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SHORT RESEARCH ARTICLE

Flowering of the endemic cactus *Tacinga palmadora*: a relation between floral production and age

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ABSTRACT

Plant age is a factor that influences production of flowers in some species. In some cacti, new cladodes and flowers buds grow from areolar meristems located in the cladodes. It is possible to determine the age of the cactus by counting the maximum number of cladodes present in a branch. Among the species of cacti that present annual vegetative growth determined by the climatic seasons is the species *Tacinga palmadora*. The objective of this study was to determine the initial reproductive age of this species and to evaluate the relation between the age of *T. palmadora* individuals and the number of flowers produced. The study was conducted at the Grota do Angico Natural Monument, in the municipality of Poço Redondo in Sergipe state in September 2017. Two hundred and seventeen individuals of *T. palmadora* were analyzed in the study area. In each individual, where counted the number of flowers and the number of cladodes present in the largest branch from the base, thus estimating the age of each individual. A positive and significant relation was observed between average number of flowers produced and age of individuals of *T. palmadora* in the evaluated population.

Highlighted Conclusion

Tacinga palmadora presents a greater number of flowers in older individuals due to the greater number of cladodes.

INTRODUCTION

Flowering is a crucial event in plants life cycle and favorable conditions are required to maximize reproductive success and thus the survival of species in their natural environment (Capovilla et al. 2015). Conversion of vegetative meristems into reproductive structures is one of the most complex events in this cycle. Floral induction is related to events that signal to plant the alteration of its development program and, consequently, vegetative meristems are restructured to produce floral primordium (Yant et al. 2010; Wellmer and Riechmann 2010). Inducing stimulus for this reproductive event may be related to plant endogenous conditions or to abiotic conditions of the ecosystem in which plants are established (Huijser and Schmid 2011). Environmental stimulus induces flowering of older plants, whereas younger plants of the same species remain vegetative under the same conditions (Bergonzi et al. 2013).

Light is an abiotic condition that is related to flowering of many species, where days length and light quality are a stimulating factor for flowering seasonality (Searle and Coupland 2004; Song et al. 2013; Fernández et al. 2016; Sams et al. 2016). Temperature is also an important environmental stimulus that contributes to floral production of many plant species (Capovilla et al. 2015; Seaton et al. 2015). Another factor that may influence plants reproduction is plant age (Hanzawa and Kalisz 1993; Ehlers and Olesen, 2004).

In most of cacti species, new cladodes and flower buds grow from areolar meristems located in cladodes (Bowers 1996); however, this meristem only differentiates once (Gibson and Nobel 1986). Thus, Bowers (1996) pointed out that for some cacti, reproductive success of a year depends on vegetative growth in rainy period of the previous year. Among the species of cacti that present annual vegetative growth determined by climatic seasons is *Tacinga palmadora* (Britton & Rose) N.P. Taylor & Stuppy. *T. palmadora* is a species that belongs to the family Cactaceae and the subfamily Opuntioideae (Taylor and Zappi 2004). Endemic to Caatinga, a Tropical Dry Forest, *T. palmadora* is distributed throughout the Northeastern region of Brazil, except for Maranhão state, and is popularly known as quipá-de-espinho or palmatória (Taylor and Zappi 2004; Zappi et al. 2015). This species shows

shrub habit and can reach 2 m in height. It occurs on sandy substrates or on rocks, in areas of 200 to 1,020 m of altitude (Zappi et al. 2015). In contrast to most Caatinga cacti, *T. palmadora* produces flowers during the dry season and its flowers, with daytime anthesis, are pollinated by hummingbirds (Locatelli and Machado 1999). Flowers grow from cladodes areolar meristem and are tubular with red perianth and floral tube with glochids (Locatelli and Machado 1999). At each rainy season, new cladodes are produced from areolar meristem present in the cladodes formed in the previous rainy seasons (Meiado 2012). In addition, size and number of cladodes in the main branch may be related to the climatic conditions of growing season (Meiado 2012). Thus, it is possible to determine cactus age by counting the maximum number of cladodes present in a branch.

This study aims determine initial reproductive age of *T. palmadora* and to evaluate the relation between individuals age and the number of flowers produced by these plants, testing the hypothesis that the number of flowers is positively related to the age of this cactus.

MATERIAL AND METHODS

T. palmadora is a species that belongs to the family Cactaceae and the subfamily Opuntioideae (Taylor and Zappi, 2004). Endemic to Caatinga, a Tropical Dry Forest, *T. palmadora* is distributed throughout the Northeastern region of Brazil, except for Maranhão state, and is popularly known as quipá-de-espinho or palmatória (Taylor and Zappi 2004; Zappi et al. 2015). This species shows shrub habit and can reach 2 m in height. It occurs on sandy substrates or on rocks, in areas of 200 to 1,020 m of altitude (Zappi et al. 2015). In contrast to most Caatinga cacti, *T. palmadora* produces flowers during the dry season and its flowers, with daytime anthesis, are pollinated by hummingbirds (Locatelli and Machado 1999). Flowers grow from cladodes areolar meristem and are tubular with red perianth and floral tube with glochids (Locatelli and Machado 1999).

The study was conducted at the Grota do Angico Natural Monument, in the municipality of Poço Redondo in Sergipe state in September 2017. According to Köppen and Geiger classification, this region climate is BSh. The annual rainfall is low, with an average of 548 mm and the average annual temperature is 25 ºC (Climate Data 2017). In the study area, we analyzed 217 individuals of *T. palmadora* and all these plants had flowers (Figure 1). In each individual, where counted the number of flowers and the number of cladodes present in the largest branch from the base, thus estimating the age of each individual (Meiado 2012). Individuals were grouped into age categories and an average number of flowers per age was calculated. Subsequently, to analyze the relation between age of the individuals and floral production, a linear regression was performed on STATISTICA® 13 software with α = 5% (Statsoft 2016).

Figure 1. A: *Tacinga palmadora* (Britton & Rose) N.P. Taylor & Stuppy (Cactaceae) during flowering period in Grota do Angico Natural Monument, in the municipality of Poço Redondo in Sergipe state. B: *T. palmadora* cladode and flowers. Photo: Ayslan T. Lima.

RESULTS AND DISCUSSION

In *T. palmadora* population evaluated, individuals with flowers were present in an age range of 8 to 31 years of age (Figure 2). In each age category, we observed an average of 12 individuals, ranging from 1 to 29 individuals by age category. The highest frequency of individuals with flowers was observed in the group of 12 to 16 years of age (Figure 3). A positive and significant relation was observed between average number of flowers produced and age of individuals of *T. palmadora* in the evaluated population ($p < 0.0001$) (Figure 2). These results corroborate the hypothesis that flowers number is positively related to cactus age.

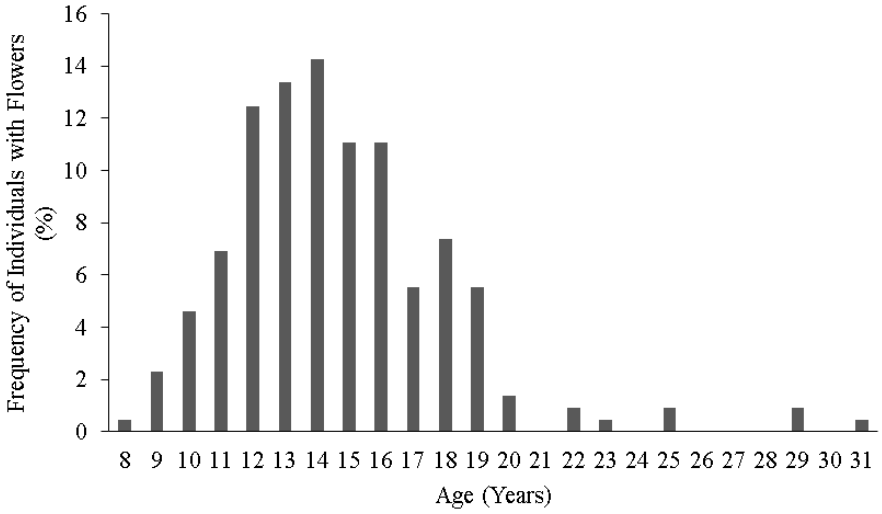

Figure 2. Frequency (%) of individuals of *Tacinga palmadora* (Britton & Rose) N.P. Taylor & Stuppy (Cactaceae) with flowers in relation to age (years).

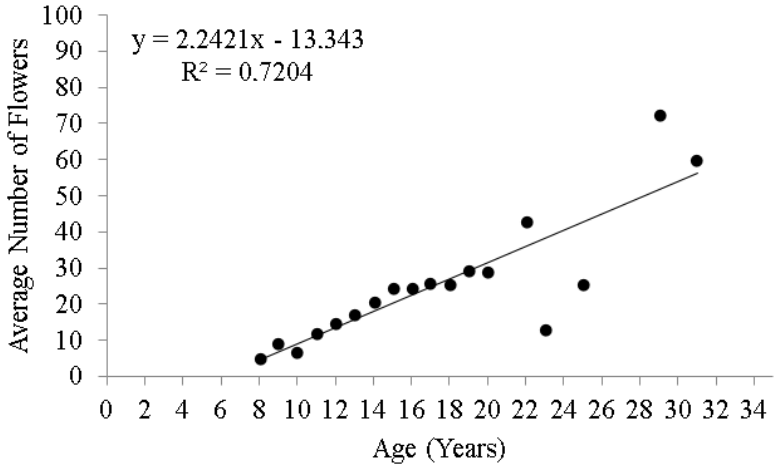

Figure 3. Average number of flowers per individual of *Tacinga palmadora* (Britton & Rose) N.P. Taylor & Stuppy (Cactaceae) in relation to age (years).

In spite of older individuals showed the highest number of flowers, they appeared less frequently in the evaluated population, a large number of specimens producing flowers were found in the age range of 12 to 16 years. Since this is the most frequent age group, individuals that present age inserted in this range are those that contribute most with the genetic variability of this population. This contribution is maximized by the presence of pollinators that visit different individuals during flowering period. Locatelli and Machado (1999) pointed out that the hummingbird *Chlorostilbon lucidus* (Shaw 1812) (Apodiformes: Trochilidae) is the main pollinator of *T. palmadora* and Ruiz-Esparza et al. (2011) pointed out that *C. lucidus* is distributed in the studied population area. The low number of plants in the largest age categories is justified by the fact that the area where we developed this study was recently assigned to creation of a conservation unit. Previously, this area was a private property used as pasture and monoculture planting area. After creation of the conservation unit, the area was expropriated and assigned to State of Sergipe government which develops actions for natural regeneration of native vegetation in the region, such as protection and non-exploitation of natural resources (Semarh 2017). These actions have provided the reappearance of several species over the last decades and the reestablishment of native populations such as *T. palmadora*.

Evaluations carried out by Meiado (2012) about the structuring of three populations of *T. palmadora* in different areas of Caatinga showed that individuals started reproductive phase in the age group of seven to eight years of age. In the present study, eight years was also the minimum age of individuals with flowers. Thus, having the adult reproductive phase started between seventh and eighth years may be a pattern in *T. palmadora,* even among populations established in different areas of Caatinga, indicating that this is the minimum age range where this species reallocates its energy also for development of reproductive structures. Thus, the results that we observe in this study reinforce the need for the creation of conservation units in Caatinga and the effective protection of these areas for native species conservation, reestablishment of their populations and the beginning of their reproductive process (Siqueira Filho et al. 2012). Some species, such as *T. palmadora*, will establish themselves in this protected area, and in a few years will begin their reproductive process, being keystone species for the natural regeneration of the environment by providing the attraction of pollinating animals and seed dispersers that will bring with it diaspores of other native species (Hale and Koprowski 2018).

As in the present study with Cactaceae, a positive relation between number of flowers produced and age of the individuals was also observed in *Corydalis intermedia* (L.) Mérat (Papaveraceae) (Ehlers and Olesen 2004) and *Trillium grandiflorum* (Michx.) Salisb. (Melanthiaceae) (Hanzwa and Kalisz 1993). Rojas-Sandoval and Meléndez-Ackerman (2011) observed that reproductive output is positively correlated with plant size in *Harrisia portoricensis* Britt. (Cactaceae). According to the authors, this positive correlation is justified by the greater number of branches and areolas present in these plants, which allows a greater number of flowers and a higher production of fruits and seeds consequently. Ehlers and Olesen (2004) pointed out that positive relation between flower production and age of individuals is related to the change in strategy throughout plant life cycle, where, over time, there is a greater allocation of energy to floral production after reach reproductive age.

In addition to the fact that older individuals have a greater number of branches and these branches provide a higher production of flowers as we observed in this study, these larger and more branched individuals also have an increase in the photosynthetic surface, which will increase photoassimilates production and storage by the plant. Consequently, these plants will have more reproductive resources and will be able to produce a greater number of flowers and maximize their seed production (Drezner 2014; Inglese et al. 2017). Drezner (2014) reported that the greater number of branches in *Carnegiea gigantea* (Engelm.) Britton & Rose (Cactaceae) not only increases photosynthetic surface of plants, but also its reproductive potential, since new branches offer more areolar meristems, from where flowers are produced. This relation can also be applied to *T. palmadora*, since flowers and new cladodes grow from areolar meristems (Locatelli and Machado 1999). Thus, the results demonstrated that *T. palmadora* presents a greater number of flowers in older individuals due to the greater number of cladodes.

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