Post-fire phenology in a *campo sujo* vegetation in the Urucum plateau, Mato Grosso do Sul, Brazil

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Abstract

Studies on the herbaceous and sub-shrub layer of cerrado showed the occurrence of modifications in its composition between different regions, demonstrating sensibility to changes in climate, soil and intensity of fires, among other factors. The aim of this study was to describe the phenological variation in a *campo sujo* vegetation in the Urucum plateau. We established eight transects of 250 m each, 50 m apart. We sampled all flowering and fruiting species located at least three meters from each side of the transect. Beginning in October 2007, one month after an accidental fire occurred in the study site, we analysed flowering and fruiting plants in the transects' area. The intensity of the flowering and fruiting phenophases was not uniformly distributed. This study provide us information about the possible fire influence on the reproductive patterns of the community, presenting flowering peaks in October and November, two months after this event. Regression analysis with monthly rainfall also provides us information about the influence of climate data on the flowering and fruiting peaks.

Keywords: flowering, fruiting, fire.

Fenologia pós-queima em uma área de campo sujo do maciço do Urucum, Mato Grosso do Sul, Brasil

Resumo

Estudos sobre o componente herbáceo-subarbustivo do cerrado indicam a ocorrência de grandes mudanças na sua composição entre diferentes regiões, demonstrando tratar-se de uma flora sensível a variações de clima, solo, intensidade de queimadas, entre outros fatores. O objetivo deste estudo foi descrever as variações fenológicas em uma comunidade vegetal de campo sujo de cerrado do maciço do Urucum. A amostragem foi feita com oito transectos de 250 m, distantes 50 m entre si, nos quais foram amostradas todas as espécies de angiospermas floridas ou frutificadas que se encontravam distantes até no máximo três metros de cada lado, no total de 0,6 ha. A partir de outubro de 2007, um mês após uma queima acidental na área de estudo, foi feito acompanhamento mensal das fenofases de emissão de flores e frutos nas plantas que se encontravam na área do transecto. A intensidade de floração e frutificação não foi uniformemente distribuída. Os dados indicam possível influência da queima na atividade reprodutiva da comunidade ao se observar os picos de floração em outubro e novembro, dois meses subsequentes ao evento. Análise de regressão com a precipitação mensal demonstra ainda influência dos dados climáticos nos picos de floração e frutificação.

Palavras-chave: floração, frutificação, fogo.

1. Introduction

The cerrado vegetation, according to the "forest-ecotone-grassland" concept (Coutinho, 1978), consists of two distinct floras: one of shrubs and trees, predominantly in forest fragments (*cerradão*), and another of herbs and sub-shrubs, characteristic of grasslands. The savannah physiognomy, the intermediate form (*campo sujo* and *cerrado* sensu stricto), is characterised by the occurrence of a mixed flora consisting of forest and grassland elements (Coutinho, 2002).

Studies on the herbaceous layer of *cerrado* showed the occurrence of modifications in its composition between different regions, demonstrating sensibility to changes in climate, soil, and intensity of fires, among other factors (Batalha and Martins, 2004; Filgueiras, 2002). The strong seasonality of this vegetation type, with rainy summers and dry winters, has been the target of investigations on the phenological pattern of individual species, groups of congeneric species and communities (Mantovani and

Martins, 1988; Oliveira, 1998; Miranda, 1995; Gouveia and Felfili, 1998; Munhoz and Felfili, 2005; Silva et al., 2009; Tannus et al., 2006).

Mantovani and Martins (1988) demonstrated that an increase in precipitation and temperature correlated positively with the increase in the number of species flowering in the herbaceous and shrub layer. Batalha and Mantovani (2000) reported more autochoric and anemochoric species dispersing in the dry season, while zoochoric species increased during the rainy season when studying differences between dispersal syndromes.

In addition, fire is an important factor causing changes in the floristic composition, physiognomy, structure and phenology reducing the density and height of the vegetation and changing biodiversity (Coutinho, 1977, 1990; Sato, 2003). Coutinho (2002) indicated that the occurrence of fires in *cerrado* dates from 30,000 years ago and the adaptation of the vegetation to fire is related to several factors like the type of fire, the burning regime, frequency, fire intensity and soil temperature (Miranda et al., 2004).

The Urucum plateau, with contrasting vegetation types including semi-deciduous forest to high-altitude *campo sujo*, has many variables that can influence the phenology of this plant community, such as iron and manganese rich soil, soil humidity and regular fire among others that have not been extensively studied.

The aim of this study was to describe the phenological variations in an area of *campo sujo* vegetation in the Urucum plateau. We attempted to answer the following questions: 1) What is the phenological pattern of a *campo sujo* community in the post-fire event period?, 2) Do the observed events correlate with the seasonal rainfall in the area, as proposed in the literature for the herbaceous and sub-shrub layer (Spina et al., 2001; Munhoz and Felfili, 2005)? and 3) Is there phenological variation of the plant species with different dispersal syndromes?

2. Material and Methods

2.1. Study site

We conducted this work in the Urucum region, a plateau with about 5,327 ha in Mato Grosso do Sul, which is considered the most prominent plateau of the Pantanal's western edge (Isquierdo, 1997). Among the hills that make up the Urucum plateau, are the Urucum (971 m), the Grande (951 m), the Santa Cruz (1065 m), the São Domingos (800 m), the Tromba dos Macacos (500 m), the Jacadigo (600 m) and the Rabichão with 700 m above sea level (Franco and Pinheiro, 1982).

The region's climate is of the megathermic tropical type (average temperature of 25 °C) with annual rainfall of about 1,120 mm and two distinct seasons, a dry season from April to September (winter) and a rainy season from October to March (summer), classified as Aw in the Köppen system (Soriano, 2000).

The landscape of the region is represented by a mosaic of different types of natural vegetation, according to the variety in the local geology and geomorphology. In the region, there are several vegetation types, such as the *cerrado* – from *campo sujo* to *cerrado* sensu stricto, deciduous forest and semi-deciduous forest (Pott et al., 2000).

The *campo sujo* vegetation is located covering the top of the hills and characterised by a coverage of grasses, herbs and shrubs with heights ranging between 30 and 40 cm. Species such as *Trachypogon spicatus* (L.f.) O. Kuntze, *Thrasya petrous* (Trin.), *Aiouea trinervis* Meissn. and *Qualea cryptantha* (Spreng.) Warm. are important for the vegetation coverage (Damasceno Junior et al., 2005).

2.2. Phenology

We carried out this study in the Santa Cruz hill (19° 12' S and 57° 35' W), in the city of Corumbá - MS. Sampling began on October 2007, approximately one month after an accidental fire occurred in the study site.

We established eight transects of 250 m, 50 m apart. We sampled all flowering and fruiting species located at least three meters from each side of the transects. Four transects were established on each side of the hill to standardise the data and the whole study area reached 0.6 ha (Figure 1).

We analysed the flowering and fruiting plants within the transect area from October 2007 to September 2008. The criterion for inclusion of species in the phenological analysis was the presence of a flowering or fruiting event during the study period. Mature and immature fruits were considered within the fruiting phenophase.

The vegetation types in this study were divided into herbs, palms, climbers, dwarf plants and sub-shrubs. The dwarf plants are species that, in normal environmental conditions, have the arboreal life-form. However, these species do not develop normally in the *campo sujo* vegetation within the study area due to the characteristics of the Urucum plateau such as soil (depth, humidity), wind and fire (Lehn et al., 2008). The sub-shrubs form was considered when the plant had secondary growing only at the base, thus not reaching the branches.

2.3. Data analysis

We classified the species, with $n \geq 10$ individuals, in the categories of the semi-quantitative scale adapted from Fournier (1974) for herbaceous species, which estimates the intensity of each phenological phase using the following scale: 0-absence of characteristic, 1-presence of characteristic in the range from 1-25%, 2-from 26-50%, 3-from 51-75%, 4-from 76-100%.

We executed a regression analysis of monthly rainfall (obtained from the Mineração Corumbaense Reunida S/A company) to the intensity of species in the flowering and fruiting events. We used the Rayleigh test (Zar, 1999) to evaluate whether the species in the study flower and fruit uniformly throughout the year. We also applied the Rayleigh test (Zar, 1999) to assess whether the anemochorous, autochorous and zoochorous species fruit uniformly throughout the year. To test whether the mean of fruiting period for the anemochorous, autochorous and zoochorous species were different, we used the Watson-William test for the three samples (Zar, 1999).

To determine dispersal syndromes, we considered field observations and the scientific literature available for the species (Pott and Pott, 1994; Jardim et al. 2003). Ballistics and barocoric syndromes were grouped into the autochoric category (Van der Pjil, 1972).

3. Results

Five out of the 53 monitored species had less than 10 individuals in the studied area and therefore were excluded from the calculation of the Fournier intensity. The most representative life-forms of this *campo sujo* community were dwarf plants with 41.45% individuals, herbs with 32.26% and sub-shrubs with 26.24%. Climbers and palms represented less than 1%.

The most abundant species in this *campo sujo* vegetation in the Urucum plateau was *Bulbostylis paradoxa* Nees with 354 individuals, followed by *Spiranthera odoratissima* A. St.-Hil. with 176, *Qualea crypthanta* (Spreng.) Warm. with 155 and *Davilla elliptica* A. St.-Hil. with 126 (Table 1).

3.1. Flowering

The intensity of the flowering phenophase (Figure 2) was not uniformly distributed ($z = 11.87$, $P < 0.01$). The correlation between rainfall and the flowering phenophase was insignificant ($r^2 = 0.21$, $P = 0.49$) (Figure 4). The late dry season was the peak period in flowering.

3.2. Fruiting

The intensity of the fruiting phenophase (Figure 2) was not uniformly distributed ($z = 11.96$, $P < 0.01$). The correlation between rainfall and the fruiting phenophase was significant

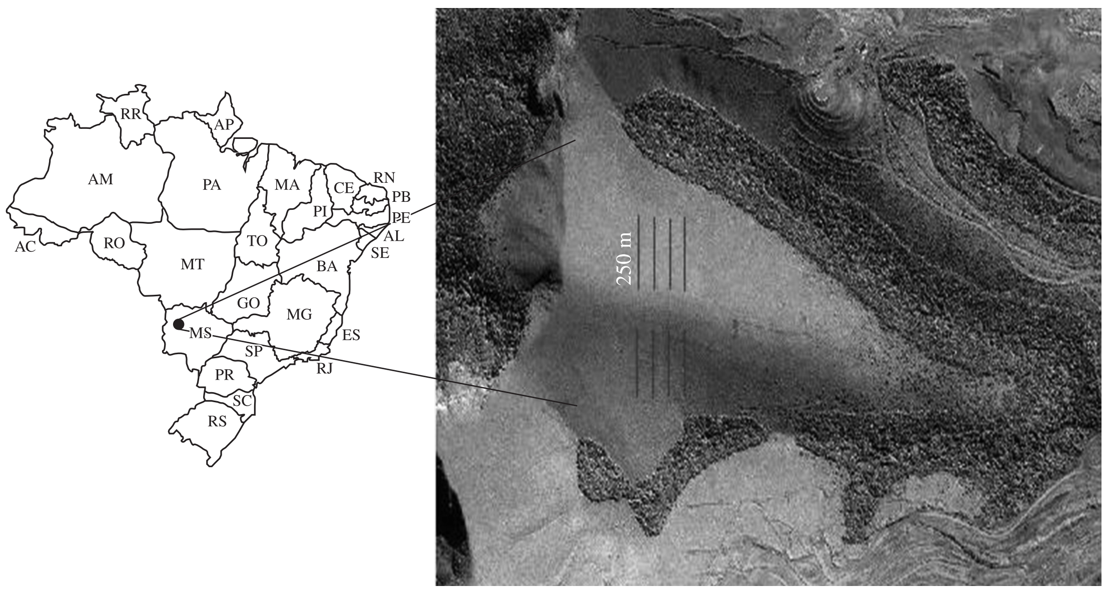

Figure 1. Map showing the study site in the Urucum plateau, Corumbá, Mato Grosso do Sul, Brazil and the four transects of 250 m on each side of the hill. Source: Mineração Corumbaense Reunida S/A-2005 IKONOS modified image.

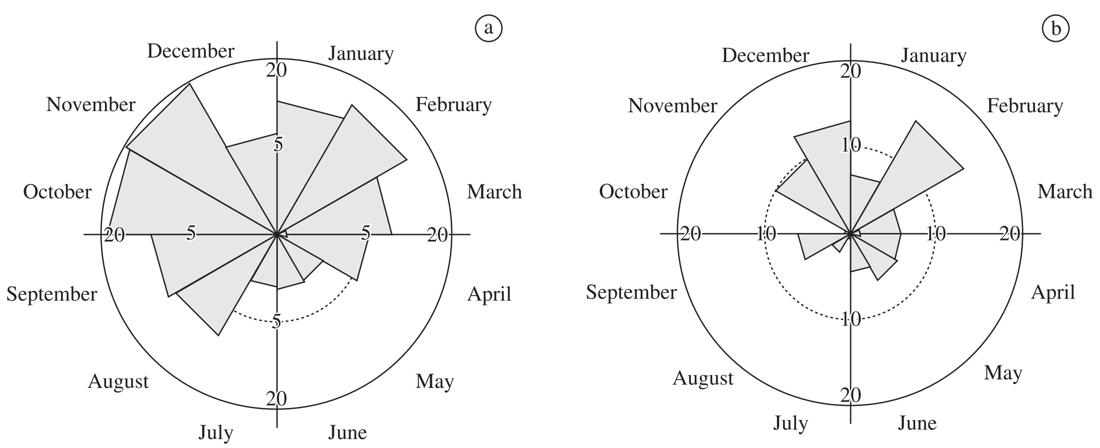

Figure 2. Circular histograms of Fournier intensity for flowering a) and fruiting b) in the *campo sujo* vegetation in the Urucum plateau, Corumbá, Mato Grosso do Sul.

Table 1. Number of individuals from each studied species in the *campo sujo* vegetation in the Urucum plateau Corumbá, Mato Grosso do Sul, classified according to life-form and dispersal syndrome.

Family	Species	Life-forms	Individuals	DS
Apiaceae	*Eryngium pristis* Cham. & Schlecht.	SBS	34	AUT
Apocynaceae	*Hemipogon acerosus* Decne.	HER	10	ANE
	Mandevilla illustris (Vell.) Woodson	HER	59	ANE
	Odontadenia lutea (Vell.) Markgr.	CLI	47	ANE
Arecaceae	*Allagoptera leococalyx* Kuntze	PAL	21	ZOO
Asteraceae	*Baccharis* sp.	SBS	26	ANE
	Eupatorium inulifolium H.B. & K.	HER	13	ANE
	Eupatorium cf. *squalidum* DC.	SBS	24	ANE
	Vernonia coriacea Less.	SBS	38	ANE
	Vernonia herbacea Rusby	HER	16	ANE
	Vernonia nitens Gardner	HER	45	ANE
	Vernonia sp.	SBS	27	ANE
	Viguiera grandiflora Gardner	SBS	56	ANE
Bignoniaceae	*Anemopaegma arvense* (Vell.) Stellfeld ex de Souza	HER	29	ANE
	Tabebuia ochracea (Cham.) Standl.	DWP	27	ANE
Bromeliaceae	*Dyckia* sp.	HER	81	ANE
Cactaceae	*Echinopsis calochlora* K. Schum.	HER	90	ZOO
Clusiaceae	*Kielmeyera coriacea* (Spreng.) Mart.	DWP	84	ANE
Cyperaceae	*Bulbostylis paradoxa* Nees	HER	354	ANE
Dilleniaceae	*Davilla elliptica* A. St.-Hil.	DWP	126	ZOO
Erythroxylaceae	*Erythroxylum campestre* A.St.Hil.	DWP	44	ZOO
	Erythroxylum suberosum A. St.-Hil.	DWP	3	ZOO
Euphorbiaceae	*Manihot tripartita* Müll.Arg.	HER	41	ZOO
	Sebastiania hispida (Mart.) Pax.	SBS	36	ZOO
Fabaceae	*Aeschynomene falcata* (Poir.) DC.	SBS	6	AUT
	Chamaechrista cordistipula (Mart.) H.S.Irwin & Barneby	SBS	33	AUT
	Clitoria guianensis (Aubl.) Benth.	SBS	22	AUT
	Eriosema crinitum (Kunth) G. Don.	SBS	21	AUT
	Indigofera lespedezioides Kunth	SBS	42	AUT
	Galactia sp.	SBS	11	AUT
	Hymenaea stygonocarpa Mart. ex Hayne	DWP	18	ZOO
	Mimosa nuda Benth.	SBS	114	ANE
	Mimosa sensibilis Griseb.	SBS	30	ANE
	Stryphnodendron obovatum Benth.	DWP	46	ZOO
	Stylosanthes macrocephala M.B.Ferreira & Sousa Costa	HER	26	ZOO
Lauraceae	*Aiouea trinervis* Meissn.	DWP	113	ZOO
Lithraceae	*Lafoensia pacari A.* St.-Hil.	DWP	22	ANE
Malpighiaceae	*Byrsonima coccolobifolia* Kunth	DWP	34	ZOO
	Byrsonima intermedia A. Juss.	DWP	4	ZOO
	Heteropterys byrsonimaefolia Adr. Juss.	DWP	60	ANE
Melastomataceae	*Miconia albicans* (Sw.) Triana	DWP	63	ZOO
	Miconia fallax DC.	DWP	14	ZOO

HER = herbaceous, CLI = climber, DWP = dwarf plant, SBS = sub-shrub, ANE = anemochoric, AUT = autochoric, ZOO = zoochoric.

Table 1. Continued...

Family	Species	Life-forms	Individuals	DS
Myrtaceae	*Blepharocalyx salicifolius* (Kunth) O.Berg	DWP	112	ZOO
	Eugenia punicifolia (Kunth) DC.	SBS	22	ZOO
	Psidium cinereum Mart. ex DC.	SBS	7	ZOO
Ochnaceae	*Ouratea spectabilis* (Mart.) Engl.	SBS	2	ZOO
Rubiaceae	*Borreria* sp.	HER	11	AUT
	Palicourea rigida Kunth	DWP	53	ZOO
Rutaceae	*Spiranthera odoratissima* A. St.-Hil.	SBS	176	AUT
Salicaceae	*Casearia sylvestris* Swartz	DWP	30	ZOO
Smilacaceae	*Smilax fluminensis* Steud.	CLI	27	ZOO
Styracaceae	*Styrax ferrugineous* Nees & Mart.	DWP	53	ZOO
Vochysiaceae	*Qualea crypthanta* (Spreng.) Warm.	DWP	155	ANE

HER = herbaceous, CLI = climber, DWP = dwarf plant, SBS = sub-shrub, ANE = anemochoric, AUT = autochoric, ZOO = zoochoric.

($r^2 = 0.64$, $P = 0.02$) (Figure 5). The late rainy season was the peak period in fruiting.

3.3. Dispersal syndromes

Analyses of the dispersal syndromes showed that 50.94% of the individuals were zoochorous, 36.36% anemochorous and 12.7% autochorous. The proportions of anemochorous, autochorous and zoochorous (Figure 3) were not uniformly distributed ($z = 11.88$, $z = 11.77$, $z = 11.95$, respectively; $P < 0.01$ in all three cases). The mean fruiting periods for these dispersal syndromes were not significant different (Table 2).

Table 2. F values and probability of Watson-Williams test for the dispersal syndromes in a *campo sujo* vegetation in the Urucum plateau, Mato Grosso do Sul, Brazil.

Syndromes 1	Syndromes 2	*F*	*P*
Anemochory	Autochory	0.094	0.763
Anemochory	Zoochory	0.598	0.448
Autochory	Zoochory	0.061	0.807

4. Discussion

Ragusa-Netto and Silva (2007) recorded the flowering peak in August and September while studying a dry forest in the bottom of Santa Cruz hill, near the study site. The flowering peak of *campo sujo* in the consecutive months can be essential to keep the pollinators in this area.

The fruiting peaks of the dry forest studied by Ragusa-Netto and Silva (2007) were in the middle of the dry season and in the transition between the dry and the rainy season. This last peak was higher and represented by the zoochoric species, such as *Protium heptaphyllum* March., *Guarea guidonia* (L.) Sleumer, *Pouteria torta* Radlk. and *Spondias lutea* L. Zoochoric species from the high-altitude *campo sujo* showed the same pattern of nearby forest species (Figure 3) and it happens during the period of greater activity of frugivorous species like small birds.

Janzen (1980) analysed different dispersal syndromes of tropical plants and demonstrated autochoric species flowering in the wet season and fruiting in the dry season. In the *campo sujo* of the present study, the intensity peak of autochoric species occurred in the late rainy season. This may be due to the fact that 40.29% of the autochoric individuals belonged to the family Fabaceae, which showed flowering peak in the dry season. This pattern must be confirmed with other phenological studies in the Urucum plateau without fire events.

Many herbs and sub-shrubs species in the *cerrado* have adaptive traits to fire (Coutinho, 1977) such as a soil layer protecting the root system (Coutinho, 1978). These species recover quickly after a fire, synchronising flowering (Sarmiento, 1992). The flowering peaks in October and November, two months after the fire, indicate the adaptation of the studied species. The insignificant difference in the means of the fruiting period was also a consequence of this synchronisation.

Another detectable effect may be the absence of zoochoric species fruiting in the months after the fire since these species are often found fruiting every month of the year (Batalha et al., 1997; Batalha and Mantovani, 2000). Gentry (1982), Morellato and Leitão-Filho (1996) and Talora and Morellato (2000) demonstrated that the proportions of zoochoric species in tropical rainforests were higher than 80%, showing the importance of these species to the maintenance of frugivorous animals.

Grasses in the studied *campo sujo* did not flower, reducing the percentage of anemochoric individuals in the community. Damasceno-Junior et al. (2005) recorded 10 grass species in the *campo sujo* community of Santa Cruz hill. *Trachypogon spicatus* (Lf) O. Kuntze, *Axonopus*

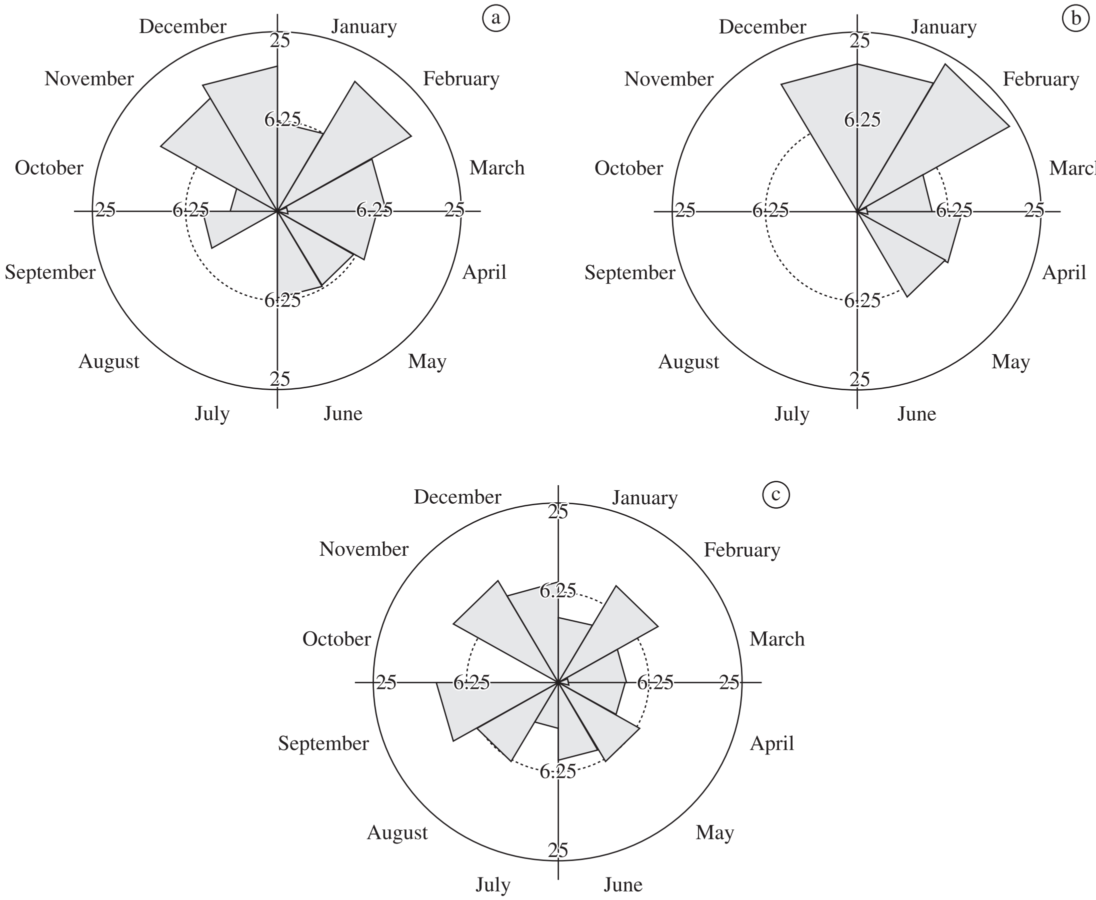

Figure 3. Circular histograms of Fournier intensity for the fruiting phenophase in the *campo sujo* vegetation in the Urucum plateau, Corumbá, Mato Grosso do Sul, and the species classified by dispersal syndromes. Anemochorous (a), Autochorous (b) and Zoochorous (c).

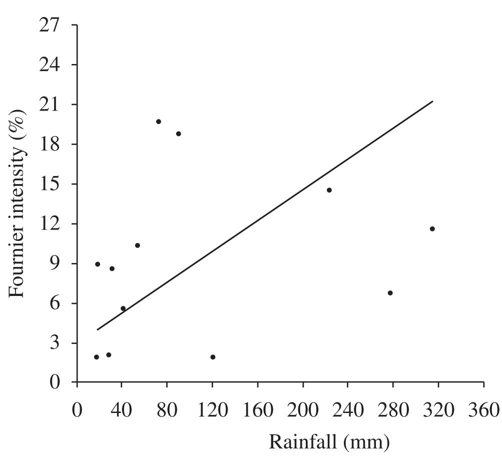

Figure 4. Regression between rainfall and the Fournier intensity for the flowering phenophase in the *campo sujo* vegetation in the Urucum Plateau, Corumbá, Mato Grosso do Sul.

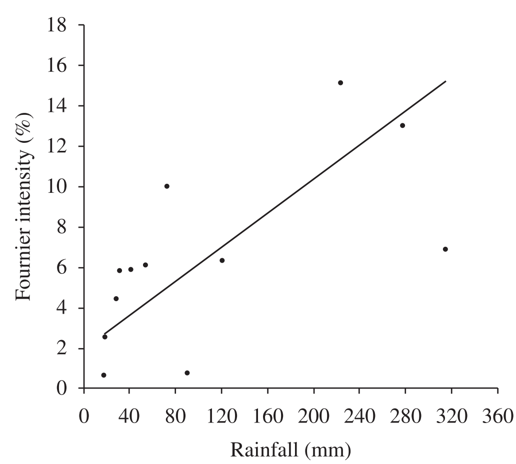

Figure 5. Regression between rainfall and the Fournier intensity for the fruiting phenophase in the *campo sujo* vegetation in the Urucum Plateau, Corumbá, Mato Grosso do Sul.

aureus Beauv. and *Thrasya petrosa* (Trin.) Chase were the most abundant. Most of the Poaceae species found in the Damasceno-Junior et al. (2005) study were flowering in the month of February. Poaceae species flowering or fruiting were not found in the present study. This is probably the main detectable effect of the fire in this study, because the fire may have changed the flowering ability of the grasses in that year.

Phenological patterns in the plant community bring important contributions to the understanding of the flowering and fruiting periods in the study site. The data indicate a possible influence of a fire in the analysed *campo sujo* vegetation, showing the absence of zoochoric species fruiting in the months following the event and the absence of grasses flowering or fruiting during the entire study.

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