Neotropical Biology and Conservation
11(3):132-140, september-december 2016
Unisinos - doi: 10.4013/nbc.2016.113.03

Bryophyte diversity in an area of Brazilian Cerrado in Central-West

Briófitas de área de Cerrado da região Centro-Oeste do Brasil

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Abstract

The Cerrado is a savanna formation predominantly located in the central Brazilian plateau; this vegetation is rich in bryophytes. This study analyzes bryophyte diversity, composition and distribution among various Cerrado vegetation types (Gallery Forest, Deciduous Forest, Rupestrian Cerrado and Rupestrian Fields) and substrates in the Área de Proteção Ambiental Morro do Macaco, from municipality of Iporá, Goiás state, in Central-West Brazil. The collection was performed in four plots of 20m x 20m, in each vegetation types, from August to December 2010, the data were analyzed with the *Shannon-Wiener* (H') and *Simpson* diversity index and the floristic similarity with UPGMA. We found 37 species, with 28 to Bryophyta and nine to Marchantiophyta. *Trichostomum brachydontium* Bruch is a new record to the Brazilian Midwest and an endemic species (*Archidium oblongifolium* Peralta *et al*.) occurs in the study area. The forested areas were the richest in species number and the substrate most colonized was soil. The results extend the information about the Cerrado bryophytes, increasing the knowledge of their taxonomic diversity and ecology.

Keywords: mosses, liverworts, community ecology, Brazilian savanna.

Resumo

O Cerrado é uma formação savânica localizada no platô Central do Brazil, apresentando vegetação rica em briófitas. Este trabalho analisou a diversidade de briófitas através da composição e distribuição de briófitas entre as fitofisionomias de Cerrado (Mata Seca, Mata de Galeria, Cerrado Rupestre e Campo Rupestre) e a colonização de substratos na Área de Proteção Ambiental Morro do Macaco, no município de Iporá, no Estado de Goiás, na região Central do Brasil. As coletas ocorreram no interior de quatro parcelas de 20m x 20m demarcadas em cada formação vegetal nos meses de agosto a dezembro de 2010. Foram analisados os índices de *Shannon-Wiener* (H') e *Simpson* e a similaridade entre as fitofisionomias através da técnica UPGMA. Foram encontradas 37 espécies, 28 da divisão Bryophyta e nove de Marchantiophyta. *Trichostomum brachydontium* Bruch é registrada pela primeira vez para o Centro-Oeste brasileiro e uma espécie endêmica, *Archidium oblongifolium* Peralta *et al*., ocorre na área estudada. As áreas florestadas apresentaram maior riqueza de espécies e o substrato mais colonizado foi solo. Os resultados obtidos ampliam as informações sobre a diversidade taxonômica e ecologia das briófitas do Cerrado.

Palavras-chave: musgos, hepáticas, ecologia de comunidades, savana brasileira.

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Introduction

The Neotropical region is extremely rich in bryophytes, congregating around a third of the known species, which are distributed in the various ecosystems that exist from Mexico to southeastern Brazil (Hallingbäck and Hodgetts, 2000). However, the actual knowledge about the composition, structure, distribution and ecology of this group of plant remains incipient or unknown to several Latin American areas, including the Brazilian Cerrado vegetation domain (Câmara and Vital, 2006; Câmara, 2008a).

The Cerrado is a savanna formation predominantly located in the central Brazilian plateau. This vegetation is rich in bryophytes and 433 species have already been recorded for this region, but comparing its area and the number of works published with the others Brazilian vegetations, it remains as one of the lesser knowledge about the Bryophyte species diversity (Câmara and Vital, 2004, 2006; Câmara and Costa, 2006; Câmara, 2008a; Forzza *et al.*, 2010). In the last decades the Cerrado vegetation has been reduced to non-continuous fragments with loss of native species (Machado *et al*., 2004; Pivello, 2005; Mittermeier *et al*., 2005), and concerning about the bryophyte diversity, the little knowledge is an impediment for conservation actions and management of their diversity (Santos, 2006).

The Goiás State is totally included in the Cerrado domain But few works were developed in this state and there is 318 bryophyte species recorded. This information comes from taxonomical works, such as Gradstein *et al.* (2005); Yano and Peralta (2007, 2008); Peralta *et al.* (2008); Sousa *et al.* (2008, 2010); Soares *et al.* (2011); Pinheiro *et al.* (2012); Carvalho *et al.* (2014); Aquino *et al.* (2015); Peralta *et al.* (2015); and Costa and Peralta (2015).

Considering the degradation level of the savannahs by human action (Myers *et al.,* 2000; Machado *et al.,* 2004) and the need of information about the Cerrado bryophytes, this study aimed to survey the bryophytes in the Área de Proteção Ambiental Morro do Macaco, in the Municipality of Iporá, state of Goiás, analyzing their diversity, composition and distribution between various Cerrado vegetation types and substrates in the area studied.

Material and methods

Study area

The Área de Proteção Ambiental (APA) Morro do Macaco (16°25'212"S and 51°02'455'W) has an average area of 1,000 ha (Gomis, 1998); the altitude ranges from 400 to 800 m.s.l. and belongs to the municipality of Iporá, the largest city in this state (IBGE, 2010). The municipality's climate type is tropical semi-humid (Alves, 2011), with dry and rainy seasons well defined, where the annual rainfall are 1,200 to 1,600 mm (Longhi *et al.,* 2005). The rainfall season is concentrated during the months of November and March, with 100 and 300 mm of month mean, this period also recorded the highest temperatures means above 30°C (SECTEC/SIMEHGO, 2011). The soils are of the Oxisol and Red-Yellow with medium texture; the topography is undulating and the vegetation composed by remnants of native Cerrado (Longhi *et al.,* 2005; Cunha *et al.,* 2007).

The vegetation of the studied area is composed mainly of Gallery Forest, Deciduous Forest, Rupestrian Cerrado and Rupestrian Fields, with the forest formations concentrated at the base and tip of the hill. This area was chosen for this survey because after observing the field we considered it a very preserved remnant, because the soil is hardly rock and hence very difficult for agriculture and farming.

The Area is a conservation unit of Sustainable Use (Brasil, 2006) named APA (Environmental Protect Area, in Portuguese "Área de Proteção Ambiental") and established by the law no. 871, of June 23, 1997 (Iporá, 1997).

Methods

Samples were collected from August to December of 2010 in the following vegetation types: Gallery Forest, Deciduous Forest, Rupestrian Cerrado and Rupestrian Fields, in all average substrates. In order to analyze the composition and distribution of bryophytes in each vegetation type we collected 16 plots, four plots of 20m x 20m (400m²) for each vegetation type, with minimum distance of 100m between them. We used the collection methodology for this group described by Wiggers and Stange (2008). The samples are deposited in the herbaria SP (Herbarium SP – "Maria Eneyda P. Kauffman Fidalgo) and UEG (Herbarium UEG – Universidade Estadual de Goiás).

The identifications were done based on Jovet-Ast (1991), Sharp *et al*. (1994), Buck (1998), Gradstein and Costa (2003), Bordin and Yano (2013), as well as the classification system by Goffinet *et al.* (2009) for the Bryophyta and Crandall-Stotler *et al.* (2009) for Marchantiophyta. The samples were also classified according to the substrate from which they were extracted, as follows: soil, bark, litter, and rock, according Robins (1952).

Diversity analyzes of Shannon-Wiener (H') and Simpson indexes was calculated with the Statistica 7.0 software. The UPGMA cluster analysis among the vegetation types was calculated using the usind the presence/absence of the species. The distances were calculated by Pearson index (Legendre and Legendre, 1998).

Three matrices were prepared for analysis: (i) Species collected from different substrates versus occurring in the Cerrado vegetation types sampled; (ii) Mosses collected from different substrates versus occurring in the Cerrado vegetation types sampled; (iii) Liverworts collected on different substrates versus occurring in the Cerrado by vegetation types sampled.

Results and discussion

348 samples and found 37 bryophyte species (Table 1), with 28 species of Bryophyta in 20 genera and 16 families were analyzed. The most represented families are Fissidentaceae (seven species) and Pottiaceae (four species). The samples were collected during the end of the dry season and the beginning of the rainy season, factors that influenced the low occurrence of sporophytes, as described by Castro *et al.* (2002).

Trichostomum brachydontium Bruch.(Pottiaceae) is described in the literature as occurring from Mexico to Brazil (Sharp *et al.*, 1994), but in Brazil it is recorded only to the Northeast and Southeast (Forzza *et al*., 2010). This new record is an important fill of the gap in the Mid-West, and encourages the development of new researches in this region, as commented by Câmara and Vital (2004).

The samples collected for this survey were used to describe *Archidium oblongifolium* Peralta *et al.* (Archidiaceae, subg. *Archidiella*). This species is recognized as

Table 1. Species list and distribution with relative frequency (%) by vegetation types and substrates in the APA Morro do Macaco, Iporá municipality, Goiás, Central-western Brazil. The species signed by "*" were collected outside the plots. The collectors are cited with abbreviations in the voucher column: Cunha= J.F. Cunha; Nascimento= J.M. Nascimento; J.Oliveira= J.P.S. Oliveira.; L.Oliveira= L.S. Oliveira; Oliveira-Neto= J.F. Oliveira-Neto; Rios = A.M. Rios; Silva= R.P. Silva. BA: Bark; DF: Dry Deciduous Forest; GF: Gallery Forest; LI: Litter; RO: Rock; SO: Soil.

Taxa	GF	DF	RC	RF	SO	BA	RO	LI	Voucher
Pseudosymblepharis schimperiana (Paris) H.A.Crum	3	22	56	19	100	-	-	-	Cunha 7
Helicophyllum torquatum (Hook.) Brid.	14	86	-	-	-	36	57	7	Silva 21
Entodontopsis leucostega (Brid.) W.R.Buck & Ireland	16	69	13	2	14	32	26	28	Rios 32
Fissidens goyazensis Broth.	17	50	33	-	100	-	-	-	Rios 153
Archilejeunea parviflora (Nees) Schiffn.	20	80	-	-	-	70	20	10	Silva 23
Hyophilla involuta (Hook.) A.Jaeger	25	75	-	-	-	25	75	-	Rios 77
Eulacophyllum cultelliforme (Sull.) W.R.Buck & Ireland	95	-	5	-	42	5	53	-	Oliveira-Neto 34
Fissidens pallidinervis Mitt.	100	-	-	-	66	17	-	17	Rios 157
Cyathodium cavernarum Kunze	100	-	-	-	67	-	33	-	Rios 148
Fissidens angustifolius Sull.	100	-	-	-	100	-	-	-	Rios 149
Fissidens flaccidus Mitt.	100	-	-	-	100	-	-	-	Rios 160
Fissidens lindbergii Mitt.	100	-	-	-	100	-	-	-	Rios 150
Fissidens zollingeri Mont.	100	-	-	-	100	-	-	-	Nascimento 6
Fabronia macroblepharis Schwägr.	100	-	-	-	-	100	-	-	Rios 115
Fissidens pellucidus Hornsch.	100	-	-	-	-	-	100	-	Rios 161
Macromitrium carionis Müll. Hal.	100	-	-	-	-	-	100	-	Rios 68
Frullania gibbosa Nees	-	60	40	-	40	20	40	-	Rios 38
Frullania dusenii Steph.	-	89	11	-	-	56	22	22	Rios 30
Acrolejeunea emergens (Mitt.) Steph.	-	100	-	-	-	40	40	20	Rios 52
Erpodium coronatum (Hook. & Wilson) Mitt.	-	100	-	-	-	50	-	50	J.Oliveira 35
Fabronia ciliaris (Brid.) Brid.	-	100	-	-	-	100	-	-	Silva 15
Ochrobryum subulatum Hampe	-	100	-	-	-	100	-	-	Rios 39
Octoblepharum albidum Hedw.	-	100	-	-	-	100	-	-	Rios 39
Acrolejeunea torulosa (Lehm. & Lindenb.) Schiffn.	-	100	-	-	-	-	100	-	Silva 17
Trichostomum brachydontium Bruch	-	-	12	88	100	-	-	-	Rios 93
Archidium oblongifolium Peralta et al.	-	-	25	75	100	-	-	-	Rios 110
Weissia controversa Hedw.	-	-	33	67	100	-	-	-	Rios 101
Riccia wainionis Steph.	-	-	50	50	100	-	-	-	L.Oliveira 36
Erythrodontium longisetum (Hook.) Paris	-	-	100	-	-	100	-	-	Rios 3
Archidium ohioense Schimp. ex Müll. Hal.	-	-	-	100	100	-	-	-	Rios 20
Bryum apiculatum Schwägr.	-	-	-	100	100	-	-	-	Rios 83
Chryso-hypnum diminutivum (Hampe) W.R.Buck *	-	-	-	-	-	-	-	-	Rios 37
Lopholejeunea nigricans (Lindenb.) Schiffn *	-	-	-	-	-	-	-	-	Rios 34
Mastigolejeunea auriculata (Wilson) Schiffn. *	-	-	-	-	-	-	-	-	Rios 77
Ochrobryum gardneri (Müll.Hal.) Lindb. *	-	-	-	-	-	-	-	-	Rios 35
Tisserantiella minutissima (Mitt.) R.H.Zander*	-	-	-	-	-	-	-	-	Rios 49
Trachyphyllum dusenii (Müll.Hal. ex Broth.) Broth. *	-	-	-	-	-	-	-	-	Silva 25

endemic of the rupestrian Cerrado and Rupestrian Fields of the APA Morro do Macaco (Peralta *et al.,* 2015).

Entodontopsis leucostega (Brid.) W.R. Buck & Ireland (Stereophyllaceae) was the most frequent species, with occurrence in 163 (47%) of the samples analyzed. This moss has wide Neotropical range and is commonly recorded in the works performed in the Cerrado by Sharp *et al.* (1994); Câmara and Leite (2005); Carvalho *et al.* (2014); and Aquino *et al.* (2015).

For the liverworts we found nine species in seven genera and four families. The Lejeuneaceae was the richest family, with five species, followed by Frullaniaceae, with two species. Similarly, in other inventories in Neotropical areas, Lejeunaceae has been recorded as the richest family of liverworts and sometimes has nearly more than 50% of the liverworts species, as listed by Peralta and Yano (2005) for a swamp area in the Cerrado region; and Valente and Pôrto (2006) and Campelo and Pôrto (2007) for remnants of Atlantic Forest.

Vilas Bôas-Bastos and Bastos (1998) related the great occurrence of leaf liverworts, such as Lejeuneaceae and Frullaniaceae, with xerophytic condition that allow the development of species of large ecological amplitude tolerant of solar radiation exposition. Similar results were found in the APA Morro do Macaco.

The species recorded comprise 8% of the bryophyte species recorded to the Cerrado region and 13% of the Goiás State (Costa and Peralta, 2015).

Table 2. Comparison among the floristic list of APA Morro do Macaco (37 species), Iporá municipality, Goiás, Central-western Brazil and the published data of Cerrado vegetation works.

Localities	Species number	Common species with APA
Municipality of Alagoinhas, BA (Vilas Bôas-Bastos e Bastos, 1998).	27	4
Jalapão, TO (Câmara e Leite, 2005).	22	4
Parque Estadual da Serra dos Pireneus and proximitys, GO (Sousa *et al.*, 2008).	58	3
Reserva do IBGE, RECOR, DF (Câmara, 2008a).	26	5
Reserva do IBGE, RECOR, DF (Câmara, 2008b).	15	1
Parque Estadual da Serra dos Pireneus, GO (Sousa *et al*., 2010).	68	10
Parque Nacional de Brasília, DF (Soares *et al.,* 2011)	55	6
Parque Nacional das Chapadas dos Veadeiros, GO (Pinheiro *et al.,* 2012)	36	1
Serra de Caldas Novas, GO (Carvalho *et al*., 2014).	36	7
Municipality of Quirinópolis, GO (Aquino *et al.,* 2015).	38	6

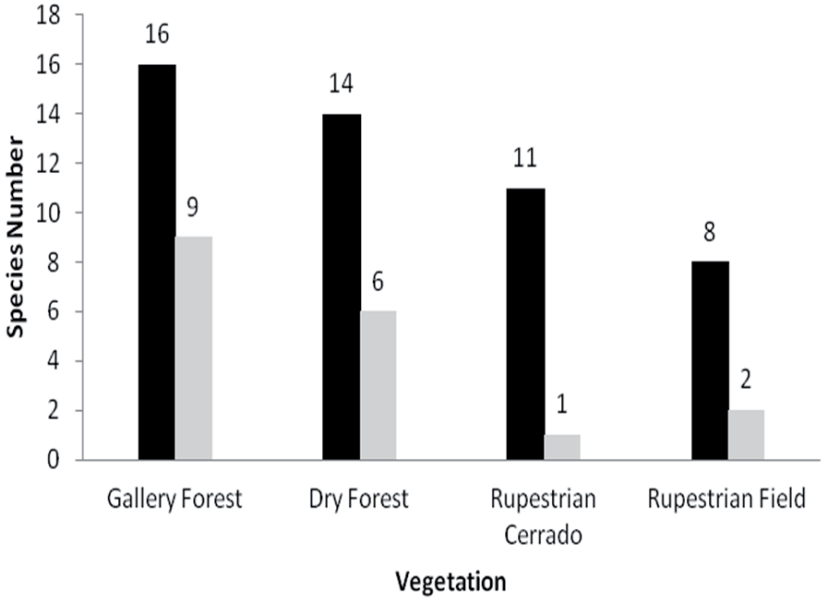

Figure 1. Bryophyte species by vegetation types in APA Morro do Macaco, Iporá municipality, Goiás, Central-western Brazil. Black: total species number; gray: number of exclusive species.

For richness comparation we discharge the sampling effort, once the work published used for comparation do not describe in details the collection methods. The works performed in the Cerrado region developed by Vilas Bôas-Bastos and Bastos (1998) recorded 23 species; Câmara and Leite, with 22 species (2005); Sousa *et al.* (2008), with 58 species; Câmara (2008a) with 26 species; Câmara (2008b), with 15 species; Sousa *et al.* (2010), with 68 species; Soares *et al.* (2011), with 55 species; Pinheiro *et al.* (2012), with 36 species; Carvalho *et al.* (2014), with 36 species and, Aquino *et al.* (2015), with 38 species. According to Pinheiro *et al.* (2012) and Peralta *et al*. (2015), the micro-habitat heterogeneity provide specific conditions of soil texture and composition and humidity essential for the establishment of the bryophytes, and the existent conditions in the APA, including forested areas and gross rock, constitute a wide gradient for bryophytes.

Table 3. *Shannon-Wiener* (H') and *Simpson* (D) index from four vegetation types in APA Morro do Macaco (November – Dezember 2010), Iporá municipality, Goiás, Central-western Brazil.

Vegetation types	*H'*	D
Gallery Forest	2.328	0.139
Dry Forest	2.005	0.220
Rupestrian Cerrado	1.740	0.276
Rupestrian Field	1.436	0.356

The Gallery Forest was the vegetation type with the highest species richness (S=16, nine of them exclusive), followed by dry forest (S=14, six exclusive), Rupestrian Cerrado (S=11 species) and Rupestrian Field (S=8, two exclusive) (Table 2, Figure 1). The highest diversity indices were found in the Gallery Forest and Dry Forest, while the highest values for the Simpson index were obtained for the formations Rupestrian Cerrado and Rupestrian Field (Table 3). These results follow the discussion provided by Vilas Bôas-Bastos and Bastos (1998); Sousa *et al.* (2010); and Aquino *et al.* (2015) relating the forested areas with greater water availability and few dry exposed areas.

Our cluster analyses of the bryophyte distribution among the vegetation types found in APA Morro do Macaco show three groups: (i) Dry Forest and Rupestrian Cerrado, (ii) Gallery Forest, (iii) Rupestrian Field (Figure 2). The Rupestrian Cerrado compared to Rupestrian Field offers greater variety of habitats, especially the occurrence of trunks, for colonization by mosses and liverworts, a factor that probably makes this vegetation type closer to Dry Forest. Visnadi (2004) found differences between species composition in grassland and savanna formations in the Reserva Biológica e Estação Experimental Mogi-Guaçu, in São Paulo state.

Considering only the mosses, the cluster topology of the vegetation types did not change the distribution pattern (Figure 3). However, to the liverworts, the topology has changed (Figure 4) for only two groups: (i) Forest formations of Gallery and Dry Forest; and (ii) Rupestrian forma-

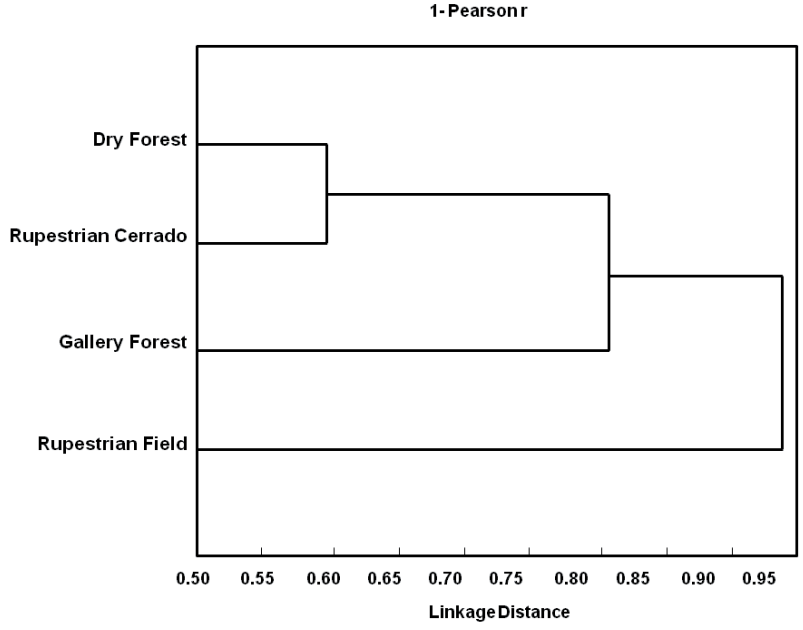

Figure 2. Vegetation types cluster by *Pearson* index and UPGMA, including all species found in APA Morro do Macaco, Iporá municipality, Goiás, Central-western Brazil.

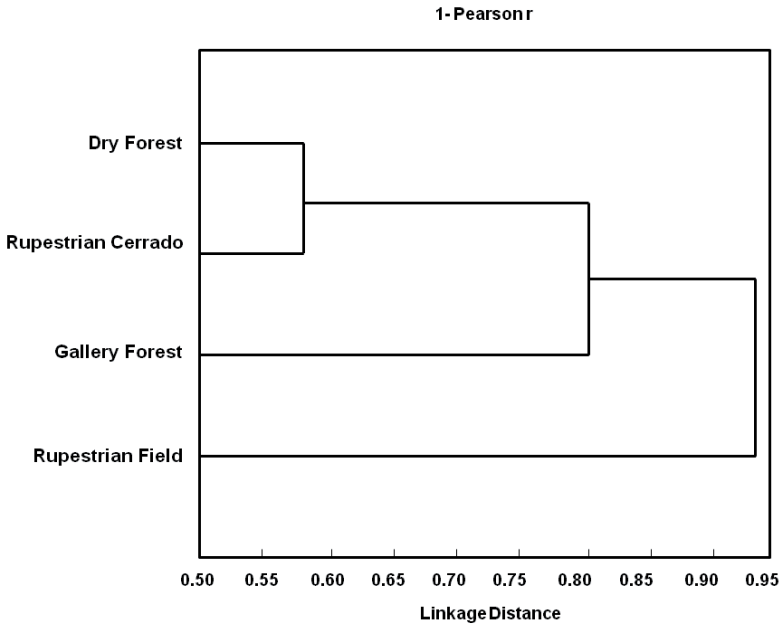

Figure 3. Vegetation type cluster by *Pearson* index and UPGMA, including only mosses found in APA Morro do Macaco, Iporá municipality, Goiás, Central-western Brazil.

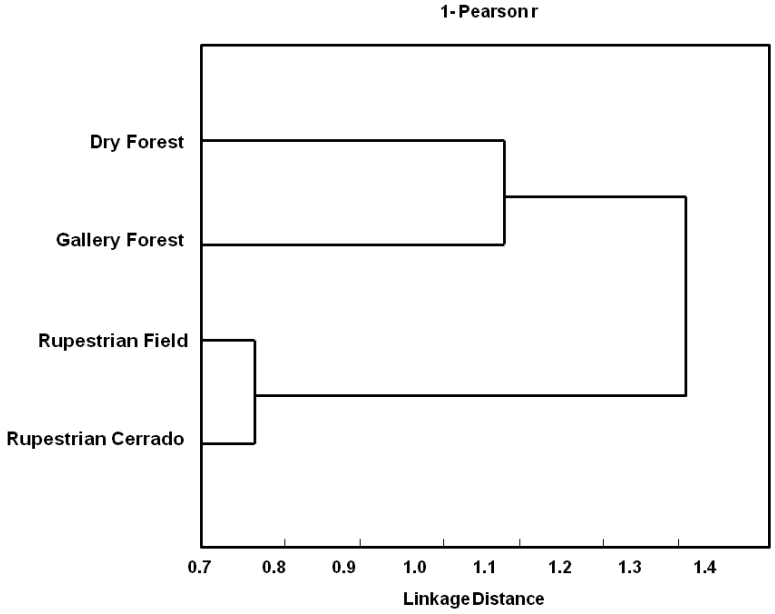

Figure 4. Vegetation type cluster by *Pearson* index and UPGMA, including only liverworts found in APA Morro do Macaco, Iporá municipality, Goiás, Central-western Brazil.

tions of Cerrado and Field. Santos *et al.* (2011) described the distribution of the bryophytes in forested areas of Atlantic Forest vegetation types as related to the stable microclimate that differ from the open vegetation. Carvalho *et al.* (2014) described the open vegetation as a barrier of dry intolerant species, similarly to our observations in the APA, because in the greatest elevations the Rupestrian is not colonized by the forest species, even with a small distance.

The cluster analysis indicate that Bryophyta is better than Marchantiophytae to group the forested areas of Gal-

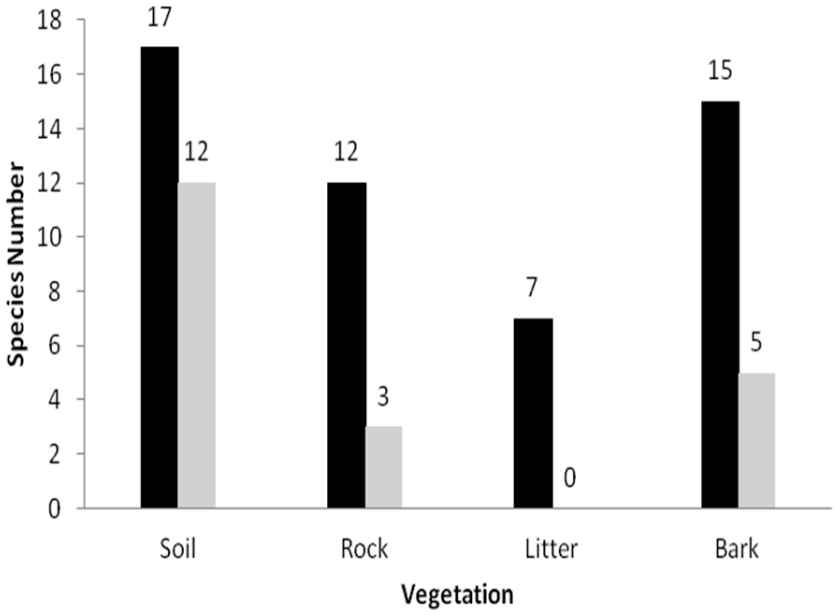

Figure 5. Species number by substrates in APA Morro do Macaco Iporá municipality, Goiás, Central-western Brazil. Black: total species number; gray: number of exclusive species.

lery Forest with Deciduous Forest and the open exposed areas of Rupestrian Cerrado with Rupestrian Fields, contrasting with the results of Visnadi (2004), in the Cerrado of Mogi Guaçu, in which liverworts is a group that established greater similarity between the vegetation types studied.

The colonization of the substrate predominance are in the following ascending order: soil (17 species); rocky surfaces (12 species), and bark (15 species) (Table 2, Figure 5). The occurrence on soil and rock of 65% of the species in the APA characterizes the area as stable and indicates specialization in the substrate colonization. These results differ from other studies in the country, in which the most colonized substrate was bark (Molinaro and Costa, 2001; Ilkiu-Borges *et al.,* 2004; Valente *et al.,* 2009). In an evaluation of the all species of the Cerrado, Costa and Peralta (2015) also describe bark and soil as the most common substrates colonized. According to Santos *et al.* (2011) and Carvalho *et al.* (2014), the vegetation acts as filters on the expansion of the communities on the ecosystems.

Our results indicate that the APA Morro do Macaco is an important remnant of Cerrado for bryophytes, since 37 species were found, with one new citation to the Mid-West region and an endemic species. The forested areas were the richest in species number and the substrate most colonized was soil.

Considering the degradation process of the Cerrado vegetation, our results encourage new surveys in this ecosystem in order to fill distribution gaps and ecological characterization of the communities, as well as to contribute for future APA conservation acts.

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Submitted on February 18, 2016
Accepted on August 25, 2016