Ciência Florestal, Santa Maria, v. 28, n. 3, p. 1035-1048, jul.- set., 2018
ISSN 1980-5098 DOI: http://dx.doi.org/10.5902/1980509833387

PHENOLOGY OF *Poincianella pyramidalis* (TUL.) L. P. QUEIROZ AND ITS RELATIONSHIP WITH THE TEMPORAL DISTRIBUTION OF RAINFALL IN THE BRAZILIAN SEMI-ARID REGION

FENOLOGIA DE *Poincianella pyramidalis* (TUL.) L. P. QUEIROZ E SUA RELAÇÃO COM A DISTRIBUIÇÃO TEMPORAL DA PRECIPITAÇÃO PLUVIAL NO SEMIÁRIDO BRASILEIRO

Cosmo Rufino de Lima[1] Riselane de Lucena Alcântara Bruno[2] Albericio Pereira de Andrade[2] Mauro Vasconcelos Pacheco[3] Zelma Glebya Maciel Quirino[4] Katiane da Rosa Gomes da Silva[5] Karialane da Silva Belarmino[6]

ABSTRACT

A remarkable feature of the Brazilian semi-arid region is its highly irregular distribution of rainfall in space and time, with two marked periods: the rainy season, with erratic precipitation, of highly variable intensity; and the dry season, the critical period of prolonged drought, when the plant species of the Caatinga (desert vegetation found in northeastern Brazil) express their most remarkable trait, the deciduousness. In such conditions, plant species have their dynamics of growth and development in accordance with rainfall events. Thus, the objective of this study was to characterize the phenophases of *Poincianella pyramidalis* and their relationship with the temporal distribution of rainfall, which takes place in the form of water pulses. For the phenological study, 32 trees were selected, identified and monitored fortnightly on Açude Farm, located in the municipality of Soledade, PB state, Brazil. To quantify the phenological events, Fournier's percent index and the activity index were adopted, recording the presence and absence of the following phenophases: sprouting, appearance of flower buds, flowering (anthesis), fruiting and senescence, whose data were related to the water pulses and inter-pulses. It was found that the sprouting, flower-bud and flowering phenophases in *Poincianella pyramidalis* happen synchronously with the temporal distribution of rain pulses in its habitat. The intensity and duration of phenophases in the development of *Poincianella pyramidalis* depend upon the extent and frequency of the water pulses throughout the rainy season. Total leaf senescence in *Poincianella pyramidalis* occurs when the inter-pulses of rainfall intensify as the dry season progresses, characterizing deciduousness.

Keywords: catingueira; stage of development; seasonality; semi-arid.

---

[1] Engenheiro Agrônomo, Dr., Rua Silvino Mangueira, 257, Centro, CEP 58985-000, Santana de Mangueira (PB), Brasil. cosmoagr@hotmail.com

[2] Engenheiro(a) Agrônomo(a), Dr., Professor(a) do Centro de Ciências Agrárias, Universidade Federal da Paraíba, Caixa Postal 22, CEP 58397-000, Areia (PB), Brasil. lanebruno.bruno@gmail.com / albericio3@gmail.com

[3] Engenheiro Agrônomo, Dr., Professor da Universidade Federal do Rio Grande do Norte, Km 03, Caixa Postal 07, Distrito de Jundiaí, CEP 59280-000, Macaíba (RN), Brasil. pachecomv@hotmail.com

[4] Bióloga, Dr^{a}., Professora do Departamento de Engenharia e Meio Ambiente, Universidade Federal da Paraíba, Rua da Mangueira, s/n, Centro, CEP 58000-000, Rio Tinto (PB), Brasil. zelmaglebya@gmail.com

[5] Bióloga, Dr^{a}., Pesquisadora no IPA, Programa de Melhoramento, Av. São Martin, 1371, Bloco 10, CEP 50761-000, Recife (PE), Brasil. katrgs@gmail.com

[6] Engenheira Agrônoma, MSc., Doutoranda pelo Programa de Pós-Graduação em Agronomia, Universidade Federal da Paraíba, Rua Professor Joaquim da Silva, 226, Pedro Perazzo, CEP 58397-000, Areia (PB), Brasil. karialane@hotmail.com

Recebido para publicação em 3/07/2013 e aceito em 10/07/2017

RESUMO

A região Semiárida brasileira tem como característica marcante a alta irregularidade da distribuição da precipitação pluvial no espaço e no tempo, com duas estações marcantes, a estação chuvosa, correspondente a um período curto com precipitações pluviais, erráticas e de intensidade muito variável, e a estação seca, período crítico, em geral, de prolongada estiagem, quando as espécies da Caatinga expressam sua fisionomia mais marcante, a caducifolia. As espécies vegetais, nestas condições, apresentam dinâmica de crescimento e desenvolvimento em consonância com os eventos de chuvas. Assim, o objetivo deste estudo foi caracterizar as fenofases de *Poincianella pyramidalis* e sua relação com a distribuição temporal da precipitação pluvial, que se dá em forma de pulsos. Para o acompanhamento fenológico, 32 indivíduos arbóreos foram selecionados, marcados e monitorados quinzenalmente, na Fazenda Açude, município de Soledade-PB. Para quantificar os eventos fenológicos, foram usados o percentual de intensidade de Fournier e o índice de atividade, registrando-se a presença e ausência das fenofases: brotamento, botão floral, floração (antese), frutificação e senescência, cujos dados foram relacionados com os pulsos e interpulsos de precipitação. Constata-se que as fenofases, brotamento, botões florais e floração em *Poincianella pyramidalis* se dão em sincronia com a distribuição temporal dos pulsos de precipitação pluvial na área de sua ocorrência. A intensidade e duração das fenofases do desenvolvimento em *Poincianella pyramidalis* dependem da amplitude e frequência dos pulsos de precipitação ao longo da estação chuvosa. A senescência total das folhas em *Poincianella pyramidalis* acontece quando os interpulsos de precipitação pluvial se intensificam à medida que avança a estação seca, caracterizando a caducifolia.

Palavras-chave: catingueira; estádio de desenvolvimento; sazonalidade; semiárido.

INTRODUCTION

The Brazilian semi-arid region is characterized by its highly variable environment in terms of soil, climate, vegetation and relief, forming a mosaic of unique ecosystems that require specific knowledge for their management (MENEZES; GARRIDO; PEREZ, 2005; ANDRADE et al., 2006; 2013). The high variability of these environmental factors was a key element to the adaptation of the typical vegetation of this region — the Caatinga —, composed mostly of deciduous xerophytes, which are related to the rainfall distribution and soil conditions. In the arid and semi-arid regions, according to Noy-Meir (1973), while temperature, solar radiation and nutrient uptake in the ecosystems are relatively constant over the year, precipitation is highly variable, usually occurring in discontinuous events, in the form of short-term pulses. According to this author, these pulses may occur in three different forms: (a) widely apart, (b) grouped and (c) with intermediate spacing. In the rainy periods, the intervals between each rain event stimulate plants growth and, consequently, the recovery of its reserves originating from the production of assimilates.

Several studies have shown that precipitation controls the phenology of many Caatinga species, although other species may start their phenophases independently of the occurrence of rain (LEITE; MACHADO, 2009; 2010). Many species present different responses to the water availability in the soil, with a little sprouting in response to occasional rains during the dry season, whereas others remain dormant (AMORIM; SAMPAIO; ARAÚJO, 2009). In the Caatinga, there are woody species in which leaf abscission occurs at the end of the rainy season, whereas other species maintain their leaves during the dry period, resulting in different tree species over time and space (MACHADO; BARROS; SAMPAIO, 1997; BORCHERT; RIVERA; HAGNAUER, 2002). Lima and Rodal (2010) observed that there is a close relationship between plant phenology and the wood density (the amount of water stored in tree trunks). These authors observed that plants with deciduous leaves, but with low-density wood, are able to store more water in their trunks, which causes sprouting and reproduction to frequently occur during the dry season. However, species with high-density wood tend to start their phenophases according to the water availability in the soil. In this context, because *Poincianella pyramidalis* — the species studied here — has anatomical characteristics of wood (proportion of vessels, rays, parenchyma and proportion and thickness of the fiber walls) and high basic density (0.84-1.01 g/cm^3), as stated by Silva et al. (2009), it is assumed that the phenology of this species is greatly synchronized with the temporal distribution of rainfall. *Poincianella pyramidalis* (Tul.) L. P. Queiroz, commonly known as catingueira, is an endemic leguminous tree of the

Caatinga considered one of the examples of species for multiple uses, because it can be used as timber and forage, in addition to being widely used in popular medicine (SALVAT et al., 2004). According to Maia (2004), *P. pyramidalis* is a species widely dispersed in the Brazilian Northeast, comprising the states of Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia. It is a medium-sized, thornless tree, with 4-6 m in height, sometimes reaching up to 12 m.

The flowering and fruiting patterns of the Caatinga species are complex; flowering occurs at the beginning of the rainy season, followed by fruiting (MACHADO; BARROS; SAMPAIO, 1997). In the dry period, when complete scarcity of rainfall prevails, species express their full production of dry, anemochorous fruits with small, orthodox, disposed seeds as a consequence of the end of the reproductive phase (JUSTINIANO; FREDERICKSEN, 2000; GRIZ; MACHADO, 2001). However, the factors controlling the phenological behavior of plant species are many and complex. Studies show that the occurrence of the phenological events, in some species, is not primarily determined by the rain, but by the availability of water for the plant (BORCHERT; RIVERA, 2001). It must also be considered that the precipitation events are never uniformly spaced in time, and that the probability of these events occurring increases during the dry season (LOIK et al., 2004). Thus, it is essential that research on the phenological events of forest species be carried out not only to better understand the biodiversity of the Caatinga, but also to examine the occurrence of greater availability of fruits and seeds that might contribute to conservation actions and guide management practices. In view of the complexity of the phenological events in the Brazilian semi-arid regions, the objective of the present study was to characterize the phenophases of *Poincianella pyramidalis* and their relationship with the temporal distribution of rain pulses.

MATERIAL AND METHODS

The field study was conducted on Açude Farm, located in the municipality of Soledade, Paraíba State (PB), Brazil, at coordinates -7º 7' 22" latitude and -36º 19' 33," longitude (Figure 1). The predominant relief in the area is mildly undulated with an altitude of approximately 535 m in relation to the sea level.

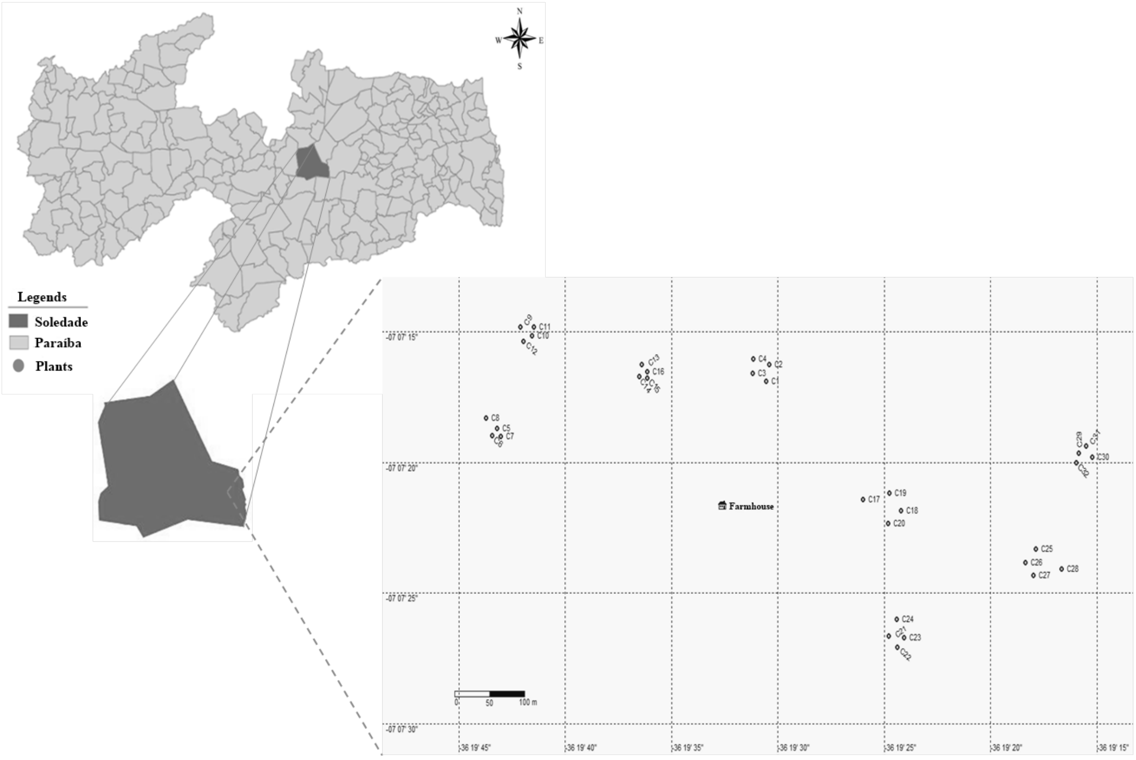

FIGURE 1: Location map of the study area, municipality of Soledade, PB state, Brazil.
FIGURA 1: Mapa de localização da área de estudo, município de Soledade-PB, Brasil.

The region is characterized by having a hot and dry climate; according to the Köppen (1948) classification, it is a semi-arid type, BS'h subtype, with an average annual precipitation of 500 mm, maximum and minimum temperatures of 31 and 16.7 ºC, respectively, with small variations over the year, and relative air humidity around 65%.

Over the course of the experiment, daily records of precipitation were collected at EMATER (Empresa de Assistência Técnica e Extensão Rural), in Soledade/PB.

The soils of the study area are mostly shallow, relatively plain to mildly undulated. They are on a crystalline geological structure where the most present types are: Chromic vertic luvisol – tc (Noncalcic brown vertic), Chromic orthic vertisol – vc (Vertisol) and Lithic entisol – rl (Litholic soil). There is also, in small proportions, Eutric Cambisol – cx (Cambisol), Eutric Fluvisol – ru (Alluvial soil), Haplic planosol – sx (Planosol sco) and rocky outcrops with evidence of Lithic entisol (CHAVES et al., 2002).

To select individuals, the sampling method adopted was the quadrat method (an adaptation of the 'plots' method): eight quadrants (approximately 40 × 40 m) within the experimental area were selected so as to represent the entire Caatinga area of the Açude Farm. The criterion for inclusion of individuals was marking a reference spot in every quadrant and selecting the four closest individuals in the north, south, east and west directions. Thirty-two trees of similar size, having a trunk with minimum diameter at breast height greater than or equal to 20 cm, were selected. Plants were identified with aluminum plates and non-woven-fabric (TNT) ribbons to be better visualized.

The observations were performed in fortnightly intervals, recording the presence and absence of the sprouting, flower-bud, full flowering, fruiting and leaf senescence phenophases. These phases were defined as follows: sprouting (emergence of leaves) – initially characterized by the presence of leaf primordia, usually of light-green or reddish color, ending when leaves acquired a dark green color; buds – period that starts when reproductive buds appear at the apical region of the branches and ends when flowers start opening (anthesis); flowering – period when the tree is at full bloom; fruiting – starts from the moment it is possible to visualize the small fruits after the flowers are fertilized and ends with dispersion of the seeds; senescence – period when the leaves change their color from dark green to brown and the spontaneous leaf abscission starts, forming empty spaces (flaws) at the crown or branches (LEAL; PERINI; CASTRO, 2007).

Evaluation methods

Fournier's intensity percentage

In this method, proposed by Fournier (1974), the values obtained in the field with a five-category (0 to 4), semi-quantitative interval scale with an interval of 25% between each category allowed us to estimate the percentage of the phenophase intensity in each individual. Every 15 days, the intensity values obtained for all individuals of the species were summed and divided by the highest maximum possible value (number of individuals multiplied by four). The result, corresponding to a ratio, was then multiplied by 100, to be converted into percentage terms.

Activity index (percentage of individuals)

This is the simplest method, in which the presence or absence of the phenophase in the individual was determined. This method of analysis is quantitative as to the population, indicating the percentage of individuals of the population that is displaying a certain phenological event. It also allows the estimation of the synchrony between the individuals of a population (MORELLATO et al., 1990), considering that more individuals showing one phenophase at the same time represent a more synchronized population. Every 15 days, all the individuals that displayed the phenophase were summed; this number was then multiplied by 100 and divided by the maximum possible value (number of individuals), and the result is obtained in percentage values.

Statistical analysis

The phenological data of intensity of each phenophase (sprouting, flower-bud, flowering, fruiting and senescence) were related to the distribution of rain pulses and through Spearman's correlation coefficient (ZAR, 1996), using the number of individuals under each phenophase and the daily climate data.

RESULTS AND DISCUSSION

Percentage of Intensity

Fournier's percent index (Figures 2 and 3) shows the peaks of intensity, indicating when a given phenophase occurs more intensively in the population, emphasizing the estimated quantity of sprouting, senescence, flower buds, flowers and fruits produced and not only the number of individuals displaying a given phenophase. In this context, we can observe that the leaf sprouting phenophase is an event that takes place as soon as the precipitation pulses in the rainy season start (Figure 1).

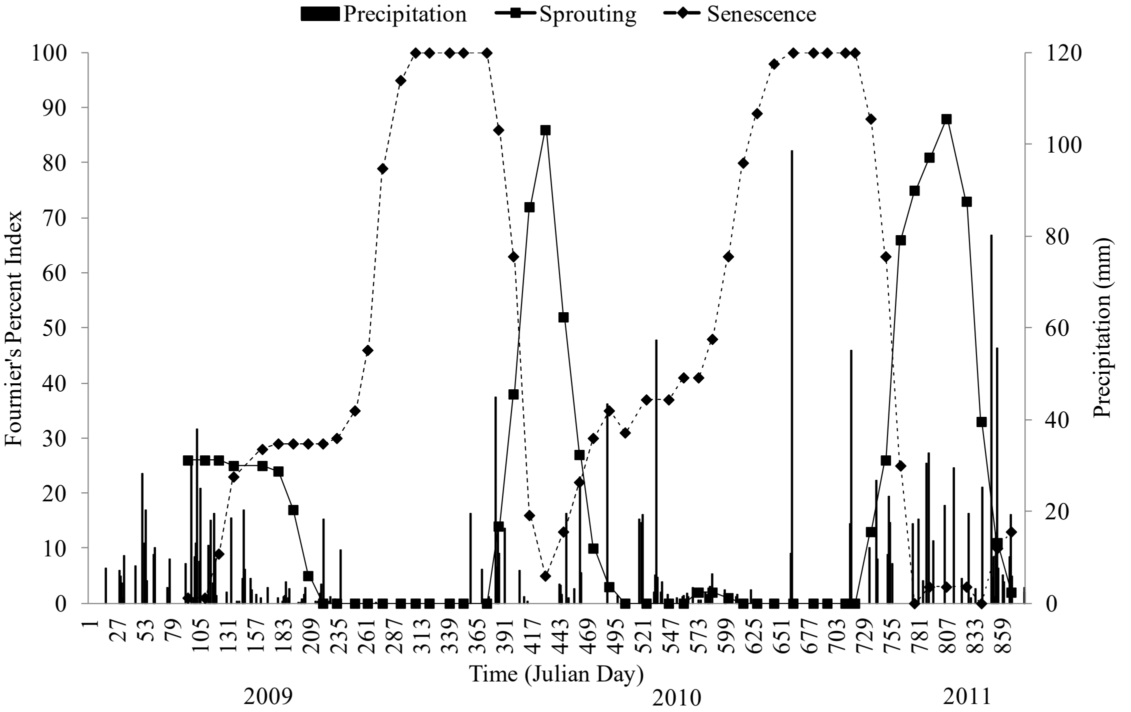

FIGURE 2: Fournier's percent index shown by *Poincianella pyramidalis* in the sprouting and senescence phenophases and daily precipitation (2009-2011).

FIGURA 2: Intensidade de Fournier apresentada por *Poincianella pyramidalis* nas fenofases de brotamento e senescência e precipitação pluvial diária (2009-2011).

Poincianella pyramidalis has a quick response of leaf emergence to the rain pulses, reaching its highest peak in few days time, provided that these pulses have some degree of distribution regularity so that the plant does not undergo strong water shortages. Additionally, the duration of leaf sprouting is short and highly intense; consequently, all the crown of the plant is immediately covered by leaves in very few days. Regarding Fournier's percent index (Figure 2), the sprouting phenophase was almost constant between the months of April and June 2009 (94 to 179 Julian days) and started to decrease with the beginning of the rain inter-pulse period until 375 Julian days (December 2009). The three precipitation pulses (183-189, 198-204 and 214-222 JD) were not sufficient to cause sprouting to start, because these were discrete rain events of low intensity. In a research study conducted in the Caatinga of the Biological Station of Canudos, in Bahia State, Neves, Funch and Viana (2010) found that the three species of *Jatropha* (*Jatropha mollissima*, *Jatropha ribifolia* and *Jatropha mutabilis*) also showed a deciduous leaf behavior, i.e. deciduousness was complete between May and July, due to the rain scarcity.

However, when precipitation pulses predominate, the water available in the soil for the plants is reduced and, consequently, *Poincianella pyramidalis* starts its leaf senescence, which in 2009 occurred between 308 JD (November 2009) at 376 JD (beginning of January 2010). In 2010, this transition took place between October and December, corresponding to the 663-721 JD interval (values accumulated since 2009). Because the wood of *Poincianella pyramidalis* has an elevated basic density, according to Silva et al. (2009), varying from 0.84-1.01 g cm^3, and given that there is a close relationship between plant phenology and the density of the wood (amount of water stored in tree trunks), according to Lima and Rodal (2010), we can affirm that the phenology of this species is greatly synchronized with the temporal distribution of rainfall. This finding corroborates Parente et al. (2012), who found similar results while also studying the phenological behavior of *Poincianella pyramidalis* in the Cariri paraibano (microregion of Paraiba State, comprising 29 cities), where the greatest leaf abscission activity occurred with the beginning of the dry period, confirming the deciduous habit of the species, in which the highest peaks of leaf fall were recorded in mid-September.

Leaf abscission begins as soon the rain inter-pulses start to predominate, and the water content of the soil by then is so low that it is no longer sufficient to meet the requirements of the plant. Even some erratic event of precipitation, like in 2010 (662 JD), of 98.7 mm in a single night, is not enough to cause the leaf-emergence phenophase to begin. Also, the rains in the semi-arid region are known for being, in general, of high intensity and short duration; this characteristic favors the surface water drainage, given that the soil of the study area has a low water-retention capacity. Addressing this subject, Andrade et al. (2006) mentioned that rain pulses induce the physiological activities of the vegetation in the Caatinga; they are responsible for triggering the processes of plant growth and development.

In January 2010 (383 JD), as soon as the rains began, sprouting was intense, with a peak of 86% at 430 JD (March 2010) (Figure 2). Although the intensity of the sprouting peak in 2011 was similar to that of 2010, it varied as to the time when the event took place (807 JD - March), as a consequence of the distribution of rains. These results agree with those obtained by Lima and Rodal (2010), who observed that despite the strong influence of precipitation on the emission of new leaves, many species — among them *Mimosa tenuiflora* — present new leaf emissions still in the dry season. As stressed by Andrade et al. (2006), greater knowledge of the events of pulses and inter-pulses of precipitation and their effects on the physiological aspects that determine plant growth is necessary. The complete loss of leaves during the driest period of the year may be related to the water deficit, causing the gas exchanges to decrease, including the exchange of water between the leaves and the environment. Many trees from climates with seasonal droughts completely lose their leaves, and as a consequence of the alleviation of water stress, they sprout still in the dry season. According to Reich and Borchert (1984) and Borchert, Rivera and Hagnauer (2002), leaf abscission represents a response to water stress, and so it is involved in the capacity to withstand water loss, which varies according to the tree species found in the Caatinga (QUIRINO, 2006).

As shown in Figure 4, in April 2009 (94 JD), at the beginning of this experiment, the trees were already in the reproductive stage (flower-buds, anthesis and fruiting), with a high percentage of buds, flowers and fruits (30, 23 and 25%, respectively). Therefore, as the plants became completely expanded, the flower-bud phenophase started, having its peak in May 2009 (123 JD) and lasting until 251st JD (September 2009). In 2010, the production of flower buds began in February (400 JD) right after sprouting, remaining until August (587 JD) and reaching its peak (19%) in April 2010 (475 JD). In 2011, this phenophase began between February and June, corresponding to the 764-868-JD interval, reaching a higher peak (47%) than the previous two years at 807 JD. The precipitation pulse between 752 and 756 JD favored the production of flower buds, and right after it there was an inter-pulse of eight days without rain, which caused a marked decrease in the formation and drop of buds.

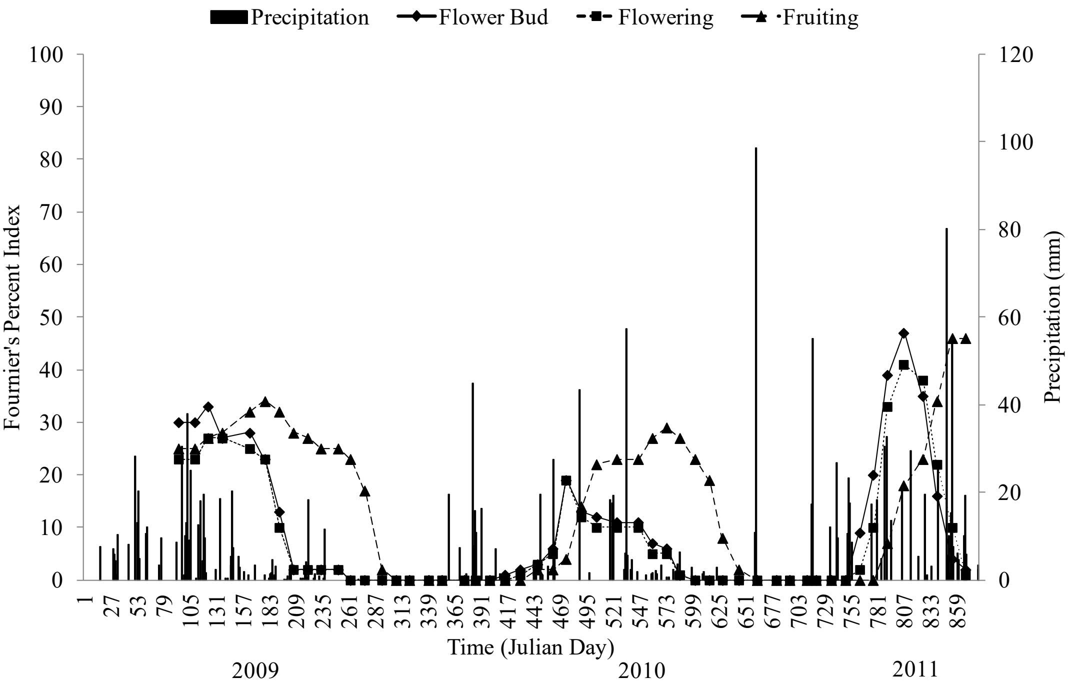

FIGURE 3: Fournier's percent index shown by *Poincianella pyramidalis* in the flower-bud, flowering and fruiting phenophases during the experiment (2009-2011).

FIGURA 3: Intensidade de Fournier apresentada por *Poincianella pyramidalis* nas fenofases de botão floral, floração e frutificação, durante realização do experimento (2009-2011).

Flowering started after the opening of flower buds, appearing once every year. In 2009, the flowering peak (27%) occurred (Figure 3) at 123 JD, as soon as there was a pulse of rain. These results confirm the dependency of *Poincianella pyramidalis* on the rain to flower, as occurs with sprouting (Figure 2). In 2010, the onset of flowering was at 415 JD (March 2010), with a duration of up to 587 JD (August), reaching its peak (19%) at 475 JD (April 2010). This assertion contradicts Santos, Machado and Lopes (2005), who found a continuous phenological pattern for two species of *Jatropha* (*Jatropha mollissima* and *Jatropha mutabilis*), in which flowering extended to all year round and the activity peak occurred in October and November. In a study conducted in Montana (USA), Lesica and Kittelsson (2010) found that not only precipitation was correlated with the development of the phenophases, but the temperature was also responsible for the earlier flowering period in some species.

Like the formation of flower buds in 2011, the maximum development of flowers (41%) occurred in the same year, surpassing the previous years of study, with an elevated percentage at 807 JD. These data allow us to infer that the referred species has an annual reproductive pattern. As a consequence of the precipitation inter-pulses between the months of July 2009, May 2010 and March 2011 (164-178 JD, 465-487 JD and 806-813 JD, respectively), there was an elevated abortion of buds and flowers in these periods, thus compromising the production of fruits. The appearance of flowers in the transition from the dry season to the beginning of the rainy season, in areas of the Caatinga, has been attributed mostly to the decrease in water stress caused by the first rains after the dry period and to the temperature increase (JOLLY; RUNNING, 2004; RUBIM; NASCIMENTO; MORELLATO, 2010).

With regard to the response of the *Poincianella pyramidalis* to the rain pulses, in 2009, the fruiting period occurred from 94 to 294 JD, corresponding to the months of April to October (Figure 2), with a peak (34%) at 179 JD. From this point on, there were no plants producing fruits, because they were in the process of physiological maturation and consequent natural dehiscence. Andrade et al. (2006) mentioned that precipitation pulses are inducers of physiological activities in the vegetation of the Caatinga and they are responsible for the onset of plant growth and development. Thus, short pulses promote a rapid abortion of flower buds, flowers and fruits when in the initial phase.

In 2010, fruiting started in March (447 JD), lasting until October (645 JD), with a peak of 29% in July (574 JD). As occurred in 2010, the formation of fruits also began in March, in 2011 (791 JD), with peak (46%) at 855 JD. Although the intensity of the fruiting peak in the three years of study occurred in different periods, this phenophase also depends on the distribution of rains, given that the formation of fruits depends on the number of buds and flowers produced in the rainy season. The results corroborate Parente et al. (2012), who observed development of fruiting in the *Poincianella pyramidalis* in areas of the Cariri, also in the rainy period, soon after flowering.

Activity index (percentage of individuals)

The emergence (sprouting) of new leaves in *Poincianella pyramidalis* (Figure 4) was concentrated between May and June 2009 (123 and 164 JD): 100% of the analyzed individuals were manifesting this phenophase at the same time. Thus, the *Poincianella pyramidalis* plants started leaf abscission approximately nine days after the end of the rains, when there was an inter-pulse of precipitation between 122-130 JD (Figure 4) as well as at the beginning of the dry season (August to December 2009) from 239 to 359 JD, when the plants were dormant, i.e. with no leaves in their crown. Also, the small and short rain pulses that occurred between 183 and 238 JD were not sufficient to cause emission of new leaves. Thus, it can be stated that leaf emergence occurs when water is available, as observed by Éder-Silva (2009), who reported that even when there was an event, it was of low intensity and did not ensure the restoration of the soil water reserve, and so it was not sufficient for the plants to release new leaves.

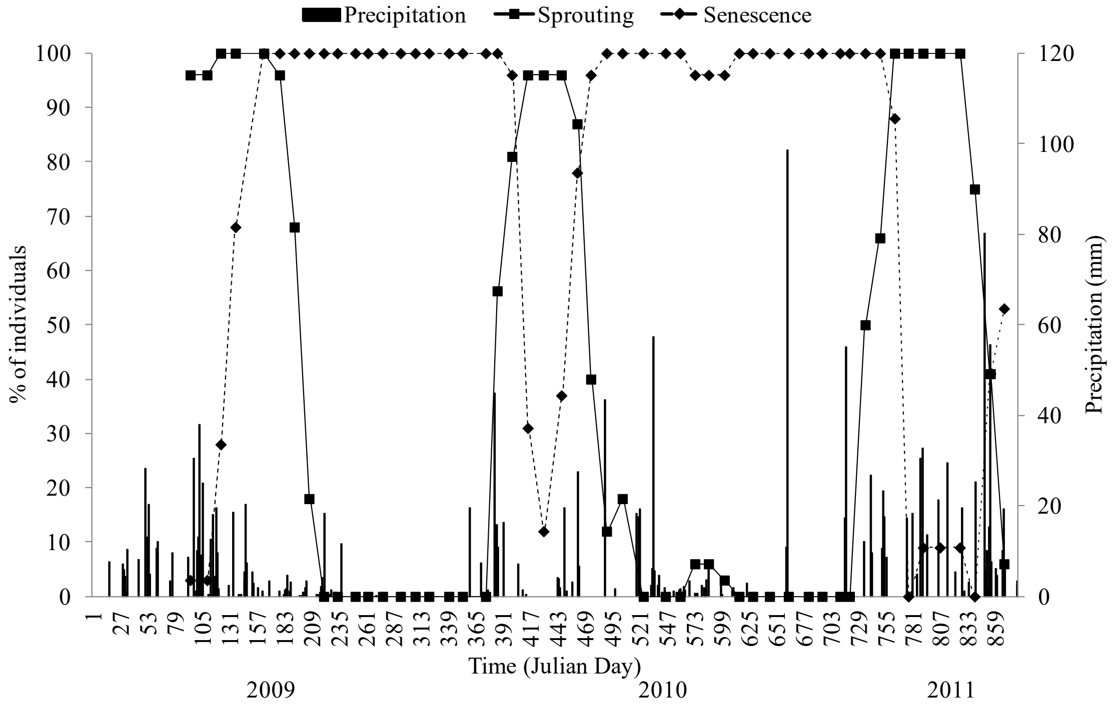

FIGURE 4: Percentage of *Poincianella pyramidalis* individuals in the sprouting and senescence phenophases during the experiment (2009-2011).

FIGURA 4: Porcentagem de indivíduos de *Poincianella pyramidalis* nas fenofases de brotamento e senescência, durante realização do experimento (2009-2011).

This species showed a high intraspecific synchrony in sprouting, suggesting induction by the same factor, which makes it dependent of the precipitation pulses. Moreover, Figure 4 also shows that the leaf-emergence phase reaches its maximum synchrony (96%) as soon as the rain pulses start, concentrating between February and March 2010. As occurred in the previous year, 2011, the greatest synchronism (100%)

for the leaf emergence phenophase between the individuals was from 764 to 826 JD (February to April), when the 32 individuals were sprouting simultaneously. The pattern observed for the first sprouts is verified as soon as the precipitation pulses begin at the end of December, always in the same period over the years.

As soon as the leaf emergence phase reaches its peak, the permanence of leaves on the plant starts to depend on the rain inter-pulses, because as the interval between one pulse and another increases, the inter-pulses start to predominate (ÉDER-SILVA, 2009). Because in this case leaf emergence no longer occurs, the permanence of leaves on the plant starts to depend essentially on the availability of water in the soil.

For some species, precipitation greater than 30 mm is high enough to cause a rapid rehydration and thereby induce synchronous sprouting in leafless trees, even before the heavier rains (BORCHERT; RIVERA, 2001; RIVERA et al., 2002). Likewise, *Poincianella pyramidalis* rehydrated soon after the water stress period, as suggested above, sprouting even with small rain pulses (Figure 4), which began in December 2009 and 2010 (360 and 717 JD) in the study region. For Van Schaik, Terborgh and Wright (1993), sprouting synchronization during a given period has been suggested to be a strategy to prevent the emission of new leaves during the unfavorable seasons. This reinforces the importance of knowing the relationships between the pulses and inter-pulses of precipitation and their effects on the physiological aspects that determine plant growth (ANDRADE et al., 2006).

Similarly, as soon as the rains ease off (Figure 4), the leaf-abscission phase begins. Such behavior demonstrates that although the *Poincianella pyramidalis* is a species adapted to the semi-arid conditions, it is sensitive to spatial and temporal rainfall variations (ANDRADE et al., 2006). Considering the three years under study, senescence began in April 2009, March 2010 and 2011 (94, 430 and 791 JD, respectively), and the synchrony of activities occurred between June 2009 and January 2010 (164-386 JD), with 100% of the individuals under senescence, and from May 2010 to January 2011 (490-750 JD), as illustrated in Figure 4. The synchrony in the senescence activity coincided with the beginning of the dry season, varying temporarily and spatially as the interval of rain pulses increased, and because it is an adaptation of the species to avoid losing water by transpiration, this ensures its survival under conditions of extreme reduction of water availability in the soil. According to Reich and Borchert (1984) and Borchert (1994), the loss of leaves causes reduction in the transpiration rate, thereby allowing the rehydration of leafless branches, and consequently the start of production of new leaves, still in the dry season; this fact was observed in many species of the Caatinga (QUIRINO, 2006), which indicates a strategy of adaptation to the highly seasonal climate issue.

Because *Poincianella pyramidalis* is a species that has a very thick stem (TELES, 2005), with consequently very limited possibilities of water reserve, it becomes more sensitive to water variations in the soil and to the increase in water stress as the rain pulses decrease. Several studies show that trees with denser wood are more sensitive to water stress and consequently lose their leaves as the soil gets drier (SINGH; KUSHWAHA, 2005). On the other hand, dense woods are more resistant to implosion of xylem vessels or rupture, and thus less vulnerable to xylem cavitation (MARKESTEIJN; POORTER, 2009).

The synchronism of the flower-bud phenophase occurred simultaneously with flowering; it was practically equal in every year (Figure 6). As occurred with sprouting (Figure 3), the plants also showed continuous emission of buds and flowers during the precipitation pulses, which decreased as the rains ended and the inter-pulses began. In 2009, the flower-bud and flowerings phenophases started when the plant was already under full reproduction, so their beginning could not be determined. However, the peak of activities for the flower-bud and flowering phenophases occurred at 94 JD (April), reaching 94%; and fruiting at 137 JD (May), with 93%.

The flower-bud and flowering phenophases take place simultaneously but sequentially: because this is a panicle-type inflorescence, anthesis happens from the base to its apex and inflorescences at different developmental stages of flower-bud, flowering and fruiting in the initial stage of formation can be found on the same plant (SOUSA, 2011).

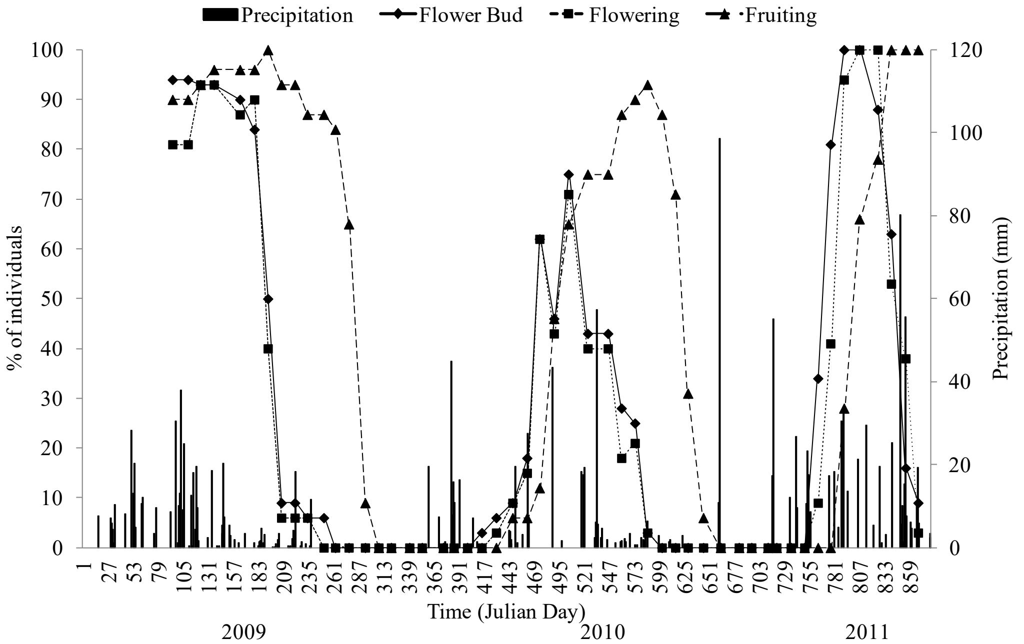

FIGURE 5: Percentage of *Poincianella pyramidalis* individuals in the flower-bud, flowering and fruiting phenophases during the experiment (2009-2011).

FIGURA 5: Porcentagem de indivíduos de *Poincianella pyramidalis* nas fenofases de botão floral, floração e frutificação, durante realização do experimento (2009-2011).

From June (164 JD), with the lack of rain, the phenophases quickly started to reduce until the months of July and September 2009 (207 to 251 JD), when there was stabilization, with only 6% of the individuals manifesting the events (flower-bud and flowering). These results show the influence of the precipitation inter-pulses on the reproductive phase, regulating the production intensity of the phenophases.

The decline in the flower-bud and flowering activities in 2010 started at 415 and 430 JD (February and March), respectively, with a duration of up to 587 JD (August 2010). The synchronism between the individuals which presented the phenophases was elevated in the first year (2009), with a lower intensity in the second year (2010), when few trees presented flowering and constant fall of buds and flowers were observed. The activity peak (Figure 5) was at 505 JD (May 2010), reaching 75 and 71% of plants manifesting the phenological events of flower-bud appearance and flowering, respectively. Also between 518 and 522 JD there were short rain pulses, stabilizing the fall of buds and flowers. This situation confirms the observation of Drumond (2012), that after an episode of rain in the dry Caatinga, lush vegetation emerges in few days time.

Reduction of flowering and fruiting intensity between reproductive cycles has been reported in other Leguminosae species such as *Copaifera langsdorffii* Desf. (PEDRONI; MARYLAND; SANTOS, 2002) and *Dipteryx alata*, which had reduced flowering and fruiting intensity in the second period of observation in relation to the first (OLIVEIRA; SIGRIST, 2008). According to Noy-Meir (1973), the occurrence of extremely short rains is typical of arid and semi-arid areas, and those can be considered rain pulses; as a consequence, the responses of the physiological processes in the plant are highly dependent on this pulse.

The flowering pattern of *Poincianella pyramidalis* in the region of the present study can be considered regular, because flowering occurred in the same period of the year; and annual, because it occurred once every year. This pattern was not observed by Amorim, Sampaio and Araújo (2009) in the municipalities of Pentecoste - CE and Serra Talhada - PE, in view of the absence of flowering for *Poincianella pyramidalis* in one of the years under study; however, this was not true in Seridó, where flowering was annual. In Alagoinha - PE, the species flowered twice per year: in addition to the most common flowering, which began between January and March, another started in September, triggered by occasional rains. Santos, Machado and Lopes (2005) found a continuous phenological pattern for the species *Jatropha mollissima* and *Jatropha mutabilis*, with flowering extending to all year long, activity peak in the months of October and November 2000, and the lowest percentages of activity in August and September 2000.

For tree species that present flowering synchronism in the population, like the studied species, a strategy would be to leave the flower more exposed and visible, facilitating its visualization and access by the pollinator; this would consequently increase the pollination rate, according to Jazen (1967) and Mantovani and Martins (1988). Distribution of species with flowers throughout the year, with greater concentration in the rainy season, has been observed in other studies in the Caatinga (MACHADO; BARROS; SAMPAIO, 1997; BARBOSA; BARBOSA; LIMA, 2003; QUIRINO, 2006) and in dry forests in Venezuela (RAMIREZ, 2002) and in Australia (WILLIAMS et al., 1999), contrasting the behavior found by many authors in seasonal tropical forests, with greater concentration in the dry period or in the transition (FOURNIER; SALAS, 1966; JANZEN, 1967; ARAÚJO, 1970; LIEBERMAN; LIEBERMAN, 1982).

The data from Figure 5 indicate that fruiting had its activity concentrated between 94 and 294 JD (April to October 2009), with a peak of 100% of individuals manifesting the event at 193 JD (July). The intensity of the event, as well as its synchrony, was high in 2010, lasting between 447 and 645 JD (March to October 2010), and reaching a peak of 93% at 587 JD (August). There was also drop of small fruits, because they were formed in the period of occasional and short rain inter-pulses (July and August 2010). These results confirm those found by Sousa (2011) in the Cariri paraibano, with fruiting intensity concentrated mainly from May to October — since the mature fruits would appear between July and November — and the greatest concentration between September and October.

In 2011, the formation of fruits began at the 777th JD and the activity boosted at 840 JD (April); thus, the rains during the months of February to May 2011 were paramount in stimulating production of fruits. Hence, given that part of the event occurs in the period of precipitation pulses and the maturation process continues during the dry season (inter-pulse), and although *Poincianella pyramidalis* presents a continuous fruiting process, the dispersion of its seeds occurs mainly in the dry season.

In short, in any exploitation system in the Caatinga, it is important to understand that the regulators of the vegetation dynamics are the water reserves of the soil, which are simultaneously associated with the rain pulses and inter-pulses. Investigating the phenology of *Dalbergia cearensis* Ducke (Fabaceae: Faboideae), an endemic deciduous species of the thorny xerophytic forest of northeastern Brazil, Nogueira et al. (2013) also found that leaf sprouting was positively correlated with the average monthly precipitation and with the water availability in the soil and negatively correlated with the average monthly temperature and average insolation.

Therefore, precipitation pulses throughout the rainy season are, as stated by Andrade et al. (2006), inducers (“triggers”) of the physiological activities that determine growth and development of most of the species of the Caatinga, with greatest evidence seen in the annual species. *Poincianella pyramidalis* is one of the Caatinga species in which the development phenophases show synchronism with the rainfall pulses. Moreover, the intensity and length of these phenophases depend on the temporal distribution of these pulses as well as on their extent and frequency throughout the rainy season.

CONCLUSIONS

The sprouting, flower-bud and flowering phenophases in *Poincianella pyramidalis* are synchronized with the temporal distribution of the precipitation pulses in its habitat;

The intensity and duration of the development phenophases of *Poincianella pyramidalis* depend on the extent and frequency of the rain pulses throughout the rainy season;

Total leaf senescence in *Poincianella pyramidalis* happens when the precipitation inter-pulses intensify as the dry season progresses, characterizing deciduousness.

ACKNOWLEDGMENTS

To CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) and CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) for the fellowships granted to the researchers and graduate students.

REFERENCES

AMORIM, I. L.; SAMPAIO, E. V. S. B.; ARAÚJO, E. L. Fenologia de espécies lenhosas da Caatinga do Seridó, RN. **Revista Árvore**, Viçosa, MG, v. 33, n. 3, p. 491-499, 2009.

ANDRADE, A. P. et al. **A Caatinga no Contexto da Variabilidade Sazonal da Disponibilidade de Forragem**. In: ALENCAR, G. S. S.; GUERRA, I. (Org.). Diversidade do saber científico: reflexões sobre ciência, saúde e esporte. 1. ed. Juazeiro do Norte: IFCE, 2013. p. 17-46.

ANDRADE, A. P. et al. Produção animal no bioma caatinga: paradigmas dos pulsos de precipitação. In: REUNIÃO ANUAL DA SBZ, 43., 2006, João Pessoa. **Anais**... João Pessoa: SBZ; UFPB, 2006. p. 138-155.

ARAÚJO, V. C. Fenologia de essências florestais amazônicas I. **Boletim do Instituto de Pesquisas da Amazônia**, Manaus, v. 4, p. 1-25, 1970.

BARBOSA, D. C. A.; BARBOSA, M. C. A.; LIMA, L. C. M. Fenologia de espécies lenhosas da Caatinga. In: LEAL, I. R.; TABARELLI, M.; SILVA, J. M. C. **Ecologia e conservação da Caatinga**. Recife: UFRPE, 2003. 822 p.

BORCHERT, R. Soil and stem water storage determine phenology and distribution of tropical dry forest trees. **Ecology**, New York, v. 75, p. 1437-1449, 1994.

BORCHERT, R.; RIVERA, G. Photoperiodic control of seasonal development and dormancy in tropical stem-succulent trees. **Tree Physiology**, Canada, v. 21, n. 4, p. 213-221, 2001.

BORCHERT, R.; RIVERA, G.; HAGNAUER, W. Modification of vegetative phenology in a tropical semi-deciduous forest by abnormal drought and rain. **Biotropica**, Lawrence, v. 34, n. 1, p. 27-39, 2002.

CHAVES, L. H. G. et al. **Salinidade das águas superficiais e suas relações com a natureza dos solos na Bacia Escola do Açude Namorado e diagnóstico do uso e degradação das terras**. Relatório Técnico. Campina Grande: [s. n.], 2002.

DRUMOND, M. A. Caatinga: bioma rico em diversidade. **Revista do Instituto Humanitas Unisinos**, São Leopoldo, n. 389, p. 13-17, 2012. Disponível em: <http://www.ihuonline.unisinos.br/>. Acesso em: 21 nov. 2013.

ÉDER-SILVA, E. Fitossociologia, regeneração e qualidade de sementes em áreas de caatinga. 2009. 237 f. Tese (Doutorado em Agronomia) – Universidade Federal da Paraíba, Areia, 2009.

FOURNIER, L. A. Un método cuantitativo para la medición de características fenológicas en árboles. **Turrialba**, Turrialba v. 24, p. 422-423, 1974.

FOURNIER, L. A.; SALAS, S. Algumas observaciones sobre la dinamica de la floracion en el bosque humedo de Villa Collon. **Revista de Biología Tropical**, Costa Rica, v. 14, n. 1, p. 75-85, 1966.

GRIZ, L. M. S.; MACHADO, I. C. S. Fruiting phenology and seed dispersal syndromes in caatinga, a tropical dry forest in the northeast of Brazil. **Journal of Tropical Ecology**, Cambridge, v. 17, n. 2, p. 303-321, 2001.

JANZEN, D. H. Synchronization of sexual reproduction of trees within the dry season in Central America. **Evolution**, Boulder, v. 21, n. 3, p. 620-637, 1967.

JOLLY, W. M.; RUNNING, S. W. Effects of precipitation and soil water potential on drought deciduous phenology in the Kalahari. **Global Change Biology**, Oxford, v. 10, n. 3, p. 303-308, 2004.

JUSTINIANO, M. J.; FREDERICKSEN, T. S. Phenology of tree species in Bolivian dry forests. **Biotropica**, Washington, v. 32, n. 2, p. 276-281, 2000.

KÖPPEN, W. **Climatologia**. Fondo de Cultura Económica, México. 1948. 479p.

LEAL, I. R.; PERINI, M. A.; CASTRO, C. C. Estudo Fenológico de Espécies de Euphorbiaceae em uma Área de Caatinga. In: CONGRESSO DE ECOLOGIA DO BRASIL, 8., Caxambu. **Anais**... [s. l.: s. n.], 2007.

LEITE, A. V. L.; MACHADO, I. C. Biologia reprodutiva da "catingueira" (*Caesalpinia pyramidalis* Tul., Leguminosae-Caesalpinioideae), uma espécie endêmica da Caatinga. **Revista Brasileira de Botânica**, São Paulo, v. 32, n. 1, p. 79-88, 2009.

LEITE, A. V. L.; MACHADO, I. C. Reproductive biology of woody species in Caatinga, a dry forest of northeastern Brazil. **Journal of Arid Environments**, Devon, v. 74, p. 1374-1380, 2010.

LESICA, P.; KITTELSON, P. M. Precipitation and temperature are associated with advanced flowering phenology in a semi-arid grassland. **Journal of Arid Environments**, Devon, v. 74, n. 9,

p. 1013-1017, 2010.

LIEBERMAN, D.; LIEBERMAN, M. The causes and consequences of synchronous flushing in a dry tropical forest. **Biotropica**, Washington, v. 16, p. 193-201, 1982.

LIMA, A. L. A.; RODAL, M. J. N. Phenology and Wood density of plants growing in the semi-arid region of northeastern Brazil. **Journal of Arid Environments**, Devon, v. 74, p. 1363-1373, 2010.

LOIK, M. E. et al. A multi-scale perspective of water pulses in dryland ecosystems: climatology and ecohydrology of the western USA. **Oecologia**, New York, v. 141, n. 2, p. 269-281, 2004.

MACHADO, I. C. S.; BARROS, L. M.; SAMPAIO, E. V. S. B. Phenology of Caatinga Species at Serra Talhada, PE, Northeastern Brazil. **Biotropica**, Washington, v. 29, n. 1, p. 57-68, 1997.

MAIA, G. N. Catingueira. In: MAIA, G. N. **Caatinga**: árvores e arbustos e suas utilidades. São Paulo: Leitura e Arte, 2004. p. 159-169.

MANTOVANI, W.; MARTINS, F. R. Variações fenológicas das espécies do cerrado da Reserva Biológica de Moji Guaçu, estado de São Paulo. **Revista Brasileira de Botânica**, São Paulo, v. 11, p. 101-112, 1988.

MARKESTEIJN, L.; POORTER, L. Seedling root morphology and biomass allocation of 62 tropical tree species in relation to drought- and shade-tolerance. **Journal of Ecology**, Oxford, v. 97, n. 2, p. 311-325, 2009.

MENEZES, R. S. C.; GARRIDO, M. S.; PEREZ, M. A. M. Fertilidade dos solos no semi-árido. In: SIMPÓSIO BRASILEIRO DE CIÊNCIA DO SOLO, 30., 2005, Recife. **Anais**... Recife: SBCS, 2005. CD-ROM.

MORELLATO, L. P. C. et al. Estratégias fenológicas de espécies arbóreas em floresta de altitude na Serra do Japi, Jundiaí, São Paulo. **Revista Brasileira de Biologia**, Rio de Janeiro, v. 50, n. 1, p. 149-62, 1990.

NEVES, E. L.; FUNCH, L. S.; VIANA, B. F. Comportamento fenológico de três espécies de *Jatropha* (Euphorbiaceae) da Caatinga, semi-árido do Brasil. **Revista Brasileira de Botânica**, São Paulo, v. 33, n. 1, p. 155-166, 2010.

NOGUEIRA, F. C. B. et al. Fenologia de *Dalbergia cearensis* Ducke (fabaceae) em um fragmento de floresta estacional, no Semiárido do nordeste, Brasil. **Revista Árvore**, Viçosa, MG, v. 37, n. 4, p. 657-667, 2013.

NOY-MEIR. Desert Ecosystems: Environment and Producers. **Annual Review of Ecology and Systematics**, Palo Alto, v. 4, p. 25-51, 1973.

OLIVEIRA, M. I. B.; SIGRIST, M. R. Fenologia reprodutiva, polinização e reprodução de *Dipteryx alata* Vogel (Leguminosae-Papilionoideae) em Mato Grosso do Sul, Brasil. **Revista Brasileira de Botânica**, São Paulo, v. 31, n. 2, p. 195-207, 2008.

PARENTE, H. N. et al. Influência do pastejo e da precipitação sobre a fenologia de quatro espécies em área de Caatinga. **Revista Árvore**, Viçosa, MG, v. 36, n. 3, p. 411-421, 2012.

PEDRONI, F.; MARYLAND, S.; SANTOS, F. A. M. Fenologia da copaíba (*Copaifera langsdorffii* Desf. - Leguminosae, Caesalpinioideae) em uma floresta semidecídua no sudoeste do Brasil. **Revista Brasileira de Botânica**, São Paulo, v. 25, n. 2, p. 183-194, 2002.

QUIRINO, Z. G. M. **Fenologia, síndromes de polinização e dispersão e recursos florais de uma comunidade de caatinga no Cariri paraibano**. 117 f. Tese (Doutorado em Biologia Vegetal) – Universidade Federal de Pernambuco, Recife, 2006.

RAMIREZ, N. Reproductive phenology, life-forms, and habitats of the Venezuelan Central Plain. **American Journal of Botany**, Columbus, v. 89, p. 836-842, 2002.

REICH, P. B.; BORCHERT, R. Water stress and tree phenology in a tropical dry forest in the lowlands of Costa Rica. **Journal of Ecology**, Oxford, v. 72, n. 1, p. 61-74, 1984.

RIVERA, G. et al. Increasing day-length induces spring flushing of tropical dry forest trees in the absence of rain. **Trees - Structure and Function**, Berlin, v. 16, n. 7, p. 445-456, 2002.

RUBIM, P.; NASCIMENTO, H. E. M.; MORELLATO, L. P. C. Variações interanuais na fenologia de uma comunidade arbórea de floresta semidecídua no sudeste do Brasil. **Acta Botânica Brasílica**, Feira de Santana, v. 24, n. 3, p. 756-764, 2010.

SALVAT, A. et al. Antimicrobial activity in methanolic extracts of several plant species from northern Argentina. **Phytomedicine**, Jena, v. 11, p. 230-234, 2004.

SANTOS, M. J.; MACHADO, I. C.; LOPES, A. V. Biologia reprodutiva de duas espécies de *Jatropha*

L. (Euphorbiaceae) em Caatinga, Nordeste do Brasil. **Revista Brasileira de Botânica**, São Paulo, v. 28, p. 361-373, 2005.

SILVA, L. B. et al. Anatomia e densidade básica da madeira de *Caesalpinia pyramidalis* Tul. (Fabaceae), espécie endêmica da caatinga do Nordeste do Brasil. **Acta Botânica Brasílica**, Porto Alegre, v. 23, n. 2, p. 436-445, 2009.

SINGH, K. P.; KUSHWAHA, C. P. Emerging paradigms of tree phenology in dry tropics. **Current Science**, India, v. 89, n. 6, p. 964-975, 2005.

SOUSA, D. M. M. **Fenologia, avaliação do tubo polínico e maturação de frutos e sementes de *Poincianella pyramidalis* (Tul.) L. P. Queiroz**. 2011. 123 f. Tese (Doutorado em Agronomia) – Universidade Federal da Paraíba, Areia, 2011.

TELES, M. M. F. **Cobertura vegetal do município de São João do Cariri- PB**: distribuição espacial da caatinga: uso de lenha como fonte de energia. 2005. 62 f. Dissertação (Mestrado em Agronomia) - Universidade Federal da Paraíba, Areia, 2005.

VAN SHAICK, C. P.; TERBORGH, J. W.; WRIGHT, S. J. The phenology of tropical forest: adaptive significance and consequences for primary consumers. **Annual Review of Ecology and Systematics**, Palo Alto, v. 24, p. 353-377, 1993.

WILLIAMS, R. J. et al. Reproductive phenology of woody species in a North Australian Tropical Savanna. **Biotropica**, Lawrence, v. 31, n. 4, p. 626-636, 1999.

ZAR, J. H. **Biostatistical analysis**. Prentice-Hall: New Jersey, 1996. 662 p.