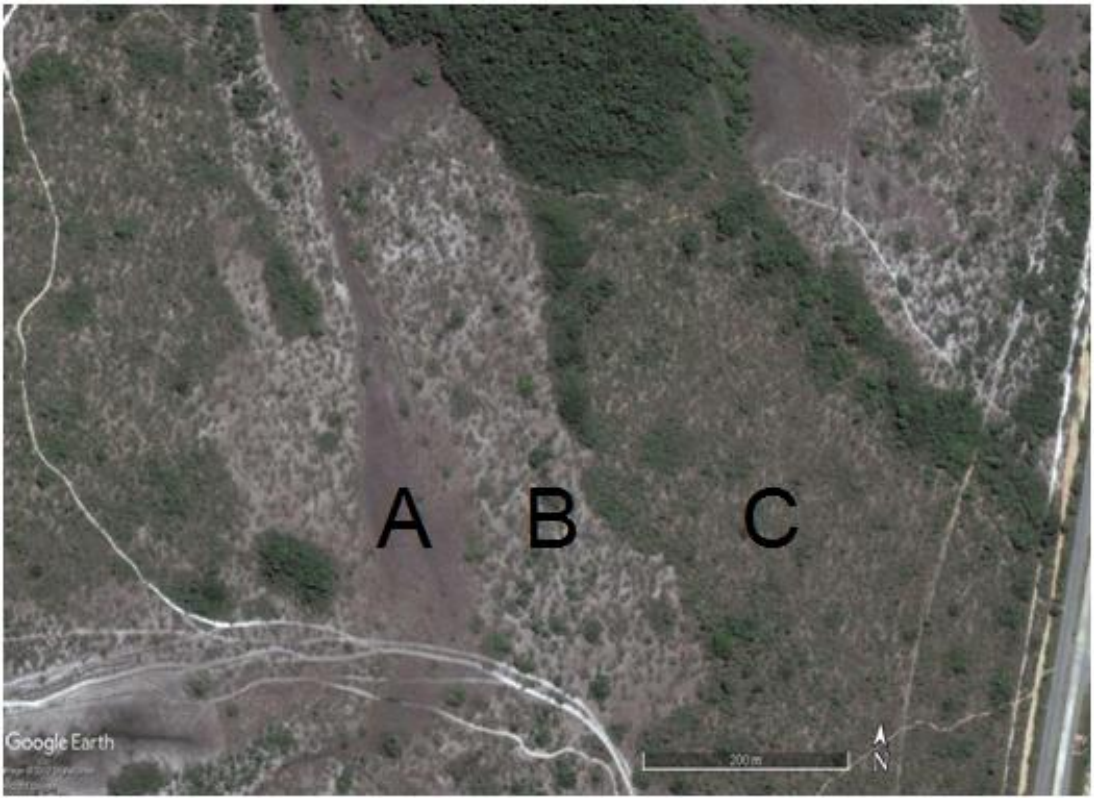

Figure 1. REBIO Guaribas, between 2014 and 2017: **A**. Area with predominance of blue grass, lowest part of the terrain; **B**. Area dominated by herbaceous vegetation, intermediary part of the terrain; **C**. Area with predominance of small-sized trees and shrubs, highest point in the terrain.

Results

Regarding the spatial distribution, in areas with a more dense vegetation and areas with dominance of *Lagenocarpus* spp., no individuals of *M. violaceus* Pfeiff. were found. However, in the more open area, we observed individuals, tallying up to 52 individuals marked for the growth rate monitoring. During the study, 15 individuals died or had their plates removed, leaving a total of 37 with data usable for the sampled period.

The mean abundance (from the 292 individuals distributed in 200 m²) was 1.46 ind.m^{-1}. The abundance of dead individuals was of 0.14 ind.m^{-1} and of fertile individuals 0.04 ind.m^{-1}. Three percent (3%) of the individuals (9 individuals) were in reproductive stage, showed average height of 5.82 ± 1.26 cm, with a maximum height of 7.96 cm and minimum of 3.87 cm, and mean diameter of 13.47 ± 0.65 cm, with a maximum diameter of 14.26 cm and minimum of 12.4 cm.

Immature individuals showed a mean height of 1.83 ± 1.23 cm, with a maximum height of 6.99 cm and minimum of 0.15 cm; mean diameter of 5.40 ± 2.89 cm, with minimum diameter of 0.99 cm and maximum of 13.63 cm. When examining the relationship between height and diameter, we noticed that there is a strong coefficient of determination (r^2 = 0.81) between the variables, indicating that the taller individuals also had the largest diameters (**Figure 2**).

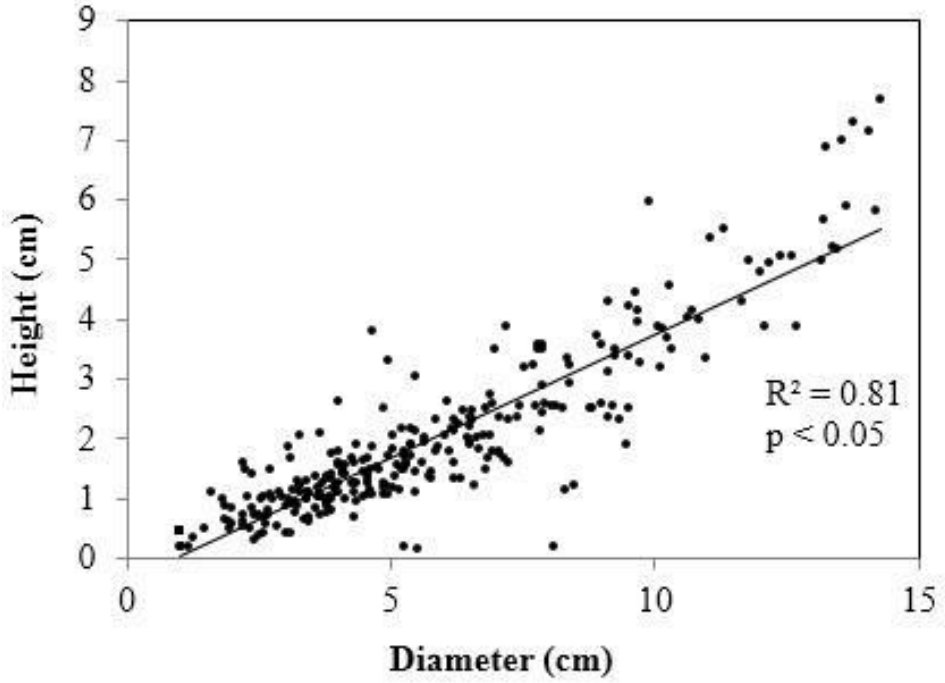

Figure 2. Strong relationship between height and diameter for the 292 individuals of *Melocactus violaceus* Pfeiff. measured in REBIO Guaribas between 2014 and 2017.

Of the 292 individuals registered within the transect, 9.6% showed diameters between 0.1 cm and 1.99 cm; 51.7% of the population presented diameter between 2 cm and 5.99 cm; with 27.7% presenting diameter between 6 cm and 9.99 cm, 10.9% presented diameter larger than 10 cm and 9.93% were dead (**Figure 3**). Regarding height, over 70% of individuals were between 2 cm and 4 cm tall.

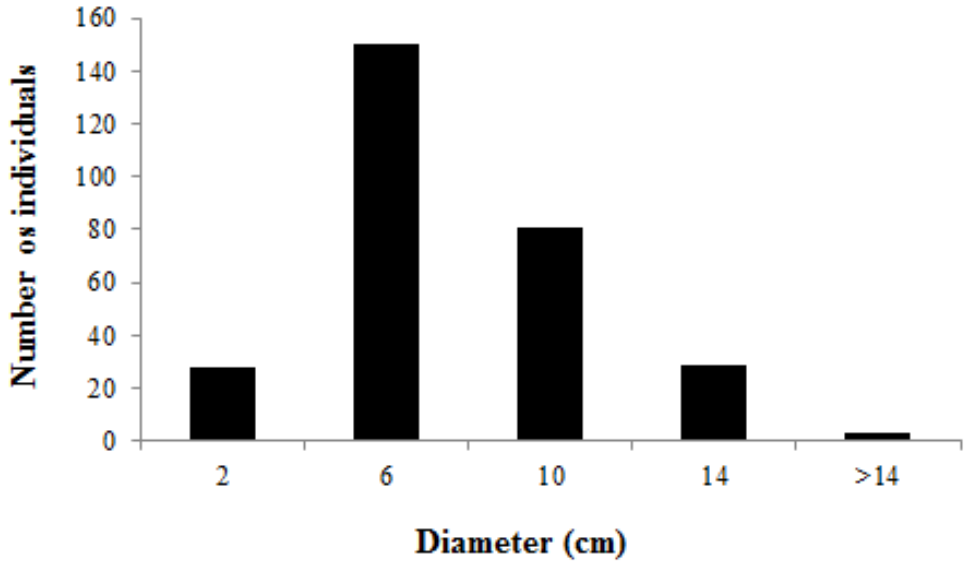

Figure 3. Diameter histogram of individuals of *Melocactus violaceus* Pfeiff. per size (cm). REBIO Guaribas-PB/BR.

Mean annual growth of the tagged individuals (37) which survived the entire study period was 1.76 ± 1.12 cm a^{-1}, with minimum of 0.04 and maximum of 4.7 cm a^{-1}. The regression testing whether larger individuals had higher growth rates, we observed that there was no relation (R^2= 0.043, p > 0.05). Hence, size does not interfere in the growth rate (**Figure 4**).

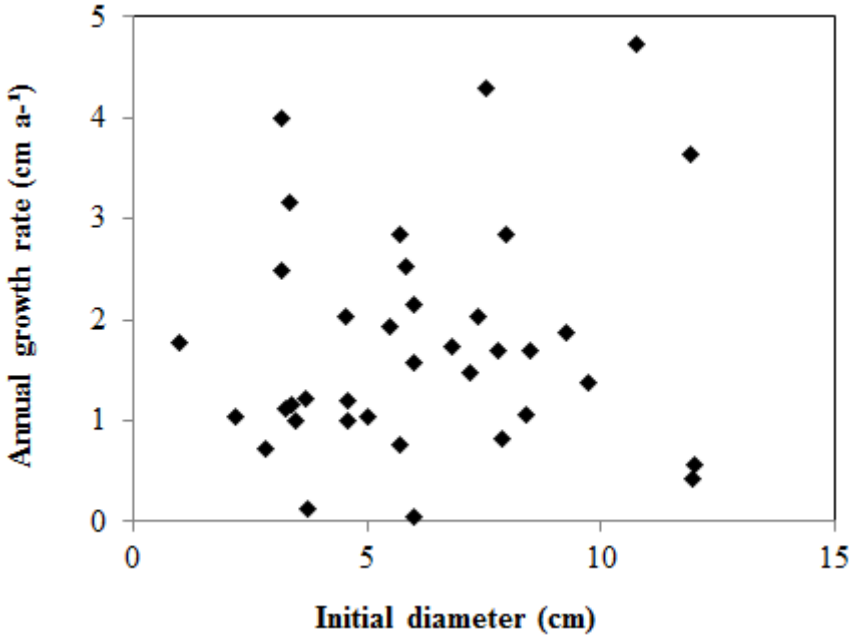

Figure 4. Insignificant relationship between diameter and annual growth rate of 37 individuals of *M. violaceus* Pfeiff. REBIO Guaribas between 2014 and 2017.

Discussion

Differing from the findings of Figueiredo (2016), where over half of the population was in pre-reproductive and reproductive stages, totalizing 56.5% of the population, only 3% of the individuals registered in our study were in reproductive stage, being closer to the population structure observed by García-González *et al.* (2016), where 28.7% of the *Melocactus nagyi* Z. Mészáros population was reproductive.

Based on the 292 individuals in the transect, the largest portion of dead individuals was concentrated between 6 to 9.9 cm in diameter (**Figure 5**). Hughes *et al.* (2011) when studying *Melocactus ernestii* Vaupel, observed that 76% of the individuals found dead were in the juvenile stage, with < 3 cm in diameter, which, according to the author, was due to environmental oscillations. However, in a study conducted by Freire (2013), no significant difference was found in the survival rate for the different size classes.

We observed that in the areas dominated by *Lagenocarpus* spp. (blue grass), *M. violaceus* Pfeiff. did not occur. It is possible that there is some type of competition between species, as one predominates over the other, with the added possibility of exclusion of *Melocactus violaceus* Pfeiff. due to seasonal flooding during the rainy season as it is the lowest part of the terrain, making it difficult for *M. violaceus* Pfeiff. individuals to survive in the area. However, in the more open area, there was a noticeable abundance of *M. violaceus* Pfeiff., although under some of the larger cashew trees (*Anacardium occidentale* L.) found in two plots, there were no specimens found, probably due to the low luminosity that would consequently hinder photosynthesis, as the soil was always covered by a litter of leaves.

The closer the plots were from the trees that shaded the soil completely, the number of individuals diminished, reaching zero in some of the plots; and the proximity to such tree individuals can influence the population density (Brito *et al.* 2007) as in some plots, the soil was completely shaded, as well as covered by a large quantity of litter that could hinder the growth

of seedlings by insufficient sunlight, as could be observed for *Melocactus bahiensis* Britton & Rose, where the ideal level of shade for its development is 20% (Lone *et al.* 2009).

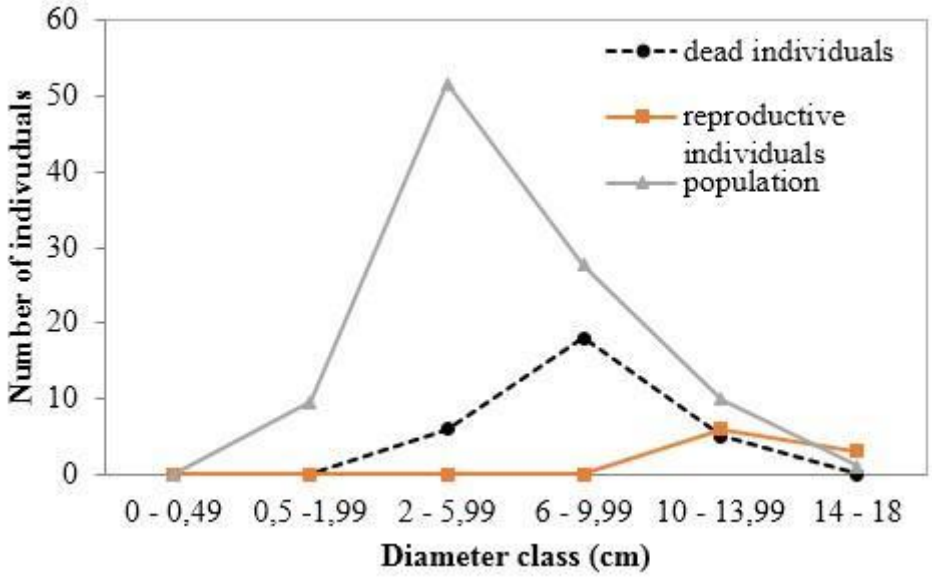

Figure 5. Relationship between percentage of dead and reproductive individuals in the population by size class of *Melocactus violaceus* Pfeiff. a the REBIO Guaribas-PB/BR.

Size class distribution of individuals presented a similar frequency as reported by Figueiredo (2016), where most of the population studied in the Jurubatiba National Park in Rio de Janeiro had mean diameter between 4 to 7 cm. The same population structure occurs with *Melocactus nagyi* Z. Mészáros *(Melocactus harlowii* Britton & Rose Vaupel*)* (García- González *et al.* 2016).

Immature individuals corresponded to the larger portion of the population, where only a small percentage was in the reproductive stage, a trend also observed in other species of *Melocactus*. Fabricante *et al.* (2010) studying *Melocactus zehntneri* Britton & Rose at an inselberg in the Caatinga of Paraíba, observed that the major part of the population was of immature individuals which, according to the author, could be caused by the competition as a consequence of the low resource availability that impedes many individuals of completing their life cycle.

From the tagged individuals for the growth rate study, only one individual in the seedling phase died, differing from the findings of Hughes *et al.* (2011) in a fragment of Deciduous Forest in Bahia, where 75.9% of the seedlings of *Melocactus ernestii* Vaupere died, and individuals bigger than 3 cm had higher survival rates.

Mean abundance found in our study was similar to the findings of Brito *et al.* (2007), in their study of the population structure of *M. Conoideus* Buining & Brederoo at the Serra do Periperi Municipal Park (BA), where a density of 1.2 individuals per m² was reported.

Regarding diameter and height, these parameters can vary according to each species in the genus. For example, *Melocactus schatzlii* H. Till & R. Gruber reaches up to 22–25 cm height, while *Melocactus andinus* R. Gruber & N.P. Taylor reaches 40 cm (Nassar *et al.* 2007). *Melocactus curvispinus* Pfeiff. *subs. Cucutensis* presents height and diameter around 11–13 cm, while *M. curvispinus* Pfeiff. *subs. lobelli*, can reach 20–25 cm in height (Fernández-Alonso & Xhonneux 2002). In a study by Fabricante *et al.* (2013) with *Melocactus ernestii* Vaupel *subsp. Ernestii* the mean diameter was 16.5 cm, while mean height was 13.6 cm, our data for *M. violaceus* Pfeiff. did not surpass 7.96 cm of height. Such differences may be due to soil characteristics and survival strategies in terms of where to allocate water storing tissues.

Considering the mean annual growth of 1.76 ± 1.12 and the minimal diameter recorded in the reproductive phase of 12 cm, we estimate that it takes roughly 6.8 years for an individual of *Melocactus violaceus* Pfeiff. to reach the adult phase, assuming linear growth rates

throughout the lifespan of an individual, which is reasonable, since we found no correlation between diameter and growth rate.

Conclusion

Based on the data presented in this paper, with an average abundance of 1.46 ind. m^{-2}, 3% of the population in reproductive state and an average annual growth rate of 1.76 ± 1.12 cm, we believe that this local population is viable and is not in danger of local extinction. Nevertheless, local fires might be a cause for concern, since we have not up to date any data on the death rate after fires in the area, which happen sometimes.

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