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Geographic distribution of epiphytic bromeliads of the Una region, Northeastern Brazil

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Abstract: Many Brazilian Atlantic Rainforest plant and animal species are geographically restricted to Southern Bahia and Northern Espírito Santo States. We investigated the geographic distribution of epiphytic bromeliads in the lowland forest of the Una region (15° 17' 34" S - 39° 04' 30" W) in Southern Bahia. Specifically, we addressed the following questions: i) what is the extent of each species distribution?; and ii) are the Bromeliaceae subfamilies distributed differently from one another? Almost half of the 40 species (47.5%) occur exclusively in the Southern Bahia-Northern Espírito Santo region and are herein referred as endemic species. The highest percentage of the 15 species of Tillandsioideae (46.7%) occur throughout the South American Continent and most of the 25 species of Bromelioideae (68.0%) are mainly represented by endemic species. The Una region has almost two times more species than a forested area located 40 km west, suggesting marked increases in diversity in over relatively short distances. The endemism data around Una indicates that species are geographically distributed over an area spanning approximately six to seven degrees in latitude and longitude. This result contrasts with the geographic distribution of Andean epiphytes, mainly represented by Tillandsioideae, that have large geographical distributions. Larger-scale analyses and standardized methods are necessary to verify whether the narrow geographical distribution of most epiphytic bromeliads in the Una region is consistent across different forest types of the Atlantic Rainforest.

Keywords: Atlantic Rainforest, Bromeliaceae, endemism, geographic distribution, epiphytes.

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Resumo: Na Floresta Atlântica, muitas espécies vegetais e animais são geograficamente restritas à região do Sul da Bahia e Norte do Espírito Santo. A distribuição geográfica das bromélias epífitas da floresta de planície da região de Una, Sul da Bahia (15° 17' 34" S - 39° 04' 30" W), foi investigada para responder às seguintes questões: i) qual a extensão da distribuição geográfica das espécies?; e ii) existe diferença na distribuição geográfica das subfamílias de Bromeliaceae? Quase metade (47,5%) das 40 espécies ocorre exclusivamente na região entre o Sul da Bahia e o Norte do Espírito Santo, aqui chamadas de endêmicas. A maior percentagem das 15 espécies de Tillandsioideae (46,7%) ocorre através do Continente Sul-Americano e a maioria das 25 Bromelioideae (68,0%) é principalmente representada por espécies endêmicas. Una possui quase duas vezes mais espécies que a região de Jussari que se localiza aproximadamente 40 km à oeste, sugerindo que a diversidade desta comunidade aumente rapidamente em uma pequena extensão geográfica. Os dados de endemismo das epífitas de Una indicam que as espécies estão distribuídas através de uma área geográfica de aproximadamente seis a sete graus quadrados. Este resultado contrasta com a distribuição geográfica das epífitas andinas, que são representadas principalmente por Tillandsioideae de ampla distribuição. Análises de larga escala e com metodologias padronizadas são necessárias para verificar se a pequena distribuição geográfica da maioria das bromélias epífitas de Una é uma característica constante nas diferentes feições da Floresta Atlântica.

Palavras-chave: Floresta Atlântica, Bromeliaceae, endemismo, distribuição geográfica, epífitas.

Introduction

Bromeliaceae may inhabit rocks, forest floors and flooded areas (Smith & Downs 1974, Scarano et al. 2002) but field surveys indicate that the most frequently inhabited substrates in the Brazilian Atlantic Rainforest are tree trunks and tree crowns. For instance, in the mountainous areas of the southeastern region of this biome, the epiphytic habit occurs in 86.9% of bromeliad species (Fontoura et al. 1997). In the forest fragments of the extreme northeastern region of this biome, this habit corresponds to 65.1% of the species (Siqueira-Filho & Tabarelli 2006). Besides the representativeness of the epiphytic habit, the bromeliad species are concentrated in a core area called the Central Corridor of the Atlantic Rainforest (Martinelli et al. 2008).

The Central Corridor of the Atlantic Rainforest is represented by the State of Espírito Santo and South region of State of Bahia (Ministério do Meio Ambiente et al. 2006) and it is recognized by the high species richness and endemism of many plant and animal species (Mori et al. 1981, Mori & Boom 1983, Thomas et al. 1998, Conservation International et al. 2001, Ministério do Meio Ambiente et al. 2006, Martini et al. 2007, Amorim et al. 2008). In some cases, the geographical restriction is extreme, and some species are registered only from the South of the Bahia State to the North of the Espírito Santo State (Thomas et al. 1998), encompassing an area of approximately 75 000 km². Thus, it should be possible that such a restriction could also occur among epiphytic bromeliads from this region. Although the Central Corridor is the richest corridor in terms of number of species in Bromeliaceae (Martinelli et al. 2008), and probably of epiphytic bromeliads, just a few studies were carried out in South Bahia indicating how geographically restricted epiphytic bromeliads could be (Reis & Fontoura 2009).

Available data on the Central Corridor indicate that drier regions located less than 80 km away from the Atlantic Ocean have about one fourth of epiphytic bromeliads restricted to the South of the State of Bahia to the North of the State of Espírito Santo (Reis & Fontoura 2009). For the subfamilies of Bromeliaceae, some indirect and general analyses indicate that, the Bromelioideae (with many epiphytic members) would be highly prone to extinction because of the restriction of the species to only a few localities (Andersen et al. 1997).

We aimed to investigate the geographic distribution of the epiphytic bromeliads of a lowland area in a South Bahia region, namely the Una region, to address the following questions: i) to what extent are the species of epiphytic bromeliads geographically distributed?; and ii) are there differences in the geographic distribution of Bromeliaceae subfamilies? These analyses allowed us to discuss the geographic distribution of epiphytic bromeliads locally, in the Central Corridor, the representativeness of the investigated flora in this region, and the extent to which this life form is geographically restricted in lowland forests of the South Bahia region.

Methods

1. Study area

The municipality of Una is located 503 km South of the city of Salvador (15° 17' 34" S - 39° 04' 30" W). The total area of the municipality is 115,853.8 ha, the highest altitude of the landscape is about 100 m above sea level.

The predominant vegetation is classified as Southern Bahian wet forest (Thomas et al. 1998) or Ombrophilous Dense Lowland Forest (Veloso et al. 1991) within an Af climatic region, according to Köppen's classification (CEPLAC & IICA 1976). The mean rainfall

is 1,800 mm/year. However, eventual one to three rainless months were already registered from December to March (Mori et al. 1981, Thomas et al. 1998).

The presence of the Una Biological Reserve (UBR) is an important feature of Una municipality. The UBR has an area of 18,500 ha (ca. 15.9% of the municipality area), and is characterized by the presence of forest fragments of different sizes, cattle pasture, palm trees, rubber and cocoa plantations. The cocoa plantations are common agroforestry systems in the region, where the remaining forest trees usually harbor high densities of bromeliads (Alves, M.C. 1990, Alves, T.F. 2005).

2. Sampling

Bromeliads were surveyed in area of 21,500 ha corresponding to the UBR and surrounding region. Forest fragments of different succession stages and sizes, and cocoa plantations were surveyed over a 30-month period. All fertile bromeliads were photographed and collected using high pruner or adaptations of the "single rope technique" (Perry 1978). Vouchers were deposited at the Universidade Estadual de Santa Cruz Herbarium (HUESC).

3. Data analysis

The geographical distribution was verified by examining vouchers in the following herbaria: Centro de Estudos e Pesquisa do Cacau (CEPEC), Herbarium Bradeanum (HB), Instituto de Botânica (IB), Jardim Botânico do Rio de Janeiro (RB), Museu Nacional (R), and the Universidade Estadual de Santa Cruz (UESC). As some herbaria are located in the southeastern region of Brazil (HB, IB, RB), it is expected a low over-representation of collections (see Nelson et al. 1990) in the investigated region, which is located in Northeastern region of Brazil.

Plant identification and geographical distribution were based on photos of plant types on the Internet, on the original descriptions of species, and the monographic studies by Smith & Downs (1977, 1979), Leme (1987, 1997, 1999, 2000), Siqueira-Filho & Leme (2006), Sousa, G.M. (2004), Sousa, L.O.F. & Wendt (2008), Martinelli et al. (2008), and all of the new species that were published after the Flora Neotropica for the State of Bahia.

After examining the bibliography and a total of 1947 vouchers, species were classified as occurring as follows: 1) from the South of Bahia to the North of the State of Espírito Santo (endemic); 2) from the South of Bahia to the North of the Atlantic Rainforest (N); 3) from Southern Bahia to the south of this biome (S); 4) along the entire Atlantic Rainforest (AR); 5) occurring throughout the continent (wide); and 6) from Southern Bahia, to Minas Gerais and southern regions of this biome (I).

Results

Forty-one species were collected distributed in 11 genera, mostly from the subfamily Bromelioideae (65.7%; Table 1). *Aechmea* (11 species) and *Vriesea* (nine species) were the most diversified genera (Table 2). One species remained unidentified and therefore was not considered in the geographic analysis.

The largest percentage of the species is endemic (47.5%), followed by species occurring from Southern Bahia to the south of the biome (17.5%) and those with a wide distribution (17.5%; Table 3). Excluding the seven species with wide distribution, 33 species (82.5%) were found in the Atlantic Rainforest, most of these belong to the Bromelioideae.

Tillandsioideae had the highest percentage of species with wide distribution (46.7%), and the highest percentage of Bromelioideae was represented by endemic species (Table 3).

Discussion

In a regional scale, the richness and percentage of endemic epiphytic bromeliads occurring in the Una region is larger than a nearby studied forest. Jussari has an estimated richness of 25 species and a percentage of endemism of 27.3% (Reis & Fontoura 2009). It is located West of Una, at a maximum distance of 60 km away from the

Atlantic Ocean, being characterized by a transitional forest between Ombrophilous Dense and Semideciduous forest (Amorim et al. 2005). As the maximum distance of the BRU from the Ocean is about 20 km, the two surveyed areas are about 36 - 40 km distant from each other. Although surveyed areas and sample methods were not the same, the differences in species richness and percentage of endemism suggest that the epiphytic community increases and modifies rapidly in a short

Table 1. Subfamilies, species and geographical distribution of epiphytic bromeliads of the Una region, Northeastern Brazil. Endemic - from the South of Bahia to the North of the State of Espírito Santo; N - from the South of Bahia to the North of the Atlantic Rainforest; S - from Southern Bahia to the South of this biome; AR - along the entire Atlantic Rainforest; Wide - in the Atlantic Rainforest or in other Brazilian biomes and/or other countries; I - from Southern Bahia to the southern and inner regions of this biome.

Subfamily/Species	Geographical distribution
BROMELIOIDEAE	
1. <i>A. blanchetiana</i> (Baker) L.B. Sm.	Endemic
2. <i>A. conifera</i> L.B. Sm.	N
3. <i>A. depressa</i> L.B. Sm.	Endemic
4. <i>A. froesii</i> Leme and J.A. Siqueira	N
5. <i>A. leonard-kentiana</i> H. E. Luther and Leme	Endemic
6. <i>A. leucolepis</i> L.B. Sm.	Endemic
7. <i>A. marauensis</i> Leme	N
8. <i>A. mollis</i> L.B. Sm.	Endemic
9. <i>A. perforata</i> L.B. Sm.	Endemic
10. <i>A. sulbahianensis</i> Leme, Amorim and J.A. Siqueira	N
11. <i>A. turbinocalyx</i> Mez	Endemic
12. <i>Aechmea</i> sp.	-
14. <i>Billbergia morelii</i> Brongn.	AR
13. <i>B. saundersii</i> Bull	I
15. <i>Hohenbergia blanchetii</i> (Baker) E.Morren ex Mez	N
16. <i>H. brachycephala</i> L.B. Smith	Endemic
17. <i>H. hatschbachii</i> Leme	Endemic
18. <i>Lymania azurea</i> Leme	Endemic
19. <i>L. corallina</i> (Beer) Read	Endemic
20. <i>L. smithii</i> Read	N
21. <i>Neoregelia crispata</i> Leme	Endemic
22. <i>N. longisepala</i> E. Pereira and Penna	Endemic
23. <i>N. wilsoniana</i> M.B. Foster	Endemic
24. <i>Nidularium amorinii</i> Leme	Endemic
25. <i>N. procerum</i> Lindm.	S
26. <i>Ronnbergia brasiliensis</i> E. Pereira and L. A. Penna	Endemic
TILLANDSIOIDEAE	
27. <i>Guzmania lingulata</i> (L.) Mez	wide
28. <i>Racinaea spiculosa</i> (Griseb.) M.A. Spencer and L.B. Sm.	wide
29. <i>Tillandsia bulbosa</i> Hook.	wide
30. <i>T. sprengeliana</i> Klotzsch ex Mez	wide
31. <i>T. stricta</i> Sol.ex Sims	wide
32. <i>T. tenuifolia</i> L.	wide
33. <i>Vriesea drepanocarpa</i> (Baker) Mez	S
34. <i>V. duvaliana</i> E. Morren	S
35. <i>V. ensiformis</i> (Vell.) Beer	S
36. <i>V. flammea</i> L.B. Sm.	S
37. <i>V. graciliscapa</i> Weber	Endemic
38. <i>V. minuta</i> Leme	Endemic
39. <i>V. procera</i> (Mart. ex Schult. F.) Wittm.	wide
40. <i>V. psittacina</i> (Hook.) Lindl. var. <i>rubro-bracteata</i> Hook.	S
41. <i>V. aff. tijucana</i> E. Pereira	S

geographical range. The use of standardized sample methodology in different areas of the Central Corridor is necessary to verify if this species turnover modification is resultant of a methodological artifact, and/or if both regions have a distinct epiphytic vegetation because of the transitional forest occurring in Jussari.

Some approximations are necessary to allow comparisons between the percentage of endemic species that occur in the present survey and the results of other studies from South America. Based on the fact that all of our records were derived from forest remnants that were less than 50 km away from the ocean and the fact that the region between Southern Bahia and the Espírito Santo State encompasses six to seven degrees of latitude, we may say that the geographical-range size of 47.5% of the Una epiphytes is approximately six to seven squared degrees. This approximation contrasts with the range size of Andean epiphytes sampled in 285.5 ha occurring in different forest types (Kessler 2002a). Fifty degrees squared and 147 degrees squared were estimated as the median range of northern and western epiphytes, including epiphytic bromeliads (Kessler 2000, 2001, 2002a, b). Based on these results and on the analysis of all bromeliad species from Eastern Brazil (Martinelli et al. 2008), it is probable that the wide geographical distribution of epiphytic bromeliads is valid only for South American regions outside the Brazilian Atlantic Rainforest (but see Kreft et al. 2004). In those regions, the epiphytic bromeliad species are represented by Tillandsioideae, which may have high dispersal abilities and physiological plasticity (Kessler 2000, 2001, 2002a, b; Givnish et al. 2007). Nevertheless, this is not the case of Una lowland forest and probably the large geographical distribution attributed to epiphytes (Nieder et al. 1999, 2001) does not apply to most of epiphytes from Eastern Brazil. This biome is largely dominated by the subfamily Bromelioideae (Smith & Downs 1974, Versieux & Wendt 2007, Martinelli et al. 2008) with geographically restricted species. In the Una region, it may be said that subfamilies contribute differently with respect to the geographical

distribution of species: the Tillandsioideae subfamily with its widely distributed species, and the Bromelioideae with its geographically restricted species, yet a restricted endemism is characteristic of the Una region.

The representativeness of the 41 species in the Central Corridor of the Atlantic Rainforest may be evaluated through a comparison with the Una Biological Reserve checklist (Amorim et al. 2008). Quantitatively, the present work recorded more species than Amorim et al. (2008) had done, whose inventory totaled 39 Bromeliaceae species. Excluding one undetermined species, the present work recorded 40 species, whereas the previous work recorded 35; eight species are exclusively epiphytic species collected by Amorim et al. (2008), 20 were only registered in the present inventory, and 20 were recorded in both studies. Thus, the probable number of epiphytic species of Bromeliaceae in the region must be around 48-50. Although several models can depict species-area relationship (see Caswell & Cohen 1993), the use a simple proportionality based on all of the identified species, reveals that the inventoried region hosts 12.4% of the 396 bromeliad species recorded in the Central Corridor of the Atlantic Rainforest (Martinelli et al. 2008). Although inventories that use standardized sample methods are desirable, it is interesting to point out that this percentage is, nonetheless, biologically significant. The Una region is one of the last areas that still possess some of the characteristics of the formerly extensive Atlantic Rainforest (Johns 1999).

Our analyses revealed that 82.5% of the Una epiphytes are endemic to the Atlantic Rainforest. This restriction is in accordance with the endemism for many plant groups (Mori et al. 1981, Thomas et al. 1998, Martini et al. 2007), including the Bromeliaceae family, with 81.3% of the species restricted to this biome (Martinelli et al. 2008). Based on the fact that many organisms are geographically restricted to the Southern Bahia-Northern Espírito Santo region (Thomas et al. 1998, Conservation International et al. 2001, Martini et al. 2007), and presuming that our results are indicative of other lowland areas from Southern Bahia, it is probable that the proposed pattern of wide distribution of epiphytic bromeliads (Kessler 2000, 2001, 2002a, b) does not apply to the entire region of the Central Corridor of the Atlantic Rainforest. However, large-scale analyses are necessary to verify whether the narrow geographic distribution of epiphytic bromeliads is a constant feature in the different forest types in the Atlantic Rainforest.

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Table 2. Species richness per genera of epiphytic bromeliads of the Una region, Northeastern Brazil.

Genera	Species (%)
<i>Aechmea</i>	12 (29.3)
<i>Billbergia</i>	2 (4.9)
<i>Hohenbergia</i>	3 (7.3)
<i>Lymania</i>	3 (7.3)
<i>Neoregelia</i>	3 (7.3)
<i>Nidularium</i>	2 (4.9)
<i>Ronnbergia</i>	1 (2.4)
<i>Guzmania</i>	1 (2.4)
<i>Racineae</i>	1 (2.4)
<i>Tillandsia</i>	4 (9.8)
<i>Vriesea</i>	9 (22.0)
Total	41 (100)

Table 3. Contribution of species and subfamilies to the geographical distribution of epiphytic bromeliads of the Una region, Northeastern Brazil.

Geographical distribution	Species (%)	Bromelioideae (%)	Tillandsioideae (%)
Southern Bahia - North of Espírito Santo	19 (47.5)	17 (68.0)	2 (13.3)
Southern Bahia - North of the Atlantic Rainforest	5 (12.5)	5 (20.0)	-
Southern Bahia - South of the Atlantic Rainforest	7 (17.5)	1 (4.0)	6 (40.0)
Along the entire Atlantic Rainforest	1 (2.5)	1 (4.0)	-
In the Atlantic Rainforest or in other Brazilian biomes and/or other countries	7 (17.5)	-	7 (46.7)
Southern Bahia - southern and inner regions of the Atlantic Rainforest	1 (2.5)	1 (4.0)	-
Total	40 (100)	25 (100)	15 (100)

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