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Study of seed rain in stretch of Submontane Open Ombrophilous Forest

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Abstract
The aim of the study was to assess seed rain in a stretch of conserved forest, addressing seasonality and the potential of seed production for natural forest regeneration. Thirty five 1 m^2 collectors were randomly distributed between seven 50 x 50 m plots. Material was collected monthly for a period of one year. Data analysis was carried out using species richness, density, frequency, period of production and type of seed dispersal. A total of 2,391 seeds (corresponding to 68 seeds.m^{-2}) were sampled from 50 different species. 19 were classified as morphospecies and the remaining 31 were distributed in 18 families, 25 genera and 17 species. The family with the highest number of seeds was Annonaceae (15.65 seeds.m^{-2}). The species with the highest seed densities were *Bocageopsis multiflora* (12.97 seeds.m^{-2}) and *Ilex affinis* (10.49 seeds.m^{-2}). In relation to frequency, B*ocageopsis multiflora* occurred in 97.1% of the points, followed by the Morphospecies 19 with 68.5%. The dry season (May to October) showed higher seed production at 47.4 seeds.m^{-2}, as well as the highest number of species dispersing seeds at 27. Finally, the wind dispersion (anemochory) predominated, characterized by the occurrence of 20 species. Overall, it was observed that the production of seeds in the study area followed a seasonal pattern in response to varying precipitation, with higher seed production and the end of the dry season correlated as a possible species survival strategy.
Keywords: Regeneration, Forest ecology, Seasonality of production.

Introduction

The Open Ombrophilous Forest, characterized as a transition type of Dense Ombrophilous Forest, is considered the most common type of forest found in Rondonia (Veloso et al. 1991). This forest typology, which surrounds the southern part of the Amazon Basin and occurs in numerous disjoint clusters in the northern and eastern parts of Hileia, is characterized by three facies dominated by typical genera, located suggestively in less humid areas. They are: *Attalea speciosa* Mart. Ex Spreng. (babassu) and *Attalea maripa* (Aubl.) Mart (inajá), which make up the "palm forest"; *Guadua superba* (taquara), which forms the "bamboo forest"; and *Phenakospermum guianensis* (A. Rich.) Endl. Ex Miq.) (Sororoca), which, when gregarious, constitutes small disjunctions throughout the Amazon, integrating the "sororoca forest" (IBGE, 2012).

Despite its pervasiveness, though, Open Ombrophilous Forest has experienced intense ecological degradation over the last few decades, resulting in fragmentation of large areas of forests, which, according to Puig (2008) and Townsend et al. (2006), threatens biodiversity, changes migrations patterns and species dispersion, and affects diversity and community composition within fragments beyond the observable impact of ecological processes (e.g., pollination, nutrient cycling and carbon storage) (Laurence and Vasconcelos, 2009).

In this sense, studies aimed at the conservation and recovery of forests are fundamental to give continuity and maintenance to these ecosystems, as well as to assist in areas recovery programs and forest management plans, which require information that helps in understanding the factors which lead to the formation of plant communities, such as natural regeneration mechanisms.

The natural regeneration represented by seed rain, seed bank and soil seed bank, is the basis of the balance and demography of plant populations, since it guarantees the renewal of individuals and the perenniality of species in the ecosystem (Puig, 2008).

Therefore, understanding the function of mechanisms responsible for forest regeneration, such as seed rain (which is formed by groups of propagules that a community receives through diverse forms of dispersion), appears as a key element in the regeneration dynamics of a natural ecosystem (Grombone-Guarantini and Rodrigues 2002; Reis et al. 2006), directly influencing the forest composition because many plant species depend on animals for seed dispersion.

Seed rain has been an object of study in different regions of the country: Caldato et al. (1996), Araújo et al. (2004), Reis et al. (2006), Chami et al. (2011) and Sccoti et al. (2011) in the South; Marimon and Felfili (2006) in the Central region; and Pivello et al. (2006) and Vieira and Gandolfi (2006) in the Southeast. Nonetheless, in the Amazon region there are only a few published studies addressing seed rain, an example is the study carried out by Vieira (1996) in primary forest of the Amazon.

The objective of this study was to investigate the seed drop in a stretch of Submontane Open Ombrophilous Forest, localized in the Municipal Park of Pimenta Bueno, RO, addressing production potential and the seed production patterns of tree species, as well as the influence of climatic factors and the type of seed dispersion.

Material and Methods

Study Area

The study was conducted in an area of 200 hectares of Open Ombrophilous Forest located in the Municipal Park of Pimenta Bueno, situated in Pimenta Bueno, RO, coordinates 11º44'00,84" S 61º29'13,24" W.

The climate is classified as Am tropical monsoon (Köppen), with an average annual temperature of 24.9 °C and annual precipitation between 2000-2300 mm (Alvares et al. 2013), comprising a well defined dry season from May to October, and humidity hovering around 85% in the rainy season from October to April.

The vegetation of the area is classified as Submontane Open Ombrophilous Forest, which is a transitional space between the Amazon and the Amazon extra areas (Cerrado), occurring between 100-600 m altitude and characterized by climatic gradient with over 60 dry days per year, and is associated with four typical structural features: palm trees, lianas, bamboos and sororocas (Veloso et al. 1991). Of these, bamboos and sororocas were most predominant in the study area.

The natural structure of the forest was affected due to exploitation in the past, probably before the area had been considered a Natural Park. Currently, there are some stretches of conserved forest and some stretches of disturbed forest. The disturbed stretches are characterized by the predominance of bamboos and typical capoeirão vegetation (Jacobsen 2014).

Sampling

The seed rain study was conducted in seven permanent sample plots, 50 x 50 m, demarcated in a more preserved stretch of the forest, representing a total of 95 hectares. These plots were divided into 25 sub-units of 10 x 10 m.

In each sample plot, five sub-units were randomly selected for the installation of collectors of 1 x 1 m, made with fine nylon mesh (shade cloth) and installed 1 meter above the soil surface under wooden stakes, following the methodology used by Chami et al. (2011).

The material in the collectors were retrieved monthly, following the methodology of Herrera et al. (1994); Grambone-Guaratini and Rodrigues (2002); Araujo et al. (2004); Chami et al. (2011); Sccoti et al. (2011), during a period of a year (March 2013 to February 2014), so that it was possible to observe the influence of the dry and rainy seasons on the behavior of seed rain in the area.

The collected material was stored in plastic bags, labeled with collector and plot numbers and then taken to the Silviculture, Forest Management and Forest Technology Lab at the Federal University of Rondônia, where viable seeds were sorted, separated, quantified, and identified according to bibliographies (Lorenzi 2002; CRIA 2005) at the lowest possible taxonomic level. The common names of the identified species were given with the aid of a local parataxonomist, and the scientific names were determined with specific literature. The unidentified seeds were germinated for possible identification of the species through seedlings.

Specific bibliographies (Lorenzi 2002), experts and specialists were consulted in order to classify the seeds by dispersion type. When it was not possible to identify the seed dispersal syndrome through bibliography, seedlings were analyzed for color, size and morphology. Then, using methodology of Van der Pijl (1982), they are classified as anemochoric (wind dispersal), when presenting wing-like structures that allow for gliding; or as zoochoric, when presenting animal seed dispersal characteristics, especially arillated seeds from drupe and berry fruits.

It is important to note that some collectors were lost due to the rotting of wood, termite attack and falling tree branches. In all there were seven numbers of lost collectors. However, it was possible to collect much of the material retained on the nylon mesh.

Data analysis

Quantification of seed rain was analyzed by assessing values of seed density (AD) (Equation 1) and absolute frequency (AF) (Equation 2) in each period of the year (dry and rainy). Calculations were performed in Microsoft Office Excel.

Absolute density:

$$DA_i = \frac{n_i}{A} \quad (1)$$

Where:
AD_i = Absolute density of the *i*th species (seed.m^{-2});
A = Total sampled area;
n_i = Number of sampled seeds of the *i*th species.

Absolute frequency:

$$FA_i = \frac{U_i}{U_T} . 100 \quad (2)$$

Where:
AF_i = Absolute frequency of the *i*th species (%).
U_i = Number of sample units in which were found seeds of the *i*th species.
U_T = Total number of sample units.

Results

A year-long evaluation of the seed rain sampled a total of 2,391 seeds (68 seeds.m-2), distributed between 50 species: 18 were identified to species level, eight at the genus level, six at the family level and 19 classified as morphospecies due to lack of botanical identification (Table 1). The family with the largest number of seeds was Annonaceae (15.68 seeds.m-²), responsible for the largest amount of scattered seeds in the study area during the assessment year.

Table 1 – Species observed in seed rain between March and August 2013 in stretch of Submontane Open Ombrophilous Forest, Pimenta Bueno, RO. AD: Absolute density (ind.ha^{-1}); AF: Absolute frequency (%).

Family	Species	Common name	Seed dispersal syndrome	N. seeds	AD	AF
Annonaceae	*Bocageopsis multiflora* (Mart.) R.E.Fr.	envira-preta	Zoochoric	454	12.98	97.13
	Xylopia aromática (Lam.) Mart.	envira	Autochoric	94	2.70	51.44
Apocynaceae	*Geissospermum leave* (Vell.) Miers	quina-quina	Autochoric	151	4.32	20.00
Aquifoliaceae	*Ilex affinis* Gardner	mate-falso	Zoochoric	367	10.49	8.58
Araliaceae	*Scheffera morototoni* (Aubl.) Maguire et al.	morototó	Zoochoric	25	0.72	19.99
Arecaceae	*Euterpe precatoria* Mart.	açaí	Zoochoric	4	0.12	11.43
	Oenocarpus bataua Mart.	patuá	Zoochoric	74	2.12	40
Bignoneaceae	Morphospecies 19	-	Anemochoric	193	5.52	68.58
	Morphospecies 29	-	Anemochoric	82	2.34	54.28
Burseraceae	*Protium* sp.	breu-branco	Zoochoric	1	0.03	2.86
Combretaceae	Morphospecies 24	-	Anemochoric	5	0.15	14.28

Fabaceae	*Hymenaea courbaril* L.	jatobá-miúdo	Zoochoric	48	1.38	20.01
	Dialium guianense (Aubl.) Sandwith	jutaí café	Zoochoric	163	4.68	62.85
	Copaifera multijuga Hayne	copaíba	Zoochoric	14	0.41	17.15
	Pterocarpus rohrii Vahl	pau-sangue	Anemochoric	2	0.06	5.72
	Morphospecies 18	-	Anemochoric / Barochoric	2	0.06	2.86
	Morphospecies 54	-	Anemochoric	39	1.14	2.86
	Acacia sp.	maricá	Anemochoric	2	0.06	2.86
	Mimosa sp.	-	Anemochoric / Barochoric	52	1.49	31.44
	Machaerium sp.	jacarandá	Anemochoric	31	0.89	28.57
	Bauhinia sp.	pata de vaca	Anemochoric / Barochoric	32	0.94	25.72
Humiriaceae	*Humiria balsamifera* (Aubl.) J.St.-Hil.	umiri	Zoochoric	1	0.03	2.86
Malpighiaceae	*Byrsonima spicata* (Cav.) DC.	murici-da-capoeira	Zoochoric	35	1.00	37.16
Meliaceae	*Cedrela* sp.	-	Anemochoric	3	0.09	8.58
Myrcinaceae	Morphospecies 6	-	Autochoric	3	0.09	5.72
Phytolaccaceae	*Seguieria langsdorffii* Moq.	limoeiro	Anemochoric	13	0.37	17.14
Salicaceae	*Casearia gossypiosperma* Briq.	camboé	Anemochoric	2	0.06	5.72
Malvaceae	*Luehea* sp.	-	Anemochoric	61	1.75	34.29
	Heliocarpus sp.	algodoeiro	Anemochoric	2	0.06	2.86
Lamiaceae	*Vitex cymosa* Bertero ex Spreng.	tarumã	Zoochoric	19	0.54	17.15
Vochysiaceae	*Qualea paraenses* Ducke	mandioqueira	Anemochoric	8	0.23	2.86
Unidentified	Morphospecies 3			42	1.2	28.57
	Morphospecies 5			2	0.06	2.86
	Morphospecies 7			1	0.03	2.86
	Morphospecies 8			41	1.17	14.29
	Morphospecies 9			3	0.09	2.86
	Morphospecies 10			2	0.06	5.72
	Morphospecies 12			7	0.2	11.43
	Morphospecies 13			5	0.14	5.71
	Morphospecies 16			2	0.06	2.86
	Morphospecies 21			207	5.91	57.14
	Morphospecies 28			5	0.14	8.57
	Morphospecies 31			18	0.51	20.00
	Morphospecies 33			10	0.29	8.57
	Morphospecies 36			10	0.31	11.44
	Morphospecies 41			2	0.06	2.86
	Morphospecies 46			21	0.6	5.72
	Morphospecies 47			9	0.26	14.29
	Morphospecies 51			2	0.06	2.86
	Morphospecies 52			16	0.46	2.86

The species that most contributed to the production of seeds in the evaluation period were *Bocageopsis multiflora* (Annonaceae) with 12.98 seeds.m^{-2}, representing 19% of the seeds dispersed in the area, and *Ilex affinis* (Aquifoliaceae) with 10.49 seeds.m^{-2} (15% of the total scattered seeds) and Morphospecies 21 with 5.91 seeds.m^{-2} and 8.6% (Table 1).

The species that showed higher values for absolute frequency were *Bocageopsis multiflora* and *Dialium guianense*, whereas *Protium sp.*, *Acacia sp.* and *Qualea paraenses* showed the lowest values for absolute frequency.
The month with the highest observed seed production in the evaluation period was September and the lowest in February (Figure 1). The peak of seed dispersal occurred during

August, September and October, presenting the greatest amount of seeds (average of 10.77 seeds.m^{-2}), and the months with lower seed production were November and February with an average of 1.05 seeds.m^{-2}.

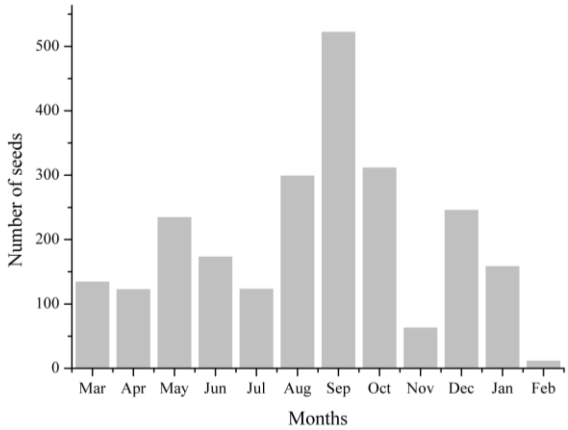

Figure 1 – Number of dispersed seeds in the period of March 2013 to February 2014 in a stretch of Submontane Open Ombrophilous Forest.

The seed dispersal of *Bocageopsis multiflora* occurred over eight months (November to June) with peak production during the months of March to June, while *Ilex affinis* presented a production concentrated between the months of September to November, with shorter, more intense production specifically between September and October. Morphospecies 19, identified as a species of the Bignoniaceae family, presented 5.51 seeds.m^{-2} dispersed between the months of July to November. Finally, the *Dialium guianens* species, although also presenting significant values of seed density produced in the study area (4.48 seeds.m^{-2}), was noted mainly for its range of production over the evaluation period. The species presented propagules every month, except February.

The highest species richness was also found in the dry season, the month of August alone showing 27 species dispersing seeds and the month of February showing lowest species richness, with only three species dispersing seeds (Figure 2). Finally, from the total number of species sampled in the seed rain study, 20 were characterized as anemocoric and 14 as zoochorous.

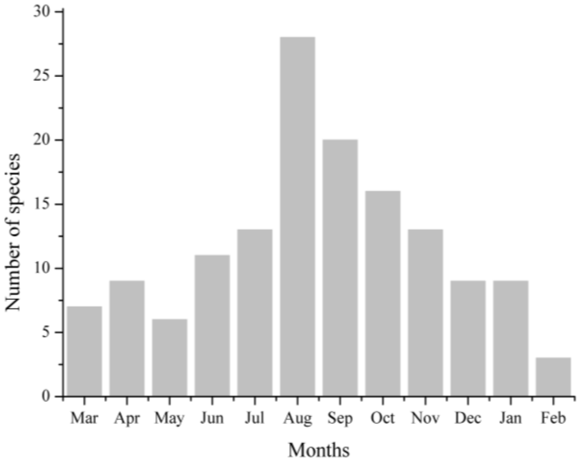

Figure 2 – Number of forest species dispersing seeds in the period of March 2013 to February 2014 in a stretch of Submontane Open Ombrophilous Forest.

Discussion

In this study, the low number of species identified could be justified by the low density of individuals of some species, which would present low germination and, consequently, impossibility in the identification of the seedlings. Moreover, it is necessary to point out the difficulty of finding support materials and trained professionals to assist in the species identification. Despite the low number of identified species, the results obtained in this study were not significantly affected since the unidentified individuals were grouped into morphospecies.

The individuals deemed as morphospecies are seeds different from each other, but whose full or partial identification could not be carried out. Considering the difficulty of identification using seeds or seedlings, this procedure was a way to include the various species in the study - a method also used by Vieira (1996), Araújo (2002), Rodrigues (2006) and Sccoti et al. (2011).

Due to the lack of studies on seed rain in Open Ombrophilous Forest, it was not possible to find preexisting scientific studies that could be used to carry out comparisons about seed production potential in this forest typology. When compared to other typologies, the remaining forest analyzed in this study showed lower seed production. Vieira (1996) observed 220 seeds.m^{-2} in primary forest in the Amazon, while Fernandes (2006) observed 6442 seeds.m^{-2} in Atlantic Ombrophilous Dense Forest. Marimon and Felfili (2006) observed 1067 seeds.m^{-2} in a mosaic of forest formations in the Vale of Araguaia (MT) and Sccoti (2012) observed 1022 seeds.m^{-2} in Deciduous Forest.

The higher seed production concentrated in the prevailing dry season (transition from winter to summer), which could be an indicative of the behavior pattern of the species, contributes intensely to the ecology of the forest, with seedlings produced mainly for regeneration. On the other hand, February stood out as having the lowest seed production. Even though February's result was partially compromised because of the loss of some collectors, a preexisting trend of decreased seed density had already been noted in the sampling.

Regarding the period of greater seed dispersal, Cavassati (2007) obtained partially similar results to those seen in this study, in stretches of Semideciduous Seasonal Alluvial Forest and Montane. The author observed higher seed dispersal in August, September, January and February; and less dispersion in March, April, May, June and July, coinciding with an unfavorable period in the region characterized by lower temperatures.

The highest species richness and highest seed production observed in the dry period also coincided with studies by Marimon and Felfili (2006) in Monodominant Forest of *Brosimum reubescens* Taub., and also in a study carried out by Lagos and Marimon (2012) in a mosaic of forest formations in the Vale do Araguaia, Mato Grosso. This behavior is associated with a survival strategy performed by these species when, in the beginning of the rainy season, they find better conditions for seed germination and seedling establishment, thus reducing mortality rates.

Bocageopsis multiflora, which presented the highest contribution of seeds in the evaluation period, is described by Lorenzi (2002) as natural species from the Amazon region in upland forests, settling preferably inside of barns and coppices, and sandy uplands which show good fertility and drainage. This species, whose fruit begin to ripen in September, produces large quantities of viable seeds widely disseminated by birds.

Ilex affinis, which was the second species with higher seed production in the area, is considered an important food source for birds (Lorenzi 2002), which ensures the wide dispersal of the seeds and suitability for restoration programs of degraded areas.

Dialium guianens, popularly known as Jutaí coffee, occurs in many states of the North region and produces large annual quantities of viable seeds which are also spread by birds (Lorenzi 2002). Although the fructification period of this species is indicated in the bibliography to be from February to October, it was verified in the study area that fruit production remained nearly constant the whole year. The species presented propagules every month, except February, which probably was affected by the loss of some collectors. Therefore, in addition to *Ilex affinis*, *Dialium guianense* also shows great potential for usage in forest restoration programs because of its dietary link to local wildlife.

Morphospecies 19, identified as a species of the Bignoniaceae family, dispersed seeds between the months of July to November. Since this species displayed wind dispersal, it is possible to affirm that the producers of propagules sampled in this study might be an important source of propagules in surrounding areas, contributing to the diversification of the floristic composition of the surroundings.

The low values of absolute frequency observed for most of the species indicate a more clustered dispersion pattern, verifying the frequent presence of seeds very close to their mother plants. The species that showed the higher values for frequency were the ones that obtained the higher values for seed density, therefore they are the species of greatest importance and ecological contribution to the area.

In relation to the seed dispersal syndromes, most research on seed rain demonstrates the predominance of animals seed dispersal (Saravi et al., 2003; Liebsch and Acra 2007; Sccoti et al., 2011). In the study area, the prevalence of anemochory can be explained by the existence of forest stretches with histories of logging practices, which contributed to the occurrence of early stage species with wind dispersal that still remain in the forest canopy.

Another fact that should be analyzed in more detail relates to the forest typology, since it is a forest with an open capony, which allows a higher incidence of early species with wind dispersal. However, studies for longer periods of time and monitoring other Open Ombrophilous Forest areas is needed to better understand this behavior.

Conclusions

Seed production showed variations between seasons, indicating the influence of climatic factors, mainly precipitation.

The species *Bocageopsis multiflora*, *Ilex affinis* and *Dialium guianense* showed potential for use in restoration programs of degraded areas because of their abilities to produce large amounts of seeds for longer periods, as well as attract wildlife.

Anemochorous species were prevalent in the area, possibly due to the occurrence of early stage species in some areas of the forest containing observable exploitation of woody plants, or due to the occurrence of open canopy areas.

For better understanding of the seed rain behavior in the area it is important to continue the study for a longer period of time, as well as monitor other Open Ombrophilous Forest areas in the region.

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