



UNIVERSIDADE FEDERAL DO RIO GRANDE DO NORTE
CENTRO DE BIOCÊNCIAS
PROGRAMA DE PÓS-GRADUAÇÃO EM SISTEMÁTICA E EVOLUÇÃO

TAXONOMIA E BIOGEOGRAFIA DE BROMELIACEAE
NA DISTRIBUIÇÃO NORTE DA CAATINGA E MATA
ATLÂNTICA DO BRASIL

EDUARDO CALISTO TOMAZ

Dissertação de Mestrado
Natal/RN, Fevereiro de 2019

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Dissertação apresentada ao Programa de Pós-graduação em Sistemática e Evolução da Universidade Federal do Rio Grande do Norte, em cumprimento às exigências para obtenção do título de mestre em Sistemática e Evolução.

Orientador: Dr. Leonardo de Melo Versieux

NATAL

2019

Universidade Federal do Rio Grande do Norte - UFRN
Sistema de Bibliotecas - SISBI
Catalogação de Publicação na Fonte. Biblioteca Central Zila Mamede

Tomaz, Eduardo Calisto.

Taxonomia e biogeografia de Bromeliaceae na distribuição norte da Caatinga e Mata Atlântica do Brasil / Eduardo Calisto Tomaz. - 2019.

222 f.: il.

Dissertação (mestrado) - Universidade Federal do Rio Grande do Norte, Centro de Biociências, Programa de Pós-Graduação em Sistemática e Evolução, Natal, RN, 2019.

Orientador: Prof. Dr. Leonardo de Melo Versieux.

1. Bromélias - Dissertação. 2. Neotrópicos - Dissertação. 3. Biodiversidade - Dissertação. 4. Morfologia - Dissertação. 5. Conservação - Dissertação. I. Versieux, Leonardo de Melo. II. Título.

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Aprovada em: 27 de fevereiro de 2019.

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À minha família,
por todo o carinho e cuidado.

AGRADECIMENTOS

À Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) e ao programa de Pós-graduação em Sistemática e Evolução da UFRN pela bolsa de estudos concedida e auxílio financeiro para trabalho de campo.

Ao meu orientador, Dr. Leonardo Versieux, por me acompanhar nessa jornada pelo mundo extraordinário das bromélias. Obrigado pelos ensinamentos e paciência.

Às professoras Fernanda Antunes e Alice Calvente, por me apresentarem ao magnífico pensamento biogeográfico.

Aos curadores, corpo técnico e colaboradores dos herbários visitados, pela boa recepção, em especial Dr. Leandro Sousa (MOSS), Dra. Iracema Loyola e Sarah Sued (EAC), Dr. Elnatan Souza (HUVA) e Ana Moraes e Dra. Karina Linhares (HCDAL).

Às companhias de campo no Ceará: Pâmela, Donis, Kadija e Paulo (Chapada do Araripe); Elnatan, Francisco, André e Ricardo (Serra da Meruoca); Elnatan, Ricardo P., Leandro, Valéria, Cecília, Marcelo e Gleidson (Maciço de Baturité); Adriano (Maranguape); e Iracema e Valéria (Serra das Matas).

Aos atuais e ex-membros do Laboratório de Botânica Sistemática da UFRN: Mayara, Ana Paula, Victor, Maurício, João Paulo, Viviane, Ana Clara, Matheus, Gabriel, *et al.*, pelos bons momentos. Aos servidores Anderson e Elaine, pela prontidão em ajudar. E ao Potiguar Flora Group, pelas dicas e dúvidas resolvidas.

A Arthur, Edwesley, Tianisa, Amanda e Alan, presentes que botânica me trouxe, pela parceria na vida, na ciência e pelos matos do Rio Grande do Norte.

À Nathalia e demais da turma de mestrado 2017.1, pelo desespero sofrido junto.

À Mariana, pelo suporte psicológico e conversas regadas à cerveja barata e café.

A Bruno, Mona, Lê, Andressa, Van, Valter e tia Silma, pela amizade e companheirismo. Obrigado pelo carinho e cuidado! E às pequenas Letícia e Beatriz, pelo brilho diário que trazem às nossas vidas.

E ao meu pai e minha mãe, Luiz e Selma, por toda dedicação e apoio dado para que eu chegasse até aqui. Mais uma vez, repito, o meu mérito é compartilhado e cientistas somos todos nós!

A todos e todas, muito obrigado!

RESUMO

Bromeliaceae é um grupo natural amplamente distribuído nos Neotrópicos e reconhecido principalmente pelo caule extremamente reduzido e folhas alterno-espíraladas. Das cerca de 3.630 espécies conhecidas, 1.177 são exclusivamente brasileiras. O Nordeste do Brasil apresenta expressiva riqueza, potencial para a descoberta de novidades em Bromeliaceae e alarmante estado de conservação, o que torna imprescindível a realização de estudos com a família na região. Assim, este trabalho objetiva analisar padrões biogeográficos de bromélias em uma porção do Nordeste do Brasil e descrever sua diversidade taxonômica, com ênfase nos estados do Ceará (CE) e Rio Grande do Norte (RN), buscando contribuir para medidas de conservação. Utilizando 2.671 registros georreferenciados compilados de plataformas *online*, analisamos riqueza, densidade de coleta, endemismo e como variáveis ambientais influenciam a distribuição de bromélias em uma ecorregião de água doce. Para os tratamentos taxonômicos, foram realizadas expedições para coleta, observação de aspectos ecológicos, fenológicos e de distribuição geográfica, e cinco herbários foram visitados para complemento das análises morfológicas. Nossa amostragem registrou 23 gêneros e 108 espécies na área estudada. Para o CE, 39 espécies foram registradas, com duas novas ocorrências e uma de variedade, além de 26 espécies para o RN, das quais quatro são novas ocorrências. Precipitação média anual e altitude são fatores importantes que afetam a riqueza e distribuição dos gêneros na área estudada, fazendo da Mata Atlântica o domínio com maior riqueza, densidade de coleta e endemismo. Por outro lado, uma faixa de baixa precipitação pode estar agindo como barreira geográfica para gêneros dependentes de umidade e precisa ser investigada mais a fundo. Concluimos que os dois estados de fato possuem riqueza subestimada e que a riqueza e endemismo de Bromeliaceae na área de estudo como um todo estão ligados a fragmentos de floresta úmida ou regiões de altitude elevada, que devem ser considerados áreas prioritárias para a conservação do grupo.

Palavras-chave: Neotrópicos, bromélias, biodiversidade, morfologia, conservação.

ABSTRACT

Bromeliaceae is a natural group widely distributed in the Neotropics and recognized mainly by the extremely reduced stem and alternate-spiraled leaves. Of the approximately 3,630 known species, 1,177 are exclusively Brazilian. Northeast Brazil has significant richness, potential for the discovery of novelties in Bromeliaceae and an alarming state of conservation, which makes it essential to carry out studies with the family in the region. Thus, this work aims to analyze biogeographical patterns of bromeliads in a portion of Northeast Brazil and to describe their taxonomic diversity, with emphasis on the states of Ceará (CE) and Rio Grande do Norte (RN), seeking to contribute to conservation measures. Using 2,671 georeferenced records compiled from online platforms, we analyzed richness, collection density, endemism, and how environmental variables influence the distribution of bromeliads in a freshwater ecoregion. For the taxonomic treatments, expeditions were carried out for collection, observation of ecological, phenological and geographical aspects, and five herbaria were visited to complement the morphological analysis. Our sample recorded 23 genera and 108 species in the studied area. Thirty-nine species were registered in CE, with two new occurrences and one of variety, besides 26 species for RN, of which four are new occurrences. Mean annual precipitation and altitude are important factors that affect the richness and distribution of the genera in the studied area, making the Atlantic Forest the domain with greater richness, collection density and endemism. On the other hand, a belt of low rainfall may be acting as a geographic barrier to moisture-dependent genera and needs to be investigated further. We conclude that the two states in fact possess underestimated richness and that the richness and endemism of Bromeliaceae in the study area as a whole are linked to fragments of wet forest or high-altitude regions, which should be considered priority areas for the conservation of the group.

Keywords: Neotropics, bromeliads, biodiversity, morphology, conservation.

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INTRODUÇÃO GERAL

As representantes de Bromeliaceae são ervas com caule em geral reduzido, folhas alterno-espiraladas e rosetadas, frequentemente formando tanques chamados fitotelma. A presença de tricomas foliares peltados, capazes de absorver água e nutrientes, e o estigma espiral-conduplicado são caracteres morfológicos que sustentam a monofilia da família (Smith & Downs 1974; Smith & Till 1998; Benzing 2000).

Bromeliaceae possui grande importância para a indústria alimentícia, na qual se destaca a espécie *Ananas comosus* L., o abacaxizeiro comum (Smith 1955). Além disso, bromélias são amplamente apreciadas pelo potencial ornamental, além de propriedades medicinais e na produção de fibras naturais (Mayo, 1992; Souza & Lorenzi 2012; Albuquerque *et al.* 2016). Também possuem significativa importância ecológica, à medida que fornecem grande variedade de recursos para outros organismos, como água, abrigo e alimento (Benzing 2000; Islair *et al.* 2015; Versieux & Wanderley 2015).

Com cerca de 3.600 espécies conhecidas, distribuídas em 70 gêneros, as bromélias ocorrem desde ambientes áridos a muito úmidos, com distribuição geográfica principalmente neotropical (Smith & Downs 1974; Butcher & Gouda 2019). No Brasil ocorrem aproximadamente 1.340 táxons, dos quais 1.177 são endêmicos (Flora do Brasil 2020). Além disso, as bromélias são particularmente diversas na Mata Atlântica, onde destaca-se o grande número de espécies epífitas, mas também são elementos importantes no domínio da Caatinga (Martinelli *et al.* 2008; Giullietii *et al.* 2012; Flora do Brasil 2020).

A Flora do Brasil 2020, em construção, lista a ocorrência de 427 espécies de bromélias no Nordeste do Brasil. Mesmo com essa expressiva riqueza de espécies, poucos estudos taxonômicos amplos têm sido realizados com a família na região até o momento, com exceção do tratamento apresentado na Flora de Sergipe (Prado *et al.* 2015). No

entanto, merecem destaque as recentes descobertas de novas espécies endêmicas no estado do Ceará e de novas ocorrências de gênero e espécies para o Rio Grande do Norte, a maioria dessas já consideradas vulneráveis, ameaçadas ou em perigo de extinção (Moura & Costa 2014; Versieux *et al.* 2013^a; Versieux *et al.* 2013b; Versieux *et al.* 2013c; Magalhães *et al.* 2014; CNCFlora 2017). Ainda na região Nordeste, Siqueira-Filho *et al.* (2006) foi pioneiro em acessar a taxonomia, distribuição geográfica, riqueza, composição de espécies e conservação de bromélias de forma conjunta na região Nordeste. No entanto, apesar desse estudo ter abordado toda a família e revelado uma grande quantidade de novas espécies, ele foi restrito aos fragmentos de Floresta Atlântica nos estados de Pernambuco e Alagoas.

Apesar de áreas prioritárias para a conservação da biodiversidade brasileira terem sido indicadas em 2007 e atualizadas para a Caatinga em 2016 pelo Ministério do Meio Ambiente, poucas medidas foram tomadas no sentido de criar e/ou ampliar unidades de conservação já existentes, o que torna crítico o estado de conservação dos remanescentes naturais de vegetação no Nordeste brasileiro (MMA 2007; MMA 2016; 2017). Nesse contexto, ao buscar uma aplicação de medidas de conservação eficientes, a pesquisa em taxonomia e a análise de padrões de distribuição de espécies têm sido indicadas com primordiais (Vane-Wright *et al.* 1991; Carvalho 2009).

Assim, levando em consideração a importância ecológica das bromélias e o alarmante estado de conservação de algumas espécies, o pouco conhecimento sobre a família no Nordeste, além do potencial para a descoberta de novidades científicas de Bromeliaceae nos estados do Ceará e Rio Grande do Norte, fazem-se necessários estudos taxonômicos e maior esforço de coleta nesses estados, visando o levantamento de dados sobre sua distribuição geográfica e variação morfológica. Aliado a isso, é evidente a necessidade de abordagens biogeográficas mais amplas, de modo a contribuir para o

conhecimento sobre a família e auxiliar na sua conservação, e conseqüentemente, da Caatinga e dos remanescentes de Mata Atlântica como um todo.

Este estudo é dividido em três capítulos. O primeiro capítulo corresponde ao tratamento taxonômico da família Bromeliaceae no estado do Rio Grande do Norte, o segundo capítulo traz um *checklist* atualizado e comentado de Bromeliaceae para o estado do Ceará e o terceiro capítulo trata de biogeografia e conservação de Bromeliaceae em uma ecorregião de água doce no Nordeste.

CAPÍTULO 1

BROMELIACEAE FROM RIO GRANDE DO NORTE STATE, NORTHEASTERN BRAZIL

Bromeliaceae from Rio Grande do Norte State, Northeastern BrazilEDUARDO CALISTO TOMAZ^{1,3} & LEONARDO M. VERSIEUX^{1, 2}

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Abstract

We present the Bromeliaceae Flora for the state of Rio Grande do Norte, Northeastern Brazil, based on extensive fieldwork, morphological analyses using herbarium and freshly collected material, and specialized literature. Twenty-six species of bromeliads were recorded in Rio Grande do Norte, distributed in ten genera and three subfamilies. Bromelioideae was the richest subfamily (eight genera/13 species), followed by Tillandsioideae (one genus/12 species), and Pitcairnioideae (one genus/one species). *Aechmea mertensii*, *Ananas ananassoides*, *Hohenbergia horrida* and *Tillandsia tenuifolia* are new records to Rio Grande do Norte. Eight species are restricted to the Eastern portion of the state, in Atlantic Forest. Caatinga dry woodlands harbor 18 species, with remarkable presence of *Bromelia laciniosa*, *Encholirium spectabile*, *Tillandsia recurvata* and *T. streptocarpa*, the four most widely distributed taxa in the state. We discuss problems related to unclear taxonomic circumscriptions of species or diverging information between authors, more expressively in *Hohenbergia*, but also in *Aechmea*, *Cryptanthus* and *Tillandsia*. The data presented here might contribute to better understand the morphological variation of these genera and indicate needed research on taxonomy. Morphological descriptions, general information about species, a map, photo plates and an identification key for all taxa are provided.

Key words: Atlantic forest, bromeliads, caatinga, distribution, floristics, taxonomy.

Introduction

Bromeliaceae are mainly herbaceous terricolous, rupicolous or epiphytic plants, generally bearing reduced stems, alternate-spiraled and rosulate leaves, often with well-developed sheaths creating a tank (phytotelma). The presence of peltate trichomes, capable of absorbing water and nutrients and protecting against over-transpiration is another remarkable trait shared by the bromeliads (Smith & Downs 1974, Smith & Till 1998, Benzing 2000).

Bromeliads have a Neotropical distribution, with nearly 3,650 species distributed in 76 genera, occurring from United States to Chile and Argentina. A single species is known to occur outside the Americas, a case of long-distance dispersal to West Africa (Smith 1934, Smith & Downs 1974, Jacques-Felix 2000, Givnish *et al.* 2004, Gouda & Butcher 2018). About 1,340 species of Bromeliaceae occur in Brazil, with 87% of that number representing endemic species (BFG 2015, Flora do Brasil 2020). In addition, bromeliads are the third most diverse family from the Atlantic Forest, to where over 653 species are restricted (Martinelli *et al.* 2008, BFG 2015).

The most recent overview of Brazil's Flora (BFG 2015) indicates the state of Rio Grande do Norte (RN), in Northeastern Brazil, as the poorest in species of plants. However, recent publications about RN's Bromeliaceae (Versieux *et al.* 2013a, Versieux *et al.* 2013b, Magalhães *et al.* 2014) presented four new occurrences for the state: *Aechmea muricata* (Câmara 1810: 21) Smith (1961: 12), *Cryptanthus zonatus* (Visiani 1847: 4) Visiani (1855: 9), *Tillandsia paraibensis* Pontes (2012: 551), and *Orthophytum disjunctum* Smith (1955: 33). In addition, Versieux *et al.* (2013b) and Versieux *et al.* (2013a) also expanded the distribution of the genera *Cryptanthus* Otto & Dietrich (1836: 227) and *Orthophytum* Beer (1854: 347), which had not been registered in the state until then. Similar results have been also evidenced in other plant families (see Versieux *et al.*

2017, Moura *et al.* 2018), corroborating previous assumptions (Forzza *et al.* 2010) that the low species richness noticed for RN is a consequence of a lack of floristic and taxonomic studies. This can be associated with scarcity of graduate programs and generally low investment in research focusing on the study of biodiversity (Versieux *et al.* 2013b).

Thus, this work aims to describe and improve taxonomical knowledge about the bromeliads of RN. Here we provide a taxonomic treatment of species for the state's Flora, along with an identification key, a map of distribution, photo plates, and general information on geographic distribution, phenology and ecology, as well as economic and ethnobotanical uses.

Material and Methods

Study area. Rio Grande do Norte is one out of nine states included in the Northeast region of Brazil and, with an extension of 52,810.7 km², it represents around 3.4% of that region. The vegetation of RN is composed by Atlantic Forest, Caatinga, Cerrado, *matas serranas*, riparian forests with *Copernicia* palm (*carnaubais*), beach and dune vegetation (also known as restingas) and mangroves. Caatinga represent most of the state's vegetation, followed by the Atlantic Forest, both treated as biomes in official vegetation maps (IDEMA 2014).

Data collection and analyses. We reviewed material from UFRN and MOSS herbaria collections (acronyms according to Thiers [cont. upd.]). We carried out ten field expeditions from the coast toward inland areas of RN, and data were collected from 2010 to 2017, with vouchers deposited in UFRN herbarium. Information on geographic distribution was obtained from field observations, herbarium data and specialized literature.

Species descriptions were based on morphological analyses of herbarium and fresh material (when available), information gathered from specimen's labels and observations and measurements taken in the field, with morphological terminology following Radford *et al.* (1974), Beentje (2010) and Koide (1998). Measurements of inflorescence only include its fertile portion and not the peduncle. Species with only sterile specimens are included in the identification key, but description is only provided for *Tillandsia usneoides* (Linnaeus 1753: 287) Linnaeus (1762: 411), which the authors confirmed the occurrence in field. Morphological characters that could not be observed are indicated as “not seen”.

Mapping. As ongoing research of the Flora of RN have not used grid cells to organize and cite collections, here we adopted the following procedure, which may be replicated by future floras of RN state. A grid containing $0.5^{\circ} \times 0.5^{\circ}$ cells was plotted over the state map and all cells overlapping the state's area (30) received an alphanumeric code, from A to E (Fig. 1). We examined the 167 state municipalities under the map grid and set their administrative center's geographic coordinates (available from IBGE 2018) as the landmark to assign municipalities to grid cells, as done by Versieux & Wendt (2007). Table 2 brings all municipalities per cell, followed by the total number of Bromeliaceae records (herbarium collections from each). Finally, based on specimen labels, cell codes were listed for all species in the taxonomic treatment, in order to represent their geographic distribution in the state. The map was created with software QGIS 2.18.18 (QGIS Development Team 2018).

Results and Discussion

When we started our fieldwork in 2010, the total number of bromeliad species reported for RN was 12 (Forzza *et al.* 2010). Here we report 26 species occurring in RN,

distributed in ten genera and three subfamilies (Table 1). Bromelioideae was the richest subfamily, represented by 13 species and eight genera, followed by Tillandsioideae, with 12 species and Pitcairnioideae, with only *Encholirium spectabile* Martius ex Schultes & Schultes f. (1830: 1233). *Tillandsia* was the richest genus, with 12 species, followed by *Aechmea* Ruiz & Pavón (1794: 47) and *Hohenbergia* Schultes & Schultes f. (1830: 1251), both with three species each (Table 1). Finally, our flora recorded 239 collections to 55 municipalities, and it deserves attention that the remaining 112 (~67%) municipalities of RN had no records of bromeliads (Table 2).

This study also made possible to enhance knowledge on geographical distribution of four species that are new occurrences to RN: *Aechmea mertensii* (Meyer 1818) Schultes & Schultes f. (1830: 1272), *Ananas ananassoides* (Baker 1889: 25) Smith (1939: 79), *Hohenbergia horrida* Harms (1935: 525) and *Tillandsia tenuifolia* Linnaeus (1753: 286).

Although the occurrence of *Tillandsia gardneri* has been cited for the state (Flora do Brasil 2020), this species was not included in the taxonomic treatment due to lack of fertile herbarium specimens. *Tillandsia gardneri* can be differentiated from the remaining species by the densely cinereous-lepidote leaves, with trichomes exceeding the leaf margins, older leaves marcescent and strongly reflexed and the compound, nearly globose inflorescence, with pale rose bracts and congested flowers (Wanderley *et al.* 2007, Versieux & Sousa 2015).

The following species are indicated to occur in RN in the Brazilian Flora 2020, under construction: *Ananas comosus* (Linnaeus 1754: 21) Merrill (1917: 133), *Dyckia retroflexa* Winkler (1982: 44), *Hohenbergia utriculosa* Ule (1909: 196) and *Tillandsia mallemonitii* Glaziov ex Mez (1894: 608) (Flora do Brasil 2020). We question these records, as they are probably consequences of misidentifications or errors in herbaria

labels. *Tillandsia mallemonitii* has been reported to be frequently confused with *T. recurvata* (Fiorato 2009), while *H. utriculosa* is considered part of the “*Hohenbergia. catingae* complex” (Baracho 2004), which might hinder identification as well. On the other hand, the reference of *D. retroflexa* seems to be a switch of state name (database mistake), from Rio Grande do Sul to Rio Grande do Norte, since that species is endemic to the extreme southern portion of Brazil. Moreover, although *Ananas comosus* might grow spontaneously in the Northeast region (Leme & Siqueira-Filho 2006), we found no herbarium or living specimens in the wild to support its occurrence in RN.

Identification key for Bromeliaceae species in RN

1. Leaf blades serrate (subfamily Bromelioideae or Pitcairnioideae)..... 2
 - Leaf blades entire (subfamily Tillandsioideae)..... 15
2. Rosette without tank..... 3
 - Rosette with tank developed..... 9
3. Leaf blade with margins strongly serrate; fruit capsule; seeds winged (subfamily Pitcairnioideae)..... *Encholirium spectabile* (5.1)
 - Leaf blade margins serrate or serrulate; fruit berry; seeds naked (subfamily Bromelioideae)..... 4
4. Inflorescence bearing an apical coma of foliaceous sterile bracts; fruit multiple (sorosis)..... *Ananas ananassoides* (2.1)
 - Inflorescence with apical coma absent; fruit simple..... 5
5. Leaf blades 6–30 cm long; petals white or slightly greenish..... 6
 - Leaf blades 30–300 cm long; petals lilac to purple..... 7
6. Rupicolous plants; leaves densely lepidote on both faces; peduncle developed..... *Orthophytum disjunctum* (8.1)

- Terricolous plants; leaves with adaxial face glabrescent or bearing white stripes of trichomes, densely lepidote only abaxially; peduncle reduced.....*Cryptanthus zonatus* (4.1)
- 7. Leaves few numbered (<10), variegate with alternated white bands; flowers conspicuously pedicellate..... *Neoglaziovia variegata* (7.1)
- Leaves numerous (>10), not variegate; flowers inconspicuously pedicellate..... 8
- 8. Leaf blades 30–90 cm long, peduncle developed; inflorescence densely white-lepidote..... *Bromelia laciniosa* (3.2)
- Leaf blades 100–300 cm long; peduncle short; inflorescence densely ferruginous tomentose..... *Bromelia* sp. (3.1)
- 9. Inflorescence simple, strobiliiform..... *Aechmea muricata* (1.3)
- Inflorescence compound, panicle or panicle of spikes..... 10
- 10. Flowers laxly arranged along the inflorescence branches; petals white.....*Wittmackia patentissima* (10.1)
- Flowers congested in inflorescence branches; petals yellow, orange or purplish..... 11
- 11. Flowers disposed in short lateral spikes or agglomerated distally in inflorescence branches; primary bracts bright red or reddish-pink; petals yellow or orange..... 12
- Flowers disposed in strobilate spikes; primary bracts paleaceous; petals lilac to purple..... 13
- 12. Plants epiphytic; primary bracts serrulate; floral bracts *ca.* 4 mm long..... *Aechmea mertensii* (1.2)
- Plants terricolous or rupicolous; primary bracts entire; floral bracts 2–3 cm long.....*Aechmea aquilega* (1.1)

13. Terricolous or epiphytic plants; floral bracts 7–12 mm long, shorter to rarely equaling or slightly exceeding the sepals; sepals with apex mucronulate, mucro *ca.* 0.5 mm long..... *Hohenbergia ridleyi* (6.3)
- Rupicolous plants; floral bracts 14–20 mm long, much exceeding the sepals; sepals with apex evidently mucronate, mucro 1–3 mm long 14
14. Floral bracts 14–15 mm long, chartaceous, markedly nerved; sepals 6–7 mm long, with apical mucro *ca.* 1 mm long and membranaceous wing equaling or slightly exceeding its apex..... *Hohenbergia catingae* (6.1)
- Floral bracts 15–20 mm long, coriaceous, finely nerved; sepals 7–10 mm long, with apical mucro 2–3 mm long and membranaceous wing evidently shorter than the apex..... *Hohenbergia horrida* (6.2)
15. Leaves distichous.....16
- Leaves spiraled..... 17
16. Plants forming dense and long clusters pending from tree branches; roots absent; stems filiform and visible..... *Tillandsia usneoides* (9.11)
- Plants forming dense nearly rounded tufts; roots present; stems reduced and covered by the leaves..... *Tillandsia recurvata* (9.6)
17. Leaf blades usually up to 3 cm long; petals yellow to orange..... 18
- Leaf blades over 5 cm long; petals white, vinaceous or purplish..... 19
18. Stem developed, with leaves distributed all along its length; inflorescence rachis straight..... *Tillandsia tricholepis* (9.10)
- Stem reduced, with leaves forming a short rosette; inflorescence rachis geniculate..... *Tillandsia loliacea* (9.2)
19. Rosette broadly open; petals strongly spatulate..... *Tillandsia streptocarpa* (9.7)

- Rosette infundibuliform, utriculose, bulbform or densely fasciculate; petals spatulate, oblanceolate or ligulate.....20
- 20. Floral bracts green or vinaceous; flowers distichous; stamens exserted.....21
- Floral bracts light to bright pink, sometimes turning white; flowers polystichous; stamens included.....23
- 21. Rosette infundibuliform; leaf blades chartaceous.....*Tillandsia polystachia* (9.5)
- Rosette utriculose or bulbform; leaf blades slightly incrassate to incrassate..... 22
- 22. Leaf sheaths strongly imbricate; inflorescence straight; flowers congested; petals purple..... *Tillandsia bulbosa* (9.1)
- Leaf sheaths not imbricate; inflorescence curved; flowers lax; petals vinaceous.....*Tillandsia paraensis* (9.3)
- 23. Leaves densely cinereous-lepidote (with color obscured by the indumentum).....24
- Leaves slightly lepidote (with color conspicuous)..... 25
- 24. Older leaves reflexed; flowers congested; petals reddish.....*Tillandsia gardneri* (9.2)
- Older leaves oriented as the younger; flowers lax; petals white.....*Tillandsia paraibensis* (9.4)
- 25. Stem developed; peduncle straight; floral bracts imbricate; petals white.....*Tillandsia tenuifolia* (9.9)
- Stem reduced; peduncle arcuate; floral bracts remote; petals bluish-purple to lilac..... *Tillandsia stricta* (9.8)

Taxonomic Treatment

1. *Aechmea* Ruiz & Pavón (1794: 47)

Epiphytic, rupicolous or terricolous herbs. Rosette infundibuliform to tubular. Leaves coriaceous; leaf sheath wide; leaf blade serrate to serrulate. Inflorescence simple

to compound, congested, strobiliform or lax; peduncle present, generally well developed and stout; peduncle bracts polystichous. Floral bracts conspicuous to inconspicuous. Flowers sessile or pedicellate. Sepals asymmetric, aristate to mucronate. Petals yellow, green, purple or white, free, bearing a basal pair of petal appendages and/or callosities. Stamens included. Fruit berry.

Aechmea comprehend around 247 species, distributed in eight subgenera. Although 187 species have occurrence cited to Brazil (Flora do Brasil 2020), 23 of these are now placed in genus *Wittmackia* (Aguirre-Santoro 2017). *Aechmea* is particularly diverse in the Brazilian Atlantic Forest, with most species occurring in the Northeast (Smith & Downs 1979, Maciel *et al.* 2015, Aguirre-Santoro 2017, Gouda & Butcher 2018, Flora do Brasil 2020). However, the genus is represented only by three species in RN, mostly distributed along the coast of the state, in fragments of Atlantic Forest, but also with one taxon in areas of Caatinga.

1.1. *Aechmea aquilega* (Salisbury, in Salisbury & Hooker 1806: pl. 40) Grisebach (1864: 592) [Fig. 2C–D]

Herb terricolous or rupicolous. *Rosette* infundibuliform, tank present. *Leaves* erect to suberect, coriaceous; *leaf sheath* 17–21 × 8–15 cm, elliptic, greenish-brown; *leaf blade* 52–10 × 6–7 cm, narrowly lanceolate, green or reddish-yellow, margin serrate, apex acuminate; *aculei* 3–6 mm long, antrorse, laxly arranged. *Peduncle* 35–90 cm long, erect, pink, lanuginose; *peduncle bracts* 12–21 × 4–4.7 cm, elliptic-lanceolate, pinkish-red, apex acuminate. *Inflorescence* 17–24 cm long, paniculate, cylindrical to pyramidal; *primary bracts* 3.5–15 × 0.6–3 cm, elliptic-lanceolate, pinkish-red, patent to reflexed, margin entire, apex acuminate, pungent; *lateral branches* with flowers agglomerated distally; *floral bracts* 2–3 × 1 cm, ovate, carinate, only partially covering the ovary,

greenish-yellow, apex pungent. *Flowers* sessile, congested; *sepals* 1.7–3 cm long, asymmetric, carinate, greenish-yellow, apex mucronulate; *petals* 3.3–3.5 cm long, slightly spatulate, bright orange, apex acute; petal appendages *ca.* 3 mm long, obovate, apex erose; *stamens* included. *Fruits* *ca.* 2.5 × 0.5 cm, ovoid, dark purple to black.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Extremoz, APA Jenipabu, 2 October 2010, fl., A.M. Marinho *et al.* 193 (UFRN); *ibid.*, 2 February 2011, fl., J.L. Costa-Lima *et al.* 319 (UFRN); *ibid.*, 31 January 2015, fl., I.C.L. Oliveira *et al.* 9 (UFRN). Natal, Redinha, 21 February 2015, fl., E.C. Tomaz & L.G. Tomaz 4 (UFRN). Nísia Floresta, lagoa Guamaré, 4 November 2007, fl., R.C. Oliveira *et al.* 2088 (MOSS). Serra de São Bento, morro da Cara Branca, 25 August 2012, fr., L.M. Versieux *et al.* 556 (UFRN); *ibid.*, *ca.* 1km da sede municipal, 21 December 2015, fl., E.C. Tomaz *et al.* 95 (UFRN). Touros, propriedade privada, 27 February 2016, fl., A.M. Marinho 229 (UFRN); *ibid.*, RN-221, 11 June 2016, fl., E.C. Tomaz *et al.* 113 (UFRN).

Distribution, habitat and phenology:—*Aechmea aquilega* is distributed in Central and South America. In Brazil, it occurs in most of the Northeastern states, but also Espírito Santo and Amazonas (Smith & Downs 1979, Leme & Siqueira-Filho 2006, Maciel *et al.* 2015, Flora do Brasil 2020). This species is present along the coast of RN in open areas of *restinga* vegetation (Fig. 2B) and it can be also observed as rupicolous on *inselbergs*, in more inland areas dominated by caatinga, completely exposed to the sun or in the shade. Flowering from October to February, fruiting in August. Map (Fig. 1, Table 1): B6, C7, D7, D8.

Comments:—This species can be easily recognized by its compound inflorescence, with flowers concentrated in the distal portion of lateral branches, also by the pinkish-red peduncle and primary bracts, the later patent or reflexed. The floral bracts and sepals are greenish-yellow, and petals are bright orange.

Aechmea aquilega is part of the *Gravisia* complex, along with *Aechmea chrysocoma* Baker (1889: 44) and several other species. *Aechmea chrysocoma* has once been considered a variety of *A. aquilega*, but it was recently validated as an independent species (Smith & Downs 1979, Leme & Siqueira-Filho 2006). Maciel *et al.* (2015) describe *A. chrysocoma* with yellow inflorescence and red peduncle bracts, opposing to an orange colored inflorescence and peduncle bracts in *A. aquilega*. However, Leme & Siqueira-Filho (2006) pointed orange floral bracts and sepals (as well as the general appearance of the inflorescence) as a trait of *A. chrysocoma*, vs. yellowish-green floral bracts and sepals in *A. aquilega*. The specimens of *A. aquilega* found in RN show pinkish-red colored primary and peduncle bracts and yellowish-green floral bracts and sepals, in accordance with Leme & Siqueira-Filho (2006).

1.2. *Aechmea mertensii* (Meyer 1818) Schultes & Schultes f. (1830: 1272) [Fig. 2E–F]

Herb epiphytic. *Rosette* infundibuliform, tank present. *Leaves* ca. 8, suberect, chartaceous; *leaf sheath* ca. 6 × 3 cm, elliptic, whitish-green; *leaf blade* ca. 8 × 1–1.5 cm, narrowly lanceolate, green, nearly patent to recurved, margin serrate, apex acuminate, recurved; *aculei* 1.5–4 mm long, slender, antrorse to patent. *Peduncle* ca. 15 cm long, erect, slender, green, glabrous; *peduncle bracts* ca. 5 × 1 cm, elliptic, greenish-red, apex pungent. *Inflorescence* ca. 6 cm long, panicle, with flowers disposed in short lateral spikes; *primary bracts* 2.8–3.6 × 0.7–1 cm, elliptic, unguiculate, bright red, margin serrulate, apex acuminate, pungent; *spikes* 9–12 mm long, laxly disposed to congested distally; *floral bracts* ca. 4 × 8 mm, membranaceous, hyaline-green, margins expanded laterally, enfolding the ovary, apex mucronate, darkened, recurved. *Flowers* sessile, congested; *sepals* 4–4.6 mm long, asymmetric, greenish-yellow, apex mucronate; *petals* 7–8 mm long, slightly spatulate, yellow, apex acuminate, apiculate; petal appendages ca.

2 mm long, partially adnate to petal, apex free, erose; *stamens* included. *Fruits* ovoid, white to blue.

Specimen examined:—BRAZIL. **Rio Grande do Norte:** Canguaretama, nascente do rio Catu, 14 February 2016, fl., *G.S. Garcia & L.M.G. Gonçalves 123* (UFRN).

Distribution, habitat and phenology:—This species occurs from Colombia to Peru and along the Brazilian Amazon and Atlantic Forest (Smith & Downs 1979, Maciel *et al.* 2015). In the Northeast of Brazil, it has been registered in the states of Alagoas, Bahia, Maranhão, Paraíba, Pernambuco and Sergipe (Sousa & Wanderley 2000, Flora do Brasil 2020). Here we fill this gap, reporting its first occurrence in RN, with epiphytic habit in seasonal semideciduous forest. However, this record is sporadic, since only one population has been registered so far. Flowering and fruiting in February. Map (Fig. 1, Table 1): D8.

Comments:—This species can be recognized by the nearly tubular rosette, with few numbered leaves (ca. 8), the inflorescence with short lateral spikes (9–12 mm) and bright red, unguiculate primary bracts. Another diagnostic trait is the floral bract with expanded margins enfolding the ovary.

Specimens of *A. mertensii* found in RN were interacting with ants, and in fact, this species has been reported to form the remarkable “ant-gardens” (Benzing 2000). Interestingly, reproductive morphology of *A. mertensii* (especially inflorescence size and flower and fruit number) was reported to change according with the different ant species the plants associate (Leroy *et al.* 2012). This could help to explain the large and small specimens that have been observed in the Amazon and the Atlantic Forest of Northeastern Brazil (Sousa & Wanderley 2000, Maciel *et al.* 2015).

1.3. *Aechmea muricata* (Câmara 1810: 21) Smith (1961: 12) [Fig. 2G–H]

Herb terricolous. *Rosette* broadly infundibuliform, tank present. *Leaves* erect to suberect, coriaceous; *leaf sheath* 14–25 × 9–13 cm, narrowly elliptic, brown-lepidote; *leaf blade* 80–100 × 5–8 cm, oblong to lanceolate, green, densely white-lepidote, margin serrate, apex attenuate, pungent; *aculei* 2–5 mm long, laxly arranged, retrorse. *Peduncle* 25–35 cm long, erect, stout, green, white-lepidote; *peduncle bracts* (5–)9–17 × 2–6 cm, lanceolate, dense, completely hiding the peduncle, pale brown-lepidote, apex pungent. *Inflorescence* 14–20 cm long, simple, strobiliform; *floral bracts* 2.6–3.5 × 1–1.3 cm, slightly asymmetric, carinate, white-lepidote, apex cuspidate. *Flowers* sessile, congested; *sepals* 22–25 mm long, asymmetric, tricarinate, light green, white-lepidote, apex mucronate; *petals* white toward the base and dark blue distally. *Fruits* 3.8–4 cm long, ovoid.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Baía Formosa, RPPN Mata Estrela, 1 May 2012, fr., J.G. Jardim *et al.* 6252 (UFRN); *ibid.*, 24 March 2013, bot., R.E.C. Magalhães 19 (UFRN); *ibid.*, 18 May 2015, fr., E.O. Moura *et al.* 389 (UFRN).

Distribution, habitat and phenology:—*Aechmea muricata* was endemic to the state of Pernambuco, where it grows as an epiphyte (Sousa & Wanderley 2000). However, it was later registered to the state of Alagoas (Sousa *et al.* 2008, Flora do Brasil 2020) and, more recently, a small terricolous population of *A. muricata* was discovered in a fragment of Atlantic Forest, the Mata Estrela Private Reserve of Natural Heritage (RPPN Mata Estrela) (Magalhães *et al.* 2014). Flowering in January, fruiting from April to May. Map (Fig. 1, Table 1): D8.

Comments:—This species has densely white-lepidote leaves, with laxly arranged, 2–5 mm long aculei and a sharply pointed acuminate apex. It can be

differentiated from all other *Aechmea* in the state by the robust peduncle and strobiliform inflorescence (Fig. 2G), generally not exceeding the leaves, and by the white to distally dark blue petals (Fig. 2H). Sousa & Wanderley (2000) described these as follows: petals 30–33 mm long, with callosities along the filaments.

Aechmea muricata is considered a threatened species (Martinelli *et al.* 2008, MMA 2014) and the only population known in RN has probably survived because the forest fragment where it occurs has been protected, similarly to what was reported by Sousa & Wanderley (2000) for Pernambuco. Therefore, we stress the importance of maintaining the conservation measures at RPPN Mata Estrela, to guarantee the survival of *A. muricata*.

2. *Ananas* Miller (1754: 70)

Terricolous herbs. Rosette open. Leaves coriaceous; leaf sheath inconspicuous; leaf blade linear, serrate, apex pungent. Peduncle well developed; bracts lanceolate. Inflorescence simple, congest, subcylindrical, generally with an apical coma of sterile bracts. Floral bracts conspicuous, serrate, white-lepidote. Flowers sessile. Sepals free or shortly connate, margin entire. Petals free, purple to reddish after anthesis; petal appendages present. Stamens included. Fruit sorosis (multiple), fleshy.

This genus occurs throughout all South America and is widely distributed in Brazil (Smith & Downs 1979, Flora do Brasil 2020). *Ananas* has a long history of taxonomic rearrangements (Leal *et al.* 1998), the most recent proposal with all species considered varieties of *Ananas comosus* and with a broadening of concept to include *Pseudananas sagenarius* (Câmara 1810: 13) Camargo (1939: 322) (Coppens d'Eeckenbrugge & Leal 2002, Coppens d'Eeckenbrugge & Goavaerts 2015). However, such changes were proposed without the appropriate sampling and analyses (Leme & Siqueira-Filho 2006)

and even all the available phylogenetic data have not been enough to precisely define the infrageneric classification (Matuszak-Renger *et al.* 2018). In this context, we followed Smith & Downs' (1979) recognition of seven species, as we understand this is still the most reliable taxonomic treatment, despite the many inconsistencies. *Ananas ananassoides* is the only species recorded in RN and it appears as an independent species in the Matuszak-Renger *et al.* (2018) phylogeny, as it is also an accepted name by the Brazilian Flora 2020.

2.1. *Ananas ananassoides* (Baker 1889: 25) Smith (1939: 79)

Herb terricolous. *Rosette* open, tank absent. *Leaves* suberect, coriaceous; *leaf sheath* not seen; *leaf blade* ca. 50 × 4 cm, narrowly lanceolate, margin revolute, serrulate, apex attenuate; *aculei* 2–3 mm long, antrorse. *Peduncle* ca. 14 cm long, erect, slightly lanuginose to glabrescent; *peduncle bracts* 18–36 × 1–2 cm, narrowly triangular-lanceolate, margin serrulate, apex attenuate. *Inflorescence* ca. 12 cm long, simple, subcylindrical, with an apical coma of foliaceous sterile bracts; *floral bracts* 18–21 × 1–1.2 mm, widely elliptic at the base to triangular distally, coriaceous, margin serrulate, apex acuminate. *Flowers* sessile; *sepals* 7–10 mm long, widely ovate, coriaceous, shortly connate, apex acute; *petals* 16–18 long, oblanceolate, apex obtuse, purple; petal appendages basal, apex erose; callosities present; *stamens* included. *Fruits* not seen.

Specimen examined:—BRAZIL. Rio Grande do Norte: Venha-Ver, serra de São José, 5 August 2010, fl., A.A. Roque 1070 (UFRN).

Distribution, habitat and phenology:—This species occurs across Central and South America (González *et al.* 2013) and in all Brazilian regions and phytogeographic domains (Flora do Brasil 2020). In the Northeast of Brazil, the only exception is the state of Sergipe (Flora do Brasil 2020). Here we first register the occurrence of *Ananas*

ananassoides in RN, at the top of São José mountain, located in the Caatinga domain. Flowering in August. Map (Fig. 1, Table 1): D2.

Comments:—*Ananas ananassoides* can be recognized by the all antrorse leaf aculei, the subcylindrical inflorescence and fleshy multiple (sorus) fruit, topped with a coma of sterile bracts, purple flowers and floral bracts not completely covering the ovary. Even though the only existing herbarium specimen from RN was collected in a crop field (A.A. Roque, pers. com.), it matched the descriptions of the wild type found in literature (such as Smith & Downs 1979, Coppens d'Eeckenbrugge & Leal 2002, Martins *et al.* 2007). Several hybrids and cultivars involving *A. ananassoides* have been developed for ornamental purposes (Souza *et al.* 2012, Souza *et al.* 2014). Indeed, this species has been widely used for landscaping in the Northeast, Central-west and Southeast of Brazil (Wanderley *et al.* 2007) and RN was once indicated as one of its main producers (Carvalho *et al.* 2014).

3. *Bromelia* Linnaeus (1753: 285)

Terricolous herbs. Leaves coriaceous, lepidote; leaf sheath ovate, triangular or elliptic; leaf blade serrate, aculei curved. Inflorescence sessile or pedunculate, mostly compound, many-flowered. Floral bracts generally smaller than ovary. Flowers shortly pedicellate. Sepals free to connate. Petals usually fleshy, adnate to filaments forming a tube. Fruits berry, fleshy, odoriferous.

This genus includes 71 accepted taxa distributed from Mexico to South America (Smith & Downs 1979, Gouda & Butcher (cont. upd.). In Northeastern Brazil, *Bromelia* is represented by 15 species (Flora do Brasil 2020), with two occurring in RN, in both Atlantic Forest and Caatinga.

3.1. *Bromelia* sp. [Fig. 2I–J]

Herb terricolous. *Rosette* open, tank absent. *Leaves* numerous (>10), erect to suberect, coriaceous; *leaf sheath* 6–8 × 3.5–5 cm, ovate to oblong, densely tomentose; *leaf blade* 1–2.2 (–3) m × 2–4 cm, linear, canaliculate, green to vinaceous, homogeneously lepidote or nearly so, margin serrate, apex attenuate; *aculei* 4–5 mm long, antrorse or retrorse. *Inflorescence* short pedunculated, densely corymbiform, densely ferruginous tomentose. *Floral bracts* 6–8 × 1–1.5 cm, narrowly oboelliptic, densely tomentose, margin entire to serrulate, apex acute to acuminate. *Flowers* inconspicuously pedicellate; *sepals* 2.8–3 cm long, oblong, tomentose at the base, slightly carinate, apex obtuse; *petals* 2.8–3.5 cm long, oblong, fleshy, adnate to the filament tube for *ca.* 1.5 cm, apex obtuse; *stamens* included. *Fruits* 6–10 × 2 cm, fusiform, yellow when mature.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Almino Afonso, sítio serra de São Miguel, 31 January 1996, st., *F.E. Sobrinho* 259 (MOSS). Ceará-Mirim, fazenda Diamante, 9 August 2014, fl., *J.G. Jardim & J.C. Sousa-Jr.*, 6700 (UFRN). Equador, serra das Queimadas, 15 August 2015, fr., *V.F. Sousa et al.* 50 (UFRN). Jucurutu, serra de São João do Vale, 11 June 1998, fr., *V.C. Moura* 19 (MOSS). Tibau do Sul, Parque Estadual da Pipa, 2 August 2012, fl., *J.G. Jardim et al.* 6333 (UFRN).

Additional specimen examined:—BRAZIL. **Ceará:** Quixadá, serra do Estevão, 13 March 2014, fl., *L.M. Versieux et al.* 751 (UFRN).

Distribution, habitat and phenology:—In RN, *Bromelia* sp. has a disjunct distribution in areas of Caatinga and Atlantic Forest, in seasonal semideciduous forests. Flowering in August, fruiting in July and August. Map (Fig. 1, Table 1): C7, D3, D4, D8, E3.

Comments:—This species has been traditionally identified as *Bromelia karatas*, however a recent revision suggests that specimens from Northeastern and Central-

Western Brazil belong to an undescribed species (Monteiro & Forzza 2016). This is congruent with previous statement by Leme & Siqueira-Filho (2006) that the circumscription of *B. karatas* was obscure and considered too broad, possibly encompassing more than one taxon. For such reasons, here we treated it as *Bromelia* sp., but in the herbaria analyzed it was identified as *B. karatas*, which according to Monteiro & Forzza (2016) only occurs from Mexico to Northern South America.

This species is part of *Bromelia* subg. *Karatas* (*sensu* Mez 1891), which diagnostic trait is the inflorescence nested in the center of the rosette and the presence of a ferruginous indumenta covering the ovary (Monteiro *et al.* 2015). Besides the short pedunculated inflorescence (Fig. 2J), *Bromelia* sp. can be recognized by its large habit, with leaf blades linear and canaliculate (Fig. 2I), up to 3 m long, the narrowly oboelliptic floral bracts, 6–8 cm long, flowers with purple petals and long fusiform fruits.

3.2. *Bromelia laciniosa* Martius ex Schultes & Schultes f. (1830: 1278) [Fig. 2K–M]

Herb terricolous, stoloniferous. *Rosette* open, tank absent. *Leaves* suberect, coriaceous; *leaf sheath* 4–6 × *ca.* 6 cm, widely ovate, brown, margin serrate; *leaf blade* 30–90 × 1.5–2.5 cm, linear, green to dark vinaceous, margin slightly revolute, serrate, apex attenuate; *aculei* 4–9 mm long, antrorse or retrorse. *Peduncle* 13–27 cm long, erect, greenish-pink, white-lepidote to glabrescent; *peduncle bracts* 18–45 × 1–2 cm, elliptic at the base, abruptly attenuate distally, green to pink or red. *Inflorescence* 15–38 cm long, panicle, stout, rachis and branches pale pink, densely white-lepidote; *floral bracts* (2–) 6–18 × 2–5 mm, triangular, pink to paleaceous, white-lepidote, apex acuminate. *Flowers* inconspicuously pedicellate; *sepals* 9–15 mm long, ovate, carinate, pink, white-lepidote, margin sometimes slightly fimbriate, apex acute; *petals* 17–22 mm long, oblong, fleshy,

white becoming purple apically, adnate to filament tube for 6 mm, apex obtuse; *stamens* included. *Fruits* 3.5–5 × 1.5–2 cm, ellipsoid, odoriferous, yellow when mature.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Alto do Rodrigues, comunidade Barrocas, 30 May 2010, fr., *D.F. Torres & E.S. Oliveira* 69 (UFRN). Apodi, sítio São João da Roça, 20 June 1998, fr., *A.K.C. Lima* 9 (MOSS); *ibid.*, lajedo de Soledade, 25 May 2015, fr., *E.C. Tomaz & R.A. Pontes* 40 (UFRN). Bento Fernandes, serra da Cachoeira do Sapo, 8 February 2012, fl., *J.L. Costa-Lima et al.* 620 (UFRN). Campo Redondo, estrada de terra vicinal a Rodovia BR-226, 7 September 2012, fr., *L.M. Versieux et al.* 598 (UFRN). Equador, estrada vicinal que liga o município de Parelhas, 14 August 2015, fr., *E.O. Moura et al.* 435 (UFRN). João Câmara, fazenda Cauaçu, 13 March 2011, fr., *J.G. Jardim et al.* 5940 (UFRN). Macau, RDS Estadual Ponta do Tubarão, 18 May 2008, fr., *J.L. Costa-Lima* 27 (UFRN). Mossoró, campus ESAM, 17 March 1993, fl., *O.F. Oliveira* 2008 (MOSS). Santa Cruz, 3 August 2011, fr., *A.A. Roque et al.* 1219 (UFRN). São Miguel do Gostoso, margem da RN-221, 15 March 2016, fl., *E.C. Tomaz et al.* 111 (UFRN); *ibid.*, ca. 4 km da sede municipal, 15 March 2016, fr., *E.C. Tomaz et al.* 113 (UFRN).

Distribution, habitat and phenology:—The distribution of *Bromelia laciniosa* is restricted to Northeastern Brazil and to the Caatinga domain, occurring in all states except Maranhão (Flora do Brasil 2020). Although broadly cultivated, most of its occurrences in RN came from areas of caatinga vegetation, but it was also found among restinga vegetation in the state's Northern coast. Flowering in March and February, fruiting from March to September. Map (Fig. 1, Table 1): B2, B3, B5, C2, C6, D6, D7, E3.

Comments:—Popularly known as *macambira*, this species has been reported for several uses by rural communities in the Northeast, such as fodder or for human consume,

especially during long droughts (Bessa 1982, Lima 1996, Nunes *et al.* 2015, Nunes *et al.* 2016). Additionally, medicinal applications and pharmacological activities have also been reported (Agra *et al.* 2007, Oliveira-Júnior *et al.* 2014).

Bromelia laciniosa can be identified by its stoloniferous habit, the infundibuliform rosette, with green to vinaceous leaves, the pedunculate inflorescence, pale pink, 15–38 cm long, with serrate peduncle bracts elliptic at the base, but abruptly attenuate towards apex (Fig. 2K). The flowers are shortly pedicellate, with pink, ovate and muticous sepals, and fleshy petals, white to purple at apex (Fig. 2L). Another remarkable trait of *B. laciniosa* is the intensely sweet odor produced by the fruits when mature.

4. *Cryptanthus* Otto & Dietrich (1836: 227)

Terricolous or saxicolous herbs. Stem straight or decumbent, stoloniferous or propagating by short basal shoots. Leaves coriaceous, serrulate. Leaf sheath broadly ovate to triangular. Leaf blade linear to triangular-lanceolate, margin generally undulate and spinulose, apex acuminate to attenuate. Inflorescence sessile, compound. Floral bracts ovate-triangular. Flowers sessile. Sepals shortly or highly connate. Petals naked or with two callosities, generally white, sometimes green to greenish. Fruit berry.

Cryptanthus is endemic to Brazil and comprises 55 species distributed through the Atlantic Forest, Caatinga and Cerrado, with distribution concentrated in the Southeast and Northeast regions (Leme & Siqueira-Filho 2006, Leme *et al.* 2017, Flora do Brasil 2020). Only one species occurs in the state of RN, restricted to fragments of Atlantic Forest.

4.1. *Cryptanthus zonatus* (Visiani 1847: 4) Visiani (1854: 9) [Fig. 3A–B]

Herb terri-colous, stoloniferous or propagating by basal shoots. *Rosette* open, tank absent. *Leaves* patent, coriaceous, often incrassate centrally; *leaf sheath* 1.5–2.5 × 1.3–2 cm, deltate, pale yellow to whitish, membranaceous; *leaf blade* 6–30 × 1.5–2.5 cm, linear to triangular-lanceolate, wholly green or dark maroon to green, abaxial face densely white-lepidote, adaxial face glabrescent or variegate with undulate stripes of white trichomes, margin undulate, serrulate, apex short attenuate, recurved. *Peduncle* reduced. *Inflorescence* axillar, in 2 to 4-flowered fascicles; *floral bracts* 13–24 × 4–7 mm, narrowly ovate, green-hyaline, carinate, apex acuminate, pungent. *Flowers* sessile; *sepals* 1.6–2 cm long, carinate, hyaline to light green distally, highly connate, apex acuminate, free; *petals* 3.7–4 cm long, ligulate, recurved, shortly connate, white, apex acute; callosities present; *stamens* exserted. *Fruits* 12–15 mm long, ovoid.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Baía Formosa, RPPN Mata Estrela, 10 March 2013, fl., R.E.C. Magalhães 18 (UFRN); *ibid.*, 14 April 2013, fl., R.E.C. Magalhães 20 (UFRN); *ibid.*, 18 May 2015, fl., J.L. Costa-Lima *et al.* 2170 (UFRN); *ibid.*, 7 September 2015, fl., G.S. Garcia & L.M.G. Gonçalves 20 (UFRN). Ceará-Mirim, área do empreendimento Dunas de Muriú, 11 February 2016, st., E.O. Moura & P.B.C.S. Moura 527 (UFRN). Natal, Parque das Dunas, 6 May 2006, st., R.T. Queiroz & A.M. Marinho 792 (UFRN); *ibid.*, 26 March 2011, st., J.L. Costa-Lima 454 (UFRN); *ibid.*, 6 May 2011, fl., L.M. Versieux 511 (UFRN); *ibid.*, trilha da Geologia, 9 April 2012, fl., L.M. Versieux 519 (UFRN); *ibid.*, trilha Peroba, 20 April 2012, fl., A.S.M. Medeiros *et al.* s.n. (UFRN 14841); *ibid.*, trilha Perobinha, 16 August 2012, fr., A.S.M. Medeiros *et al.* 9 (UFRN).

Distribution, habitat and phenology:—The distribution of *Cryptanthus zonatus* is restricted to four states of Northeastern Brazil: Pernambuco, Alagoas, Sergipe, and recently registered to RN (Versieux *et al.* 2013b, Flora do Brasil 2020). In RN, this

species occurs in Atlantic Forest, in shaded and humid areas of seasonal semideciduous forest and restinga often hidden by the litter of shrubs or trees. Flowering from March to May, fruiting from August to September. Map (Fig. 1, Table 1): C7, D8.

Comments:—*Cryptanthus zonatus* can be recognized by its small habit, open rosette not forming a tank, with patent leaves generally touching the ground (Fig. 3A), and the sessile axillary inflorescences and flowers with white corollas (Fig. 3B). Three leaf color morphs have been registered in the Atlantic Forest reserves in RN: concolorous green, greenish to dark maroon, and dark maroon with variegate white bands of trichomes. Recent studies support that such color morphs all belong to *C. zonatus*, since they represent the natural variation of the species. For instance, individuals growing side by side, or even the same leaf, may change color or loose trichomes, which has been related to age, nutrition, and light conditions (Versieux *et al.* 2013b).

According to Ramírez-Morillo 1996, *Cryptanthus zonatus* is part of a species complex also including *C. burle-marxii*. Some questioning regarding the occurrence of *C. zonatus* in RN remains, as a recent phylogenetic molecular work indicates an individual from the coast of the state to be closely related to *C. burle-marxii* (Cruz *et al.* 2017). However, the more comprehensive sampling of populations in this complex together with the integrative approach provided by Ferreira (2016) suggests that *C. burle-marxii* is a synonym of *C. zonatus*. Indeed, in congruence with Ferreira (2016), our description presents characters considered by Leme & Siqueira-Filho (2006) as belonging to both species, for instance: flower and sepal size are closer to those of *C. zonatus* and leaf blade dimensions, vegetative propagation and habitat are more related to *C. burle-marxii*. Therefore, due to such morphologic inconsistencies and molecular evidence for synonymy, this species is herein treated as *C. zonatus*. Important nomenclatural notes on this species were also published by Alves & Marcucci (2015).

Cryptanthus zonatus is considered a vulnerable species (Martinelli 2008, MMA 2014). It is also found at the RPPN Mata Estrela, along with *Aechmea muricata*, reinforcing the importance of that conservation unit in the survival of threatened Bromeliaceae species in RN. This species has been widely used as ornamental since the 19th century (Leme & Siqueira-Filho 2006) and its trade after collection in the wild was observed in some local nurseries in Natal (L. Versieux, pers. obs.).

5. *Encholirium* Martius ex Schultes & Schultes f. (1830: 1233)

Rupicolous or terricolous herbs. Stems rhizomatous. Leaves coriaceous. Leaf sheath wide, ovate. Leaf blade triangular to lanceolate, serrate. Peduncle erect, generally glabrous. Inflorescence racemose, usually many flowered. Flowers pedicellate, patent. Sepals free, triangular-lanceolate or obovate. Petals free, elliptic, ovate or obovate, green to yellow, appendages absent. Stamens included or exserted. Fruit capsule.

Encholirium has currently 36 species, all endemic to Brazil. In general, this genus is associated with rocky environments, thus largely distributed in the Caatinga and Cerrado domains (Forzza 2005, Gouda & Butcher 2018, Flora do Brasil 2020). In RN, *Encholirium* is represented by a single species, restricted to the Caatinga domain.

5.1. *Encholirium spectabile* Martius ex Schultes & Schultes f. (1830: 1233) [Fig. 3C–D]

Herb rupicolous, rhizomatous. *Rosette* open, orbicular in outline, tank absent. *Leaves* suberect to recurved, coriaceous; *leaf sheath* 3.5–4.5 × 3–5.5 cm, widely ovate, brown; *leaf blade* 30–60 × 1.5–2 cm, narrowly triangular, green or yellowish-green, margin strongly serrate, apex attenuate; *aculei* 3–10 mm long, antrorse or retrorse. *Peduncle* 80–170 cm long, erect, green; *peduncle bracts* 3–27 × 0.5–2 cm, narrowly triangular, yellowish-green, margin serrate to serrulate, apex long attenuate. *Inflorescence* 40–80 cm

long, racemose (rarely branching from the base), many-flowered; *floral bracts* 10–12 × 3–4 mm, triangular-lanceolate, brown to vinaceous, apex attenuate. *Flowers* pedicellate; *pedicels* 8–9 mm long; *sepals* 8–9 mm long, ovate, ecarinate, green to brown, apex retuse; *petals* 14–16 mm long, narrowly elliptic, greenish-yellow, apex retuse; *stamens* exserted. *Fruits* 1.6–2 cm long, capsule, black when mature.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Apodi, Lajedo de Soledade, 25 May 2015, fl., *E.C. Tomaz & R.A. Pontes* 39 (UFRN). Caicó, RN-288 sentido Currais Novos, 15 August 2009, fl., *J.G. Jardim et al.* 5546 (UFRN). Jucurutu, RPPN Stoessel de Brito, 22 September 2007, st., *A.A. Roque* 307 (UFRN). Olho D'água do Borges, RN-078, 19 April 2015, fl., *E.C. Tomaz et al.* 30 (UFRN). São João do Sabugi, serra do Mulungu, 11 June 1980, fl., *O.F. Oliveira et al.* 1023 (MOSS). São José do Seridó, sítio localizado próximo à estrada em direção a Caicó, 17 August 2013, fr., *G.M. Araújo* 1 (UFRN). Serra Negra do Norte, Estação Ecológica do Seridó, 15 April 2006, st., *R.T. Queiroz* 697 (UFRN); *ibid.*, 24 May 2006, st., *R.T. Queiroz* 959 (UFRN).

Additional specimen examined:—BRAZIL. **Ceará:** Quixadá, Fazenda Ouro Preto, 12 March 2014, fr., *L.M. Versieux et al.* 684 (UFRN).

Distribution, habitat and phenology:—*Encholirium spectabile* is restricted to Brazil and distributed in almost all Northeastern states, except Maranhão (Flora do Brasil 2020). Endemic to the Caatinga, this is the most widely distributed species in the genus and a frequent element in the semi-arid region of the Northeast (Giulietti *et al.* 2002, Forzza 2005). In RN, this species is found with rupicolous life form on rocky outcrops. Flowering from April to August, fruiting in March and August. Map (Fig. 1, Table 1): C2, D4, D5, E2.

Comments:—This species can be recognized by its strictly rupicolous habit, with strongly hirsute leaves and an orbicular-shaped rosette, as well as the generally simple

and many-flowered racemose inflorescence, with peduncle 80–170 cm long (Fig. 3C–D). The tall and narrow inflorescence resembles an arrow, justifying its popular name as “macambira-de-flecha”.

Besides being the first bromeliad reported to be pollinated by a non-flying mammal (Queiroz *et al.* 2016), populations of *E. spectabile* are known to provide shelter for a rare gecko species, *Hemidactylus agrius* Vanzolini (1978), in the Caatinga of RN (Silva-Jorge *et al.* 2014). Moreover, *E. spectabile* is known to provide raw material to the manufacture of utensils by locals, for example, the peduncle has been reported to be used in the production of hand-crafted bottle stoppers and the leaves for the extraction of natural fibers, to produce rope and hammocks (Corrêa 1931, Roque & Loiola 2013).

6. *Hohenbergia* Schultes & Schultes f. (1830: 1251)

Epiphytic, rupicolous or terricolous herbs. Tank developed. Leaves coriaceous, erect to reflexed. Leaf sheath wide, elliptic. Leaf blade linear to lanceolate, margin serrate. Peduncle erect or suberect, with colorful to paleaceous and mucronate bracts. Inflorescence generally compound, panicle of strobilate spikes, with branches up to fourth order, generally with congested flowers in their distal portion. Floral bracts convex, triangular to ovate, generally mucronate. Flowers sessile. Sepals asymmetric, free or shortly connate. Petals free, linear, oblong, elliptic or spatulate, violet to blue, appendages present. Stamens included to slightly exserted. Ovules caudate. Fruit berry.

Recent molecular phylogenetic and morphological studies in *Hohenbergia* have supported the polyphyly of this genus, as its two traditionally recognized subgenera emerge from different positions in the phylogeny of the Core Bromelioideae (Evans *et al.* 2015, Aguirre-Santoro *et al.* 2016). Current classification segregates the whole *Hohenbergia* subg. *Wittmackiopsis* Mez (1896: 132) into the resurrected genus

Wittmackia, also including species of *Ronnbergia* Morren & André (1874: 120), and *Aechmea* (Aguirre-Santoro 2017). Consequently, *Hohenbergia* has been restricted to *H.* subg. *Hohenbergia*, with 49 species mostly distributed in Eastern Brazil, but also reaching Central America (Smith & Downs 1979, Baracho 2004, Gouda & Butcher 2018). Even though 44 of these occur in Northeastern Brazil (Flora do Brasil 2020), only three are found in Rio Grande Norte, distributed in caatinga and Atlantic forest vegetation.

6.1. *Hohenbergia catingae* Ule (1909: 195) [Fig. 3E–F]

Herb rupicolous. *Rosette* infundibuliform. *Leaves* suberect, coriaceous; *leaf sheath* 15–18 x 8–10 cm, narrowly elliptic, densely brown-lepidote; *leaf blade* 40–50 × 3.5–4 cm, narrowly lanceolate, green to vinaceous, margin serrate, apex attenuate to a stiff mucro; *aculei* 2–4 mm long, retrorse or patent. *Peduncle* ca. 35 cm long, erect, pink, densely white-lanuginose; *peduncle bracts* 8–10 × 2–3 cm, triangular-lanceolate, paleaceous, apex mucronate. *Inflorescence* ca. 35 cm long, panicle of strobilate spikes, with double ramification, narrowly pyramidal; *primary bracts* 2–8 × 0.5–1.5 cm, lanceolate, paleaceous, apex mucronate; *branches* well-developed and pedunculate proximally to gradually reducing distally; *spikes* 2–2.5 cm long, ellipsoid, lax; *floral bracts* 14–15 × 10–12 mm, widely ovate to orbicular, pink, chartaceous, markedly nerved, much exceeding the sepals, apex mucronate, mucro 4–7 mm long. *Flowers* sessile, congested; *sepals* 6–7 mm long, asymmetric, green, with membranaceous wing equaling to slightly exceeding the apex, apex mucronate, mucro ca. 1 mm; *petals* 11–12 mm long, spatulate, apex acute to obtuse; petal appendages ca. 4 mm, spatulate, adnate to petal proximally, apex free, erose; *stamens* included. *Fruits* not seen.

Specimen examined:—BRAZIL. **Rio Grande do Norte:** Monte das Gameleiras, próximo ao portal de entrada da sede municipal, 21 December 2015, fl., *E.C. Tomaz et al.* 96 (UFRN).

Distribution, habitat and phenology:—This species is endemic to Brazil and one of the most widely distributed within the genus. It can be found throughout the Northeast (except in Piauí and Maranhão) and Minas Gerais, in the domains of Caatinga, Cerrado and Atlantic Forest (Baracho 2004, Flora do Brasil 2020). In RN, the distribution of *H. catingae* is still poorly known and restricted to the Caatinga domain, occurring on granitic outcrops among rupicolous vegetation. Flowering in December. Map (Fig. 1, Table 1): D7.

Comments:—We followed the wide synonym proposed by Baracho (2004), which considered four out of the five varieties that formed a group addressed as “*catingae* complex”, namely var. *catingae*, var. *elongata*, var. *exbrimcata* and var. *extensa* (*sensu* Smith & Downs 1979), to be part of the phenotypic variation of *H. catingae*. The only exception was to variety *horrida*, which that author elevated to species status (see below).

This species can be identified by the rupicolous and xerophytic habit, the infundibuliform rosette, the paniculate inflorescence, with flowers arranged in ellipsoid spikes (Fig. 3E–F), floral bracts 14–15 cm long, mucronate, chartaceous, markedly nerved, much exceeding the sepals, which are 6–7 mm long, with membranaceous wings equaling to slightly exceeding the apex.

Hohenbergia catingae is morphologically related to *H. horrida*, from which it differs by having generally shorter floral bracts (14–15 mm vs. 15–20 mm), which are mostly erect (vs. spreading), and flowers with proportionally shorter sepals (6–7 mm long vs. 7–10 mm long), with membranaceous wing equaling or slightly exceeding the apex

(vs. evidently shorter than the apex), apex with a shorter mucro (*ca.* 1 mm vs. 2–3 mm), and petals shorter (11–12 mm vs. 15 mm).

No specimens were observed to support the occurrence of *H. catingae* in the coast of RN as stated by Leme & Siqueira-Filho (2006). Moreover, many herbarium specimens collected in RN's restinga vegetation and stored under the name of *H. catingae* were, in fact, *H. ridleyi*.

6.2. *Hohenbergia horrida* Harms (1935: 525) [Fig. 3G–H]

Herb rupicolous. *Rosette* infundibuliform. *Leaves* suberect, coriaceous; *leaf sheath* 22–25 × (3) 11–13 cm, narrowly elliptic, white to densely brown-lepidote distally; *leaf blade* 45–70 × 2–5 cm, narrowly oblong-lanceolate, green, margin serrate, apex attenuate to a stiff mucro; *aculei* 1.7–2.5 mm long, retrorse or antrorse. *Peduncle* 62–70 cm long, erect or arcuate, pink, lanuginose to glabrescent; *peduncle bracts* 6.5–11 × 2–4 cm, lanceolate, green to paleaceous, apex mucronate. *Inflorescence* 30–65 cm long, panicle of strobilate spikes, with double to triple ramification, subcylindrical or pyramidal; *primary bracts* 3–8 × 0.4–1.5 cm, triangular to lanceolate, apex mucronate; *branches* reduced and subsessile or well developed and pedunculate proximally to gradually reducing distally; *spikes* 2–4 cm long, ovoid to ellipsoid, dense to laxly arranged; *floral bracts* 15–20 × 9–11 cm long, ovate-triangular, coriaceous, finely nerved, much exceeding the sepals, spreading, apex long mucronate, mucro 5–7 mm long. *Flowers* sessile, congested; *sepals* 7–10 mm long, asymmetric, carinate, with a membranaceous wing evidently shorter than the apex, apex mucronate, mucro *ca.* 2–3 mm; *petals* *ca.* 15 mm long, spatulate, lilac, apex acute, petal appendages *ca.* 5 mm, spatulate, connate proximally, apex free, erose; *stamens* included. *Fruits* not seen.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Equador, serra das Queimadas, 13 August 2015, fr., V.F. Sousa *et al.* 49 (UFRN). Monte das Gameleiras, próximo ao portal de entrada da sede municipal, 21 December 2015, fl., E.C. Tomaz *et al.* 97 (UFRN).

Distribution, habitat and phenology:—This species' distribution was restricted to Paraíba, Pernambuco and Sergipe (Flora do Brasil 2020), and here we provide the first occurrence of *Hohenbergia horrida* in RN. It is restricted to the Caatinga phytogeographic domain, especially in the Borborema plateau (Baracho 2004, Flora do Brasil 2020). In RN, this species can be found as rupicolous among rocky outcrop vegetation. Flowering in December, fruiting in August. Map (Fig. 1): D7, E3.

Comments:—The original concept of *H. horrida* was proposed by Harms (1935) as a species, but it was later reduced to a variety of *Hohenbergia catingae* (Smith & Read 1976). According to Smith & Read (1976) and Smith & Downs (1979), *Hohenbergia catingae* var. *horrida* has a pyramidal inflorescence with long basal branches. Baracho (2004) reestablished *Hohenbergia horrida*, following Harms (1935), but did not indicate the branches size or inflorescence shape as its diagnostic traits; still, showing a variation of 2.5–15 cm in the branches' length. On the other hand, Leme & Siqueira-Filho (2006) stressed a subcylindrical inflorescence with “short basal branches” (8–10 cm in length) as a diagnostic trait of *H. horrida*.

While all these authors (Smith & Read 1976, Smith & Downs 1979, Baracho 2004; Leme & Siqueira-Filho 2006) are in accordance with other distinctive traits of *Hohenbergia horrida* (mostly floral bracts and sepal morphologies), we understand that the broader taxonomic treatment provided by Baracho (2004) encompass the morphologic variation in inflorescence of *Hohenbergia horrida*, especially regarding size of the branches.

In RN, *Hohenbergia horrida* (Fig. 3G–H) presents both pyramidal and subcylindrical inflorescence, with basal branches well developed or reduced. This species can be differentiated from other *Hohenbergia* by its proportionally larger (15–20 mm long), strongly mucronate and pungent and spreading floral bracts, by the asymmetric and mucronate sepals, with an apical mucro 2–3 mm long and membranaceous wing evidently shorter than the apex. It can be found in sympatry with *Hohenbergia catingae*.

6.3. *Hohenbergia ridleyi* (Baker 1889: 41) Mez (1891: 266) [Fig. 3I–K]

Herb terricolous or epiphytic. *Rosette* infundibuliform, tank present. *Leaves* suberect, coriaceous; *leaf sheath* (15–)20–25 × 8–13 cm, elliptic, vinaceous, densely brown-lepidote; *leaf blade* 35–68 × 3–7.5 cm, oblong-lanceolate, green to yellowish, margin serrate, apex mucronate; *aculei* 1.5–4 mm long, retrorse or antrorse. *Peduncle* 55–82 cm long, erect or arcuate, reddish-pink or green, densely lanuginose to glabrescent; *peduncle bracts* 6–13 × 2–4 cm, elliptic-lanceolate, paleaceous, imbricate, apex mucronate. *Inflorescence* 35–65 cm long, panicle of strobilate spikes, narrowly to broadly pyramidal; *primary bracts* 1.5–9.5 × 0.4–1.5 cm, triangular, paleaceous, apex acuminate; *branches* reduced and short pedunculate or well-developed and long pedunculate proximally to gradually reducing distally; *spikes* 2.5–9 cm long, ellipsoid to cylindrical, densely to laxly arranged; *floral bracts* 7–12 × 9–15 mm, widely ovate, strongly convex, green to reddish, generally shorter to rarely equaling or slightly exceeding the sepals, apex mucronulate to mucronate, mucro 1–4 mm. *Flowers* sessile, congested; *sepals* 4–7 mm long, asymmetric, carinate, green, with membranaceous wing exceeding the apex, rarely equaling, apex mucronulate, mucro ca. 0.5 mm long; *petals* 9–13 mm long, oblanceolate to spatulate, lilac to purple, apex acute; *petal appendages* ca. 5 mm long, spatulate, partially adnate to

petal, apex free, erose; *stamens* included. *Fruits* ca. 1 × 0.5 cm, ovoid, whitish to dark purple, when mature.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Canguaretama, 10 November 1980, fl., *O.F. Oliveira et al. 1480* (MOSS). Ceará-Mirim, Área do empreendimento Dunas de Muriú, 4 February 2016, fl., *E.O. Moura & P.B.C.S. Moura 507* (UFRN). Espírito Santo, caminho para a barragem do rio Piquiri, 15 May 2015, fr., *J.L. Costa-Lima et al. 2149* (UFRN). Extremoz, APA Jenipabu, 2 February 2011, fl., *J.L. Costa-Lima et al. 318* (UFRN); *ibid.*, 31 January 2015, fl., *I.C.L. Oliveira et al. 8* (UFRN). Macaíba, mata do Bebo, 6 March 2000, fr., *L.A. Cestaro 00-0020* (UFRN); 20 February 2016, fl., *E.C. Tomaz et al. 106* (UFRN). Natal, Capim Macio, 4 October 1980, fl., *Projeto Parque das Dunas 178* (MOSS); *ibid.*, Parque Estadual das Dunas de Natal, 14 December 2006, fl., *S/Coletor* (UFRN 3824); *ibid.*, trilha da Geologia, 29 June 1999, fr., *L.A. Cestaro 99-0160* (UFRN); *ibid.*, 3 February 2009, fl., *Costa-Lima et al. 78* (UFRN); *ibid.*, 14 May 2010, fr., *L.M. Versieux et al. 493* (UFRN); *ibid.*, trilha Ubaia Doce, 13 April 2012, fl., *A.S.M. Medeiros 01* (UFRN); *ibid.*, trilha Peroba, 15 January 2013, fl., *E.C. Tomaz et al. 3* (UFRN); *ibid.*, Parque da Cidade Dom Nivaldo Monte, 6 May 2015, fr., *A.A. Roque et al. 1572* (UFRN). Nísia Floresta, Lagoa de Búzios, 8 December 2011, fl., *L.M. Versieux et al. 586* (UFRN); *ibid.*, Floresta Nacional, 7 December 2013, fl., *L.M. Versieux et al. 620* (UFRN); *ibid.*, APA Bonfim-Guarairas, 7 February 2015, fl., *A.C.D. Souza et al. 40* (UFRN); *ibid.*, lagoa de Alcaçuz, 21 August 2015, fl. & fr., *E.C. Tomaz et al. 94* (UFRN). Parnamirim, Centro de Lançamentos Barreira do Inferno, 17 March 2012, fl. & fr., *C.A. Brito et al. 9* (UFRN); *ibid.*, 17 March 2012, fr., *L.M. Versieux et al. 520* (UFRN). Touros, propriedade privada, 27 February 2016, fl., *A.M. Marinho 228* (UFRN).

Distribution, habitat and phenology:—This species is distributed in the Southeastern and Northeastern regions, including the states of Ceará, RN, Paraíba, Pernambuco, Alagoas, Sergipe, Bahia, Minas Gerais, and São Paulo (Baracho 2004). In RN, it is frequently seen as terricolous, only rarely as an epiphyte, forming dense populations close to coastal environments such as in restingas and semideciduous forests or shrubby areas associated to the coastal zone, in the Atlantic forest domain. Flowering from September to April, fruiting from March to August. Map (Fig. 1, Table 1): B6, C7, D8.

Comments:—There is an ongoing taxonomic disagreement regarding *Hohenbergia ridleyi* and its alleged synonymous *Hohenbergia ramageana* Mez (1896: 127) (Baracho 2004, Leme & Siqueira-Filho 2006, Gonçalves-Oliveira & Wanderley 2017). The description presented here has some morphologic variation that encompass the conjoint variation of those taxa in traits stated as diagnostic by Leme & Siqueira-Filho (2006), and future work may indicate the need to treat populations from Rio Grande do Norte as a separate species. Previous works (Leme & Siqueira-Filho 2006) describe the floral bracts as being 7–10 mm long for *H. ramageana* vs. 10–12 mm long in *H. ridleyi*, while the specimens treated here exhibit a range of 7–12 mm in length of floral bracts. Similarly, we found variation of 4–7 mm in length of sepals, that accommodates the 4–5 mm long sepals of *H. ridleyi* and 5–6 mm long in *H. ramageana* reported by Leme & Siqueira-Filho (2006). This is in accordance with the broad circumscription proposed by Baracho (2004), which includes *H. ramageana* under *H. ridleyi*. According to Gonçalves-Oliveira & Wanderley (2017) the segregation of these two species is still problematic and demands more revisions, and in their broad population genetics analysis, specimens from RN grouped with the *H. ridleyi* from Pernambuco (Gonçalves-Oliveira, pers. com. 2018).

Nevertheless, we observe a very consistent morphological delimitation for the populations of Rio Grande do Norte, although some plasticity is noted (see below).

Hohenbergia ridleyi (Fig. 3I–K) is polymorphic, especially in rosette color and size (individuals may be totally yellowish when growing under full sun) and in inflorescence size and shape, which varies from narrow to widely pyramidal, 90–140 cm long. This species can be differentiated from *H. horrida* and *H. catingae* conjointly by having generally longer spikes (up to 9 cm vs. not over 4 cm), shorter floral bracts (7–12 mm vs. 14–20 mm long), shorter or rarely equaling to slightly exceeding the calyx, and sepal apex mucronulate (mucro *ca.* 0.5 mm vs. 1–3 mm long), with membranaceous wing exceeding it vs. evidently shorter in only *H. horrida*.

7. *Neoglaziovia* Mez (1894: 426)

Saxicolous or terricolous herbs. Leaves long, serrate, few numbered, coriaceous. Peduncle erect. Inflorescence racemose, simple. Floral bracts conspicuous. Flowers pedicellate. Sepals free, subsymmetric. Petals free, ligulate to oblanceolate, appendages present. Stamens included. Fruit berry.

Neoglaziovia is endemic to Brazil, encompassing three species restricted to the Caatinga vegetation and widely distributed in the Northeastern states and Minas Gerais (Flora do Brasil 2020). Only one species has been found in RN.

7.1. *Neoglaziovia variegata* (Câmara 1810: 7) Mez (1894: 427) [Fig. 3L–M]

Herb terricolous. *Rosette* fasciculate, tank absent. *Leaves* erect to suberect, few-numbered (<10), coriaceous; *leaf sheath* 15–16 × 3–3.5 cm, narrowly elliptic, green, densely cinereous lepidote, strongly imbricate; *leaf blade* 1–1.3 m × 1–1.5 cm, linear, canaliculate, dark green, variegate with alternate bands of white scales, margin serrate,

apex attenuate, pungent; *aculei* 2–4.5 mm long, mostly antrorse, laxly arranged. *Peduncle* 60–75 cm long, erect or flexuose, green to brownish, densely lanuginose; *peduncle bracts* 3–20 × 0.5–1 cm, narrowly lanceolate, green to pink at margin, margin serrulate, apex short to very long attenuate. *Inflorescence* 20–26 cm long, suberect, rachis pink; *floral bracts* 11–30 × 2–5 mm, narrowly triangular, paleaceous, lanuginose, apex acuminate. *Flowers* laxly arranged, conspicuously pedicellate; *pedicels* 7–12 mm long; *sepals* 8–9 mm long, widely ovate, pink, apex obtuse; *petals* 23–26 mm long, oblanceolate, purple, apex rounded, slightly involute; petal appendages basal, erose distally, callosities present; *stamens* included. *Fruit* not seen.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Equador, serra das Queimadas, 13 August 2015, fl., *E. O. Moura et al.* 416 (UFRN). Serra Caiada, serra Caiada, 12 January 2017, fl., *G. S. Garcia* 468 (UFRN).

Distribution, habitat and phenology:—*Neoglaziovia variegata* is endemic to the Caatinga domain, occurring in all Northeastern states and Minas Gerais (Smith & Downs 1979, Giulietti *et al.* 2002, Flora do Brasil 2020). In RN, it has been found in shrubby and arboreal caatinga vegetation, also associated with rocky outcrops. Flowering in January and August. Map (Fig. 1, Table 1): D7, E3.

Comments:—This species is often reported for its potential as a natural fiber source, particularly in the Northeast of Brazil (Corrêa 1931, Mayo 1992, Silveira *et al.* 2009, Silveira *et al.* 2013). It is also indicated as a fodder plant (Nunes *et al.* 2015). *Neoglaziovia variegata* can be identified by its fasciculate rosette with leaf blades strongly imbricate and not forming a tank. In addition, leaves are few numbered, with long and linear blades (mostly over 1 m long), which are variegated with alternate bands of white scales (Fig. 3L).

8. *Orthophytum* Beer (1854: 347)

Rupicolous or rarely terricolous herbs. Leaves forming an open rosette. Leaf sheath inconspicuous. Leaf blade linear to ovate-triangular, serrate. Peduncle inconspicuous or well developed, inflorescence spike, spike of spikes or spike of glomerules. Floral bracts ovate to triangular, carinate or ecarinate. Flowers sessile or short-pedicellate. Sepals generally triangular, free. Petals spatulate or ligulate, forming a tubular corolla, white to green, appendages present or absent. Stamens included. Fruit berry.

Orthophytum has 58 species, all endemic to the Eastern Brazil, from RN to Minas Gerais. This genus has notably two centers of diversity: the rocky outcrops of the Espinhaço Range (BA and MG) and *inselbergs* in the Atlantic Forest of MG and ES (Wanderley 1990, Louzada & Wanderley 2010, Gouda & Butcher 2018, Flora do Brasil 2020). Based on morphologic and molecular phylogenetic studies, current classification supports the subdivision of *Orthophytum* in five subgenera (Leme *et al.* 2017), as well as the segregation of some species to the re-established *Sincoraea* (Louzada & Wanderley 2016). In RN, the genus is represented by only one species.

8.1. *Orthophytum disjunctum* Smith (1955: 33) [Fig. 3N–O]

Herb rupicolous. *Rosette* open, tank absent. *Leaves* suberect to patent, coriaceous; *leaf sheath* inconspicuous; *leaf blade* 10–15 × 1–2.5 cm, triangular, green or vinaceous, densely white-lepidote on both faces, margin serrate, apex attenuate; *aculei* patent or retrorse, 2–3 mm long. *Peduncle* 20–25 cm long, erect, greenish, densely lanuginose to glabrescent; *peduncle bracts* 4–13 × 0.8–2 cm, triangular, green or vinaceous, foliaceous, densely lepidote. *Inflorescence* 6.5–11 cm long, spike of spikes, lateral spikes laxly arranged, apical portion capitate; *primary bracts* 1.5–4 × 0.5–1.4, triangular, patent to

strongly recurved, green or vinaceous, foliaceous, margin serrate, apex attenuate; *floral bracts* 10–15 × 6–10 mm, triangular, carinate, recurved, margin serrate, apex acuminate. *Flowers* sessile; *sepals* 8–11 mm long, asymmetric, carinate, green; *petals* 12–14 mm long, spatulate, green to white distally, apex acute; petal appendages basal, fimbriate; *stamens* included. *Fruits* ca. 3 × 4 mm, globose.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Monte das Gameleiras, pedra da mesa, 23 July 2016, fr., G.S. Garcia 285 (UFRN); *ibid.*, 30 December 2016, fl., G.S. Garcia 491 (UFRN). Serra de São Bento, serra do Cruzeiro, 28 July 2012, fl./fr., J.G. Jardim *et al.* 6290 (UFRN); *ibid.*, 24 August 2012, fl., L.M. Versieux *et al.* 542 (UFRN).

Distribution, habitat and phenology:—*Orthophytum disjunctum* is distributed in Northeastern Brazil, including Alagoas, Bahia, Paraíba, Pernambuco and it was recently reported to occur in RN (Versieux *et al.* 2013a; Flora do Brasil 2020). In RN, this species occurs within rupicolous vegetation on *inselbergs* in the Caatinga domain. Flowering from July to December, fruiting from July to August. Map (Fig. 1, Table 1): D7.

Comments:—*Orthophytum disjunctum* was part of the traditional “pedunculate inflorescence group” (Louzada & Wanderley 2010, Louzada *et al.* 2014) and is now placed under *Orthophytum* subg. *Orthophytum* (Leme *et al.* 2017). The leaves with densely white-lepidote faces, triangular and conspicuously serrate blades can distinguish this species, as well as the foliaceous peduncle and primary bracts and the pedunculate spike inflorescence bearing lateral spikes. Additionally, green and vinaceous color morphs were observed sympatrically in RN (Fig. 3N).

9. *Tillandsia* Linnaeus (1753: 286)

Epiphytic or rupicolous herbs. Leaves forming a rosette or disposed along the stem, polystichous or distichous. Leaf sheath slightly widened. Leaf blade linear-filiform to narrowly triangular. Peduncle well developed or absent. Inflorescence terminal, erect to pendulous, rarely reduced to a single flower. Flowers polystichous or distichous. Sepals free or shortly connate. Petals free, white, purple, pink, blue or yellow, appendages absent. Stamens included or exserted. Fruit septicidal capsule.

Tillandsia is the largest genus of Bromeliaceae, with more than 700 species widely distributed in the Neotropics, occurring from highly xeric to mesophytic environments (Smith & Downs 1977, Smith & Till 1998, Gouda & Butcher 2018). The systematics of *Tillandsia* is currently under rearrangement, with profound modifications in generic delimitations made by Barfuss *et al.* (2016). In Brazil, 87 species have been registered, occurring in all states except Tocantins (Flora do Brasil 2020). We registered the presence of 12 species in RN, predominantly in caatinga vegetation, but also in fragments of Atlantic Forest. The subgenus *Diaphoranthema* (Beer 1854: 349) Baker (1878: 236) was the richest, with four species.

9.1. *Tillandsia bulbosa* Hooker (1827: 173) [Fig. 4A]

Herb epiphytic. *Rosette* bulbform. *Leaves* spiraled, suberect to spreading; *leaf sheath* 1.5 × 2–2.5 cm, widely elliptic, subcoriaceous, strongly imbricate, cinereous-lepidote; *leaf blade* 8–15 × 0.2–0.5 cm, strongly involute-subulate, incrassate, slightly flexuose, green to vinaceous, margins strongly involute, apex attenuate. *Peduncle* 3–7 cm long, incurved, cinereous-lepidote; *peduncle bracts* 2–15 × 0.5–0.6 cm, elliptic at the base, involute-subulate towards apex. *Inflorescence* 2.5–4.5 cm long, spike, straight, erect; *floral bracts* 15–20 × 5–6 mm, elliptic, acuminate, lepidote. *Flowers* sessile, congested; *sepals* 14–15

mm long, oblong, carinate, apex acute; *petals* 25–27 mm long, oblanceolate, light purple, apex acute; *stamens* exserted. *Fruits* ca. 3.5 cm long, cylindrical, green when immature.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Macaíba, Escola Agrícola de Jundiá, 25 June 1999, fl., L.A. Cestaro 99-0156 (UFRN). Natal, Parque da Cidade, 13 November 2008, fr., Lisboa s.n. (UFRN 2812). Nísia Floresta, Dunas do Pium, 14 November 2007, st., A.H. Ribeiro & I. Lira 275 (UFRN); *ibid.*, APA Bonfim-Guarairas, 25 September 2015, fl., G.S. Garcia et al. 26 (UFRN). Parnamirim, Pium, 1 January 2008, st., I.B. Lira s.n. (UFRN 7741).

Distribution, habitat and phenology:—*Tillandsia bulbosa* occurs from Mexico to Central and South America (Smith & Downs 1977). In Brazil, it is found in the states of Amazonas, Amapá and Pará, in six Northeastern states and Espírito Santo (Leme & Siqueira-Filho 2006, Pontes & Agra 2006, Flora do Brasil 2020). In RN, its distribution is restricted to the Atlantic Forest domain, as epiphyte in seasonal semideciduous forest. Flowering in June, fruiting in September. Map (Fig. 1, Table 1): C7, D8.

Comments:—*Tillandsia bulbosa* has been placed in subgenus *Tillandsia* (Smith & Downs 1977). This species can be recognized by its bulbform rosette, produced by the widened and strongly imbricate leaf sheaths (Fig. 4A). In addition, the leaf blades are strongly involute-subulate and spreading, varying from green to vinaceous. *Tillandsia bulbosa* is slightly similar to *Tillandsia paraensis*, but the latter has much less imbricate leaf sheaths, and vinaceous petals (Fig. 4D–E) (vs. the purple petals of *T. bulbosa*; Fig. 4A).

9.2. *Tillandsia loliacea* Martius ex Schultes & Schultes f. (1830: 1204) [Fig. 4B–C]

Herb epiphytic. *Rosette* open. *Leaves* spiraled, erect; *leaf sheath* 2–4 × 3–4.5 mm, very widely ovate, membranaceous, hyaline; *leaf blade* 12–22 × 1–4 mm, narrowly triangular,

green to castaneous, slightly incrassate, densely cinereous-lepidote, margins involute, apex attenuate. *Peduncle* 2.5–7 cm, erect to suberect, lepidote near the internodes; *peduncle bracts* 7–14 × 4–5 mm, elliptic-lanceolate, densely lepidote, closely wrapping the peduncle, apex acute. *Inflorescence* 1–2.5 cm long, spike, erect, rachis geniculate, to 2-flowered; *floral bracts* 5–8 × 4–6.5 mm, ovate, densely lepidote, strongly enfolding the flowers, apex acute. *Flowers* sessile, distichous; *sepals* 6–7 mm long, narrowly elliptic, green, glabrous, ecarinate, shortly connate, apex acute; *petals* ca. 8 mm long, ligulate, yellow, apex obtuse; *stamens* deeply included. *Fruits* 2.2–3.5 cm long, cylindrical.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Bento Fernandes, serra da Cachoeira do Sapo, 8 February 2012, fr., J.L. Costa-Lima et al. 611 (UFRN). Campo Redondo, serra do Doutor, 24 March 2012, fr., A.A. Roque et al. 1323 (UFRN). Cerro Corá, fazenda Pitombeira, 24 March 1981, fr., O.F. Oliveira et al. 1741 (MOSS). Equador, serra das Queimadas, 13 August 2015, fl./fr., E.O. Moura et al. 447 (UFRN). Lajes, Sítio Amarante, 13 May 2017, fr., E.C. Tomaz et al. 121 (UFRN). Serra Negra do Norte, serra Negra, 11 February 1981, fl., O.F. Oliveira et al. 1597 (MOSS); *ibid.*, 12 February 1981, bt, O.F. Oliveira et al. 1622 (MOSS). Sítio Novo, 1 January 2008, I.B. Lira s.n. (UFRN 7736).

Distribution, habitat and phenology:—This species is known to occur throughout South America, being found in Argentina, Bolivia, Brazil, Paraguay and Peru (Smith & Downs 1977). It occurs in almost every region of Brazil, except for the North (Flora do Brasil 2020). In RN, it is found as an epiphyte in the Caatinga domain. Flowering in February and August, fruiting from February to May and August. Map (Fig. 1, Table 1): C5, C6, D6, D7, E2, E3.

Comments:—*Tillandsia loliacea* is the smallest species of bromeliad occurring in RN, thus it can be easily recognized by its rosette size, with 1.2–2.2 cm long leaf blades,

densely lepidote, the small inflorescence (4–9 cm long), with geniculate rachis, and short flowers with yellow petals (Fig. 4C).

This species is placed in subgenus *Diaphoranthema* (Smith & Downs 1977) and tends to form dense clumps on trees twigs in dry caatinga vegetation. Indeed, that subgenus is characterized by cleistogamous flowers, a trait that has been associated with success in colonizing environments with harsh conditions and where pollinators might be limited (Till 1992, Benzing 2000).

9.3. *Tillandsia paraensis* Mez (1894: 586) [Fig. 4D–E]

Herb epiphytic. *Rosette* utriculose. *Leaves* spiraled, erect to suberect; *leaf sheath* ca. 3 × 2 cm, elliptic, densely cinereous-lepidote abaxially, chartaceous; *leaf blade* 8–25 × 0.3–0.5 cm, triangular proximally to slightly involute-subulate, green, slightly incrassate, cinereous-lepidote, apex long attenuate to subulate. *Peduncle* 12–15 cm long, suberect; *peduncle bracts* 2–12 × ca.1 cm, elliptic, long attenuate to acuminate. *Inflorescence* 5–10 cm long, spike, curved; *floral bracts* 25–30 × 15 mm, widely elliptic to oblong, yellowish green to vinaceous, chartaceous, ecarinate, lepidote, apex acute. *Flowers* sessile, distichous, lax; *sepals* 23–25 mm long, elliptic, yellowish green to vinaceous, ecarinate, apex acute; *petals* ca. 3 cm long, ligulate, erect, vinaceous; *stamens* exerted. *Fruits* ca. 4 cm long, cylindrical, castaneous to dark green.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Espírito Santo, caminho para a barragem do rio Piquiri, 15 May 2015, fr., *Costa-Lima et al.* 2143 (UFRN). Macaíba, mata do Bebo, 20 February 2016, fl., *E.C. Tomaz et al.* 103 (UFRN). Parnamirim, mata da chácara pau-brasil, 30 November 2007, st., *A. Ribeiro* 278 (UFRN); *ibid.*, 1 January 2008, fl., *I.B. Lira s.n.* (UFRN 7742). Taipu, área para instalação da LT Ceará-Mirim - Parazinho, 22 January 2016, fl., *E.O. Moura & A.R.V. Nunes* 468 (UFRN).

Distribution, habitat and phenology:—*Tillandsia paraensis* is restricted to South America, with a disjunct occurrence in the Amazon basin (Colombia, Venezuela, Peru, Bolivia, Northern Brazil) and in the Atlantic Forest of Northeastern Brazil (Smith & Downs 1977, Leme & Siqueira-Filho 2006, Flora do Brasil 2020). Its occurrence in RN is registered in Atlantic forest and fragments of Cerrado. Flowering from January to February, fruiting in May. Map (Fig. 1, Table 1): C6, C7, D8.

Comments:—This species can be differentiated from other *Tillandsia* in RN by its utriculose rosette, with nearly erect leaves with blades attenuate to subulate distally, as well as by the spiked inflorescence, 17–25 cm long and curved (Fig. 4D). The floral bracts and sepals can be yellowish green to vinaceous, while petals are entirely vinaceous (Fig. 4E), differing from *T. bulbosa*, in which petals are purple. *Tillandsia paraensis* is placed in subgenus *Tillandsia* (Smith & Downs 1977).

9.4. *Tillandsia paraibensis* Pontes (2012: 551) [Fig. 4F–G]

Herb rupicolous. *Rosette* densely fasciculate, tank absent. *Leaves* strongly secund, nearly erect, imbricate; *leaf sheath* inconspicuous, membranaceous; *leaf blade* 6–12 × 0.8–1.5 cm, triangular, slightly coriaceous, densely cinereous-lepidote, margin involute distally, apex attenuate. *Peduncle* 8–10 cm long, erect, greenish; *peduncle bracts* 3–8.5 × 0.5–0.8 cm, narrowly elliptic, light pink to pink, apex long to shortly caudate, densely lepidote, margins membranaceous. *Inflorescence* 3.5–6.5 cm long, spike, erect, straight; *floral bracts* 17–26 × 11–16 mm, widely elliptic to oblong, light pink, apex shortly caudate to acute, lepidote to glabrescent. *Flowers* sessile, polystichous, lax; *sepals* 12–15 mm long, elliptic, apex acuminate, the anterior free, the posterior ones shortly connate; *petals* 20–22 mm long, spatulate, white, apex obtuse; *stamens* included. *Fruits* not seen.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Montes das Gameleiras, pedra da mesa, 15 October 2016, fl., *G.S. Garcia* 446 (UFRN); *ibid.*, afloramento próximo a estrada para Japi, 5 November 2016, fl., *G.S. Garcia & L.M.G. Gonçalves* 429 (UFRN).

Distribution, habitat and phenology:—*Tillandsia paraibensis* was recently described and originally considered endemic to the state of Paraíba, but shortly later, its distribution was expanded also to RN (Pontes 2012; Versieux *et al.* 2013a). Its distribution is restricted to the Caatinga domain, occurring as rupicolous on *inselbergs* near the border of these two states. Flowering in October to November. Map (Fig. 1, Table 1): D7.

Comments:—This species can be recognized by the strongly secund, nearly erect and numerous leaves, the simple and erect inflorescence, with light pink floral and peduncle bracts, and flowers with white corollas (Fig. 4G). In addition, specimens present a strongly xerophytic habit, frequently observed growing on nearly vertical rock sides (Fig. 4F). *Tillandsia paraibensis* is rarely observed in reproductive stage, what explains the low sampling presented here, and probably also why fruits or seeds have never been described. It has been placed in subgenus *Anoplophytum* (Beer 1854: 346) Baker (1888: 12) (Pontes 2012).

9.5. *Tillandsia polystachia* (Linnaeus 1753: 286) Linnaeus (1762: 410) [Fig. 4H–I]

Herb epiphytic. *Rosette* infundibuliform. *Leaves* spiraled, suberect to slightly recurved; *leaf sheath* 3–7.5 × 2–6 cm, elliptic, brownish; *leaf blade* 11–32 × 0.7–1.3 cm, narrowly triangular, chartaceous, green to purplish, slightly cinereous-lepidote, apex long attenuate. *Peduncle* 10–22 cm long, erect; *peduncle bracts* (2–)5–15(–20) × 1–1.2 cm, elliptic, long or shortly attenuate to acuminate. *Inflorescence* 7.5–15 cm long, spike or panicle of spikes, erect, lateral branches (when present) ascending; *floral bracts* 20–24 ×

10–13 mm, elliptic to ovate, green, coriaceous, carinate, apex acuminate to acute. *Flowers* distichous; *sepals* 16–20 mm long, narrowly elliptic to oblong, two shortly connate and carinate, the third free and ecarinate, apex acute; *petals* ca. 35 mm long, spatulate, lilac to purple, apex acute, erect; *stamens* exserted. *Fruits* 4–5 cm long, cylindrical.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Cerro Corá, rod. BR-104, 2 July 2014, fr., *D.V. Oliveira s.n.* (UFRN 17774). Ceará-Mirim, 1 January 2008, st., *I.B. Lira s.n.* (UFRN 7739); *ibid.*, rod. RN-309, 9 August 2014, fr., *J.G. Jardim & J.C. Sousa Jr.* 6692 (UFRN). São Tomé, rod. BR-104 sentido Currais Novos/Santa Cruz, 13 January 2013, fl., *A.A. Roque et al.* 1486 (UFRN). Taipu, área para instalação da LT Ceará-Mirim - Parazinho, 22 January 2016, fl., *E.O. Moura & A.R.V. Nunes* 469.

Distribution, habitat and phenology:—This species occurs from North to Central America, Brazil and Bolivia (Smith & Downs 1977). In Brazil, it is distributed in the Central-West and Northeast to the Southeast, comprehending areas of Caatinga, Cerrado and Atlantic Forest, most commonly found growing under xerophytic conditions (Leme & Siqueira-Filho 2006, Flora do Brasil 2020). In RN, it was observed with epiphytic habit in caatinga vegetation as well as in a fragment of Cerrado in the eastern side. Flowering in January, fruiting in July and August. Map (Fig. 1, Table 1): C5, C6, C7, D6.

Comments:—Compared to the other *Tillandsia* species in RN, *T. polystachia* can reach the largest size, presenting an infundibuliform rosette, capable of holding water. This species can also be recognized by its erect to suberect, slightly recurved leaves, with blades 11–32 cm long; the erect inflorescence, 22–37 cm long, simple or compound, with branches (when present) ascending give the inflorescence a narrow contour. The floral bracts are imbricate and coriaceous, and the petals are purple to lilac and erect, producing

a tubular corolla (Fig. 4H–I). As pointed out by Pontes & Agra (2006), it has a high potential for ornamental use.

Tillandsia polystachia is placed in subgenus *Tillandsia* (Smith & Downs 1977), and has morphological affinity with *Tillandsia parvispica* Baker, what has caused disagreement among specialists. Smith & Downs (1977) considered them as synonyms, but Luther & Sieff (1994) and Luther (2008, 2010) have listed the two as accepted names. According to Versieux & Wendt (2006), Harry Luther considered all material from Brazil to be *T. parvispica*. Walter Till also supported such statement, adding that *T. polystachia* would only occur in North and Central America, as reported by Leme & Siqueira-Filho (2006). Here we follow Smith & Downs (1977) until a full revision of these taxa is provided.

9.6. *Tillandsia recurvata* (Linnaeus 1753: 287) Linnaeus (1762: 410) [Fig. 4J–K]

Herb epiphytic, forming dense nearly rounded tufts. *Stem* reduced and covered by the leaves. *Rosette* absent. *Leaves* distichous, strongly recurved, chartaceous; *leaf sheath* 7–12 × 4–6 mm, elliptic, membranaceous, imbricate, lepidote; *leaf blade* 3–7 cm × 1 mm, linear-filiform, strongly conduplicate, densely cinereous-lepidote. *Peduncle* 2–8 cm long, erect, castaneous, glabrous; *peduncle bracts* 9–10 × 3–4 mm, elliptic-lanceolate, apex acuminate. *Inflorescence* spike, single to two-flowered; *floral bracts* ca. 8 × 3 mm, elliptic-lanceolate, apex acuminate. *Flowers* sessile; *sepals* 5–7 mm long, lanceolate, apex acute; *petals* lilac; *stamens* included. *Fruits* 1.6–2.4 cm long, cylindrical, castaneous to brown.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Campo Redondo, serra do Doutor, 27 May 2010, st., J.G. Jardim et al. 5706 (UFRN); *ibid.*, estrada de terra de acesso à BR-226, 7 September 2012, fl./fr., L.M. Versieux et al. 612 (UFRN). Ceará-Mirim, 1

January 2008, st., *I.B. Lira s.n.* (UFRN 7740). Cerro Corá, fazenda Tupã, 28 February 1980, fr., *O.F. Oliveira et al.* 87 (MOSS 2654); *ibid.*, serra próximo à fazenda Pitombeira, 24 March 1981, fl., *O.F. Oliveira et al.* 1742 (MOSS). Coronel João Pessoa, 26 May 1981, fl./fr., *O.F. Oliveira et al.* 1880 (MOSS). Florânia, Sítio Cajueiro, 15 February 2009, fr., *A.M.S. Araújo* 36 (MOSS). Luís Gomes, estrada para cachoeira do Rela, 31 May 2008, fr., *R.C. Oliveira et al.* 2200 (MOSS). Monte das Gameleiras, estrada de terra a 3.4 km da sede municipal, 21 December 2015, fr., *E.C. Tomaz et al.* 98 (UFRN). Santo Antônio, serra da Micaela, 13 August 2009, fr., *J.L. Costa-Lima* 194 (UFRN). Serra Caiada, afloramento de Serra Caiada, 24 November 2007, st., *A.H. Ribeiro & I. Lira* 277 (UFRN). Serra Negra do Norte, serra Negra, 12 February 1981, fl., *O.F. Oliveira et al.* 1621 (MOSS); *ibid.*, 25 March 2005, fl., *M.I.B. Loiola* 855 (UFRN). Serra de São Bento, serra do Cruzeiro, 28 July 2012, fl./fr., *J.G. Jardim et al.* 6298 (UFRN); *ibid.*, morro da Cara Branca, 25 August 2012, fr., *L.M. Versieux et al.* 557 (UFRN); *ibid.*, próximo a pedra da Boca, 24 August 2012, fr., *L.M. Versieux et al.* 545 (UFRN). Riachuelo, sítio Mulungu, 28 September 1980, fl./fr., *O.F. Oliveira et al.* 1221 (MOSS).

Distribution, habitat and phenology:—This is one the most widespread bromeliad species, ranging from Southern North America to the Caribbean, Central and South America (Smith & Downs 1977). *Tillandsia recurvata* occurs in all Brazilian regions (Flora do Brasil 2020). In RN, this species is commonly found as epiphyte or rupicolous in the Caatinga domain, in dry woodlands or on inselbergs. Flowering and fruiting from February to September. Map (Fig. 1, Table 1): C6, C7, D2, D5, D6, D7, D8, E2.

Comments:—*Tillandsia recurvata* can be recognized by the distichously arranged leaves, very short and delicate stems, with short (4–7 cm long), densely cinereous-lepidote, strongly recurved blades, as well as by erect, few-flowered

inflorescence, and lilac petals (Fig. 4J–K). This species has been reported to be used as fodder and for medicinal purposes in the Northeast of Brazil (Albuquerque *et al.* 2007, Nunes *et al.* 2015).

As stated earlier, *Tillandsia recurvata* presents morphological similarity to *T. mallemontii*, but according to Wanderley *et al.* (2007), *T. mallemontii* presents a larger habit (18–25 cm vs. 4–12 cm) and larger flowers, with 12–16 mm long sepals and spatulate petals (vs. 5–7 mm long sepals and ligulate petals). Additionally, the two species are placed into different subgenera, *T. recurvata* in subg. *Diaphoranthema* and *T. mallemontii* in subg. *Phytarrhiza* (Visiani 1855: 340) Baker (1887: 214) (Smith & Downs 1977, Barfuss *et al.* 2016).

9.7. *Tillandsia streptocarpa* Baker (1887: 241) [Fig. 4L–M]

Herb rupicolous or epiphytic. *Rosette* broadly open, lax. *Leaves* spiraled, generally patent, chartaceous; *leaf sheath* 1–1.7 × 1.5–2 cm, widely elliptic to ovate; *leaf blade* 8–35 × 0.2–1 cm, linear-triangular, densely cinereous-lepidote, strongly recurved to spiraling distally, margin involute, apex long attenuate. *Peduncle* 8–24 cm long, erect, glabrous; *peduncle bracts* (1.5–)3–10(–14) × 0.4–0.7 cm, elliptic-lanceolate, densely cinereous-lepidote, apex long to short caudate or acuminate. *Inflorescence* 6–20 cm long, spike or panicle of spikes, erect; spikes linear; *floral bracts* 1–1.6 × 0.5–0.6 cm, elliptic-lanceolate, lepidote, apex acuminate. *Flowers* sessile, distichous; *sepals* 10–12 mm long, lanceolate, carinate, apex acute; *petals* 22–23 mm long, strongly spatulate, light to bluish purple, apex obtuse; *stamens* included. *Fruits* 2.5–3.5 cm long, cylindrical.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Acari, sítio Talhado, 26 February 2011, fr., A.A. Roque *et al.* 883 (UFRN). Campo Redondo, 4 August 2011, fr., A.B. Jardim *et al.* 266 (UFRN); *ibid.*, serra do Doutor, 24 March 2012, fl., A.A. Roque *et*

al. 1325 (UFRN). Cerro Corá, fazenda Tupã, 28 February 1980, fl., *O.F. Oliveira et al.* 86 (MOSS). Currais Novos, 4 August 2011, fr., *A.A. Roque* 1226 (UFRN). Equador, 08 June 1998, fl., *N. Yamaraka et al.* 112 (MOSS). Luís Gomes, estrada para cachoeira do Rela, 31 May 2008, fr., *R.C. Oliveira et al.* 2201 (MOSS). Monte das Gameleiras, estrada de terra a 3.4 km da sede municipal, 21 December 2015, fl., *Tomaz et al.* 99 (UFRN). São Tomé, rodovia BR-104 sentido Currais Novos/Santa Cruz, 13 January 2013, fr., *A.A. Roque et al.* 1485 (UFRN). Serra Caiada, afloramento de Serra Caiada, 24 November 2007, st., *A.H. Ribeiro & I. Lira* 276 (UFRN); *ibid.*, 1 January 2008, fl., *I.B. Lira s.n.* (UFRN 7743). Serra de São Bento, morro do Cruzeiro, 24 August 2012, fl., *L.M. Versieux et al.* 535 (UFRN); *ibid.*, 24 August 2012, fr., *L.M. Versieux et al.* 536 (UFRN). Sítio Novo, 1 January 2008, st., *I.B. Lira s.n.* (UFRN 7734). Serra Negra do Norte, serra Negra, 12 February 1981, fl., *O.F. Oliveira et al.* 1620 (MOSS).

Distribution, habitat and phenology:—The distribution of *Tillandsia streptocarpa* is restricted to South America, occurring in Brazil, Peru, Bolivia and Paraguay (Smith & Downs 1977, Pontes & Agra 2006). In Brazil, it is present in all regions, in the domains of Amazon Rainforest, Caatinga, Cerrado, Atlantic Forest and Pampa (Flora do Brasil 2020). In RN, it is found in the Caatinga domain, as epiphytes in dry woodlands or as rupicolous on *inselbergs*. Flowering from January to August, fruiting from December to August. Map (Fig. 1, Table 1): C5, D2, D5, D6, D7, E2, E3.

Comments:—*Tillandsia streptocarpa* is included in subgenus *Phytarrhiza* (Smith & Downs 1977) and it can be easily identified by its densely cinereous-lepidote leaves, with blades 8–35 cm long, spiraling towards de apex (Fig. 4L). The inflorescence is 6–20 cm long, simple or compound, with linear spikes (Fig. 4L). Flowers have a sweetened scent and petals are generally light purple and strongly spatulate (Fig. 4M). Medicinal uses are also indicated for this species (Albuquerque *et al.* 2007).

9.8. *Tillandsia stricta* Solander ex Sims (1813: 1529) [Fig. 4N–O]

Herb epiphytic. *Stem* reduced. *Rosette* open. *Leaves* spiraled, suberect; *leaf sheath* 8–10 × 13 mm, membranaceous; *leaf blade* 7–15 × 0.3–0.7 cm, narrowly lanceolate, slightly coriaceous, green, slightly cinereous-lepidote, apex long attenuate. *Peduncle* 3–4 (–10) cm long, arcuate; *peduncle bracts* 3–10 × 0.4–0.8 cm, elliptic, densely lepidote, apex caudate. *Inflorescence* 3–4(–7) cm long, spike, lax; *floral bracts* 10–30 × 4–10 mm, elliptic, remote, apex acute to caudate, pink, turning white as the inflorescence matures. *Flowers* sessile, tubular; *sepals* 10–15 mm long, elliptic, carinate, shortly connate, apex acute; *petals* 13–18 mm long, ligulate, erect, bluish-purple to lilac, apex obtuse; *stamens* included. *Fruits* 2.8–3 cm long, cylindrical.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Ceará-Mirim, margem do rio Ceará-Mirim, 18 October 2007, fr., A.H. Ribeiro & I. Lira 279 (UFRN); *ibid.*, 1 January 2008, fr., I.B. Lira s.n. (UFRN 7735). Goianinha, próximo Usina Estivas, 12 November 1980, fr., O.F. Oliveira et al. 1567 (MOSS). Parnamirim, 17 June 2008, fr. A.C.P. Oliveira 1294 (UFRN). Serra de São Bento, morro do Cruzeiro, 27 November 2015, fl., G.S. Garcia & L.M.G. Gonçalves 87 (UFRN).

Distribution, habitat and phenology:—*Tillandsia stricta* is widely distributed in South America, occurring in dry or wet forests from Venezuela to Argentina (Smith & Downs 1977). Its distribution in Brazil comprehends states of the Northeast and all the Southeast, South and Central West regions (Smith & Downs 1977, Pontes & Agra 2006, Flora do Brasil 2020). In RN, this species is found with epiphytic habit in fragments of Atlantic Forest and in caatinga vegetation, associated with rocky outcrops. Fruiting in January to November; flowered in cultivation in November. Map (Fig. 1, Table 1): C7, D7, D8.

Comments:—*Tillandsia stricta* is easily identified by the spike with floral bracts 1–3 cm long, bright pink, but often becoming whitish or greenish with aging and the flowers with tubular dark purple corollas (Fig. 4N–O). Additionally, the peduncle is arcuate, usually 3–4 cm long, but reaching up to 10 cm in cultivated specimens. The vibrant and different colors support this species ornamental use (Fiorato 2009). This species belongs to subgenus *Anoplophytum* (Barfuss *et al.* 2016).

9.9. *Tillandsia tenuifolia* Linnaeus (1753: 286) [Fig. 4P]

Herb rupicolous. *Stem* developed. *Rosette* infundibuliform or absent, tank absent. *Leaves* spiraled, erect to recurved, disposed along the stem; *leaf sheath* 5–6 × 13–15 mm, membranaceous; *leaf blade* 6–8 × 0.3–0.5 cm, narrowly triangular, coriaceous, green, slightly lepidote, apex attenuate. *Peduncle* 4.5–6 cm long, straight, glabrous; *peduncle bracts* 3.5–6 × 0.7 cm, elliptic at the base, pink, the inferior long attenuate towards apex, the superior with apex caudate, lepidote. *Inflorescence* 2.5–3 cm long, spike, straight; *floral bracts* 13–20 × ca. 7 mm, ovate to elliptic, imbricate, pink, apex acute or sometimes aristate. *Flowers* sessile, polystichous; *sepals* 9–11 mm long, narrowly lanceolate, apex acuminate, the anterior one free, ecarinate, slightly shorter, the posterior ones connate for ca. 5 mm, slightly carinate; *petals* 15–16 mm long, spatulate, white, apex obtuse; *stamens* included. *Fruits* not seen.

Specimen examined:—BRAZIL. **Rio Grande do Norte:** Monte das Gameleiras, 5 November 2016, fl., G.S. Garcia & L.M.G. Gonçalves 433 (UFRN).

Distribution, habitat and phenology:—*Tillandsia tenuifolia* is widely distributed from Central to South America (Smith & Downs 1977) and all over Brazil, except for the North, including the domains of the Amazon, Atlantic Forest, Caatinga and Cerrado (Flora do Brasil 2020). Here we provide the first report of its occurrence to RN,

where it grows on inselbergs, among rupicolous vegetation in the Caatinga domain. Flowering in November. Map (Fig. 1, Table 1): D7.

Comments:—*Tillandsia tenuifolia* belongs to subgenus *Anoplophytum* (Barfuss *et al.* 2016). This species can be identified by the caulescent habit, with imbricate leaves disposed along the stem, the leaf blades coriaceous, the pink peduncle bracts, the simple inflorescence with pink floral bracts and flowers with white tubular corollas (Fig. 4P). The bright pink overall appearance of the inflorescence and the white corollas provide ornamental potential to this species (Pontes & Agra 2010).

9.10. *Tillandsia tricholepis* Baker (1878: 237)

Herb epiphytic. *Stem* developed, delicate, 4–6 cm long. *Rosette* absent. *Leaves* spiraled, erect, closely disposed along the stem; *leaf sheath* 5–7 × 4–5 mm, ovate, membranaceous; *leaf blade* 10–20 × 3 mm, narrowly triangular, apex long attenuate. *Peduncle* 4–5 cm long, erect, glabrescent; *peduncle bracts* 7–14 × 2.5–3.5 mm, elliptic to lanceolate, ecarinate, apex acuminate or short to long attenuate. *Inflorescence* 1.2–2.5 cm, spike, few-flowered (2–5), straight; *floral bracts* 5–6.5 × 4–5 mm, ovate, apex acute, ecarinate, lepidote. *Flowers* sessile, distichous; *sepals* ca. 8 cm long, elliptic, apex acute, lepidote at apex; *petals* orange; *stamens* included. *Fruits* 2–3 cm long, cylindrical.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Coronel João Pessoa, 26 May 1981, fr., *O.F. Oliveira et al.* 1879 (MOSS). Luís Gomes, estrada para cachoeira do Rela, 31 May 2008, fr., *R.C. Oliveira et al.* 2202 (MOSS).

Additional specimen examined:—BRAZIL. **Ceará:** Monsenhor Tabosa, fazenda Oitis, 29 March 2018, fl., *E.C. Tomaz* 206 (UFRN).

Distribution, habitat and phenology:—The distribution of *Tillandsia tricholepis* comprehend Bolivia, Paraguay, Argentina and Brazil (Smith & Downs 1977).

In Brazil, it is particularly frequent in the South and Southeast and was only known to occur in the Northeastern states of Ceará, Pernambuco and Paraíba (Leme & Siqueira-Filho 2006, Flora do Brasil 2020). In RN, it is currently restricted to the Caatinga domain. Fruiting in May. Map (Fig. 1, Table 1): D2.

Comments:—*Tillandsia tricholepis* is frequently found forming clumps that hang from branches of trees or fences due to the development of the stem, which is its most diagnostic character. This species is also part of the subgenus *Diaphoranthema* (Smith & Downs 1977) and it can be confused with *T. loliacea*. The two can be differentiated by the caulescent habit, with leaves disposed along the stem, and straight inflorescence in *T. tricholepis* in contrast with the extremely reduced stem, rosulate leaves, and geniculate inflorescence in *T. loliacea*.

9.11. *Tillandsia usneoides* (Linnaeus 1753: 287) Linnaeus (1762: 411) [Fig. 4Q–R]

Herbs epiphytic, forming dense and long clusters pending from tree branches. *Stem* filiform, visible. *Rosette* absent. *Leaves* distichous, suberect; *leaf sheath* 7–10 × 2–4 mm, elliptic, membranaceous, imbricate; *leaf blade* 20–60 × ca. 1 mm, cylindrical, patent to recurved, slightly incrassate, green, densely cinereous-lepidote. *Flowers and fruits* not seen.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Ceará-Mirim, margem do rio Ceará-Mirim, 18 October 2007, st., A.H. Ribeiro & I. Lira 280 (UFRN); *ibid.*, 1 January 2008, st., I.B. Lira (UFRN 7738).

Distribution, habitat and phenology:—*Tillandsia usneoides* is distributed through the American continent, from southern United States to Argentina and Chile (Smith & Downs 1977). In Brazil, its occurrence has been reported in all regions, including areas of Caatinga, Cerrado, Atlantic Rainforest and Pampa (Flora do Brasil

2020). In RN, *T. usneoides* was collected growing on riparian vegetation in the Atlantic Forest domain. Through photography, we also evidenced its presence on arboreal caatinga vegetation (Fig. 4Q–R). Map (Fig. 1, Table 1): C7.

Comments:—Along with *T. loliacea*, *T. recurvata* and *T. tricholepis*, *Tillandsia usneoides* is also included in subgenus *Diaphoranthema* (Smith & Downs 1977, Barfuss *et al.* 2016). The species can be easily recognized by its growth form, as obligate epiphyte forming large and dense pendulous clumps. In addition, individuals are rootless when mature, presenting a filiform stem and densely cinereous-lepidote leaves. Flowers were not observed in material from RN or in the field, and in fact, *Tillandsia usneoides* has been reported to be rarely found and collected during the reproductive stage (Wanderley *et al.* 2007, Coffani-Nunes *et al.* 2010). The scape is nearly absent, the inflorescence presents a single flower, with petals varying from green to yellow (Wanderley *et al.* 2007, Coffani-Nunes *et al.* 2010, Versieux & Sousa 2016) and blue (Smith & Downs 1977).

10. *Wittmackia* Mez (1891: 274)

Epiphytic, rupicolous or terricolous herbs. Rosette infundibuliform. Leaf sheath wide; leaf blade entire or serrate. Inflorescence simple or compound. Peduncle present. Floral bracts membranaceous to strongly coriaceous. Flowers sessile. Sepals strongly asymmetric, unarmed to strongly mucronate. Petals white or green, free, naked or with a pair of lobulated appendages. Stamens included. Fruit berry.

The genus *Wittmackia* was recently resurrected and re-circumscribed based on a broad phylogenetic study (Aguirre-Santoro 2017). The genus' current concept comprehends, besides the three species proposed by Mez (1891), taxa included before in the genera *Ronnbergia*, *Aechmea* and *Hohenbergia* subg. *Wittmackiopsis*, with

occurrence throughout Central America and the North and coast of South America (Aguirre-Santoro 2017). Only one species was recorded in RN.

10.1. *Wittmackia patentissima* (Martius ex Schultes & Schultes f. 1830: 1270) Mez (1891: 278) [Fig. 3P–Q]

Herbs terricolous or epiphytic. *Rosette* infundibuliform, tank present. *Leaves* erect to suberect, sub-coriaceous; *leaf sheath* (7–)11–18 × 7–10 cm, oblong, castaneous to vinaceous; *leaf blade* 54–64 × 4.5–7 cm, oblong, light green, margin serrulate, apex abruptly acuminate, darkened, rigid; *aculei* 1–3 mm long, antrorse, densely arranged. *Peduncle* 25–45 cm long, erect, light green, slightly lanuginose to glabrescent; *peduncle bracts* 5–9 × 1–1.7 cm, lanceolate, paleaceous, apex pungent. *Inflorescence* 21–47 cm long, panicle of spikes, lax, nearly ellipsoid; *primary bracts* 0.8–7 × 0.2–1 cm, triangular to lanceolate, paleaceous, apex acuminate; *branches* 9–25 in number, 2.5–18 cm long; *floral bracts* 4–7 mm long, 5–10 mm wide at the base, ovate or lanceolate, coriaceous, apex caudate or attenuate. *Flowers* sessile; *sepals* 3.5–4.5 mm long, asymmetric, yellowish-green, apex aristate; *petals* ca. 8 mm long, slightly spatulate, white, apex obtuse, slightly recurved; callosities present; *stamens* included. *Fruits* ca. 8 × 3 mm, whitish to dark purple when mature.

Specimens examined:—BRAZIL. **Rio Grande do Norte:** Baía Formosa, Mata Estrela, 10 September 2011, fl., J.L. Costa-Lima & W.M.B. São-Mateus 579 (UFRN). Canguaretama, entre os rios Espinho e Curimatam, 9 November 1980, fl., O.F. Oliveira et al. 1467 (MOSS). Natal, 6 November 1980, fl., Projeto Parque das Dunas 223 (MOSS); *ibid.*, Parque das Dunas, 13 April 2012, fr., A.S.M. Medeiros & E.C. Tomaz 2 (UFRN); *ibid.*, 21 September 2012, fl., E.C. Tomaz & A. Medeiros 1 (UFRN); *ibid.*, 18 December 2012, fr., E.C. Tomaz & R. Magalhães 2 (UFRN). Nísia Floresta, Floresta

Nacional, 7 December 2013, fl., *L. M. Versieux* 628 (UFRN). São José do Mipibu, Fazenda Muriaé, 11 February 2011, fr., *J.L. Costa-Lima et al.* 346 (UFRN). Vera Cruz, Sítio Araçá I, 27 November 1994, fr., *J.O. Freire et al.* 17 (MOSS); *ibid.*, s/d, fl., *J.O. Freire & M. Hermogenes s.n.* (MOSS 9991).

Distribution, habitat and phenology:—The distribution of *W. patentissima* is restricted the Brazilian Atlantic Forest, more expressively in the Northeastern region, but also found in Espírito Santo and Rio de Janeiro (Maciel *et al.* 2015, Aguirre-Santoro 2017). In RN, this species can be found in open or shaded areas of restinga vegetation and seasonal semideciduous forest. Flowering from September to December, fruiting from November to February and April. Map (Fig. 1, Table 1): C7, D8.

Comments:—*Wittmackia patentissima* can be recognized by its leaves with dark, rigid and abruptly acuminate apex, densely serrulate margins, with aculei 1–3 mm long, and the many flowered and branched (branches 9–25 in number), lax and pale green inflorescence (Fig. 3P–Q). The flowers have aristate sepals and white petals.

Wittmackia patentissima is part of the “*Aechmea lingulata* complex” (Leme & Siqueira-Filho 2006, Maciel *et al.* 2015, Aguirre-Santoro 2017). The species is morphologically related to *Wittmackia lingulatoides* (Leme & H. Luther 1998: 187) Aguirre-Santoro (2017: 635), from which it differentiates by the mesophytic/hygrophytic habit (vs. xerophytic), cespitose vegetative growth (vs. stoloniferous), spikes shorter (vs. longer spikes), sepal mucro 1–1.5 mm long (vs. 2–3 mm long), petals 8–9 mm long (vs. ca. 11 mm long) (Leme & Siqueira-Filho 2006, Aguirre-Santoro 2017). Aguirre-Santoro (2017) also indicates the existence of individuals with intermediary morphology between *W. patentissima* and *Wittmackia lingulata* (Linnaeus 1753: 285) Mez (1891: 275), suggesting the necessity of a deeper investigation.

Acknowledgements

We are primarily thankful to PROPESQ/UFRN, CAPES, and Graduate Program in Systematics and Evolution, for the first author's Scientific Initiation Scholarship (Project PVA10623-2014) and M. Sc. Fellowships; and to CNPq, for the second author's Productivity Scholarship (#304778/2013-3) and grant (#455510/2014-8). We thank the Program of Research on Biodiversity of the Brazilian Semi-arid (PPBio Semi-árido Project) for providing funds to enhance knowledge about the Caatinga in RN, thus contributing to the development of this research (especially to Prof. Reyjane P. de Oliveira and Daniela C. Torres for multiple assistances during organizations of field expeditions). We also thank L.O.F. Sousa, G.S. Garcia and R. Magalhães for providing photographs and the collectors and staff from the cited herbaria. Lastly, we are grateful to Eric Gouda, Elton Leme, and one anonymous reviewer for important comments and suggestions on this paper.

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TABLE 1. Bromeliaceae species by subfamily and genera (followed by species count) in Rio Grande do Norte, Brazil.

Bromelioideae		<i>Aechmea aquilega</i> (Salisb.) Griseb.
	<i>Aechmea</i> (3)	<i>Aechmea mertensii</i> (G.Mey.) Schult. & Schult. f. <i>Aechmea muricata</i> L.B.Sm.
	<i>Ananas</i> (1)	<i>Ananas ananassoides</i> (Baker) L.B.Sm.
	<i>Bromelia</i> (2)	<i>Bromelia</i> sp. <i>Bromelia laciniosa</i> Mart. ex Schult. & Schult.f.
	<i>Cryptanthus</i> (1)	<i>Cryptanthus zonatus</i> (Vis.) Vis. <i>Hohenbergia catingae</i> Ule
	<i>Hohenbergia</i> (3)	<i>Hohenbergia horrida</i> Harms <i>Hohenbergia ridleyi</i> (Baker) Mez
	<i>Neoglaziovia</i> (1)	<i>Neoglaziovia variegata</i> (Arruda) Mez
	<i>Orthophytum</i> (1)	<i>Orthophytum disjunctum</i> L.B.Sm.
	<i>Wittmackia</i> (1)	<i>Wittmackia patentissima</i> (Mart. ex Schult. & Schult.f.) Mez
Pitcairnioideae	<i>Encholirium</i> (1)	<i>Encholirium spectabile</i> Mart. ex Schult. & Schult.f.
Tillandsioideae	<i>Tillandsia</i> (12)	<i>Tillandsia bulbosa</i> Hook.
		<i>Tillandsia gardneri</i> Lindl.
		<i>Tillandsia loliacea</i> Mart. ex Schult. & Schult.f.
		<i>Tillandsia paraensis</i> Mez
		<i>Tillandsia paraibensis</i> R.A. Pontes
		<i>Tillandsia polystachia</i> (L.) L.
		<i>Tillandsia recurvata</i> (L.) L.
		<i>Tillandsia streptocarpa</i> Baker
		<i>Tillandsia stricta</i> Sol. ex Sims
		<i>Tillandsia tenuifolia</i> L.
		<i>Tillandsia tricholepis</i> Baker
		<i>Tillandsia usneoides</i> (L.) L.

TABLE 2. Total number of Bromeliaceae records per municipality of Rio Grande do Norte State, Brazil. All 167 state municipalities are grouped under map grid cells (GC), corresponding the alphanumeric codes listed in figure 1. Missing cell codes in this table refer to grid cells that harbor only fractions of municipality(ies) area(s), not including any administrative center (see methods).

GC	Municipalities (total record number)
A2	Areia Branca (0), Grossos (0), Tibau (0)
B1	Baraúna (0), Governador Dix-Sept Rosado (0)
B2	Mossoró (1), Serra do Mel (0)
B3	Afonso Bezerra (0), Alto do Rodrigues (1), Carnaubais (0), Ipanguaçu (0), Macau (1), Pendências (0), Porto do Mangue (0)
B4	Caiçara do Norte (1), Galinhos (0), Guamaré (0), Jandaíra (0), São Bento do Norte (0)
B5	Parazinho (0), Pedra Grande (0), Pureza (0), São Miguel do Gostoso (3)
B6	Rio do Fogo (4), Touros (5)
C1	Rodolfo Fernandes (0), Taboleiro Grande (0)
C2	Apodi (3), Cararábas (0), Felipe Guerra (0), Itaú (0), Olho d'Água do Borges (1), Riacho da Cruz (0), Severiano Melo (0), Umarizal (0), Viçosa (0)
C3	Augusto Severo (0), Paraú (0), Triunfo Potiguar (0), Upanema (0)
C4	Assú (1), Angicos (0), Fernando Pedroza (0), Itajá (0), Santana do Matos (0), São Rafael (0)
C5	Bodó (0), Lajes (2), Pedra Preta (0), Pedro Avelino (0), São Tomé (2)
C6	Barcelona (0), Bento Fernandes (2), Bom Jesus (0), Caiçara do Rio do Vento (0), Ielmo Marinho (0), Jardim de Angicos (0), João Câmara (3), Lagoa de Velhos (0), Poço Branco (0), Riachuelo (1), Ruy Barbosa (0), Santa Maria (0), São Paulo do Potengi (0), São Pedro (0), Taipu (2)
C7	Ceará-Mirim (20), Extremoz (6), Macaíba (5), Maxaranguape (1), Natal (26), Parnamirim (6), São Gonçalo do Amarante (0)
D2	Água Nova (0), Alexandria (0), Coronel João Pessoa (2), Doutor Severiano (0), Encanto (0), Francisco Dantas (0), José da Penha (0), Luís Gomes (3), Major Sales (0), Marcelino Vieira (0), Paraná (0), Pau dos Ferros (0), Pilões (0), Rafael Fernandes (0), Riacho de Santana (0), São Miguel (0), São Francisco do Oeste (0), Tenente Ananias (0), Venha-Ver (1)
D3	Almino Afonso (1), Antônio Martins (0), Frutuoso Gomes (0), João Dias (0), Lucrécia (0), Martins (2), Messias Targino (0), Patu (0), Portalegre (0), Rafael Godeiro (0), Serrinha dos Pintos (0)
D4	Caicó (1), Janduís (0), Jardim de Piranhas (0), Jucurutu (2), São Fernando (0), Timbaúba dos Batistas (0)

- D5 Acari (1), Cruzeta (0), Currais Novos (2), Florânia (1), São José do Seridó (1), São Vicente (0), Tenente Laurentino Cruz (0)
- D6 Campo Redondo (8), Cerro Corá (7), Coronel Ezequiel (0), Jaçanã (0), Lagoa Nova (0), Lajes Pintadas (0), Santa Cruz (4), São Bento do Trairí (0)
- D7 Januário Cicco (0), Japi (1), Lagoa d'Anta (0), Monte das Gameleiras (22), Passa e Fica (0), Serra Caiada (8), São José do Campestre (0), Senador Elói de Souza (0), Serra de São Bento (11), Serrinha (0), Sítio Novo (2), Tangará (0)
- D8 Arês (0), Baía Formosa (9), Brejinho (0), Canguaretama (3), Espírito Santo (2), Goianinha (4), Jundiá (0), Lagoa de Pedras (0), Lagoa Salgada (0), Montanhas (0), Monte Alegre (0), Nísia Floresta (16), Nova Cruz (2), Passagem (0), Pedro Velho (1), Santo Antônio (3), São José de Mipibu (2), Senador Georgino Avelino (0), Tibau do Sul (2), Várzea (0), Vera Cruz (2), Vila Flor (0)
- E2 Ipueira (0), São João do Sabugi (1), Serra Negra do Norte (7)
- E3 Carnaúba dos Dantas (0), Equador (8), Jardim do Seridó (0), Ouro Branco (0), Parelhas (0), Santana do Seridó (0)
-

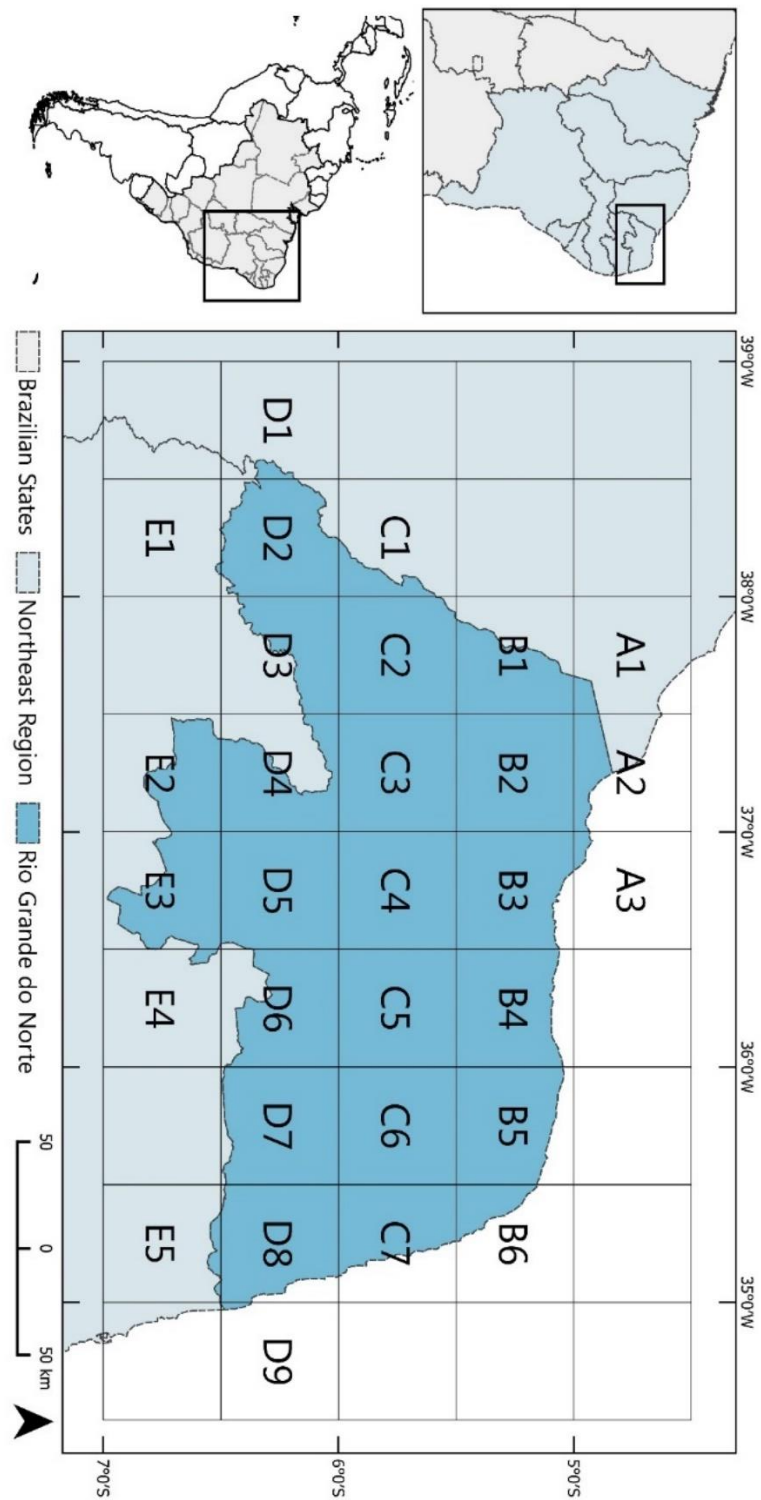


FIGURE 1. Map of Rio Grande do Norte State, Brazil. Grid cells are $0.5^\circ \times 0.5^\circ$.

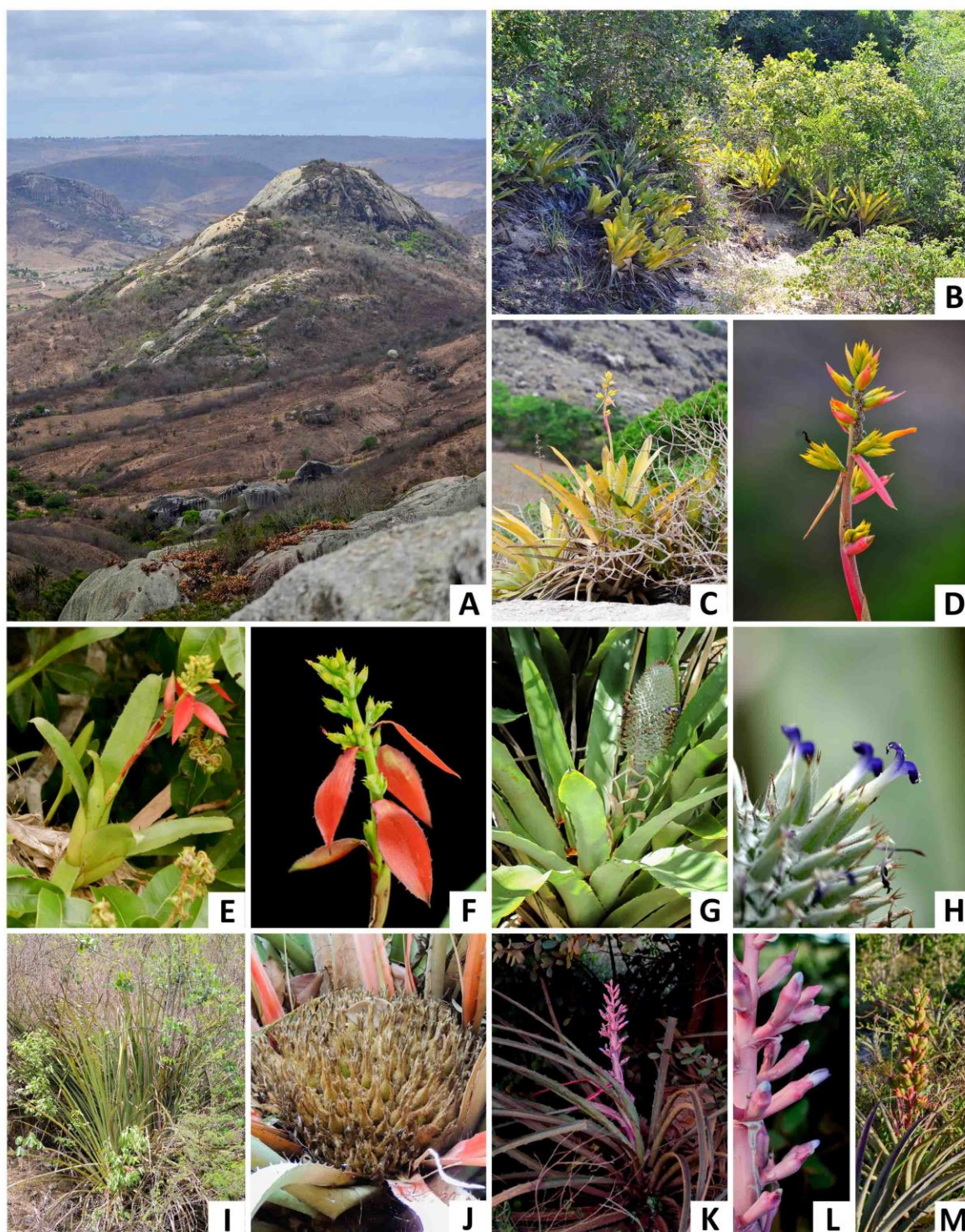


FIGURE 2. A–B. Examples of the habitat diversity in RN: **A.** Landscape of Caatinga with rocky outcrops in Monte das Gameleiras; **B.** Shrubby restinga vegetation in Touros. **C–D.** *Aechmea aquilega*: **C.** habit; **D.** inflorescence. **E–F.** *Aechmea mertensii*: **E.** habit; **F.** inflorescence. **G–H.** *Aechmea muricata*: **G.** habit; **H.** flowers in detail. **I–J.** *Bromelia* sp.: **I.** habit; **J.** inflorescence. **K–M.** *Bromelia laciniosa*: **K.** habit; **L.** detail of flowers; **M.** fruiting individual. Photos: E.C. Tomaz (A–D, F, H, K–M), G.S. Garcia (E), R. Magalhães (G), L.O.F. Sousa (I, J).

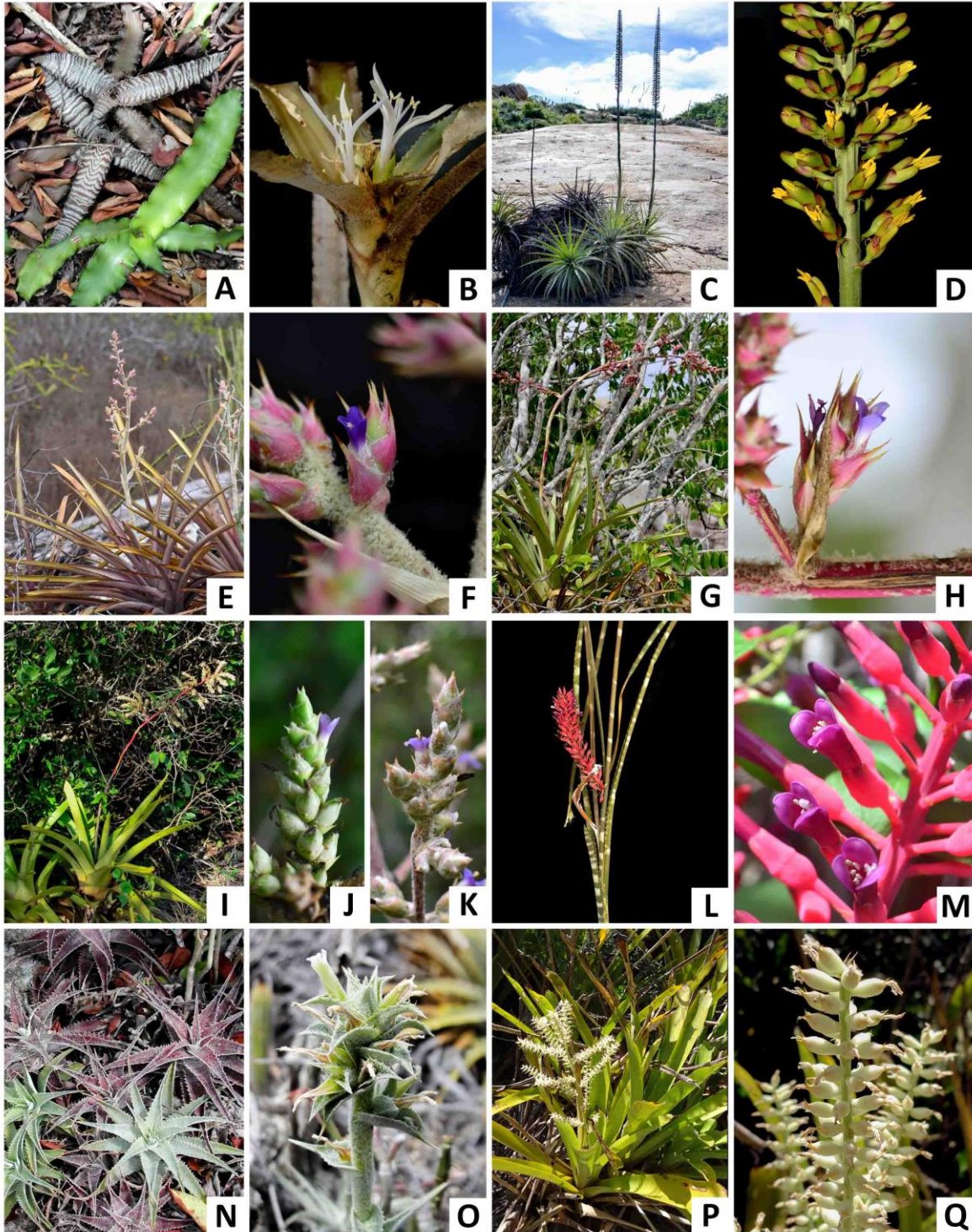


FIGURE 3. A–B. *Cryptanthus zonatus*: A. two different morphotypes in sympatry; B. detail of inflorescence. C–D. *Encholirium spectabile*: C. habit; D. flowers. E–F. *Hohenbergia catingae*: E. habit; F. detail of flower. G–H. *Hohenbergia horrida*: G. habit; H. detail of flower. I–K. *Hohenbergia ridleyi*: I. habit; J. flower and developing fruits; K. detail of flower. L–M. *Neoglaziovia variegata*: L. habit; M. flowers. N–O. *Orthophytum disjunctum*: N. green and vinaceous morphotypes; O. detail of inflorescence. P–Q. *Wittmackia patentissima*: P. habit; Q. detail of inflorescence. Photos: E.C. Tomaz (A–L, O–Q), G.S. Garcia (M), L.M. Versieux (N).

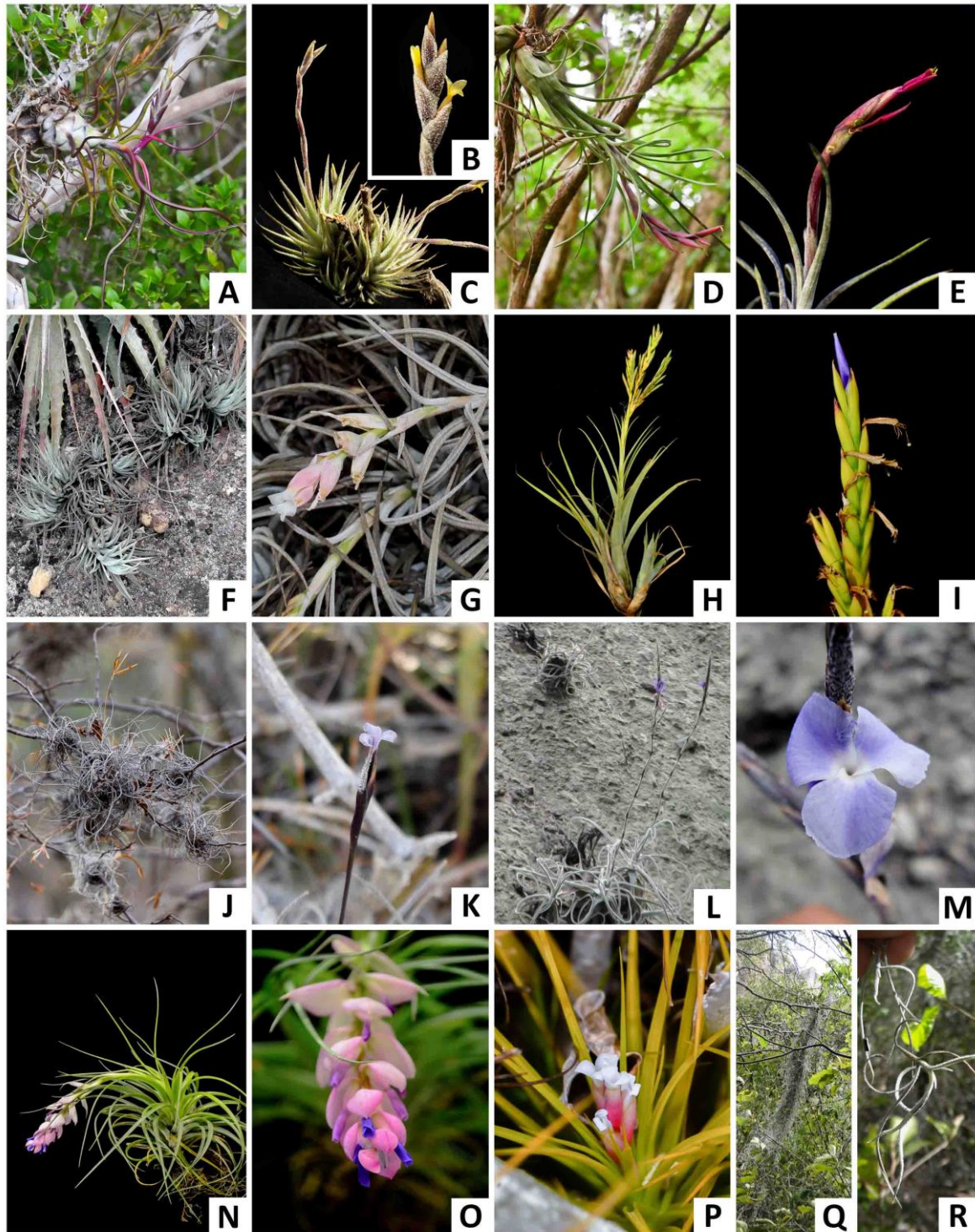


FIGURE 4. A. *Tillandsia bulbosa*: habit. B–C. *Tillandsia loliacea*: B. habit; C. detail of flowers. D–E. *Tillandsia paraensis*: D. habit; E. detail of inflorescence. F–G. *Tillandsia paraibensis*: F. habit; G. inflorescence. H–I. *Tillandsia polystachia*: H. habit (fruiting individual); I. detail of inflorescence. J–K. *Tillandsia recurvata*: J. habit; K. inflorescence. L–M. *Tillandsia streptocarpa*: L. habit; M. detail of flower. N–O. *Tillandsia stricta*: N. habit; O. detail of inflorescence. P. *Tillandsia tenuifolia*: habit. Q–R. *Tillandsia usneoides*: Q. clump pending from trees; R. detail of individual. Photos: E.C. Tomaz (B–E, H, J–O, Q, R), G.S. Garcia (A, G, I, P), L.M. Versieux (F).

CAPÍTULO 2

AN UPDATED AND ANNOTED CHECKLIST OF BROMELIACEAE FROM CEARÁ, BRAZIL

Abstract

This work consists of an updated and annotated checklist of Bromeliaceae from the state of Ceará, Northeastern Brazil. Thirty-five species were recorded in the state, distributed in 14 genera and three subfamilies. *Aechmea tocantina*, *Aechmea leptantha* and *Aechmea bromeliifolia* var. *albobracteata* are recorded for the first time in the state. Dubious records for the state are discussed. We provide identification keys for genera and species. In addition, we comment on morphology, habits, distribution, habitat, conservation and phenology. A plate with photos of the species observed in the field is provided. We hope this work will help to produce a complete treatment of Bromeliaceae for the Flora of Ceará in the near future.

Key-words: bromeliads, Northeastern Brazil, taxonomy, distribution, new records.

Introduction

The state of Ceará (CE), in Northeastern Brazil, has an Angiosperm Flora estimated to be around 2.430 species (BFG 2015). This state has been traditionally included in the Caatinga domain in a broad sense, what has caused neglect of the great variability of vegetation types in the state (Moro *et al.* 2015).

Bromeliaceae is one of the richest monocotyledon families in Ceará (Freitas *et al.* 2011), state for which the Flora of Brazil 2020 (under construction), lists the occurrence of 45 species. In addition, seven of these are currently considered endemic to CE (Flora do Brasil 2020) and most of them have been published over the past decade (Leme *et al.* 2010; Leme & Scharf 2011; Versieux *et al.* 2013; Moura & Costa 2014). Also, four are already classified as “endangered” (Moura & Costa 2014; Martinelli & Moraes 2013).

Many bromeliads are in alarming state of threat (Martinelli *et al.* 2008), which is critical as they have an extreme ecologic importance in the habitats they occur (Benzing 2000; Islair *et al.* 2015; Versieux & Wanderley 2015). In addition, bromeliads have been largely explored due to their overall economic importance, including their use in landscaping and by the food industry, as well as in the production of natural fibers and even for their medicinal properties (Smith 1955; Reinhardt *et al.* 2000, Mayo, 1992; Souza & Lorenzi 2012; Albuquerque *et al.* 2016).

Even with the expressive richness of Bromeliaceae in Ceará, the only list of the family was provided by Versieux *et al.* (2013) and is restricted to Pico Alto, a ridge peak in the Baturité massif. Thus, the objective of this work is to provide an updated and annotated checklist based on the literature, field work and herbaria data, in order to facilitate the preparation of a complete Bromeliaceae Flora for Ceará and assist species

identification through taxonomic key for genera and species, and notes on distribution, habitat, conservation, morphology and phenology.

Material and methods

Study area:—Located in northeastern Brazil, the state of Ceará covers approximately 148,886 km², with its borders defined at North by the Atlantic Ocean, at South by the state of Pernambuco, at the west by Piauí and East by Rio Grande do Norte and Paraíba (Figure 1). The warm semi-arid tropical climate predominates in the entire state and is characterized by scarce and irregular rainfall and high evapotranspiration (IPECE 2017).

The vegetation in CE (Figure 1) was categorized in 11 phytoecologic units by Moro *et al.* (2015) and is herein referred to as follows: coastal vegetation (COV), mangrove (MAN), coastal cerrado and *cerradão* (CCC), inner cerrado and *cerradão* (ICC), carnaubal (CAR), crystalline caatinga (CRC), sedimentary caatinga (SEC), dry crystalline forest (DCF), wet crystalline forest (WCF), dry sedimentary forest (DSF) and wet sedimentary forest (WSF).

Taxonomy:—Data was compiled firstly from the literature and the List of Species of the Brazilian flora (Flora do Brasil 2020). After that, visits to herbaria UFRN, MOSS, EAC, HCDAL and HUVA (acronyms according to Thiers 2019), in order to analyze specimens from CE. Finally, field work and sample effort prioritized areas known to be rich in Bromeliaceae, including localities with occurrence of endemic species and/or areas with occurrence of species of restricted distribution in CE (Table 1). All collected material as deposited in the collection of herbarium UFRN.

Based on this data gathering, for each taxon we provide the binomial, *obra princeps*, and indicate distribution, habitat, habit, elevation of occurrence within CE, and provide a list of specimens confirmed by the authors. In addition, comments regarding important morphologic characters and conservation are also provided. Descriptive terminology follows Koide (1998) and Beentje (2010).

Results and discussion

A total of 14 genera and 35 species, with one variety, are herein listed for CE (Table 2). The subfamily Tillandsioideae concentrated most of the species (53%), followed by Bromelioideae and Pitcairnioideae (Figure 2). The epiphytic habit was the most commonly observed among the studied taxa (Figure 3).

Aechmea leptantha (Harms) Leme & J.A.Siqueira, *Aechmea tocantina* Baker and *Aechmea bromeliifolia* var. *albobracteata* Philcox are new records for Ceará, with the last herein reported for the first time in Northeastern Brazil.

Taxa names listed in Table 3 were previously cited for Ceará but have been excluded from the present list due to either the lack of voucher or because they represent outdated determinations. The two known varieties of *Aechmea bromeliifolia* (Rudge) Baker have been separated only by color (Faria *et al.* 2009), which makes difficult the identification of dry material in herbaria. Although the presence of *Aechmea bromeliifolia* var. *bromeliifolia* has been reported to Ceará (Maciel *et al.* 2015, Faria *et al.* 2009; Flora do Brasil 2020), only specimens with morphology of var. *albobracteata* were observed during our field work. For this reason, the typical variety is not reported in the present work.

In addition, the name *Aechmea patentissima* (Mart. ex Schult. & Schult.f.) Baker had been applied to specimens from Serra de Maranguape, all of which were later placed under *Aechmea maranguapensis* Leme & Scharf and are currently in *Wittmackia maranguapensis* (Leme & Scharf) Aguirre-Santoro. Similarly, *Vriesea rodigasiana* É.Morren was mistaken by *Vriesea baturitensis* Versieux & Tomaz, and the same seems to happen with the name *V. procera* (Mart. ex Schult. & Schult.f.) Wittm.

Identification key for Bromeliaceae genera in Ceará

1. Leaf margins entire; seeds with plumose appendages (**subfamily Tillandsioideae**)...2
 - Leaf margins serrate to serrulate, sometimes only at base and entire towards apex; seeds naked or winged (**subfamilies Pitcairnioideae and Bromelioideae**).....6
2. Rosette absent or open, with tank generally absent; leaf blade linear or narrowly triangular to triangular.....3
 - Rosette infundibuliform or utriculose, with tank generally developed; leaf blade oblong, ligulate or lanceolate.....4
3. Leaves with reddish longitudinal stripes at base.....**Wallisia (13)**
 - Leaves lacking longitudinal stripes.....**Tillandsia (11)**
4. Petals bearing two basal appendages.....**Vriesea (12)**
 - Petals naked.....5
5. Inflorescence always simple, corymbose or spike; petals shortly connate.....**Guzmania (6)**
 - Inflorescence compound or rarely simple, spike; petals free.....6

6. Rosette utriculose; flowers distichous; fruit cylindrical..... ***Racinaea* (10)**
- Rosette infundibuliform; flowers polystichous; fruit ovoid.....***Catopsis* (4)**
7. Ovary superior or semi-inferior; fruit capsule, dehiscent; seeds winged (**subfamily *Pitcairnioideae***).....8
- Ovary inferior; fruit berry, indehiscent; seeds naked (**subfamily *Bromelioideae***).....9
8. Rosette fasciculate; younger leaves serrulate only at base, chartaceous; flowers reddish..... ***Pitcairnia* (9)**
- Rosette open; all leaves strongly serrate, coriaceous; flowers greenish or yellow to red..... ***Encholirium* (5)**
9. Inflorescence bearing an apical coma of sterile bracts; fruit multiple, sorosis.....***Ananas* (2)**
- Inflorescence lacking an apical coma; fruit simple, berry.....10
10. Rosette fasciculate; leaves variegate with dense white-lepidote bands, strongly canaliculate.....***Neoglaziovia* (7)**
- Rosette open or infundibuliform; leaves with indumentum uniform, flat or only slightly canaliculate.....11
11. Sheaths usually with hair-like trichomes (villous); petals connate to the filament tube.....***Bromelia* (3)**
- Sheaths with adpressed scales (lepidote); petals free or only connate between themselves.....12
12. Leaf blades triangular, densely cinereous-lepidote; peduncle bracts like the leaves.....***Orthophytum* (8)**

- Leaf blades oblong to lanceolate or ligulate, usually sparsely lepidote; peduncle bracts differing from leaves.....13

13. Leaf blades oblong, margins densely and minutely serrulate, apex often abruptly attenuate and darkened; petals lilac; ovules naked.....**Wittmackia (14)**

- Leaf blades lanceolate, margins laxly and strongly serrate to serrulate, apex acute to acuminate; petals yellow, orange or bluish; ovules appendaged..... **Aechmea (1)**

1. *Aechmea* Ruiz & Pav., Fl. Peruv.: 47 (1794)

Identification key for species of *Aechmea* in Ceará

1. Inflorescence simple, strobiliiform.....*Aechmea bomeliifolia* (1.2)

- Inflorescence compound, paniculate.....2

2. Flowers aggregated in fascicles.....*Aechmea aquilega* (1.1)

- Flowers disposed in spikes or racemes.....3

3. Inflorescence in a panicle, at least 3-branched, flowers pedicellate, ca. 5 cm long.....

.....*Aechmea leptantha* (1.4)

- Inflorescence in panicle of spikes, branches only of first order, flowers sessile, 1.2–2.2 cm long.....4

4. Peduncle bracts lanceolate, with margins armed; primary branches strongly geniculate; floral bracts inconspicuous, aciculate from the base; petals bluish.....*Aechmea castelnavii* (1.3)

- Peduncle bracts narrowly elliptic, margins entire; primary branches straight to slightly flexuose; floral bracts conspicuous, ovate; petals yellow.....*Aechmea tocantina* (1.5)

1.1. *Aechmea aquilega* (Salisb.) Griseb., Fl. Brit. W. I.: 592 (1864) [Fig. 4 A–C]

Distribution and habitat:—Found from Central America to Brazil (Smith & Downs 1979). Occasional in Ceará. Epiphytic, rupicolous or terricolous in wet crystalline forests of the Baturité massif, Serra de Maranguape and Serra da Aratanha, in dry crystalline forests of the Meruoca massif and in interior Cerrado and *cerradão* of the Ibiapaba plateau; 600–1000 m.

Conservation:—Not evaluated globally. Found in three Areas of Environmental Protection (APAs, in Portuguese): APA Serra de Maranguape, APA Serra de Baturité and APA Serra da Meruoca.

Morphology:—Its inflorescence with flowers aggregated in fascicles is unique among all other species of *Aechmea* in Ceará. In addition, floral bracts are conspicuous, ovate, greenish to yellow, flowers sessile, from 40 to 44 mm long, with petals lightly spatulate and bright orange, and fruits ovoid. Specimens from Aratuba presented a whiteish exudate, which according to Leme & Siqueira-Filho (2006), is a feature common to species in the *A. aquilega* complex but has not been reported in any population from Brazil so far.

Phenology:—Blooming in December to January, May to August and October. Fruiting in March, July to August, October to December.

Specimens examined:—BRAZIL. **Ceará:** Aratuba, pico do Mussum, 30 June 2017, fl., Tomaz, E.C. 136 (UFRN). Caucaia, serra do Juá, 21 November 2014, fl., R. Moura 1134 (EAC). Guaramiranga, sítio Cana Brava, 9 August 1993, fl., Oliveira, M.R.L. 13 (EAC); *ibid.*, Sítio Lagoa, 20 August 2003, fr., Gomes, V. 546 (EAC); *ibid.*, sítio Lagoa, 6 July 2004, fr., Gomes, V. 607-05 (EAC); *ibid.*, estrada de Inhuporanga (Campos Belos) para Guaramiranga., 13 July 2008, fl., Menezes, M.O.T. 38 (EAC); *ibid.*, pico Alto., 9 March 2010, fr., Carvalho, A.M.M. s.n. (EAC 46828); *ibid.*, pico Alto., 4 November 2011, fr.,

Fortunato, M.E.M. 63 (EAC); topo do Pico Alto, 29 May 2015, fl., *Tomaz, E.C.* 82 (UFRN). Maranguape, serra de Maranguape, 10 January 1999, fl., *Oliveira, R.* s.n. (EAC); *ibid.*, pico da Rajada, 22 October 2011, fl., *Fortunato, M.E.M.* 60 (EAC). Meruoca, serra da Meruoca, 28 December 1958, fl., *Fernandes, A.* s.n. (EAC 1836); *ibid.*, serra da Meruoca, 14 August 1998, fl., *Martinelli, G.* 15059 (EAC). Mulungu, sítio Jardim, 19 August 2003, fr., *Gomes, V.* 353 (EAC). Pacatuba, serra da Aratanha, 10 October 1979, fr., *Fernandes, A.* s.n. (EAC 4189). Pacoti, 0 December 1986, fr., *L.W. Lima-Verde* s.n. (EAC 15694); *ibid.*, Sítio Olho D'água dos Tangarás, 7 July 1995, fl., *L.W. Lima-Verde* s.n. (EAC 23031). Tianguá, Santa Rita, 23 August 2004, fl., *L.W. Lima-Verde* 3009 (EAC).

1.2. *Aechmea bromeliifolia* (Rudge) Baker in Bentham & Hooker f., Gen. Pl. 3: 664 (1883) [Fig. 4 D–F]

Distribution and habitat:—Central America do Brazil, Argentina and Paraguay (Smith & Downs 1979; Faria *et al.* 2009). Occasional in Ceará. Epiphytic or terricolous in wet and dry crystalline forests of Baturité and Meruoca massifs as well as in sedimentary caatinga of the Ibiapaba plateau (*carrasco* vegetation) and interior Cerrado and *cerradão* and wet sedimentary forests of the Araripe plateau; 500–800 m.

Conservation:—This species is evaluated as “Least concern” (Martinelli & Moares 2013). Found within the APAs of Meruoca and Baturité, and the Araripe National Forest.

Morphology:—*Aechmea bromeliifolia* can be differentiated by its simple and strobiliform inflorescence, densely white lanose, and flowers with yellow corollas at anthesis but soon turning black. According to Faria *et al.* (2009), *A. bromeliifolia* var. *albobracteata* distinguish from the typical variety by the greenish to white peduncle

bracts (vs. pink), green peduncle (vs. vinaceous to dark purple) and floral bracts green (vs. vinaceous or purplish).

Phenology:—Blooming from March to November. Fruiting from May to December.

Specimens examined:—BRAZIL. **Ceará:** Caucaia, Serra do Juá, 21 November 2014, fl., *R. Moura 1133* (EAC). Crato, Chapada do Araripe, 30 May 1997, fr., *A.A. Castro* (MOSS); *ibid.*, Flona do Araripe, 6 October 1999, fr., *Lima-Verde, L.W. 1766* (EAC); *ibid.*, Flona do Araripe, 3 November 1999, fl., *Lima-Verde, L.W. 1794* (EAC); *ibid.*, 20 July 2012, fr., *E.N. Seixas 41* (HCDAL); *ibid.*, Minguiriba, 7 May 2013, fl., *M.S. Macêdo 10544* (HCDAL); *ibid.*, chapada do Araripe, 24 July 2018, fl., *E.C. Tomaz 209* (UFRN). Guaramiranga, sítio Sinimbu, 5 September 2003, fl., *Gomes, V. 712* (EAC); *ibid.*, sítio Lagoa, 21 September 2004, fr., *Gomes, V. 210917* (EAC); *ibid.*, mata do Lixão, 14 November 2007, fl., *Lima-Verde, L.W. 344403* (EAC). Meruoca, sítio Antônio, 28 December 1958, fr., *Fernandes, A. s.n.* (EAC). Mulungu, 18 October 1986, fr., *Lima-Verde, L.W. s.n.* (EAC 15693). Pacoti, estrada para Guaramiranga, 14 March 2014, fl., *Versieux, L.M. 689* (UFRN); *ibid.*, trilha da torre de telefonia/CE-065, 29 May 2015, fr., *Tomaz, E.C. 89* (UFRN). São Benedito, sítio Genipapo, 10 October 1997, veg., *Borges-Nojosa, D.M. s.n.* (EAC 26148). Tianguá, sítio Buaçu, 8 October 2005, fr., *M.M. Boto 10* (HUVA). Ubajara, planalto da Ibiapaba, 30 September 2016, fr., *E.B. Souza 4361* (HUVA); *ibid.*, sítio São Luís, 23 August 2017, fl., *E.B. Souza 4765* (HUVA). Uncertain origin, serra do Araripe, 11 February 1935, veg., *Luetzelburg, P. 26461* (EAC).

1.3. *Aechmea castelnavii* Baker, Handb. Bromel.: 39 (1889)

Distribution and habitat:—Central to South America (Smith & Downs 1979). Rare in Ceará. Epiphytes in interior Cerrado and *cerradão* at North of the state, in dry crystalline

forests in the Uruburetama massif, as well as in *carnaubal* growing on *Copernicia prunifera* (Mill.) H.E. Moore (Carnaúba palm); 20–700m.

Conservation:—Not evaluated for risk of extinction globally. Found in APA Serra da Ibiapaba.

Morphology:—This species can be recognized by the peduncle bracts with armed margins and inflorescence in a panicle of spikes, branched to first order only, with strongly geniculate primary branches. In addition, floral bracts are inconspicuous, aciculate from the base, flowers are 21–22 mm long, sessile and polystichous, with bluish petals.

Phenology:—Blooming in July. Fruiting in December and January.

Specimens examined:—BRAZIL. **Ceará:** Caucaia, poço Salgado, 16 December 2007 fr., A.S.F. Castro 1981 (EAC). Itapipoca, serra dos Picos, 13 January 2006, fr., D.C. Lima s.n. (EAC). Viçosa do Ceará, serra das Flores, 4 August 2005, fl., Lima-Verde, L.W. 3401 (EAC).

1.4. *Aechmea leptantha* (Harms) Leme & J.A.Siqueira, *Fragm. Atlantic Forest N. E. Brazil*: 213 (2006)

Distribution and habitat:—Endemic to Northeastern Brazil, in Paraíba, Pernambuco, Alagoas (Leme & Siqueira-Filho 2006; Silva *et al.* 2018) and Ceará. Rare in the study area. Found in wet sedimentary forest in the Araripe plateau; approximately at 800 m.

Conservation:—Evaluated by Silva *et al.* (2018) as “Vulnerable” but appears as “Least concern/Near threatened” in Tomaz *et al.* (Chapter 3). Occurs in APA Chapada do Araripe.

Morphology:—The compound inflorescence (ca. 32 cm long, excluding the peduncle) in a wide panicle, at least 3-branched, with pedicellate flowers is distinctive for *A. leptantha*. In addition, floral bracts are inconspicuous, elliptic and long mucronate, flowers are ca. 5 cm mm long, lax, with orange ligulate petals.

Phenology:—Blooming in January to March and September.

Specimen examined:—BRAZIL. **Ceará:** Jardim, boca da mata, 8 January 2010, fl., A.S.F. Castro 2253 (EAC).

Additional specimens examined:—BRAZIL. **Pernambuco:** Caruaru, serra da Quitéria, 11 September 2009, fl., *M. Sobral-Leite 1016* (UFRN). Taquaritinga do Norte, área aberta de afloramento do lado esquerdo do estacionamento, 1 March 2016, fl., *R.A. Pontes 1102* (UFRN). **Paraíba:** Natuba, área antropizada, sítios e fazendas, 29 February 2016, fl., *R.A. Pontes 1096* (UFRN).

1.5. *Aechmea tocantina* Baker, Handb. Bromel.: 39 (1889)

Distribution and habitat:—Distributed in Venezuela, Guiana, Bolivia, and in Brazilian Amazon and Cerrado (Smith & Downs 1979; Flora do Brasil 2020). Rare in Ceará. Epiphytes in interior Cerrado and *cerradão* of the Ibiapaba plateau; approximately at 800 m.

Conservation:—Status not evaluated globally. Occurs in APA Serra da Ibiapaba.

Morphology:—*Aechmea tocantina* can be recognized by the narrowly elliptic peduncle bracts, with margins entire, inflorescence in panicle of spikes, branched to first order only, and primary branches straight to slightly flexuose. Additionally, floral bracts are

conspicuous and ovate, flowers are 12–15 mm long (*in sicco*), sessile and distichous, with yellow petals.

Phenology:—Blooming from August to December.

Specimens examined:—BRAZIL. **Ceará:** Viçosa do Ceará, December 1993, fl., *Lima-Verde*, L.W. s.n. (EAC 21248). Tianguá, Santa Rita, 23 August 2004, fl., *Lima-Verde*, L.W. 3008A (EAC). Unknown origin, Ibiapaba, 26 November 1994, fl., *Lima-Verde*, L.W. s.n. (EAC 21507).

Additional specimen examined:—BRAZIL. **Amapá:** Oiapoque, Parque Nacional do Cabo Orange, 13 November 2016, fl. & fr., R.A. *Pontes 1184* (UFRN).

2. *Ananas* Mill., Gard. Dict. Abr. 4: 70 (1754)

Identification key for species of *Ananas* in Ceará

- 1. Leaf blades, scape and floral bracts with margins serrate....*Ananas ananassoides* (2.1)
- Leaf blades, scape and floral bracts with margins entire.....*Ananas lucidus* (2.2)

2.1. *Ananas ananassoides* (Baker) L.B.Sm., Bot. Mus. Leaf. 7: 79 (1939)

Distribution and habitat:—Eastern Brazil to Argentina and Paraguay (Smith & Downs 1979). Rare in Ceará. Possibly cultivated.

Conservation:—Extinction risk not evaluated in its entire range of occurrence.

Morphology:—*Ananas ananassoides* can be distinguished from *A. lucidus* by the leaf blades, peduncle and floral bracts with margins serrate.

Phenology:—Blooming in October. Fruiting in January and February.

Specimens examined:—BRAZIL. **Ceará:** Pacatuba, serra da Aratanha, 2 January 1996, fr. *Lima-Verde*, L.W. s.n. (EAC 23884). Pacoti, sítio Olho D'água dos Tangarás, 14 October 1995, fl., *Lima-Verde*, L.W. s.n. (EAC 23311); *ibid.*, sítio Olho D'água dos Tangarás, 20 February 1999, fr., *Lima-Verde*, L.W. s.n. (EAC 31573).

2.2. *Ananas lucidus* Mill., Gard. Dict. 8: (1768)

Distribution and habitat:—Native to Northern South America (Smith & Downs 1979).

Rare in Ceará. Possibly cultivated.

Conservation:—Extinction risk not evaluated.

Morphology:—The leaf blades, peduncle and floral bracts entire are distinctive of *Ananas lucidus* in Ceará.

Phenology:—Blooming in February.

Specimens examined:—BRAZIL. **Ceará:** Paracuru, 28 February 1994, fl., *Almeida*, J.S. s.n. (EAC 20363).

3. *Bromelia* L., Sp. Pl. 1: 285 (1753)

Identification key for species of *Bromelia* in Ceará

1. Peduncle developed; inflorescence paniculate..... *Bromelia laciniosa* (3.3)
- Peduncle short; inflorescence corymbiform.....2
2. Leaf blades 2.5–3.5 cm wide, margin serrate; inflorescence many-flowered.....*Bromelia aff. karatas* (3.2)
- Leaf blades 0.8–1 cm wide, margin serrulate; inflorescence few-flowered.....
.....*Bromelia auriculata* (3.1)

3.1. *Bromelia auriculata* L.B.Sm., Phytologia 15: 172 (1967)

Distribution and habitat:—Endemic to Northeastern Brazil, in Ceará and Maranhão (Flora do Brasil 2020). Rare in Ceará. Terricolous in crystalline and sedimentary caatinga, and dry sedimentary forest; 300–750 m.

Conservation:—Not evaluated in its whole range of occurrence but listed as “Endangered” in Ceará by Tomaz *et al.* (Chapter 3). Occurs in APA Serra da Ibiapaba.

Morphology:—This species is characterized by the linear leaf blades, 36–56 x 0.8–1 cm, with margins serrulate, the simple, corymbiform, few-flowered inflorescence, with a short peduncle only slightly above the center the rosette, and flowers with purple petals.

Phenology:— Blooming in January to March.

Specimens examined:—BRAZIL. **Ceará:** Barbalha, Estrada do Fio., 30 March 2000, st., Lima-Verde, L.W. 1233 (EAC). Granjeiro, área com estrato herbáceo estacional, 10 January 1934, Luetzelburg, P. 25990 (EAC).

3.2. *Bromelia aff. karatas* L., Sp. Pl. 1: 285 (1753) [Fig. 4 G–H]

Distribution and habitat:—Restricted to Northeastern Brazil (Monteiro & Forzza 2016). Frequent in Ceará. Terricolous in coastal vegetation, crystalline caatinga, dry sedimentary and crystalline forests, and the wet sedimentary forests; 130–800 m.

Conservation:—Extinction risk not evaluated. Occurs in APA Serra de Maranguape, APA Serra da Meruoca, APA Chapada do Apodi, Araripe-Apodi National Forest and Aiuaba Ecological Station.

Morphology:—*Bromelia aff. karatas* is the largest species among bromeliads from Ceará, with leaves reaching 210–270 x 2.5–3.5 cm, with margins serrate. In addition, it can also be distinguished by the short pedunculated, many-flowered and corymbiform inflorescence nested in the rosette, densely ferruginous tomentose except for the petals, with involucre bracts and internal leaves red when flowering. Flowers are 6.4–9.6 cm long, with purple petals connate for half of its size. This taxon represent a novel species revealed with the typification of *B. karatas* L. by Monteiro & Forzza (2016), yet to be published by these authors.

Phenology:—Blooming in January to March, June and November. Fruiting February, May, August to September.

Specimens examined:—BRAZIL. **Ceará:** Aiuaba, Estação Ecológica de Aiuaba, 19 May 1998, fr., *Andrade, I.M.* 295 (EAC). Barbalha, Malhada Bonita, 20 February 2008, fr., *L.K.P. Dutra s.n.* (HCDAL 3691); *ibid.*, 28 June 2016, fl., *M.A.P. Silva s.n.* (HCDAL 2271). Capistrano, fazenda Araçanga, 30 May 1994, veg., *Medeiros, J.B.L.P. s.n.* (EAC 21626). Caucaia, Camará, 24 September 2006, fr., *Castro, A.S.F.* 1852 (EAC). Crateús, serra das Almas, 22 February 2000, fl., *Lima-Verde, L.W.* 1217 (EAC). Crato, FLONA, 26 November 1999, fl., *Lima-Verde, L.W.* 1014 (EAC); *ibid.*, casa do IBAMA, 3 February 2000, fl., *Lima-Verde, L.W. s.n.* (EAC 31575). Granjeiro, 10 January 1934, fl., *Luetzelburg, P.* 26014 (EAC). Quixadá, serra do Estevão, 13 March 2014, fl., *L.M. Versieux* 751 (UFRN). Maranguape, serra de Maranguape, 11 January 1999, veg., *Oliveira, R. s.n.* (EAC 27278); *ibid.*, 19 February 2005, fl., *Monteiro, F.J.S.* 26 (EAC). Meruoca, pico do Sinistro, 08 March 2018, fl., *E.C. Tomaz* 195 (UFRN). Novo Oriente, planalto da Ibiapaba., 9 March 1991, veg., *Araújo, F.S.* 353 (EAC); *ibid.*, 6 April 1991, veg., *Araújo, F.S.* 396 (EAC). São Gonçalo do Amarante, atrás do Jardim Botânico, 28

July 2010, veg., *Castro, A.S.F.* 2353 (EAC). Ubajara, Jaburuna/sul, 26 August 1994, fr., *Araújo, F.S.* 944 (EAC); *ibid.*, 21 February 1995, fl., *Araújo, F.S.* 1088 (EAC).

Additional Specimens examined:—BRAZIL. **Rio Grande do Norte:** Ceará-Mirim, Faz. Diamante, 11 July 2016, fl., *G.S. Garcia* 258 (UFRN).

3.3. *Bromelia laciniosa* Mart ex. Schult. & Schult.f., Syst. Veg. 7: 1278 (1830)

Distribution and habitat: Restricted to Northeastern Brazil (Smith & Downs 1989; Flora do Brasil 2020). Rare in Ceará. Terricolous in crystalline caatinga; 110–400 m.

Conservation:—Not evaluated in its complete range of occurrence, but due to its wide distribution in Northeastern Brazil, should be considered of “Least concern”.

Morphology:—*Bromelia laciniosa*, known locally as *macambira*, can be identified by the developed peduncle, the pinkish paniculate inflorescence, flowers short-pedicellate and with purple petals. In addition, fruits in maturity produce a strongly sweet scent.

Phenology:—Blooming in March. Fruiting February and May to September.

Specimens examined:—BRAZIL. **Ceará:** Crateús, serra das Almas., 22 February 2000, fr., *Lima-Verde, L.W.* 1216 (EAC); *ibid.*, 22 February 2000, veg., *Lima-Verde, L.W.* 980 (EAC). Quixeré, Fazenda Mato Alto, 18 September 1996, fr., *Loiola, M.I.B.* 235 (EAC); *ibid.*, Fazenda Mato Alto, 13 May 1997, fr., *Melo, L.M.R.* 59 (EAC); *ibid.*, Manga do Mamoeiro, 16 June 1997, fr., *Lima-Verde, L.W.* 795 (EAC); *ibid.*, 16 August 1997, fr., *Melo, L.M.R.* 132 (EAC).

Additional Specimens examined:—BRAZIL. **Rio Grande do Norte:** Touros, 4.2 km da sede municipal, 15 March 2016, fl., *Tomaz, E.C.* 111 (UFRN).

4. *Catopsis* Griseb., Fl. Brit. W. I.: 599 (1864)

4.1. *Catopsis sessiliflora* (Ruiz & Pavon) Mez, Monogr. Phan. 9: 625 (1896)

Distribution and habitat:—From Mexico to Brazil (Smith & Downs 1977). Rare in Ceará. Epiphytes in wet crystalline and sedimentary forests of Baturité Massif, Serra de Maranguape and the Northern Ibiapaba plateau; approximately at 800 m.

Conservation:—Listed as “Least concern” by Miller *et al.* 2013. Found in APA Serra de Maranguape and APA Serra de Baturité.

Morphology:—The species can be identified by the infundibuliform rosette with leaf blades 7.5–15 cm long, the greenish inflorescence, 5–9 cm long, in a simple spike, only rarely compound. In addition, flowers are *ca.* 7 mm long, sessile, polystichous, with white petals and fruits ovoid.

Phenology:—Blooming in November. Fruiting in May to November.

Specimens examined:—BRAZIL. **Ceará:** Guaramiranga, 27 September 1986, fr., *Lima-Verde, L.W. s.n.* (EAC). Maranguape, Serra de Maranguape, 24 May 2003, fr., *Monteiro, F.J.S. 5* (EAC); *ibid.*, morro Pedra do Gigante, 1 November 2007, fr., *Monteiro, F.J.S. 57F* (EAC); *ibid.*, no topo do morro, 1 November 2007, fl., *Monteiro, F.J.S. F57* (EAC). São Benedito, sítio Penha, 6 July 2010, fr., *E.B. Souza 1921* (HUVA).

5. *Encholirium* Mart. ex Schult. & Schult.f., Syst. Veg. 7: 1233 (1830)

Identification key for species of *Encholirium* in Ceará

1. Inflorescence compound, branches patent; flowers strongly secund, ascending; petals orange at anthesis.....*Encholirium erectiflorum* (5.1)

- Inflorescence usually simple, only rarely branched, erect; flowers polystichous, patent; petals greenish to yellow.....*Encholirium spectabile* (5.2)

5.1. *Encholirium erectiflorum* L.B. Sm., Phytologia 20: 180 (1970)

Distribution and habitat: Endemic to Northeastern Brazil, in Ceará and Piauí (Forzza 2005). Rare in Ceará. Rupicolous crystalline caatinga; approximately at 700 m.

Conservation:—Extinction risk not fully assessed. Occurs in the RPPN Serra das Almas and in the APA Ibiapaba.

Morphology:—This species, along with *Encholirium spectabile*, have the tallest size when flowering, not rarely reaching *ca.* 2 m. The compound inflorescence, with lateral branches patent, and flowers strongly secund and ascending are unique to *E. erectiflorum*. Floral bracts are inconspicuous, very narrowly triangular, flowers are pedicellate, 30–33 mm long, with orange petals at anthesis.

Phenology:—Blooming in February and May to June.

Specimens examined:—BRAZIL. **Ceará:** Carnaubal, Sertão de dentro, 16 June 1979, fl., *Fernandes, A. s.n.* (EAC 6607, UFRN 121). Crateús, Serra das Almas., 22 February 2000, fl., *Lima-Verde, L.W. 981* (EAC); *ibid.*, 22 February 2000, fl., *Lima-Verde, L.W. 1225* (EAC).

Additional specimen examined:—BRAZIL. **Piauí:** Cocal, entre Viçosa do Ceará e Cocal, 30 May 1979, fl., *E. Nunes s.n.* (EAC 6200).

5.2. *Encholirium spectabile* Mart. ex Schult. & Schult. f., Syst. Veg. 7: 1233 (1830)

Distribution and habitat:—Distributed in Northeastern Brazil (Forzza 2005). Occasional in Ceará. Rupicolous on rocky outcrops in crystalline caatinga and dry crystalline forests; 120–600 m.

Conservation:—This species is “Least concern” (IUCN 2014). Occurs in APA Serra da Meruoca, APA Serra da Ibiapada, and the Aiuaba Ecological Station.

Morphology:—*Encholirum spectabile* is easily recognized by the strictly rupicolous habit, strongly serrate leaves in a non-impounding rosette and inflorescence erect and usually simple and racemose, only rarely branched, greenish, reaching over 2 m long. Flowers are polystichous and patent, with petals greenish to yellow.

Phenology:—Blooming in August. Fruiting January to September.

Specimens examined:—BRAZIL. **Ceará:** Aiuaba, estrada Aiuaba/Antonina, 26 November 1999, *veg.*, Lima-Verde, L.W. s.n. (EAC); *ibid.*, Estação Ecológica de Aiuaba, 10 September 2004, fr., J.R. Lemos 270 (EAC, HUVA). Graça, Cachoeirão, 28 January 2012, fr., A.V. Araújo 001 (HUVA); Granja, localidade de São Miguel, 6 August 2014, fl., Souza, E.B. 3158 (EAC, HUVA). Santa Quitéria, Fazenda Bálsamo, 6 July 1956, fr., Fernandes, A. s.n. (EAC). Quixadá, fazenda Ouro Preto, 12 March 2014, fr., Versieux, L.M. 684 (UFRN). Quixeré, Letreiro, 4 July 1996, fr., Loiola, M.I.B. 206 (EAC). Viçosa do Ceará, Trapiá, 13 January 2012, fr., Castro, A.S.F. 2602 (EAC).

Additional specimen examined:—BRAZIL. **Rio Grande do Norte:** Olho d’Água do Borges, RN 078 a ca. 9km de Patu, 19 April 2015, fl., Tomaz, E.C. 30 (UFRN).

6. *Guzmania* Ruiz & Pav., Fl. Peruv. 3: 37 (1802)

Identification key for species of *Guzmania* in Ceará

1. Leaf blades ca. 5 cm wide; internal leaves reddish when flowering; inflorescence short pedunculated.....*Guzmania sanguinea* (6.3)
- 1'. Leaf blades 1.4–2.4 cm wide; inflorescence with peduncle developed.....2
2. Inflorescence spike, straight; floral bracts red or green and striped to paleaceous, petals white.....*Guzmania monostachia* (6.2)
- 2'. Inflorescence corymbose, congested; floral bracts green to yellowish, petals yellowish.....*Guzmania lingulata* (6.1)

6.1. *Guzmania lingulata* (L.) Mez, Monogr. Phan. 9: 899 (1896) [Fig. 4 I–J]

Distribution and habitat:—Found from Central to South America (Smith & Downs 1977). Rare in Ceará. Epiphytes in wet crystalline forests of Baturité massif and Maranguape and Aratanha ridges; 700–1000 m.

Conservation:—Classified as of “Least concern” by Miller *et al.* (2013). Occurs in APA Serra de Baturité, APA Serra de Maranguape and APA Aratanha.

Morphology:—*Guzmania lingulata* can be identified by leaf blades 2.1–2.4 cm wide, the pedunculate, simple, corymbose and apical inflorescence, with peduncle and involucre bracts foliaceous and green. Floral bracts are green to yellowish and flowers are pedicellate with yellowish petals. The inflorescence presents a mucilaginous secretion.

Phenology:—Blooming from January to March, possibly also in May and June. Fruiting from March to October.

Examined specimens:—BRAZIL. **Ceará:** Guaramiranga, sítio cana brava, 21 May 1994, Oliveira, M.R.L. 456 (EAC); *ibid.*, sítio Arvoredo, 14 March 2003, fl., Silveira, A. 1029 (EAC); *ibid.*, sítio Arvoredo, 11 September 2003, fr., Gomes, V. 728 (EAC); *ibid.*,

granja-Bonfim, 5 February 2004, fl., *Gomes, V.* 802-15 (EAC). Maranguape, serra de Maranguape, 1989, fr., *Lima-Verde, L.W.* s.n. (EAC); *ibid.*, 10 January 1999, fl., *Lima-Verde, L.W.* s.n. (EAC); *ibid.*, 28 June 2003, fl., *Monteiro, F.J.S.* 10 (EAC); *ibid.*, 24 May 2003, fr., *Monteiro, F.J.S.* 2 (EAC); *ibid.*, Beija Flor, 26 March 2011, fr., *Fortunato, M.E.M.* 56 (EAC); *ibid.*, Pico da Rajada, 30 March 2012, *Fortunato, M.E.M.* 66 (EAC); *ibid.*, trilha para o pico da rajada, 2 March 2018, fr., *Tomaz, E.C.* 190 (UFRN). Pacatuba, pico do Letreiro, 18 February 2004, fl., *Monteiro, F.J.S.* 12 (EAC); *ibid.*, pedra do Letreiro, 25 February 2003, fl., *Lima-Verde, L.W.* 2455 (EAC). Pacoti, sítio Brejinho, 8 September 1989, fr., *Figueiredo, M.A.* s.n. (EAC); *ibid.*, sítio Arvoredo, 14 October 1990, fr., *Figueiredo, M.A.* s.n. (EAC); *ibid.*, mata do Tasso, 15 August 1998, fr., *Martinelli, G.* 15065 (EAC); *ibid.*, sítio Pau do Alho, 12 July 2008, fr., *Lima-Verde, L.W.* 3503 (EAC).

6.2. *Guzmania monostachia* (L.) Rusby ex Mez, Monogr. Phan. 9: 905 (1896) [Fig. 4 K–M]

Distribution and habitat:—Distributed from Florida, Central and Northern South America, Bolívia, and in Brazil, currently restricted to Ceará (Smith & Downs 1977; Siqueira *et al.* 2006). Occasional. Epiphytes in wet crystalline forests of Batutirité massif, Maranguape and Aratanha ridges, and in the Uruburetama massif, and wet sedimentary forests of the Ibiapaba plateau; 760–1009 m.

Conservation:—Listed as “Vulnerable” in the Red List of the Brazilian Flora (Martinelli & Moraes 2013), in Brazil’s Official Threatened Flora Species List (MMA 2014) and by Tomaz *et al.* (Chapter 3).

Morphology:—Recognized by leaf blades 1.4–2.1 cm wide, the simple and pedunculate inflorescence, in spike, straight, with peduncle and floral bracts green and striped at base

and red towards the apex of the inflorescence in anthesis and turning paleaceous with maturation. Flowers are polystichous, with white petals.

Phenology:—Blooming from November to March and May. Fruiting February to October.

Examined specimens:—BRAZIL. **Ceará:** Baturité, entre Baturité e Mulungu, 19 October 1978, fr., *Fernandes, A. s.n.* (EAC 4190). Guaramiranga, sítio cana brava, 9 January 1994, fl., *Oliveira, M.R.L. s.n.* (EAC 20909); *ibid.*, sítio Arvoredo, 8 August 2002, fr., *Silveira, A. 28* (EAC); *ibid.*, sítio Lagoa, 10 May 2003, fl., *Gomes, V. 307* (EAC); *ibid.*, sítio Lagoa - mata do pico Alto, 21 August 2003, fr., *Gomes, V. 627* (EAC); *ibid.*, sítio Arvoredo, 2 November 2003, fl., *Gomes, V. 1031* (EAC); *ibid.*, pico Alto., 9 March 2010, fl., *Carvalho, A.M.M. s.n.* (EAC 46827); *ibid.*, coleta em casa de vegetação, 3 March 2012, fr., *Fortunato, M.E.M. 65* (EAC); *ibid.*, pico Alto, 14 March 2014, fl., *Versieux, L.M. 753* (UFRN); *ibid.*, topo do pico Alto, 29 May 2015, fr., *Tomaz, E.C. 84* (UFRN). Itapagé, morro do Coquinho, 13 December 2007, fl., *Monteiro, F.J.S. 112* (EAC). Maranguape, serra de Maranguape, 24 May 2003, fr., *Monteiro, F.J.S. s.n.* (EAC 33782); *ibid.*, Beija Flor, 26 March 2011, fr., *Fortunato, M.E.M. 55* (EAC). Pacatuba, serra da Aratanha, 7 February 1999, *A.G. Weber s.n.* (EAC); *ibid.*, Lagoa Boaçu, serra da Aratanha., 18 February 2004, fl., *Monteiro, F.J.S. 14* (EAC). Pacoti, February 1987, fr., *Lima-Verde, L.W. s.n.* (EAC 15316); *ibid.*, sítio Olho D'água dos Tangarás, 12 March 1994, fl., *Lima-Verde, L.W. s.n.* (EAC); *ibid.*, mata do Tasso, 15 August 1998, fr., *Martinelli, G. 15066* (EAC); *ibid.*, sítio Olho d'Água dos Tangarás, 12 December 2004, *Lima-Verde, L.W. 3093* (EAC); *ibid.*, pico Alto, 6 February 2007, fl., *Moro, M.F. 27* (EAC); *ibid.*, CE-065 - trilha da torre de telefonia, 29 May 2015, fr., *Tomaz, E.C. 88* (UFRN). São Benedito, Ibiapaba, 9 September 1997, veg., *Borges-Nojosa, D.M. s.n.* (EAC 26144). Uruburetama, Retiro, 4 May 2008, fl., *Monteiro, F.J.S. F164* (EAC).

Ubajara, cachoeira de São Félix, 5 March 2012, fl., *E.B. Souza* 2400 (HUVA); *ibid.*, Ubajara, sítio São Luís, 2 March 2015, fl., *E.B. Souza* 3237 (HUVA).

6.3. *Guzmania sanguinea* (André) André ex Mez, Monogr. Phan. 9: 901 (1896) [Fig. 4 N–O]

Distribution and habitat:—Distributed in Central and Northern South America, with distribution in Brazil restricted to Ceará (Smith & Downs 1977; Flora do Brasil 2020). Rare in Ceará. Epiphytes in wet crystalline forests of Batutirité massif, Maranguape and Aratanha ridges and Uruburetama massif; 772–1000 m.

Conservation:—Listed as “Endangered” in the Red List of the Brazilian Flora (Martinelli & Moares 2013), in Brazil’s Official Threatened Flora Species List (MMA 2014) and by Tomaz *et al.* (Chapter 3). Occurs in the APAs of Baturité, Maranguape and Aratanha.

Morphology:— Easily recognized by internal leaves turning reddish when flowering, the leaf blades 5 cm wide, the inflorescence short pedunculated and corymbose, nested in the rosette. Floral bracts are hyaline and membranaceous, and flowers are polystichous and pedicellate, with yellow petals highly connate.

Phenology:—Blooming in February and March. Fruiting March to August.

Examined specimens:—BRAZIL. **Ceará:** Guaramiranga, sítio cana brava, 21 May 1994, fr., *Oliveira, M.R.L. s.n.* (EAC 20901); *ibid.*, 20 March 2000, fr., *Brito, H.M. s.n.* (EAC 15752); *ibid.*, pico Alto e trilha na mata nebulosa, 14 March 2014, fl., *Versieux, L.M. 752* (UFRN); *ibid.*, pico Alto, 30 June 2017, fr., *Tomaz, E.C. 143* (UFRN). Pacatuba, pico do Letreiro, 18 February 2004, fl., *Monteiro, F.J.S. 11* (EAC). Pacoti, mata do Tasso, 15 August 1998, fr., *Martinelli, G. 15067* (EAC); *ibid.*, escada de acesso à torre da TIM, fl.,

14 March 2014, *Versieux, L.M. 708* (UFRN). Maranguape, pico da Rajada, 2 March 2018, fl., *Tomaz, E.C. 180* (UFRN). Uruburetama, serra do Cachorro Morto, 4 May 2008, fr., *Monteiro, F.J.S. F163* (EAC).

7. *Neoglaziovia* Mez in Mart., Fl. Bras. 3: 427 (1894)

7.1. *Neoglaziovia variegata* (Arruda) Mez in Mart., Fl. Bras. 3: 427 (1894)

Distribution and habitat:—Endemic to the Caatinga domain, in Northeastern Brazil and Minas Gerais (Smith & Downs 1979; Flora do Brasil 2020). Rare in Ceará. Terricolous or saxicolous herbs in crystalline and sedimentary caatinga (*carrasco*); 626–830 m.

Conservation:—Species not evaluated but should of “Least concern” due to extent of occurrence. Occurs in the RPPN Serra das Almas.

Morphology:—Linear, strongly canaliculate leaves reaching up to 2.4 m, usually dark vinaceous and variegate with densely white-lepidote bands, in a fasciculate non-impounding rosette are distinctive of *Neoglaziovia variegata*. In addition, the simple pink inflorescence wholly pink and pedicellate flowers with purple petals are also important to identify the species.

Phenology:—Blooming in November to January. Fruiting in February, May and August.

Examined specimens:—BRAZIL. **Ceará:** Aiuaba, lagoa do Rosio, 11 April 1991, veg., *Figueiredo, M.A. 166* (EAC); *ibid.*, Alecrim, 6 August 1996, veg., *Lima-Verde, L.W. 301* (EAC); *ibid.*, Barra, 10 December 1997, fl., *Lima-Verde, L.W. 851* (EAC); *ibid.*, Barra, 10 December 1997, fl., *Lima-Verde, L.W. 852* (EAC). Carnaubal, estrada para Piauí., 10 December 2000, fl., *Castro, A.S.F. 909* (EAC); *ibid.*, congl. 88, sub. 2, ár. 9H., 3 February 2014, fr., *Batista, W. 218* (EAC). Crateús, serra das Almas, 28 November 2007,

fl., *Monteiro, F.J.S.* 98 (EAC); *ibid.*, RPPN Serra das Almas, 14 January 2017, fl., *H.M. Meneses* 77 (EAC). Ubajara, planalto da Ibiapaba, 23 April 1994, veg., *Araújo, F.S.* 653 (EAC); *ibid.*, planalto da Ibiapaba, 18 May 1994, fr., *Araújo, F.S.* 728 (EAC); *ibid.*, planalto da Ibiapaba, 26 August 1994, fr., *Araújo, F.S.* 945 (EAC).

8. *Orthophytum* Beer, Flora 27: 347 (1854)

8.1. *Orthophytum cearense* Leme & F.J.S. Monteiro, Rodriguésia 6: 49 (2010) [Fig. 5 A–B]

Distribution and habitat:—Endemic to Ceará (*Leme et al.* 2010). Rare. Terricolous or saxicolous among rocky outcrops and dry crystalline forests of the Serra das Matas; 1092–1154 m.

Conservation:—Classified as “Endangered” by Tomaz *et al.* (Chapter 2).

Morphology:—*Orthophytum cearense* can be identified by its small size, the triangular, densely cinereous-lepidote leaves with margins serrate, inflorescence compound, usually congested towards the apex, densely lepidote (except for the petals), with peduncle bracts foliaceous, patent to slightly recurved. Flowers are sessile, with upper floral bracts and sepals slightly pinkish and petals greenish-white.

Phenology:—Flowering in January.

Examined specimens:—BRAZIL. **Ceará:** Monsenhor Tabosa, afloramento, 24 January 2011, fl., *Menezes, M.O.T.* 271 (EAC).

9. *Pitcairnia* L’Hér., Sertum Anglicum 7 (1788)

9.1. *Pitcairnia limae* L.B.Sm., Phytologia 7: 254 (1960) [Fig. 5 C–F]

Distribution and habitat:—Endemic to Ceará (Smith & Downs 1974). Rare. Rupicolous or saxicolous on rocky outcrops among wet crystalline forests of Maranguape ridge and Meruoca massif, and wet sedimentary forests at North of the Ibiapaba plateau; 800–985 m.

Conservation:—Classified as “Critically endangered” by Martinelli & Moares (2013) and MMA (2014) and as “Endangered” by Tomaz *et al.* (Chapter 2). Occurs in APA Serra de Maranguape, APA Serra da Meruoca and Ubaraja National Park.

Morphology:—This species can be identified by the fasciculate rosette with older leaves coriaceous and serrate and the younger chartaceous and serrulate only at the base, the slender and simple reddish inflorescence. Floral bracts are inconspicuous, and the flowers are zygomorphic, pedicellate, with sepals and petals red.

Phenology:—Blooming in November to December, March and June and August. Fruiting in March.

Examined specimens:—BRAZIL. **Ceará:** Ibiapina, estrada Mucambo, 9 December 2000, fl., *Castro, A.S.F.* 896 (EAC); *ibid.*, 18 December 2007, fl., *Lemos, J.R.* 14 (UFRN); *ibid.*, ch. da Ibiapababa, 14 November 2011, fl., *Castro, A.S.F.* 2559 (EAC); *ibid.*, paredão das samambaias, 4 June 2012, fl., *Loiola, M.I.B.* 1746 (EAC). Maranguape, Serra de Maranguape, 4 December 2004, fl., *Monteiro, F.J.S.* 22 (EAC); Meruoca, pico do Sinistro, 8 March 2018, fl., *Tomaz, E.C.* 197 (UFRN).

10. *Racinaea* M.A. Spencer & L.B. Sm., Phytologia 74: 152 (1993)

10.1. *Racinaea spiculosa* (Griseb.) M.A. Spencer & L.B. Sm., Phytologia 74: 157 (1993)

[Fig. 5 G]

Distribution and habitat:—Distributed in Central and South America (Smith & Downs 1977). Rare in Ceará. Epiphytes in wet crystalline forests of the Baturité massif and Maranguape ridge; 856–1096 m.

Conservation:—Classified as “Least concern” by Martinelli & Moares (2013). Occurs in APA Serra de Baturité and APA Serra de Maranguape.

Morphology:—This species can be identified by the utriculose rosette, with subcoriaceous leaves, the slender compound inflorescence, small sessile and distichous flowers with white petals, and fruits are cylindrical capsules.

Phenology:—Blooming from October to March. Fruiting from March to November.

Examined specimens:—BRAZIL. **Ceará:** Guaramiranga, sítio Arvoredo, 18 February 2002, fl., *Silveira, A.* 522 (EAC); *ibid.*, sítio Arvoredo, 12 February 2003, fl., *Silveira, A.* 799 (EAC); *ibid.*, sítio Arvoredo, 5 May 2003, fr., *Gomes, V.* 721 (EAC); *ibid.*, sítio Arvoredo, 6 July 2004, fr., *Gomes, V.* 607-15 (EAC); *ibid.*, pico Alto., 4 November 2011, fr., *Fortunato, M.E.M.* 64 (EAC); *ibid.*, pico Alto e trilha na mata nebulosa, fl., 14 March 2014, *Versieux, L.M.* 750 (UFRN); *ibid.*, pico Alto, 30 June 2017, fr., *Tomaz, E.C.* 141 (UFRN). Maranguape, serra de Maranguape, 10 January 1999, fl., *Oliveira, R.* s.n. (EAC 27279); *ibid.*, morro Pedra do Gigante, 1 November 2007, fr., *Monteiro, F.J.S.* 61F (EAC); *ibid.*, pico da Rajada, 30 April 2011, fr., *Fortunato, M.E.M.* 58 (EAC); *ibid.*, pico da Rajada, 22 October 2011, fl., *Fortunato, M.E.M.* 62 (EAC); *ibid.*, pico da Rajada, 2 March 2018, fr., *E.C. Tomaz* 174 (UFRN). *ibid.*, sítio Arvoredo, 23 June 1990, fr., *Fernandes, A.* s.n. (EAC 19809); *ibid.*, sítio Arvoredo, 1 December 1990, fl., *Figueiredo,*

M.A. s.n. (EAC 19806); *ibid.*, sítio Arvoredo, 10- 1992, fr., Lima-Verde, L.W. s.n. (EAC 20144); *ibid.*, mata do Tasso, 15 August 1998, fr., Martinelli, G. 15061 (EAC).

11. *Tillandsia* L., Sp. Pl. 1: 286 (1753)

Identification key for species of *Tillandsia* in Ceará

1. Inflorescence always simple.....2
 - Inflorescence usually compound or rarely simple.....7
2. Leaves distichous.....3
 - Leaves polystichous.....4
3. Plants pendulous; roots absent in maturity; inflorescence sessile.....*Tillandsia usneoides* (11.10)
 - Plants forming small round clumps; roots present in maturity; inflorescence pedunculated.....*Tillandsia recurvata* (11.6)
4. Flowers with yellow to orange petals.....5
 - Flowers with white petals.....6
5. Stem developed; leaves disposed along the stem; inflorescence with rachis straight.....*Tillandsia tricholepis* (11.9)
 - Stem inconspicuous; leaves forming an open rosette; inflorescence with rachis geniculate..... *Tillandsia loliacea* (11.3)
6. Stem developed; leaves sparsely lepidote; inflorescence suberect; floral bracts imbricate, pink.....*Tillandsia tenuifolia* (11.8)
 - Stem inconspicuous; leaves densely cinereous-lepidote; inflorescence pendulous; floral bracts inflated, orangish to greenish.....*Tillandsia pohliana* (11.4)
7. Leaf blades filiform..... *Tillandsia juncea* (11.2)
 - Leaf blades narrowly triangular to linear-triangular.....8

8. Leaf trichomes exceeding its margin; inflorescence congested, pendulous; petals reddish.....*Tillandsia gardneri* (11.1)
 - Leaf trichomes restricted to margin; inflorescence linear, erect; petals lilac to purple...9
9. Rosette open; leaf blade margins involute; petals spreading, strongly spatulate.....*Tillandsia streptocarpa* (11.7)
 - Rosette infundibuliform; leaf blades margins flat; petals erect, slightly spatulate.....*Tillandsia polystachia* (11.5)

11.1. *Tillandsia gardneri* Lindl., Edwards's Bot. Reg. 28: pl. 63 (1842) [Fig. 5 H–I]

Distribution and habitat:—Disjunctly distributed in Colombia and Eastern Brazil (Smith & Downs 1977). Rare in Ceará. Epiphytes in wet crystalline forests of the Baturité massif and Maranguape ridge; 670–840 m.

Conservation:—Classified as “Least concern” by Martinelli & Moares (2013). Occurs in APA Serra de Baturité, APA Serra de Maranguape and APA Serra da Meruoca.

Morphology:—Leaves are narrowly triangular, densely cinereous-lepidote, with the older strongly reflexed, with foliar trichomes exceeding the blade’s margins. In addition, inflorescence is compound, congested and pendulous. Floral bracts are pale pink, and flowers are sessile, polystichous, with reddish petals.

Phenology:—Blooming in October. Fruiting in March, June and November.

Examined specimens:—BRAZIL. **Ceará:** Guaramiranga, 18 October 1986, veg., *Lineu*, C. s.n. (EAC 15747); *ibid.*, sítio São Paulo, 10 October 2007, veg., *Lima-Verde*, L.W. 3452 (EAC). Maranguape, serra de Maranguape, 26 November 1955, fr., *Lima*, A. s.n. (EAC 1506). Mulungu, mata do Damário, 19 September 2007, veg., *Lima-Verde*, L.W. 3414 (EAC); *ibid.*, localidade Lorena, 29 June 2017, fr., *Tomaz*, E.C. 124 (UFRN). Pacoti,

17 October 1987, fl., *Lima-Verde*, L.W. s.n. (EAC 15679); *ibid.*, sítio São Pedro, 10 October 2007, veg., *Lima-Verde*, L.W. 345007 (EAC).

11.2. *Tillandsia juncea* (Ruiz & Pav.) Poir., *Encycl. Suppl.* 5: 309 (1817)

Distribution and habitat:—From Mexico do South America (Leme & Siqueira-Filho 2006). Rare in Ceará. Epiphytes in wet crystalline forests of the Baturité massif; 500–840 m.

Conservation:—Not evaluated globally. Occurs in APA Serra de Baturité.

Morphology:—Among the species of *Tillandsia* in Ceará, *T. juncea* can be identified by the leaves with filiform blades in a non-impounding rosette, inflorescence is compound, a congested panicle of spikes. Flowers were not seen.

Phenology:—Fruiting in October and November.

Examined specimens:—BRAZIL. **Ceará:** Guaramiranga, November 1989, fr., *Lima-Verde*, L.W. s.n. (EAC); *ibid.*, margem do riacho São Paulo, 10 October 2007, fr., *Lima-Verde*, L.W. 345507 (EAC); *ibid.*, sítio Lagoa, 13 February 2003, veg., *Silveira*, A. 899 (EAC).

11.3. *Tillandsia loliacea* Mart. ex. Schult. & Schult.f., *Syst. Veg.* 7: 1204 (1830) [Fig. 5 J]

Distribution and habitat:—Restricted to mid- and Eastern South America (Smith & Downs 1977). Frequent in Ceará. Epiphytes in crystalline caatinga, dry sedimentary and

crystalline forests, wet sedimentary forests, and interior cerrado and *cerradão*; 290–822 m.

Conservation:—*Tillandsia loliacea* has not been evaluated globally but due to the wide distribution should be treated as “Least concern”. Occurs in Ecological Station of Aiuaba, Araripe-Apodi National Forest and APA Chapada do Araripe.

Morphology:—One the of the smallest bromeliads in Ceará, it can be identified by the inconspicuous stem, densely lepidote leaves forming an open rosette, and the simple inflorescence, with rachis geniculate. In addition, floral bracts are dark vinaceous to green and densely lepidote, and flowers are sessile, distichous, with yellow petals.

Phenology:—Blooms and fruits throughout the year.

Examined specimens:—BRAZIL. **Ceará:** Aiuaba, Estação Ecológica, 28 April 1981, veg., *Martins, P. s.n.* (EAC 10185); *ibid.*, Estação Ecológica, 22 June 1982, fr., *Viana, F.A. s.n.* (EAC 11819); *ibid.*, Gameleira, 7 August 1996, fl., *E. L. Paula-Zárate 284* (EAC); *ibid.*, Riacho do Caldeirão, 6 August 1996, veg., *Lima-Verde, L.W. 299* (EAC); *ibid.*, Estação Ecológica de Aiuaba, 7 November 1996, fl., *Lima-Verde, L.W. 350* (EAC); *ibid.*, Estação Ecológica de Aiuaba, 9 June 1998, fl. & fr. *Lima-Verde, L.W. 940* (EAC); *ibid.*, Estação Ecológica de Aiuaba, 10 June 1998, fl., *Figueiredo, M.A. 1007* (EAC); *ibid.*, Estação Ecológica de Aiuaba, 26 November 1999, fl., *Lima-Verde, L.W. s.n.* (EAC 31548); *ibid.*, próx. a Chaparral, 1 May 2000, fr., *Lima-Verde, L.W. 1281* (EAC); *ibid.*, Estação Ecológica de Aiuaba, 10 September 2004, fr., *Lemos, J.R. 271* (EAC, HUVA); *ibid.*, Estação Ecológica de Aiuaba., 8 October 2013, fl., *Loiola, M.I.B. 2156* (EAC); *ibid.*, 20 February 2014, *Silva, F.K.G. 30* (EAC). Aratuba, distrito de Balanga, 17 April 2008, fl. & fr., *Lima-Verde, L.W. 348908* (EAC). Assaré, fazenda Extrema, 25 March 2005, fl., *Monteiro, F.J.S. 2S* (EAC). Barbalha, sítio próx. ao Caldas, 19 September 1992, fl., *Lima-*

Verde, L.W. s.n. (EAC 20159); *ibid.*, cabeça da ladeira da macaúba, 10 May 2007, fr., *B.M. Gomes s.n.* (HCDAL 3304). Boa Viagem, cachoeirão, 5 July 1997, fl., *Otoch, R. s.n.* (EAC 26153). Campos Sales, salitre, 10 February 1984, fr., *Fernandes, A. s.n.* (EAC 12299). Crato, sítio Fundão, 9 August 1993, fr., *Figueiredo, M.A. s.n.* (EAC 20080); *ibid.*, FLONA do Araripe, 11 August 1999, fl. & fr., *Lima-Verde, L.W. 1628* (EAC 45746); *ibid.*, FLONA do Araripe, 4 May 2000, fr., *Lima-Verde, L.W. 2107* (EAC 45748); *ibid.*, subida para sede da FLONA, 25 July 2018, fl., *E.C. Tomaz 210* (UFRN). Farias Brito, buqueirão, 6 June 1985, fr., *Fernandes, A. s.n.* (EAC 13224). Lavras da mangabeira, talhado do Rio Salgado, 4 October 1980, fl., *Fernandes, A. s.n.* (EAC 9031); *ibid.*, congl. 342, 1 November 2014, fr., *R. Moura 1119* (EAC). Missão Velha, APA Cachoeira da Missão Velha, 18 August 2011, fr., *E. Melo 10225* (HUVA). Monsenhor Tabosa, Fazenda Oitis, 29 March 2018, fr., *E.C. Tomaz 207* (UFRN). Parambu, Arredores de Monte Sion, 8 January 1999, fl. & fr., *Castro, A.S.F. 631* (EAC). São Benedito, Sítio Cigarra, Planalto da Ibiapaba., 4 December 1989, fl. & fr., *Figueiredo, M.A. s.n.* (EAC 19799). Tauá, serra dos Coqueiros, 5 February 2015, fr., *Gomes, R.C. s.n.* (EAC 57777).

11.4. *Tillandsia pohliana* Mez, Fl. Bras. 3: 597 (1894) [Fig. 5 K]

Distribution and habitat:—Restricted to South America (Smith & Downs 1977). Occasional in Ceará. Epiphytes in crystalline caatinga, dry and wet sedimentary forests, and interior cerrado and *cerradão*; 400–822 m.

Conservation:—Not evaluated globally but due to the wide distribution should be treated as “Least concern”. Occurs in Araripe-Apodi National Forest and APA Chapada do Araripe.

Morphology:—*Tillandsia pohliana* has an inconspicuous stem, densely cinereous-lepidote leaves, a simple and pendulous inflorescence, with floral bracts inflated, orange to greenish and flowers are sessile, distichous, with white petals.

Phenology:—Blooming in January and March. Fruiting in February, May to August, and November.

Examined specimens:—BRAZIL. **Ceará:** Barbalha, Quatro espero, 20 February 2008, fr., *F.O.M.B. Carmo s.n.* (HCDAL 3793); *ibid.*, Parque Riacho do Meio, 27 July 2018, fr., *E.C. Tomaz 211* (UFRN). Crato, sítio Fundação, 9 August 1993, fr., *Figueiredo, M.A. s.n.* (EAC 20078); *ibid.*, subida do Belmonte, 28 August 1993, veg., *Cavalcanti, F.S. s.n.* (EAC 20181); *ibid.*, Flona do Araripe, 11 August 1999, fr., *Lima-Verde, L.W. 1629* (EAC); *ibid.*, Flona do Araripe, 3 November 1999, fr. *Lima-Verde, L.W. 1792* (EAC). Croatá, sobre a Serra Grande, 15 May 1983, fr., *Figueiredo, M.A. s.n.* (EAC 12015). Farias Brito, estrada Monte-Rio-Contendas, 8 June 1985, fr., *Fernandes, A. s.n.* (EAC 13261). Jardim, Boa Vista, 9 January 2010, fl., *Castro, A.S.F. 2254* (EAC). Porteiras, ladeira para Porteiras, fl., 30 March 2000, *Souza, S.S.G. s.n.* (EAC 31566).

11.5. *Tillandsia polystachia* (L.) L., Sp. Pl. 2: 410 (1762)

Distribution and habitat:—Southern United States and Mexico to Central and South America (Smith & Downs 1977). Rare in Ceará. Epiphytes in sedimentary caatinga of Araripe and Ibiapaba plateaus; 500–800 m.

Conservation:—Listed as “Least concern” by Miller *et al.* (2013). Occurs in Araripe-Apodi National Forest and APA Chapada do Araripe.

Morphology:—This is the only *Tillandsia* species presenting an infundibuliform and water impounding rosette in Ceará. It has leaf blades with flat margins, a usually erect compound inflorescence, only rarely simple. Floral bracts are imbricate and green, flowers are distichous, with purple, slightly spatulate and erect petals forming a tubular corolla. The exerted stamens and style are also unique features of *T. polystachia* among other species of this genus in the study area.

Phenology:—Blooming in June and October. Fruiting in January.

Examined specimens:—BRAZIL. **Ceará:** Ubajara, Jaburuna/sul, 17 May 1994, veg., Araújo, F.S. 711 (EAC); *ibid.*, 5 October 1996, fl., Lima-Verde, L.W. 2431 (EAC); *ibid.*, 17 June 1998, fl., Lima-Verde, L.W. 2447 (EAC); *ibid.*, Jabuarana, 1 January 2000, fr., Lima-Verde, L.W. s.n. (EAC 31450). Crato, Flona do Araripe, 4 October 1999, fl., Lima-Verde, L.W. 1713 (EAC).

11.6. *Tillandsia recurvata* (L.) L., Sp. Pl. 2: 410 (1762) [Fig. 5 L–M]

Distribution and habitat:—Southern United States to Argentina (Smith & Downs 1977). Frequent in Ceará. Epiphytes in crystalline and sedimentary caatinga, dry and wet crystalline forests, and interior cerrado and *cerradão*; 440–760 m.

Conservation:—Listed as “Least concern” by Miller *et al.* 2013. Occurs in APA Serra da Meruoca, APA Serra de Baturité, APA Chapada do Araripe and Ecological Station of Aiuaba.

Morphology:—*Tillandsia recurvata* is commonly found forming small round clumps, with roots present in maturity. Leaves are densely cinereous-lepidote and distichous. The

inflorescence is pedunculated, usually single flowered, with an erect, filiform peduncle and flowers with lilac petals.

Phenology:—Blooming in February and March. Fruiting throughout the year.

Examined specimens:—BRAZIL. **Ceará:** Aiuaba, E. E. de Aiuaba, 29 May 1996, fr., *Loiola, M.I.B. 605* (EAC). Aratuba, Balança, 9 October 2008, veg., *Lima-Verde, L.W. 3438* (EAC); *ibid.*, distrito de Balanga, 17 April 2008, fr. *Lima-Verde, L.W. 3488-08* (EAC). Barbalha, Arajara, 29 June 1997, fr., *Machado, D.A.N. s.n.* (EAC); *ibid.*, Floresta Nacional do Araripe, 10 January 2001, fr., *Costa, I.R. s.n.* (EAC). Crato, chapada do Araripe., 10 October 1991, fr., *Cavalcanti, F.S. s.n.* (EAC); *ibid.*, sítio Fundação, 9 August 1993, fr., *Figueiredo, M.A. s.n.* (EAC). Farias Brito, buqueirão, 6 June 1985, veg., *Fernandes, A. s.n.* (EAC). Guaramiranga, mata do Lixão, 14 November 2007, fr., *Lima-Verde, L.W. 344404* (EAC); *ibid.*, sítio salva vidas, 30 August 2008, fr., *Lima-Verde, L.W. 3520* (EAC); *ibid.*, sítio Salva-Vidas, 6 January 2004, veg., *Gomes, V. 297* (EAC); *ibid.*, sítio Salva-Vidas, 21 September 2004, fr., *Gomes, V. 21099* (EAC). Jardim, Gravatá, 7 January 2010, veg., *Castro, A.S.F. 2251* (EAC). Lavras da Mangabeira, talhado do Rio Salgado, veg., 4 October 1980, *Fernandes, A. s.n.* (EAC 9025). Meruoca, sítio Santo Antônio, 25 July 1956, fr., *Fernandes, A. s.n.* (EAC 1658); *ibid.* sítio Santo Antônio, 25 February 1981, fl., *Fernandes, A. s.n.* (EAC 9730); *ibid.*, Pico do Sinistro, 08 March 2018, fl., *E.C. Tomaz 196* (UFRN). Monsenhor Tabosa, 24 January 2011, fr., *Menezes, M.O.T. 265* (EAC); *ibid.*, Fazenda Oitis, 29 March 2018, fr., *E.C. Tomaz 208* (UFRN). Mulungu, mata do Damásio, 19 September 2007, fr., *Lima-Verde, L.W. 3413* (EAC); *ibid.*, mata do Damázio, 24 June 2008, veg., *Lima-Verde, L.W. 3488* (EAC); *ibid.*, sítio Jardim, 21 August 2003, fr., *Gomes, V. s.n.* (EAC); *ibid.*, sítio Jardim, 23 January 2003, veg., *Silveira, A. 724* (EAC). Novo Oriente, serra da Ibiapaba, 25 July 1979, fr., *Fernandes, A. s.n.* (EAC). Pacoti, Chalé Nosso Sítio, 29 May 2015, fr., *Tomaz, E.C. 87* (UFRN). Pedra

Branca, serra de Pedra Branca, 1 September 1987, fr., *Lima-Verde, L.W. s.n.* (EAC).
 Porteiras, ladeira para Porteiras, 30 March 2000, fr., *Souza, S.S.G. s.n.* (EAC 31565). São
 Benedito, sítio Cigarra, 4 December 1989, fr., *Figueiredo, M.A. s.n.* (EAC). Tauá, bacia
 do riacho Carrapateira, 10 December 2014, veg., *Gomes, R.C. s.n.* (EAC 57344). Sobral,
 serra do Rosário, 23 January 2011, veg., *Souza, E.B. 2046* (HUVA, EAC).

11.7. *Tillandsia streptocarpa* Baker, J. Bot. 25: 241 (1887)

Distribution and habitat:—Restricted to subequatorial South America (Smith & Downs 1977). Occasional in Ceará. Epiphytes or rupicolous in crystalline caatinga, dry sedimentary and crystalline forests; 290–800 m.

Conservation:—Listed as “Least concern” by Martinelli and Moares (2013). Occurs in APA Ibiapaba, APA Chapada do Araripe Arapipe-Apodi National Forest and Ecological Station of Aiuaba.

Morphology:—*Tillandsia streptocarpa* has an open rosette and densely lepidote, linear-triangular leaves, generally spiraling towards the apex, with margins involute. The species can also be identified by the long pedunculated inflorescence compound or rarely simple, with imbricate floral bracts and distichous flowers with petals spreading, strongly spatulate and lilac.

Phenology:—Blooming in April and December. Fruiting June to November.

Examined specimens:—BRAZIL. **Ceará:** Aiuaba, Estação Ecológica, 22 June 1982, veg., *Viana, F.A. s.n.* (EAC 11894); *ibid.*, Riacho do Caldeirão, 6 August 1996, veg., *Lima-Verde, L.W. 300* (EAC); *ibid.*, Mirador, 9 June 1998, veg., *Lima-Verde, L.W. 941* (EAC); *ibid.*, Estação Ecológica de Aiuaba, 10 June 1998, fr., *Figueiredo, M.A. 1009*

(EAC); *ibid.*, Estação Ecológica de Aiuaba, 25 January 2005, veg., *Lemos, J.R.* 298 (HUVA, EAC). Assaré, Fazenda Extrema, 25 March 2005, veg., *Monteiro, F.J.S.* 3S (EAC). Boa Viagem, April 1987, fl., *Lima-Verde, L.W.* s.n. (EAC 15318); *ibid.*, cachoeirão, 5 July 1997, fr., *Otoch, R.* s.n. (EAC 26154). Crato, sítio Fundão, 9 August 1993, veg., *Figueiredo, M.A.* s.n. (EAC 20077); *ibid.*, Flona do Araripe, 3 November 1999, fr., *Lima-Verde, L.W.* 1793 (EAC). Croatá, Melancia, 2 January 2008, *Castro, A.S.F.* 1988 (EAC). Monsenhor Tabosa, área de nascentes do rio Acaraú, 2 September 2016, veg., *E.B. Souza* 4343 (HUVA). Quixadá, 28 September 1992, fr., *Félix, L.P.* s.n. (EAC 19068). Tauá, bacia do riacho Carrapateira, 10 December 2014, fl., *Gomes, R.C.* s.n. (EAC 57343). Viçosa do Ceará, Cocalzinho, 16 June 2006, fr., *Silveira, E.* s.n. (EAC 39323).

11.8. *Tillandsia tenuifolia* L., Sp. Pl. 1: 286 (1753) [Fig. 5 N–O]

Distribution and habitat:—Central to South America (Smith & Downs 1977). Rare in Ceará. Epiphytes or rupicolous in wet and dry crystalline forests; 600–1000 m.

Conservation:—Listed as “Least concern” by Martinelli and Moares (2013). Found in APA Serra de Maranguape and APA Serra de Baturité.

Morphology:—This species can be recognized by the caulescent habit, with coriaceous and sparsely lepidote leaves disposed along the developed stem. Also, the inflorescence is a simple spike, suberect, with pink floral bracts imbricate and polystichous flowers bearing white petals.

Phenology:—Blooming from April to June and October to November. Fruiting in May and October to December.

Examined specimens:—BRAZIL. **Ceará:** Aratuba, pico do Mussum, 30 June 2017, fl., Tomaz, E.C. 135 (UFRN). Guaramiranga, 18 October 1986, fl., Lineu, C. s.n. (EAC 15744); *ibid.*, sítio Arábia, 17 December 1988, fr., Figueiredo, M.A. s.n. (EAC); *ibid.*, sítio São José, 14 November 2007, fl., Monteiro, F.J.S. F76 (EAC); *ibid.*, pico Alto, estrada das Torres., 18 April 2008, fl., Lima-Verde, L.W. 3493-08 (EAC);). *ibid.*, topo do Pico Alto, 29 May 2015, fl., Tomaz, E.C. 85 (UFRN). Maranguape, serra de Maranguape, 24 May 2003, fr., Monteiro, F.J.S. s.n. (EAC 33784); *ibid.*, serra de Maranguape, 28 June 2003, fl., Monteiro, F.J.S. s.n. (EAC 33783). Monsenhor Tabosa, serra Branca, October 2009, fr., Coelho, P. s.n. (EAC 50702). Pacoti, pico Alto, 17 June 1989, fl., Figueiredo, M.A. s.n. (EAC 16720); *ibid.*, sítio São Pedro, 10 October 2007, fr., Lima-Verde, L.W. 3451 (EAC). São Benedito, Fazenda Penha - trilha do Buraco da Velha, 22 March 2000, veg., Souza, E.B. 395 (EAC). Uruburetama, serra do Cachorro Morto, 4 May 2008, fl., Monteiro, F.J.S. F154 (EAC).

11.9. *Tillandsia tricholepis* Baker, J. Bot. 16: 237 (1878) [Fig. 6 A–B]

Distribution and habitat:—Restricted to subequatorial South America (Smith & Downs 1977). Rare in Ceará. Epiphytes in crystalline caatinga, dry crystalline forest and wet sedimentary forests; 200–800 m.

Conservation:—Listed as “Least concern” by Martinelli and Moares 2013. Occurs in APA Chapada do Araripe.

Morphology:—*Tillandsia tricholepis* has a caulescent habit, with the stem developed, and is commonly found forming dense pendulous clumps. Leaves are polystichous, disposed along the stem and generally erect, the inflorescence is a simple spike, erect, with rachis straight, and flowers have orangish petals.

Phenology:—Blooming in January to March and September. Fruiting in November.

Examined specimens:—BRAZIL. **Ceará:** Jardim, Gravatá, 7 January 2010, fl. & fr. Castro, A.S.F. 2248 (EAC). Itatira, cachoeira da serrinha, 21 September 2007, fl., Monteiro, F.J.S. 36 (EAC). Mosenhor Tabosa, fazenda Oitis, 29 March 2018, fl., E.C. Tomaz 206 (UFRN). Santa Quitéria, fazenda Itatiaia, 29 February 1984, fl., Nunes, E. s.n. (EAC 12334).

11.10. *Tillandsia usneoides* (L.) L., Sp. Pl. 2: 411 (1762) [Fig. 6 C]

Distribution and habitat:—Widely distributed in the Neotropics (Smith & Downs 1977). Frequent in Ceará. Epiphytes in wet crystalline forests, dry crystalline forests, and crystalline caatinga; 600–970 m.

Conservation:—Listed as “Least concern” by Martinelli and Moraes (2013) and Miller *et al.* (2013). Occurs in APA Serra de Baturité, APA Serra de Maranguape and APA Serra da Aratanha.

Morphology:—*Tillandsia usneoides* is an obligate epiphyte with roots absent in maturity. It can be easily recognized by the dense clumps pending from branches of trees, as well as by the distichous, densely cinereous-lepidote and linear leaves, the sessile and single-flowered inflorescence, and flowers with greenish petals.

Phenology:—Fruiting in October.

Examined specimens:—BRAZIL. **Ceará:** Aratuba, pico do muçum, 30 June 2017, veg., Tomaz, E.C. 134 (UFRN). Baturité, sítio São Miguel, 10 July 2008, veg., Lima-Verde, L.W. 3500 (EAC); *ibid.*, sítio Taveira, 30 October 2007, veg., Lima-Verde, L.W. 343407 (EAC). Guaramiranga, sítio Arábia, 17 December 1988, veg., Fernandes, A. s.n. (EAC);

ibid., pico alto, 8 October 2008, veg., *Lima-Verde*, L.W. 3433 (EAC). Itapipoca, serra dos Picos, 13 January 2006, veg., *Lima*, D.C. s.n. (EAC). Itatira, serra do Machado, 24 July 2011, veg., *Castro*, A.S.F. 2536 (EAC). Maranguape, Serra de Maranguape, 28 June 2003, veg., *Monteiro*, F.J.S. s.n. (EAC). Monsenhor Tabosa, 24 January 2011, veg., *Menezes*, M.O.T. 274 (EAC). Pacatuba, sítio Pitaguari, 1 October 1979, veg., S/C s.n. (EAC 6995). Pacatuba, sítio do Prof. Miguel, 25 February 2003, veg., *Lima-Verde*, L.W. 2460 (EAC). Quixadá, distrito de Dom Maurício, 1 October 1992, fr., *Lima-Verde*, L.W. s.n. (EAC 20160). Santa Quitéria, serra do Pajé, 8 May 1997, veg., *Lima-Verde*, L.W. s.n. (EAC 25532). Tianguá, Cauã, 6 June 2012, veg., *Loiola*, M.I.B. 1843 (EAC). Uruburetama, serra do Cachorro Morto, 4 May 2008, veg., *Monteiro*, F.J.S. F151 (EAC).

12. *Vriesea* Lindl., Edwards's Bot. Reg. 29: pl. 10 (1843)

Identification key for species of *Vriesea* in Ceará

1. Leaf blade 6.5–8 cm wide, widely oblong; inflorescence simple, robust.....*Vriesea carmenae* (12.2)
- 1'. Leaf blade 2.5–4 cm wide, ligulate; inflorescence compound (rarely simple), slender.....2
2. Leaf blade 10–21 cm long; inflorescence erect, yellowish; flowers distichous, sessile; petals bright yellow.....*Vriesea baturitensis* (12.1)
- 2'. Leaf blade 40–45 cm long; inflorescence spreading, brownish-green; flowers secund, shortly pedicellate; petals yellowish to pale brown..... *Vriesea cearensis* (12.3)

12.1. *Vriesea baturitensis* Versieux & Tomaz, Phytotaxa 117: 45 (2013) [Fig. 6 I–K]

Distribution and habitat:—Endemic to Ceará (Versieux *et al.* 2013). Rare. Epiphytes in wet crystalline forests; 850–1080 m.

Conservation:—Listed as “Endangered” by Tomaz *et al.* (Chapter 3). Occurs in APA Serra de Baturité, APA Serra de Maranguape and APA Aratanha.

Morphology:—This species can be identified by the leaf blades $10\text{--}21 \times 2.5$ cm, ligulate, the compound or rarely simple, yellowish, erect and slender inflorescence, peduncle yellow to greenish, and floral bracts yellow. Additionally, flowers are sessile and distichous, with bright yellow sepals and petals, and bluish anthers.

Phenology:—February to August, November and December. Fruiting in March, May, June and November.

Examined specimens:—BRAZIL. **Ceará:** Guaramiranga, pico Alto, 8 February 1990, fl., *Fernandes, A. s.n.* (EAC 16286); *ibid.*, estrada do Pico Alto, 24 April 2000, fl., *Lima-Verde, L.W. s.n.* (EAC 31513); *ibid.*, sítio Lagoa, 2004, fl., *Silveira, A. 376* (EAC); *ibid.*, pico Alto., 26 June 2008, fl., *Gomes, V. 12822* (EAC); *ibid.*, estrada de acesso às torres de TV, 8 May 2012, fl., *Versieux, L.M. 525* (UFRN); *ibid.*, pico alto e trilha na mata nebulosa, 14 March 2014, *Versieux, L.M. 706* (UFRN, HUVA, HUEFS); *ibid.*, pico Alto., 28 March 2015, fl., *Loiola, M.I.B. 2547* (EAC). *ibid.*, topo do Pico Alto, 29 May 2015, *Tomaz, E.C. 86* (UFRN, RB); *ibid.*, pico Alto, 30 June 2017, fl., *Tomaz, E.C. 142* (UFRN). Itapagé, Morro do Coquinho, 13 December 2007, fl., *Monteiro, F.J.S. 105* (EAC). Maranguape, serra de Maranguape, 26 November 1955, fl., *Lima, A. s.n.* (EAC 1534); *ibid.*, serra de Maranguape, 22 November 1974, fr., *Fernandes, A. s.n.* (EAC 2025); *ibid.*, cultivo em Pacoti, 1989, fr., *Lima-Verde, L.W. s.n.* (EAC 16638); *ibid.*, trilha para o Pico Rajada., 27 August 1998, fl., *Matias, L.Q. s.n.* (EAC 27710); *ibid.*, serra de Maranguape, 24 May 2003, fl., *Monteiro, F.J.S. s.n.* (EAC 33789); *ibid.*, serra de

Maranguape, 28 June 2003, fr., *Monteiro, F.J.S. s.n.* (EAC 33788); *ibid.*, morro Pedra do Gigante, 1 November 2007, fr., *Monteiro, F.J.S. 63F* (EAC); *ibid.*, morro Pedra do Gigante, 1 November 2007, fl., *Monteiro, F.J.S. 45* (EAC). *ibid.*, trilha para Pico da Rajada, 2 March 2018, fr., *E.C. Tomaz 189* (UFRN). Pacatuba, pico do Letreiro., 18 February 2004, fl., *Monteiro, F.J.S. s.n.* (EAC 33779). Pacoti, pico Alto, próximo à antenas da Teleceará., 28 December 1997, fl., *Otoch, R. s.n.* (EAC 26156); *ibid.*, serra de Baturité, 17 June 1989, fr., *Figueiredo, M.A. s.n.* (EAC 20333); *ibid.*, pico Alto., 6 February 2007, *Moro, M.F. 23* (EAC).

12.2. *Vriesea carmenae* R. Moura & A.F. Costa, Systematic Botany 39: 794 (2014) [Fig. 6 D–E]

Distribution and habitat:—Endemic to Ceará (Moura & Costa 2014). Rare. Epiphytes in wet crystalline forests; 640–1000 m.

Conservation:—Listed as “Endangered” by Moura & Costa (2014) and Tomaz *et al.* (Chapter 3). Occurs in APA Serra de Baturité, APA Serra de Maranguape and APA Aratanha.

Morphology:—The widely oblong leaf blades, 6.5–8 cm wide, the robust, simple and complanate inflorescence characterize *V. carmenae* amongst *Vriesea* in Ceará. Additionally, floral bracts are imbricate, green to brown, and flowers are sessile, with pale-yellow petals.

Phenology:—Blooming in March. Fruiting in January to February, May to June, September and November.

Examined specimens:—BRAZIL. **Ceará:** Guaramiranga, sítio Guaramiranga, 16 June 1989, fr., *Figueiredo, M.A. s.n.* (EAC 16713); *ibid.*, sítio Riacho Fundo, 25 February 1989, fr., *Figueiredo, M.A. s.n.* (EAC 16418); *ibid.*, sítio Cana Brava, 21 May 1994, veg., *Oliveira, M.R.L. s.n.* (EAC 20908); *ibid.*, sítio Batalha, 29 March 1995, fl., *Lima-Verde, L.W. s.n.* (EAC 22069). *ibid.*, sítio Arvoredo, 11 September 2003, fr., *Gomes, V. 726* (EAC); *ibid.*, topo do Pico Alto, 29 May 2015, fr., *Tomaz, E.C. 83* (UFRN). Maranguape, serra de Maranguape, 10 January 1999, fr., *Oliveira, R. s.n.* (EAC 27282); *ibid.*, morro Pedra do Gigante, 1 November 2007, fr., *Monteiro, F.J.S. 62F* (EAC); *ibid.*, trilha da Pedra da Rajada, 3 January 2008, fr., *Monteiro, F.J.S. F120* (EAC). Pacoti, sítio Olho D'água dos Tangarás, August 1993, *Lima-Verde, L.W. s.n.* (EAC 19767).

12.3. *Vriesea cearensis* L.B. Sm., Phytologia 7: 255 (1960) [Fig. 6 F–H]

Distribution and habitat:—Endemic to Ceará (Smith & Downs 1977; Flora do Brasil 2020). Rare. Epiphytes in wet crystalline forests of Maranguape ridge; 800–980 m.

Conservation:—Listed as “Endangered” Martinelli & Moraes (2013), MMA (2014) and Tomaz *et al.* (Chapter 3). Occurs in APA Serra de Maranguape.

Morphology:—*Vriesea cearensis* can be identified by the lingulate leaf blades 40–45 × 4 cm, the peduncle mostly hidden by the peduncle bracts, the inflorescence compound, spreading, slender and brownish-green. In addition, floral bracts are greenish brown, flowers are short pedicellate, secund, with petals yellowish to pale brown.

Phenology:—Blooming in February and May. Fruiting in February to March and August.

Examined specimens:—BRAZIL. **Ceará:** Maranguape, picada p/ Pedra da Rajada, 16 August 1998, fr., *Martinelli, G. 18069* (EAC); *ibid.*, próx. ao Pico da Rajada, 13 February

2003, fr., *Lima-Verde*, L.W. 2441 (EAC); *ibid.*, pico da Pedra Rajada., 14 March 2004, fr., *Monteiro*, F.J.S. s.n. (EAC 33790); *ibid.*, 5 February 2006, fl., *Lima-Verde*, L.W. 3405A (EAC); *ibid.*, trilha da Pedra da Rajada, 4 May 2008, fl., *Monteiro*, F.J.S. F121 (EAC); *ibid.*, pico da Rajada, 26 March 2011, fr., *Fortunato*, M.E.M. 57 (EAC); *ibid.*, pico da Rajada, 2 March 2018, fr., *E.C. Tomaz* 175 (UFRN).

13. *Wallisia* (Regel) E. Morren, *Belgique Hort.* 20: 97 (1870)

13.1. *Wallisia anceps* (G. Lodd.) Barfuss & W. Till, *Phytotaxa* 279: 47 (2016)

Distribution and habitat:—Central American to Brazil (Smith & Downs 1977; Flora do Brasil 2020). Rare in Ceará. Epiphytes in wet crystalline forests of Maranguape ridge; 800–980 m.

Conservation:—Risk of extinction not evaluated but should be of “Least concern”. Occurs in APA Serra de Maranguape.

Morphology:—*Wallisia anceps* can be identified by the reddish longitudinal stripes towards the base of leaves, as well as by the inflorescence in a complanate simple spike.

Phenology:—Blooming in May. Fruiting in November.

Examined specimens:—BRAZIL. **Ceará:** Maranguape, trilha para a Pedra da Rajada, 16 May 2005, fl. *Monteiro*, F.J.S. 25 (EAC); *ibid.*, Morro Pedra do Gigante, 1 November 2007, fr., *Monteiro*, F.J.S. 53F (EAC).

14. *Wittmackia* Mez, in Mart., Fl. Bras. 3: 274 (1891)

14.1. *Wittmackia maranguapensis* (Leme & Scharf) Aguirre-Santoro, Plant Syst. Evol. 303: 636 (2017) [Fig. 6 L–N]

Distribution and habitat:—Endemic to Ceará (Aguirre-Santoro 2017). Rare. Epiphytes in wet crystalline forests of Maranguape ridge; 600–980 m.

Conservation:—Listed as “Endangered” by Tomaz *et al.* (Chapter 3). Occurs only in APA Serra de Maranguape.

Morphology:—Leaves with blades oblong, with margins densely and minutely serrulate, and apex often abruptly attenuate and darkened. In addition, it can be identified by the wide compound spike, the inconspicuous floral bracts, aciculate from the base, whitish flowers with lilac petals, naked ovules and fruits bright purple.

Phenology:—Blooming in August and January. Fruiting in January to May and August to November.

Examined specimens:—BRAZIL. **Ceará:** Maranguape, serra de Maranguape, 26 November 1955, fr., Lima, A. s.n. (EAC 1536); *ibid.*, serra de Maranguape, 2 November 1996, fr., Lima-Verde, L.W. 155 (EAC); *ibid.*, picada para Serra rajada, 16 August 1998, fr., Martinelli, G. 15071 (EAC, RB); *ibid.*, serra de Maranguape, trilha para o Pico da Rajada, 27 August 1998, fl., Matias, L.Q. s.n. (EAC 27661); *ibid.*, trilha para Rajado, 10 January 1999, fl., Oliveira, R. s.n. (EAC 27380); *ibid.*, serra de Maranguape, 24 May 2003, fr., Monteiro, F.J.S. 8 (EAC); *ibid.*, trilha para Pedra Rajada., 14 March 2004, fr., Monteiro, F.J.S. 15 (EAC); *ibid.*, trilha da Pedra da Rajada, 3 January 2008, fr., Monteiro, F.J.S. F117 (EAC); *ibid.*, pico da Rajada, 26 May 2011, fr., Fortunato, M.E.M. 59 (EAC); *ibid.*, pico da Rajada, 22 October 2011, fr., Fortunato, M.E.M. 61 (EAC); *ibid.*, trilha para Pico da Rajada, 2 March 2018, fr., E.C. Tomaz 188 (UFRN).

Acknowledgements

We are thankful to CAPES and Graduate Program in Systematics and Evolution, for the ECT's M. Sc. Scholarship and additional financial aid for field work, and to CNPq, for LV's Productivity Scholarship (#304778/2013-3) and grant (#455510/2014-8). We also thank curators and staff of cited herbaria.

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TABLE 1. Visited localities for collection of Bromeliaceae in Ceará. SPP: number of collected species.

Locality	Municipalities	SPP
Maciço do Baturité	Guaramiranga, Pacoti	9
Serra das Matas	Monsenhor Tabosa	3
Chapada do Araripe	Crato, Barbalha	3
Serra da Meruoca	Meruoca	3
Serra de Maranguape	Maranguape	6

TABLE 2. List of Bromeliaceae species by subfamily and genera (followed by species count) in Ceará.

Bromelioideae	<i>Aechmea</i> (5)	<i>Aechmea aquilega</i> (Salisb.) Griseb.
		<i>Aechmea bromeliifolia</i> var. <i>albobracteata</i> Philcox
		<i>Aechmea castelnavii</i> Baker
		<i>Aechmea leptanta</i> (Harms) Leme & J.A.Siqueira
		<i>Aechmea tocantina</i> Baker
	<i>Ananas</i> (2)	<i>Ananas ananassoides</i> (Baker) L.B.Sm. <i>Ananas lucidus</i> Mill.
Pitcairnioideae	<i>Bromelia</i> (3)	<i>Bromelia auriculata</i> L.B.Sm. <i>Bromelia</i> aff. <i>karatas</i> L. <i>Bromelia laciniosa</i> Mart. ex Schult. & Schult.f.
	<i>Neoglaziovia</i> (1)	<i>Neoglaziovia variegata</i> (Arruda) Mez
	<i>Orthophytum</i> (1)	<i>Orthophytum cearense</i> Leme & F.Monteiro
	<i>Wittmackia</i> (1)	<i>Wittmackia maranguapensis</i> (Leme & Scharf) Aguirre-Santoro
Tillandsioideae	<i>Encholirium</i> (2)	<i>Encholirium erectiflorum</i> L.B.Sm. <i>Encholirium spectabile</i> Mart. ex Schult. & Schult.f.
	<i>Pitcairnia</i> (1)	<i>Pitcairnia limae</i> L.B.Sm.
	<i>Catopsis</i> (1)	<i>Catopsis sessiliflora</i> (Ruiz & Pav.) Mez
	<i>Guzmania</i> (3)	<i>Guzmania lingulata</i> (L.) Mez var. <i>lingulata</i> <i>Guzmania monostachia</i> (L.) Rusby ex Mez <i>Guzmania sanguinea</i> (André) André ex Mez
Tillandsioideae	<i>Racinaea</i> (1)	<i>Racinaea spiculosa</i> (Griseb.) M.A.Spencer & L.B.Sm.
	<i>Tillandsia</i> (10)	<i>Tillandsia gardneri</i> Lindl. <i>Tillandsia juncea</i> (Ruiz & Pav.) Poirer <i>Tillandsia loliacea</i> Mart. ex Schult. & Schult.f. <i>Tillandsia pohliana</i> Mez <i>Tillandsia polystachia</i> (L.) L. <i>Tillandsia recurvata</i> (L.) L. <i>Tillandsia streptocarpa</i> Baker <i>Tillandsia tenuifolia</i> L. <i>Tillandsia tricholepis</i> Baker <i>Tillandsia usneoides</i> (L.) L.
Tillandsioideae	<i>Vriesea</i> (3)	<i>Vriesea baturitensis</i> Versieux & Tomaz <i>Vriesea carmeniae</i> R. Moura & A.F. Costa <i>Vriesea cearensis</i> L.B.Sm.
Tillandsioideae	<i>Wallisia</i> (1)	<i>Wallisia anceps</i> (Lodd.) Barfuss & W. Till

TABLE 3. Bromeliaceae species excluded from the present checklist.

Taxa	Reference
<i>Aechmea bromeliifolia</i> (Rudge) Baker var. <i>bromeliifolia</i>	Faria <i>et al.</i> (2009), Flora do Brasil 2020
<i>Aechmea patentissima</i> (Mart. ex Schult & Schult. f.) Baker	Flora do Brasil 2020
<i>Ananas bracteatus</i> (Lindl.) Schult. & Schult.f.	Flora do Brasil 2020
<i>Billbergia portiana</i> Brong. ex Beer	Smith & Downs (1977), Flora do Brasil 2020
<i>Bromelia arenaria</i> Ule	Flora do Brasil 2020
<i>Hohenbergia catingae</i> Ule	Flora do Brasil 2020
<i>Hohenbergia ramageana</i> Mez	Flora do Brasil 2020
<i>Hohenbergia ridleyi</i> (Baker) Mez	Flora do Brasil 2020
<i>Pseudananas sagenarius</i> (Arruda) Camargo	Flora do Brasil 2020
<i>Tillandsia stricta</i> Sol.	Flora do Brasil 2020
<i>Vriesea procera</i> (Mart. ex Schult. & Schult.f.) Wittm.	Smith & Downs (1977), Flora do Brasil 2020
<i>Vriesea rodigasiana</i> E. Morren	Smith & Downs (1977), Flora do Brasil 2020

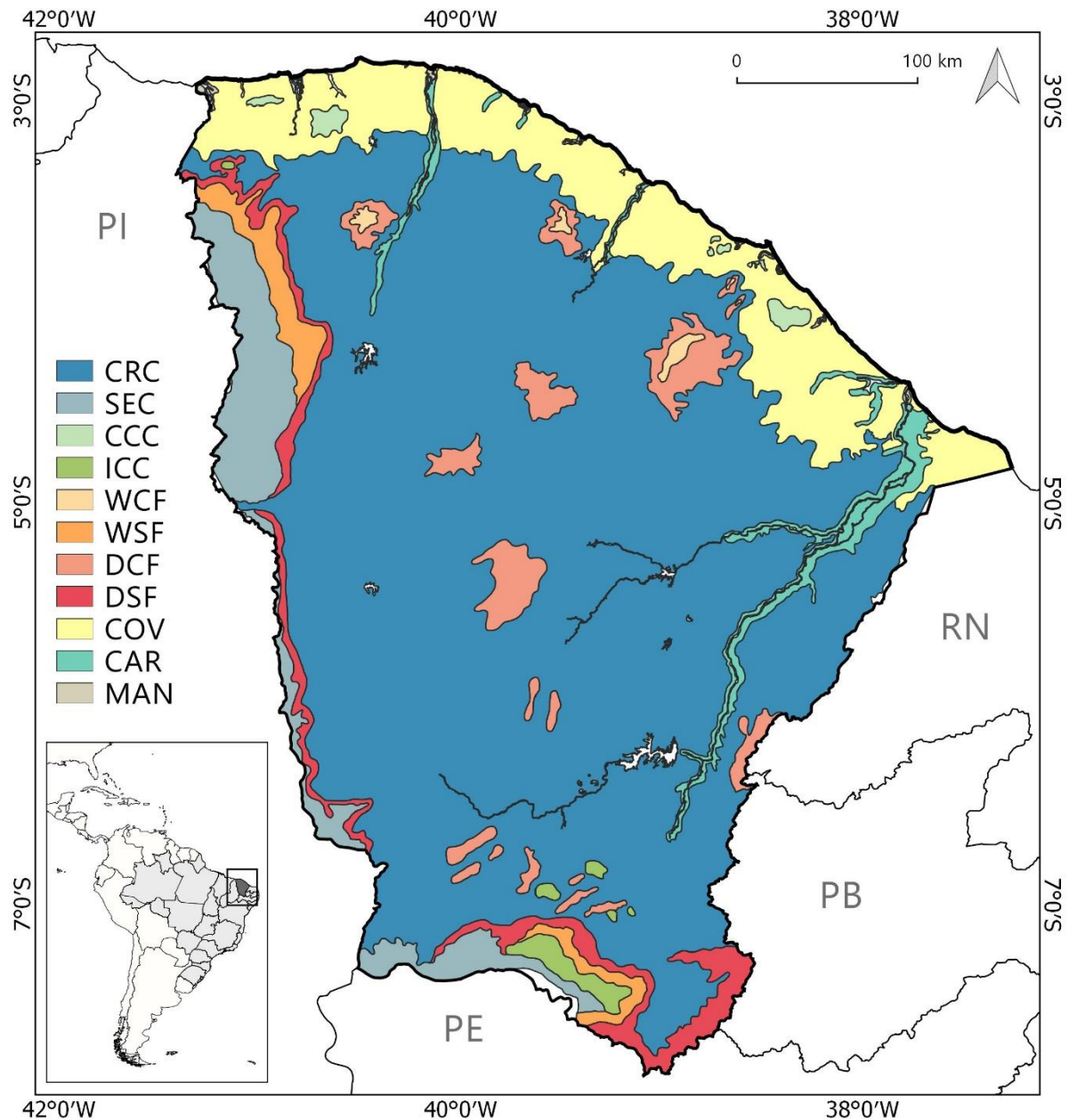


FIGURE 1. Phytoecologic units of Ceará *sensu* Moro *et al.* (2015). CRC: crystalline caatinga; SEC: sedimentary caatinga; CCC: coastal Cerrado and *cerradão*; ICC: interior cerrado and *cerradão*; WCF: wet crystalline forests; WSF: wet sedimentary forest; DCF: dry crystalline forest; DSF: dry sedimentary forest; COV: coastal vegetation; CAR: *carnaubal*; MAN: mangroves; PB: Paraíba; PE: Pernambuco; PI: Piauí; RN: Rio Grande do Norte.

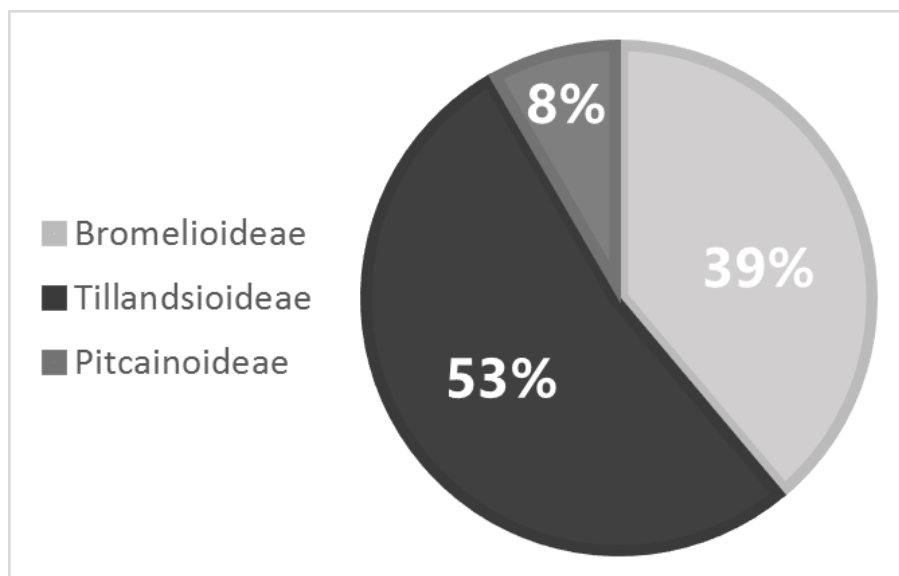


FIGURE 2. Bromeliaceae species richness by subfamilies in Ceará.

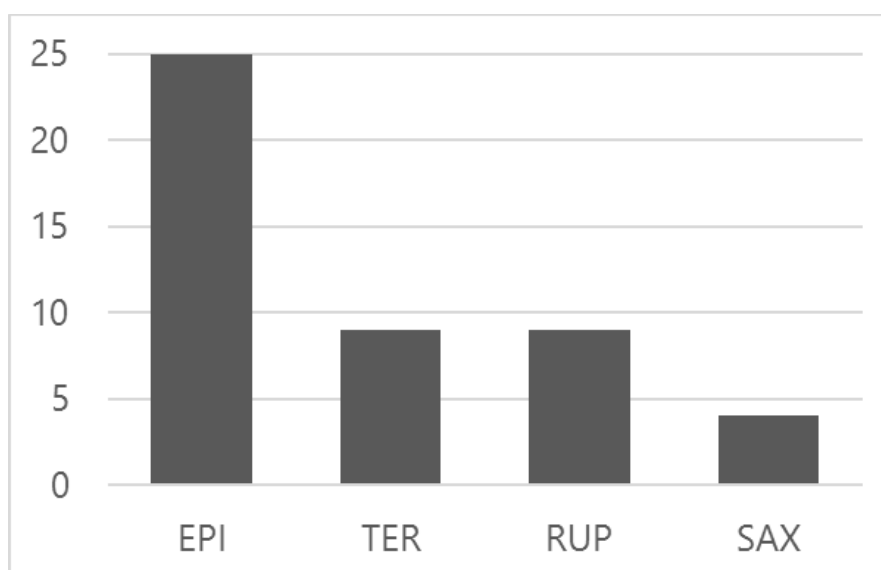


FIGURE 3. Number of Bromeliaceae species by habit in Ceará.

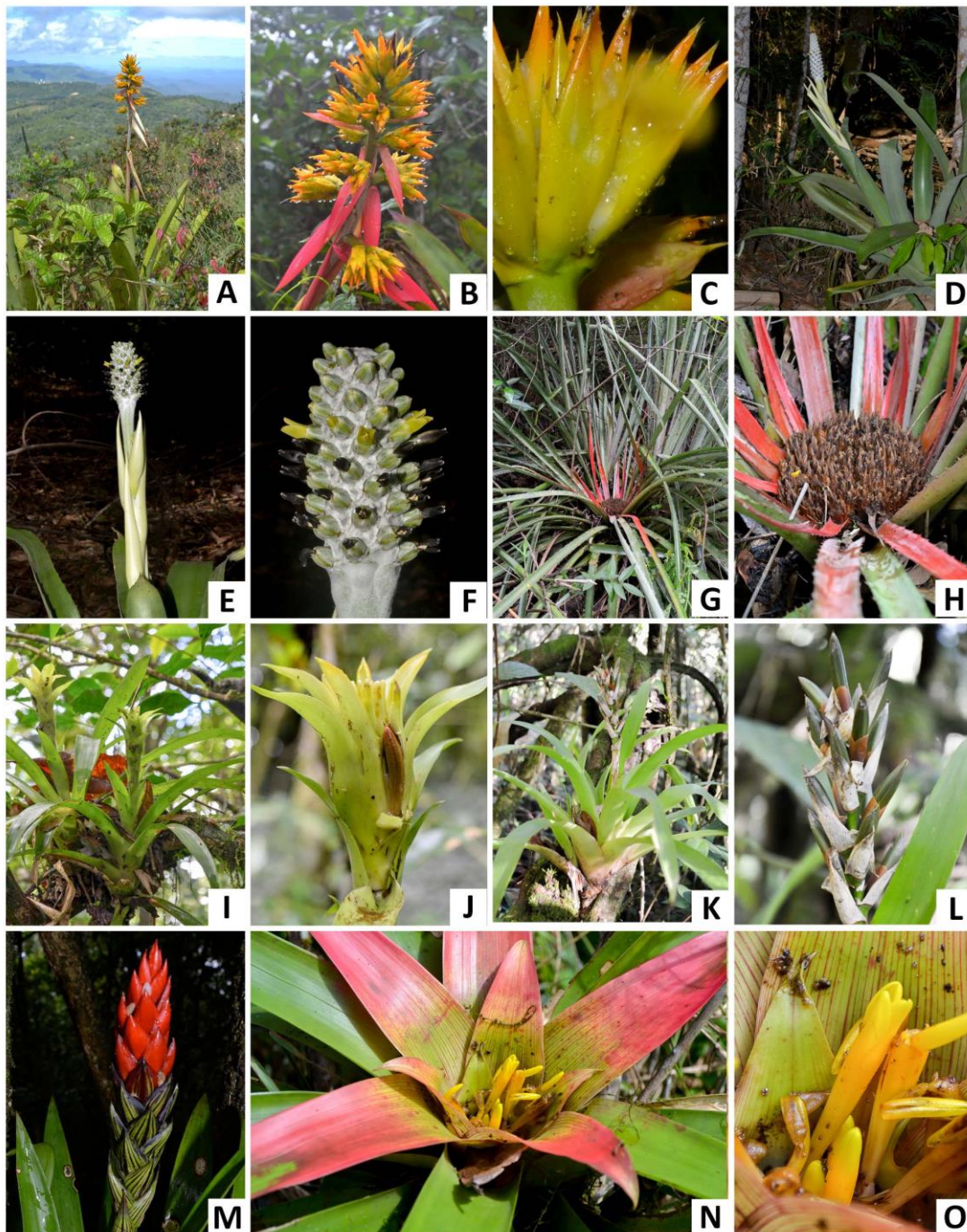


FIGURE 4. Bromeliaceae species in Ceará. **A–C.** *Aechmea aquilega*: **A.** habit; **B.** inflorescence; **C.** detail of flowers with withish mucilaginous secretion. **D–F.** *Aechmea bromeliifolia* var. *albobracteata*: **D.** habit. **E.** inflorescence; **F.** detail of flowers. **G–H.** *Bromelia* aff. *karatas*: **G.** habit; **H.** inflorescence. **I–J.** *Guzmania lingulata*: **I.** habit; **J.** detail of inflorescence with fruit (involucral bracts had been removed). **K–M.** *Guzmania monostachia*. **K.** habit; **L.** detail of fruits; **M.** inflorescence in beginning of flowering. **N–O.** *Guzmania sanguinea*. **N.** habit; **O.** flowers.

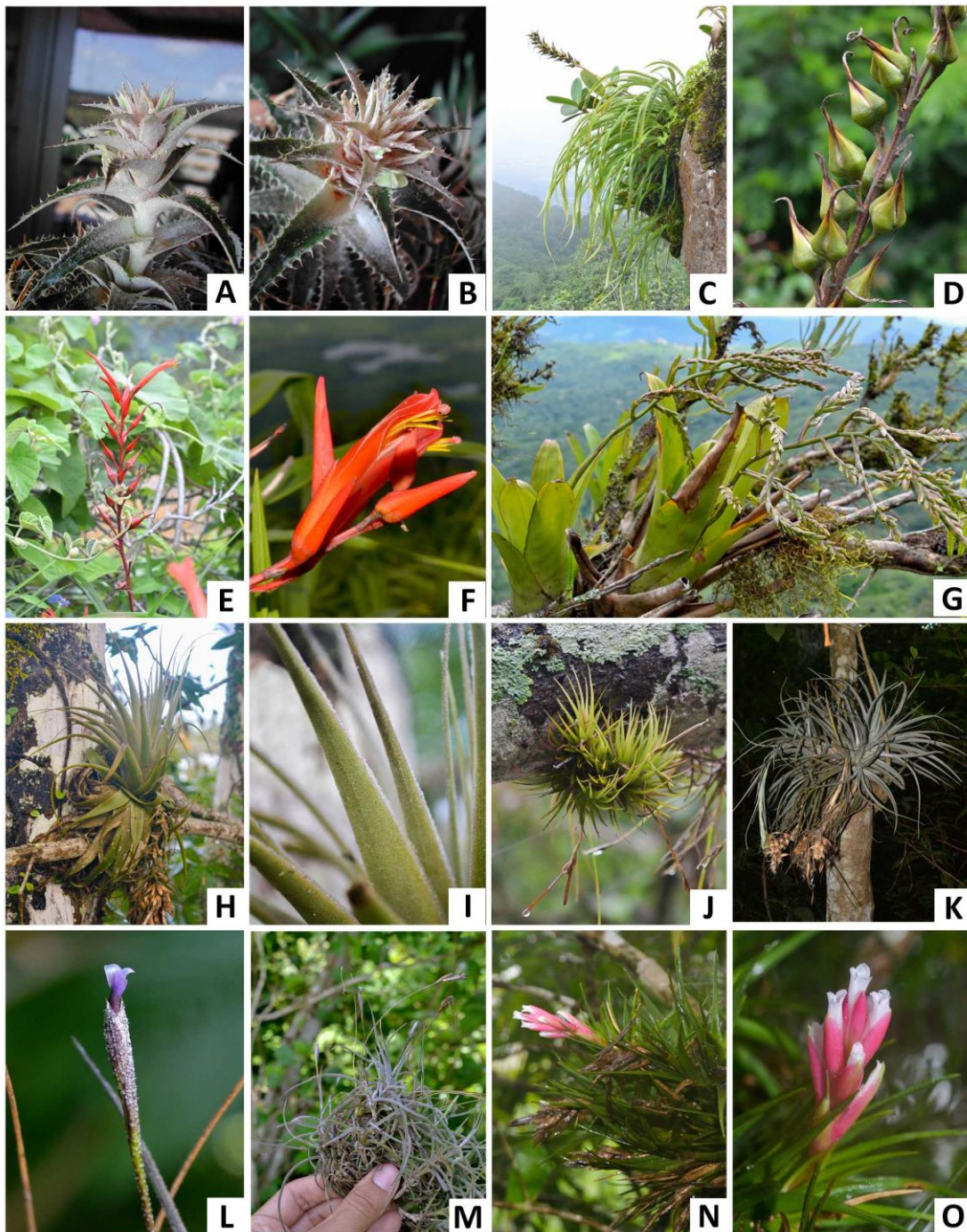


FIGURE 5. Bromeliaceae species in Ceará. **A–B.** *Orthophytum cearense*: **A.** side view of the inflorescence; **B.** inflorescence form above. **C–F.** *Pitcairnia limae*: **C.** habit; **D.** detail of fruits; **E.** inflorescence; **F.** detail of flower. **G.** *Racinaea spiculosa*: mature individual with fruits. **H–I.** *Tillandsia gardneri*: **H.** habit; **I.** detail of leaves with exceeding scales. **J.** *Tillandsia loliacea*: habit. **K.** *Tillandsia pohaliana*: habit. **L–M.** *Tillandsia recurvata*: **L.** detail of flower; **M.** habit. **N–O.** *Tillandsia tenuifolia*: **N.** habit; **O.** detail of inflorescence.

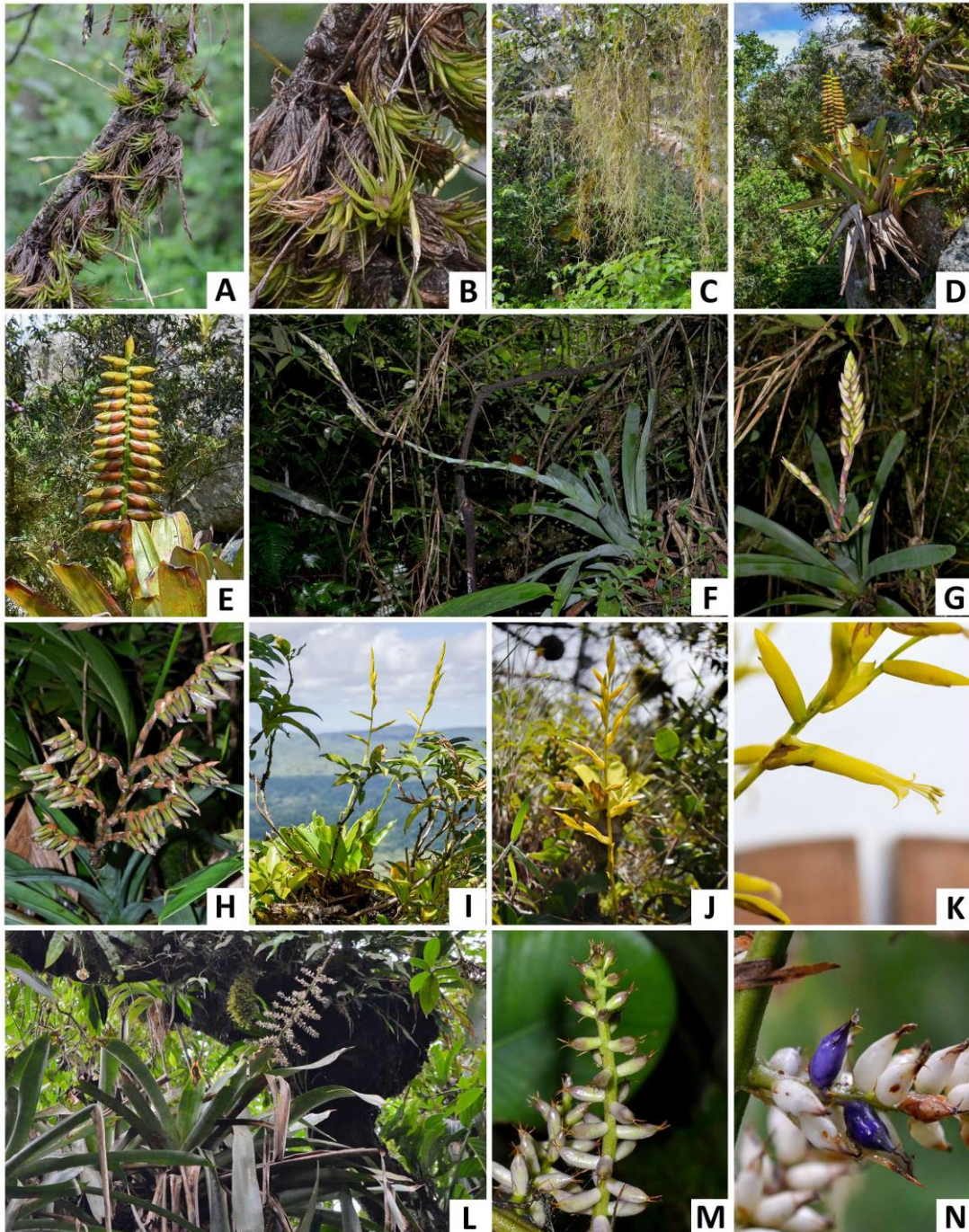


FIGURE 6. Bromeliaceae species in Ceará. **A–B.** *Tillandsia tricholepis*: **A.** habit; **B.** flowering individual. **C.** *Tillandsia usneoides*: habit. **D–E.** *Vriesea carmenae*: habit; **E.** inflorescence. **F–H.** *Vriesea cearensis*: **F.** habit; **G.** detail of juvenile inflorescence; **H.** fruiting inflorescence. **I–K.** *Vriesea baturitensis*: **I.** habit; **J.** inflorescence; **K.** detail of flower. **L–N.** *Wittmackia maranguapensis*: **L.** habit; **M.** detail of lateral branch; **N.** detail of ripening fruits (in purple).

CAPÍTULO 3

BIOGEOGRAPHY AND CONSERVATION OF BROMELIACEAE IN THE NORTHERNMOST DISTRIBUTION OF THE BRAZILIAN ATLANTIC FOREST AND CAATINGA

Biogeography and conservation of Bromeliaceae in the northernmost distribution of the Brazilian Atlantic forest and Caatinga

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Abstract

Bromeliads feature among the richest and most threatened angiosperm families in Brazilian flora and play a key role in different ecosystems due to its interactions with other organisms. Despite several genera underwent a profuse speciation in Brazil, conservation strategies for the group as whole can be improved by documenting areas with high levels of endemism, diversity and patterns of distribution. In this work, we study the distribution patterns, endemism, species richness and indicate cases needing conservation for the Bromeliaceae in the Northeastern Caatinga and Coastal drainages ecoregion, mostly covered by Atlantic rain forest and Caatinga, the largest patch of seasonally dry tropical forest in the Neotropics. Using information from herbarium specimens and environmental variables, we analyzed patterns of distribution at genus level, species richness, collection efforts, conservation status and endemism of bromeliads inside a freshwater ecoregion. Our sampling recorded 23 genera and 108 species of Bromeliaceae in the study area. The analyses show that mean annual precipitation is the most relevant factor affecting richness and genera distribution. Species richness and collection intensity are concentrated in the Atlantic forest, while fewer and xeromorphic taxa occur throughout the Caatinga area. Five general patterns of distribution were recognized, and a region of extremely low precipitation might act as a biogeographic barrier blocking a northward dispersion of mesophytic genera. Two main areas of endemism were recovered, reflecting mostly fragments of Atlantic forests. Such areas of endemism together shelter 29 threatened species, most ranked as endangered (19 spp.). We found that Bromeliaceae richness and endemism in the study area is concentrated in fragments of humid forests, mostly at higher altitudes, which should be considered priority areas for conservation of the group.

Key words: endemism, flora, *brejo de altitude*, phytogeography, taxonomy.

Introduction

Along with taxonomic studies, the analysis of species distribution patterns has been indicated as primordial for the effective application of conservation measures (Vane-Wright *et al.* 1991; Carvalho 2009). Although such patterns, also addressed as biogeographic patterns, might be approached in many different ways and scales, they all relate to the organization and distribution of groups of organisms in geographic space (Espinosa-Organista *et al.* 2002; Morrone 2009).

Important historical factors, or biogeographic processes might influence species distribution patterns, such as dispersion, vicariance and extinction (Morrone 2009). However, these processes alone do not explain contemporary patterns of distribution, taking in consideration that ecology might as well play relevant role in shaping geographic distribution of species observed today (Wiens & Donoghue 2004), as environmental factors can affect their spatial distribution, consequently richness and species composition. As an example, water availability tends to be directly proportional to species richness, although other variables such as altitude, temperature and edaphic features have known relevance (Pausas & Austin 2001; Austin 2013; Dubius *et al.* 2013). It is important to note that these climatic or physical features might prevent organisms from colonizing certain habitats, therefore functioning as barriers (Wiens & Donoghue 2004; Wiens 2011).

In South America, and particularly in Brazil, a remarkable climatic feature acting as a biogeographic barrier for vegetation is the Dry Diagonal. Regardless which roles this region has played in the past in the evolution of Brazilian tropical forests, today it is a clear barrier between the Brazilian Atlantic forests and the Amazon and is dominated by Seasonally Tropical Dry forests (STDFs) and savannas, notably Caatinga and Cerrado (Fiasch & Pirani 2009; Carvalho & Almeida 2010).

Thus, since broad biogeographic processes can act producing specific patterns of species distribution, these are not aleatory (Carvalho 2011). An area of endemism is defined when the distribution of different species converge to a same region (Morrone 1994; Szumik *et al.* 2002). Therefore, since an endemic taxon is found exclusively in one region, this is one of the aspects related to species distribution most important for conservation, as identification of areas of endemism can contribute to effective conservation planning (Szumik *et al.* 2002; Figueredo *et al.* 2006).

The tropical Atlantic forests in Eastern Brazil have been indicated as one of the most important regions for conservation of the world's biodiversity. In fact, AF is one of the leading hotspots of diversity with endemic plants and vertebrates accounting for 2.7% and 2.1%, respectively, of the total world richness of those taxa (Myers *et al.* 2000). Unfortunately, according to those authors, only 7,5% of the original extent of domain is left. This fact is especially alarming in Northeastern Brazil, an area historically transformed by agriculture (Ab'Saber 2007), that shelter an important and probably the most threatened biogeographic unit of the Atlantic forest domain, known as Pernambuco Center of Endemism (Silva & Casteletti 2005; Tabarelli *et al.* 2005).

One of the highly diverse groups of Angiosperms occurring in Brazilian Atlantic forests are the bromeliads (Bromeliaceae) (Smith 1955; Martinelli *et al.* 2008). Bromeliaceae are monocotyledons widely distributed in the Neotropics, with a great level of endemism in Brazil (Smith and Downs 1974; Benzing 2000; Flora do Brasil 2020). It is broadly recognized the influence of some remarkable morphological features and physiological adaptations, such as absorptive epidermal trichomes and CAM photosynthesis, as well as different life strategies that have allowed bromeliads to colonize different habitats and thrive under a wide range of environmental conditions (Benzing 2000; Givnish *et al.* 2014). For example, they can grow as epiphytes and as

rupicolous or terricolous herbs and, in some cases, all growth forms are evidenced in the same species (Smith and Downs 1974; 1979).

Siqueira-Filho *et al.* (2006) have accessed distribution, richness, species composition and conservation of bromeliads in Northeastern Brazil. Their study was pioneer once it included the whole family and revealed an impressive number of new species. However, no correlation with environmental variables was presented and the study was restricted to fragments of Atlantic Forest in the states of Pernambuco and Alagoas. Bromeliads are also important elements in the vegetation of Caatinga (Giulietti *et al.* 2000; Pennington *et al.* 2000), with around 70 species considered endemic of this domain (Flora do Brasil 2020).

The present study aims to enhance knowledge on biogeographic patterns of Bromeliaceae and promote conservation of species in the Northeastern Caatinga and Coastal drainages ecoregion, located to the north of São Francisco' river, an area still poorly known botanically (Versieux *et al.* 2017). For this purpose, we searched for areas of high species richness and collection density, as well as areas of endemism, and analyzed how the genera are distributed within a freshwater ecoregion.

MATERIAL AND METHODS

Study area

We analyzed Bromeliaceae records from the Northeastern Caatinga and Coastal drainages ecoregion of freshwater regionalization provided by Abell *et al.* (2008). This ecoregion is located in the extreme Northeast of Brazil and includes all coastal drainages at north of the São Francisco River. Mean annual rainfall ranges from 350 to 1140 mm/year and elevation goes from sea level up to around 1100 m. Most of the ecoregion

extension is dominated by Caatinga vegetation, with Atlantic forests concentrated in the coast or on the top of isolated ridges (Hales & Petry 2018).

Data gathering and curation

We compiled 2,671 occurrence records of 108 species in 23 genera of Bromeliaceae from 46 Brazilian and five international botanical collections (see Supplementary Material 1) available in the online platforms SpeciesLink (CRIA 2017), Global Biodiversity Information Facility (GBIF 2017) and REFLORA (JBRJ 2017), either through polygon search or looking for Brazilian states individually. Data from herbaria MOSS, UFRN, EAC, HCDAL and HUVA (acronyms according to Thiers 2018) were analyzed personally by the first author. In addition, fieldwork was conducted in the states of Rio Grande do Norte and Ceará, covering areas of Atlantic forest and Caatinga.

Records without original geographic coordinates were assigned to collection localities informed in specimen labels or to the municipal seat location when collection sites were not available. Geographic coordinates from municipal seats or localities were obtained from the Geonames webpage (<http://geonames.com>) or using the geoLoc tool from speciesLink (<http://splink.cria.org.br/geoloc>). Collection records that could not be georeferenced at least to municipality level and collections with doubtful identification were excluded from the database.

Species binomials were checked against the New Bromeliad Taxon List by Butcher & Gouda (2017), and all synonyms were updated to the accepted name, with the following few exceptions. First, we followed Smith & Downs' (1979) recognition *Ananas* Mill. and *Pseudananas* Hassl. ex Harms as independent genera, as well as in the infrageneric classification of *Ananas*. Second, all records identified as *Cryptanthus burlemarxii* Leme are herein treated as *Cryptanthus zonatus* (Vis.) Vis., since their synonymy

has become clear recently (Ferreira 2016). And finally, although Butcher & Gouda (2017) listed *Encholirum pernambucanum* L.B.Sm. & Read as a valid name, it has been placed under *Encholirium spectabile* Mart. ex. Schult. & Schult.f. in the revision provided by Forzza (2005) that was adopted here. In addition, we follow Aguirre-Santoro (2017) in the resurrection of genus *Wittmackia* Mez and the consequent restriction of *Hohenbergia* Schult. & Schl.f. to *H.* subg. *Hohenbergia*.

Environmental variables, geographic data and mapping

In order to evaluate how environmental factors affects bromeliads distribution in the study area we downloaded Data on Climate and altitude from Worldclim database as raster files (<http://www.worldclim.org/>; Fick & Hijmans 2017). We used the limits of the study area provided by WWF & TNC (2018; <http://www.feow.org/>). We, then overlap the shapefiles of the Terrestrial Ecoregions of the World (Olson *et al.* 2001) acquired through the World Wildlife Fund website (WWF 2018, <https://www.worldwildlife.org/>) to analyze species distributions. Olson's classification of "Caatinga moist forest enclaves" and "Pernambuco interior forests" for fragments of forest nested in the semi-arid Caatinga of Northeastern Brazil are herein regarded as together as high-altitude wet forests or *brejos de altitude*, as known locally.

Richness and sampling intensity

We analyzed species richness and collection effort with DIVA-GIS 7.5 (Hijmans 2017). A map of species richness was generated using the tool *point to grid* and selecting as output variable "Richness – number of different classes" which counts the number of different species in each cell of a grid. Sampling intensity was calculated using as output variable "Richness – number of observations", that calculates the number of occurrences

of each species in each cell of a grid. Cell size was set to a 0.5 map unit that resulted in half square degree grid cells. Both grids in shapefile format were later imported to QGIS (QGIS Development Team 2018) for production of maps.

Conservation assessment

The degree of threatens of each species was evaluated using the R package ConR (R Core Team 2018; Dauby 2017), following methodology described by Dauby (2017). ConR performs a rapid and automated batch analysis based on distribution data and categorizes taxa in a preliminary way according to IUCN Red List criterion B, which categorizes species using their geographic range (IUCN 2012). We compared our results to the categories of MMA (2014) and Martinelli & Moraes (2013) who provided risk assessment for the Brazilian flora.

Parsimony Analysis of Endemicity (PAE)

PAE analysis searches for areas of endemism by applying the principle of parsimony to areas as terminals and using the species occurrences as characters. Areas are therefore grouped based on shared species, considered synapomorphies (Rosen 1988). Following Morrone (1994), here we used grid cells as operational units. For comparative purposes, georeferenced grids with two spatial resolutions ($1^\circ \times 1^\circ$ and $0.5^\circ \times 0.5^\circ$) were defined, using QGIS 2.18.18 (QGIS Development Team 2018). Presence-absence data matrices of species occurrences and cells covering the study area were mounted in R software (R Core Team 2018), with one additional cell with all species absent representing a primitive area (analogous to an outgroup). PAE analyses were then performed in software TNT (Goloboff & Catalano 2016) and consensus between most

parsimonious trees was obtained by heuristic search. Finally, clades in the consensus area cladograms sharing two or more species were selected as areas of endemism.

RESULTS

Spatial patterns of genera distribution

Bromeliaceae is distributed in the study area along coastal and interior Atlantic forests, including the Caatinga moist forests enclaves herein considered as enclaves of Atlantic forest or *brejos de altitude*, and in the dry forests and xeric shrublands of Caatinga (Figure 1A). *Aechmea* Ruiz & Pav. was the most representative genus, with 23 species, followed by *Tillandsia* L. (18 spp.), *Vriesea* Lindl. (15 spp.) and *Hohenbergia* Schult. & Schult.f. (7 spp.) and the remaining genera all represented by six or less species (Table 1). Our study area is divided by a belt of extremely low rainfall (annual precipitation 468–747 mm; Figure 1C), named here as Northern dry diagonal (NDD). According to similar patterns of distribution of genera we could identify five groups (Table 1). Group I clusters widely distributed genera (Figure 2), that have successfully colonized areas inside the NDD or are present throughout most of the study area independently of the precipitation levels (*Aechmea* Ruiz & Pav., *Bromelia* L., *Hohenbergia* Schult. & Schult.f. and *Tillandsia* L.). In group II (Figure 3), there are genera restricted or more common in arid regions (*Dyckia* Schult. & Schult.f., *Encholirium* Mart. ex Schult. & Schult.f., *Neoglaziovia* Mez and *Orthophytum* Beer). Group III (Figure 4) is composed of mesophytic genera with distribution to East and West the NDD (*Ananas* Mill., *Catopsis* Griseb., *Guzmania* Ruiz & Pav., *Racinaea* M.A.Spencer & L.B.Sm., *Vriesea* Lindl., *Wittmackia* Mez). Group IV (Figure 5A–G) are genera restricted to humid areas to West of the dry diagonal (*Araeococcus* Brongn., *Billbergia* Thunberg, *Canistrum* E.Morren, *Cryptanthus* Otto. & A.Dietr., *Lymania* Read,

Neoregelia L.B.Sm., *Pseudananas* Hassl. ex. Harms), opposing to pattern of group V (Figure 5H–I), for the genera distributed only on the left side of the NDD (*Pitcairnia* L'Hér. and *Wallisia* E.Morren).

Species richness and sampling intensity

The highest species richness (31–49 spp.; Figure 6A) is found between the states of Pernambuco and Alagoas, in high lands dominated by Atlantic forest, at the southeast of the Borborema plateau. Expressive richness (medium and dark gray cells, 11–30 spp.; Figure 6A) is also observed around the above described area, going North through the state of Paraíba to the coast of Rio Grande do Norte and in the North of Ceará. These are mostly patches of Atlantic forest associated with the Borborema plateau in Paraíba, with crystalline plateaus to the North of Ceará, and Caatinga in Rio Grande do Norte and Paraíba. The remaining grid cells with a lower number of species (1–10 spp.; Figure 6A) cover areas of Caatinga, coastal Atlantic forests in Alagoas, Paraíba and Northern Rio Grande do Norte, the ecotonal forests of Araripe and Ibiapaba sedimentary plateaus of and crystalline plateaus in Northern Ceará.

Sampling intensity follows the patterns described above for species richness, with concentration in the Atlantic forests of Pernambuco's coast and inland plateaus, as in the boundary of Pernambuco and Alagoas, Areia ridge in Paraíba and the Baturité massif, in Northern Ceará (122–204 records; Figure 6B). Medium and darker grey cells represent areas of Atlantic forest in Alagoas, in the coast of Pernambuco, inland forests in Pernambuco and Paraíba, coastal Paraíba and Rio Grande do Norte, northern and southern Ceará and areas of Caatinga in Paraíba and Rio Grande do Norte. Finally, like the species richness patterns, fewer collections (1–41 records; Figure 6B) were done in areas covered by low altitude forests, coastal forests and Caatinga.

Conservation Assessment

According to risk evaluation of the 108 taxa present in the study area, 13 species are “Critically endangered”, 43 are “Endangered”, 14 are “Vulnerable” and 38 are considered “Least Concern or Near threatened” (Table 2). Only 13 and 27 out of 108 species were treated by the studies of MMA (2014) and Martinelli & Moraes (2013), respectively.

Parsimony Analysis of Endemism

PAE based on $0.5^{\circ} \times 0.5^{\circ}$ grid cells recovered seven areas of endemism (Figure 7A). Three of these are in Northern Ceará, in Caatinga (Figure 7A: A) and high-altitude wet forests (Figure 7A: C and B). The remaining four are concentrated in the East and Southeast of the study area, comprising areas of coastal and interior Atlantic forests (Figure 7A: D, F and G) and Caatinga (Figure 7A: E). On the other hand, PAE based on $1^{\circ} \times 1^{\circ}$ cells resulted in only two areas of endemism, as shown in Figure 7B: area H representing areas of high-altitude wet forests in Northern Ceará and area I, which concentrates almost all the interior and coastal Atlantic forests, including high-altitude wet forests, and areas of Caatinga.

DISCUSSION

Spatial patterns of genera distribution

While four genera are widely distributed in the study area (Group I; Fig. 2), four are restricted or appear to be more associated to dry environments (Group II; Fig. 3) and the remaining 15 occur in fragments of humid forests (Groups III, IV and V; Figs. 4 and 5). Such results suggest that despite the family’s adaptations to xeric conditions (Smith

& Downs 1974; Benzing 2000), taxonomic diversity and distribution of Bromeliaceae in the study area is more likely influenced by humidity. Altitude might also play an important role, but since low coastal areas are almost just as rich as areas with high elevation, it comes as a secondary factor. Indeed, Siqueira-Filho *et al.* (2006) have shown that lowland and montane forests fragments in Pernambuco and Alagoas had no significative difference in bromeliad species diversity in Northeastern Brazil.

Most of our study area is placed inside the Caatinga core area of South America dry diagonal (SDD) or diagonal of open formations (Prado & Gibbs 1993). The NDD evidenced here represents its Northeastern limit and marks the division of the Caatinga and the Atlantic forest domain in Northeastern Brazil. Notably dominated by low dry forests and xeric shrublands (Prado 2003; Queiroz 2006), such Caatinga core shelter genera with distribution pattern of groups I and II (Fig. 2 and Fig. 3, respectively).

In Group I (Table 1, Fig. 2), genera did not show signals of habitat specificity. *Tillandsia* is present throughout the study area regardless of precipitation levels or altitude, which is not surprising since this the most widely distributed genus of Bromeliaceae, with species occurring from North to South America, in many kinds of environments (Smith & Downs 1977). Additionally, *Tillandsia* is variable regarding vegetative and ecophysiological adaptations, being classified under three ecological types according to Benzing (2000; Types I, IV, V), including the extreme atmospheric, miniaturized and CAM forms. *Bromelia* is also widely distributed, occurring from deserts of Mexico and Central America and dry regions of Central Brazil to wet tropical forests as the Amazon and Atlantic forest (Monteiro *et al.* 2015; Smith & Downs 1979). Also, within group I, *Hohenbergia* is disjointly distributed in Eastern Brazil and Central America, with expressive richness in the Northeastern region (Flora do Brasil 2020), especially along the Atlantic forest. *Hohenbergia* is classified as part of the ecological

type III by Benzing (2000), and present adaptations that allow them to thrive under water stress, such as well-developed phytotelma, absorptive trichomes, and CAM photosynthesis. Lastly, *Aechmea* is the richest genus in our dataset (23 spp.; Table 1) is also the third largest in the family (Butcher & Gouda 2019), and despite the high number of species, most of them (19) are restricted to the East of the NDD, while only four (*A. aquilega*, *A. bromeliifolia*, *A. castelnavii* and *A. leptantha*) were able to cross it.

All genera classified within group II are notably well adapted to thrive under xerophytic conditions. *Encholirium* and *Dyckia* are part of the xeric clade of subfamily Pitcairnioideae, a lineage that has been successful in colonizing the SDD (Gomes-da-Silva *et al.* 2017). The only species of *Neoglaziovia* in the study area, *N. variegata* (Arruda) Mez, has been widely known as restricted to the Caatinga (Mayo 1992; Flora do Brasil 2020). Finally, the presence of *Orthophytum* in Group 2 follows its known distribution as a genus restricted to Eastern Brazil, with many xerophilic species distributed in Cerrado and Caatinga, and humid forests associated to rocky outcrops (Leme 2004; Louzada *et al.* 2014).

Meanwhile, mesophytic characteristics explain a different habitat restriction observed in genera with distribution patterns III, IV and V, which are generally distributed in the study area towards areas with higher rainfall, either at higher altitudes or lower coastal lands. The habitat convergence of genera from different subfamilies observed in group II is also observed in group III, with Bromelioideae and Tillandsioideae. The tillandsioid genera *Catopsis*, *Guzmania*, *Racinaea* and *Vriesea* present a similar extension of occurrence, from Mexico and Central America and to South America following the Andes and reaching Eastern Brazil (Smith & Downs 1977; 1979). In the bromelioid side, genus *Ananas* is native to South America, while *Wittmackia* has a disjunct distribution from Mexico to Northern South America and in Eastern Brazil, and both genera occur in

wet to dry tropical forests (Aguirre-Santoro *et al.* 2017; Smith & Till 1998). All these six genera are restricted in the study area to interior and coastal Atlantic forests of Paraíba, Pernambuco and Alagoas and in *brejos de altitude* of Northern Ceará.

Group IV includes only bromelioid genera, all well distributed in the Atlantic forest. Together, *Canistrum*, *Cryptanthus* and *Lymania* are endemic to Brazil and almost completely restricted to the Atlantic forest (Flora do Brasil 2020), following the pattern found here. *Araeococcus* and *Neoregelia* are disjointly distributed between Amazonia and Atlantic forest (Smith & Downs 1979). *Billbergia* is the most widely distributed genus in this group, occurring from Mexico to Argentina and in all phytogeographic domains of Brazil (Flora do Brasil 2020). The monotypic genus *Pseudananas*, is distributed in South America, in open to dense forests from Ecuador to Argentina (Smith & Downs 1979). Among genera in group IV, *Cryptanthus*' distribution goes up to the most Northern area to the East of the NDD, which is related to the presence of *Cryptanthus zonatus* (Vis.) Vis. in the semideciduous fragments of Atlantic forest in the coast of Rio Grande do Norte, as well as for *Cryptanthus bahianus* L.B.Sm. in rocky outcrops of Caatinga.

The only two genera belonging to Group V, *Wallisia* (*sensu* Barfuss *et al.* 2017) and *Pitcairnia* (Table 1), have a narrow distribution along islands of high-altitude wet forests known as “*Brejos de altitude*”. *Wallisia* (former *Tillandsia*) *anceps* (Lodd.) Barfuss & W.Till presents a disjunct distribution in Central America and Northern South America with isolated occurrences in Northern Ceará, to the west of NDD (Barfuss *et al.* 2016; Flora do Brasil 2020). Other species typical from Northern South America also reach the high-altitude wet forests of Ceará, as *Guzmania sanguinea*, suggesting that taxa from Central America and Northern South America may have reached Ceará state by dispersion, but have not cross the dry diagonal to reach similar habitats in the Eastern portion. On the other hand, *Pitcairnia limae* L.B.Sm. is endemic to high altitude wet

forests of Northern Ceará, following a pattern of the genus that includes endemic species for several mountain ranges in eastern Brazil (Smith & Downs 1974).

Such high-altitude wet forests (locally known as *brejos de altitude*) emerge from the semiarid environment of SDD in Northeastern Brazil and stand in an intermediary position between the two largest areas of tropical wet forests in the Neotropics, the Amazon – Northern South America – and the Atlantic Forest – Eastern coast of Brazil (Silva & Casteletti 2005; Tabarelli & Santos 2005; Queiroz *et al.* 2017). These areas are isolated fragments of rainforest and evidences from different groups of organisms show that they harbor floristic and faunistic elements characteristic of the Amazonian and Atlantic forests (Borges-Nojosa & Camaraschi 2003; Tabarelli & Santos 2005; Moro *et al.* 2015). Additionally, the occurrence of taxa with disjunct distribution between the Amazon and wet forests of Northeastern Brazil is common (Prance 1973; Rizzini 1963; Borges-Nojosa & Camaraschi 2003; Cavalcanti & Tabarelli 2005; Fiasch & Pirani 2009). Such pattern has also been reported for bromeliads occurring along patches of rainforests in Pernambuco and Alagoas (Siqueira-Filho *et al.* 2006).

In this context, our dataset has genera extensively distributed and highly diversified in the Amazon, such as *Racinaea*, *Catopsis* and *Guzmania* (Smith & Downs 1977; Barfuss *et al.* 2016), that are found in the isolated wet forests of Northern Ceará and inside the main distribution of AF, at East of the NDD (distribution pattern of group III). Since group III is composed mostly by genera with large extension of occurrence in South America, those isolated occurrences in Northern Ceará may be considered either products of vicariance, reflecting the ancient connections of the Amazon and the Atlantic forest (Wang *et al.* 2004) or a simple limitation of dispersion and inability to overcome the dry belt of Caatinga separating those *brejos de altitude* from the Eastern patches of Atlantic forest in the Eastern coast.

On the other hand, genera also distributed in the Amazon, such as *Araeococcus* and *Neoregelia* (Smith & Downs 1979), are present in the Eastern rainforest but absent in *brejos* of Northern Ceará (pattern of group IV). Biogeographic connections among Amazon and Atlantic forests have occurred since 40 Ma with considerable increase in the last 10 Ma (Antonelli *et al.* 2018). The biota interchange between these two areas may have occurred via three main past forest corridors, one of them includes the Ceará *brejos* region (Fine & Lohmann 2018). Therefore, these genera might have not survived the dramatic climatic changes that led to separation of the humid forests or dispersed after the establishment of the SDD, rather into or out of the Atlantic forest.

Considering only the genera with complete range of occurrence restricted to Eastern Brazil, such as *Cryptanthus*, *Canistrum* and *Lymania* (Leme & Siqueira-Filho 2006; Sousa & Wendt 2008; Leme *et al.* 2017), the Northern dry diagonal might play a role as geographic barrier, blocking their northward dispersion into the more isolated humid forest fragments in Ceará. The Atlantic forest is one of the centers of diversity of Bromeliaceae, expressively for some groups of subfamily Bromelioideae (Sass & Spetch 2010; Schulte *et al.* 2005). Since many lineages diversified in this biome, it is interesting to investigate the importance of the NDD as a biogeographical barrier along the northernmost portion of the coastal Atlantic forest.

Further studies on the disjunct distribution patterns observed here should consider phylogenetic relationships of specific lineages, as well as their morphology. For instance, Tillandsioid morphologic features such as dehiscent capsules and wind-dispersed seeds (Smith & Downs 1979) might have favored long distance dispersion of some genera included in our group III.

Interestingly, it may be possible that the bromelioid *Wittmackia* and *Ananas* arrived in Ceará by long distance dispersal or more recently during the expansion of

rainforests that formed a northeastern corridor connecting the Amazon and the AF (for a review see Fine & Lohamnn 2018). On the other hand, other mesophytic bromelioid with similar morphology are restrict to rainforests of Eastern Brazil (group IV) and may be result of event of diversification within the Atlantic forests that happened after the time when the Amazon and AF were connected, during the last glacial maximum. Still, we must not disregard the possibility of human action in dispersion of *Ananas* species largely used in landscaping.

Species richness and sampling intensity

One of the clearest patterns observed here is that species richness and sampling is concentrated in areas of Atlantic forest, either inside the main extension of this phytogeographic domain or in isolated fragments. In fact, Bromeliaceae is the third richest plant family in the Atlantic forests of Brazil (BFG 2015). Although richness is concentrated in the Southern region (741 spp.), an expressive number of species are found in the Northeast as well (427 spp.), with many restricted to this region (Flora do Brasil 2020), as commented for a few genera above.

The cell with highest species richness (49 spp., Figure 6A) overlaps the cells with highest record count (204 records, Fig. 6B) in the southeastern border of the Borborema plateau, and also correspond to cells holding higher species richness in fragments forest sampled by Siqueira-Filho *et al.* (2006). This region includes the *Serra do uburu*, a hot-spot of diversity in the Northern Atlantic forest, dominated by montane and submontane forests of massive importance for different groups of organisms (Melo *et al.* 2016). The species *Vriesea freicanecana* J.A.Siqueira & Leme and *Vriesea barbosae* J.A.Siqueira & Leme evaluated here as “endangered” and “critically endangered” (Table 1), respectively, are endemic to the state of Pernambuco, with distribution restricted to forest fragments of

Serra do Urubu (Leme & Siqueira-Filho 2006). This area also shelter an impressive diversity of orchids and it is considered an important area for conservation of this family (Pessoa & Alves 2015). In addition, species of snakes and amphibians under different degrees of threat are found in this region, that also harbors a high richness of snakes and lizards (Roberto *et al.* 2017).

Discrepant accumulation of knowledge in occurrence data is common and has been related to the existence of research programs and scientific interest in specific areas or taxonomic groups (Meyer *et al.* 2016), which can lead well explored areas to reflect higher richness and even endemism, as has been reported for the Amazon (Nelson 1990; Hopkins 2007; Schulman *et al.* 2007) and Caatinga (Versieux *et al.* 2017). In our study, Pernambuco state alone has 35% (950 records) of all collections in the study area, which is impressive considering that only an Eastern portion of the state is included in the study area. Such plant collection intensity can be associated to a long history of studies in botany since the 1950's, such as works of Dárdano de Andrade-Lima about Pernambuco's flora (Andrade-Lima 1954; Andrade-Lima 1957]) and even on bromeliads (Andrade-Lima 1964). More recently, a large Bromeliaceae taxonomic treatment for Pernambuco and Alagoas done by Leme & Siqueira-Filho (2006) probably accounts for most of this knowledge density, and not surprisingly J. Siqueira-Filho accounts for most of the herbarium specimens in our dataset (325 records). Similarly, the taxonomic treatment of genus *Aechmea* in Pernambuco by Sousa & Wanderley (2000) and studies of R.A. Pontes (2005; Pontes & Agra 2009; Pontes 2012) in Paraíba also stand out.

The Caatinga phytogeographic domain stands in the fourth position in the rank of seed plant diversity in Brazil (BFG 2015). In our analysis, low richness cells (Fig. 6A) cover most of the Caatinga, in an area equivalent to Velloso's (2001) *Depressão Sertaneja*. This ecoregion is defined by lowlands with low precipitation (Velloso 2001),

with markedly presence of xeric species of *Tillandsia*, *Bromelia* (distribution pattern I), and *Encholirum* (distribution pattern II). Although these patterns mostly reflect the distribution of widespread species in Northeastern Brazil, we also show the occurrence of endemic species in areas of Caatinga, such as *Orthophytum cearense* Leme & F.Monteiro and *Tillandsia paraibensis* R.A.Pontes (Leme *et al.* 2010; Pontes 2012), or with small extent of occurrence as *Encholirium erectiflorum* L.B.Sm. (Forzza 2005). Thus, even with lower diversity when compared to other phytogeographic domains, this shows the potential of Caatinga to harbor microendemic taxa and more attention should be given regarding basic research in unexplored areas as well maintenance of conservation policies, particularly along inselbergs inside the Caatinga matrix, where such endemics have been collected and are heavily threatened by agriculture.

Conservation Assessment

Only 27 taxa out of the 108 listed here had been cited in official lists of endangered species (Martinelli & Moraes 2013; MMA 2014) and 26 endemic species are evaluated for the first time here, including several which were only recently taxonomically described. In our analysis five out of the 13 species evaluated elsewhere are classified into categories of lower threat (Table 2): *Pitacairnia limae* L.B.Sm. is classified as Critically Endangered by Martinelli & Moraes (2013) and here it is Endangered; *Canistrum alagoagum* Leme & J.A.Siqueira changed from Endangered (Martinelli & Moraes 2013) to Vulnerable; *Aechmea muricata* L.B.Sm. and *Canistrum aurantiacum* E.Morren from Endangered (Martinelli & Moraes 2013) to Least Concern or Not Threatened; and *Cryptanthus zonatus* (Vis.) Vis. from Vulnerable (Martinelli & Moraes 2013) to Least Concern or Not threatened.

Patterns of endemism

The finer the resolution of grid cells used in PAE, more areas are evidenced (Sigrist & Carvalho 2008). With our dataset, analysis with half square degree cells yielded seven areas (A–G, Fig. 7A), while the one with square degree cells resulted in only two areas of endemism (H–I, Fig. 7B). However, in both scales of analysis, AEs are concentrated in Northern Ceará within the region of *brejos de altitude* and the Eastern portion of the study area, mostly Atlantic Forest.

Area H of the coarser analysis (Fig. 7B) contains area C of the finer analysis (Fig. 7A), corresponding to Baturité massif and the Serra de Maranguape and Serra de Aratanha, but also expands west to include the Uruburetama massif (Figures 7A: C; 7B: H). Together they also overlap cells of high species richness (medium and dark grey; Fig. 6A) and shelter practically the whole northern distribution of group III genera *Catopsis*, *Guzmania*, *Racinaea*, *Vriesea*, *Wittmackia* and *Ananas*, and partially of the group V *Pitcairnia* and *Wallisia*.

It deserves attention that the entire known occurrence range of *Vriesea baturitensis* Versieux & Tomaz, *Vriesea cearense* L.B.Sm., *Vriesea carmenae* R.Moura & A.F.Costa and *Wittmackia maranguapensis* (Leme & Scharf) Aguirre-Santoro are restricted to areas H and C together, all of which are evaluated here as “endangered” (Table 1). In addition, it also covers the complete Brazilian distribution of *Guzmania sanguinea* (L.) Rusby ex Mez, one of the few known localities of occurrence of the Ceará endemic and endangered *Pitcairnia limae* (Table 2), and other species with restricted distribution in the study area, such as *Aechmea castelnavii* Baker, *Bromelia auriculata* L.B.Sm. and *Wallisia anceps* (Lodd.) Barfuss & W.Till. Finally, besides a single record in the municipality of Aratuba, at the southern extremity of the Baturité massif, most of the records of *Guzmania monostachia* (L.) Rusby ex Mez in our dataset are also restricted

to NCB, although its occurrence has also been cited for Pernambuco and Bahia (Flora do Brasil 2020). According to Siqueira-Filho *et al.* (2006), the only recorded subpopulation of *G. monostachia* in eastern Pernambuco has possibly gone extinct, as it has not been collected since the 1970's. Regarding *Vriesea baturitensis*, the species has been observed in local markets after being extracted from the wild. Therefore, the region of brejos de altitude to the north of Ceará state deserve special attention for conservation purposes since the pattern observed here may also be true for other taxonomic groups with similar distribution.

Half square degree areas A and B (Figure 7A) do not overlap with any of the one-degree areas (Fig 7B). Cells of area A cover areas of Caatinga, with species distribution probably more associated with rocky outcrops, and does not reflect distribution of any endemic taxa. On the other hand, area B corresponds to the high-altitude wet forests in the Meruoca massif and in the Northern portion of the Ibiapaba plateau. Area B represents mainly the remaining distribution of *Pitcairnia limae*, and with areas H and C, constitute the whole known range of occurrence of such endangered species. PAE areas of endemism H (one-degree), B and C (half-degree) together will be addressed herein as Northern Ceará Brejos (NCB).

The second one-degree area (I) includes all the remaining half degree areas (D, E, F, G; Fig. 7), all located in the eastern portion of the study area, covering Caatinga and domains of Atlantic forest and therefore addressed here as Eastern Caatinga and Atlantic Forest (ECAF). This unit also overlaps the areas of highest species richness and sampling intensity (Fig. 6). The portion of the Atlantic forest included in ECAF represents most of the Pernambuco Centre of Endemism (PCE), a biogeographic unit delimited at South by the São Francisco River and extends from state of Alagoas following the coast northward to Rio Grande do Norte (Silva & Casteletti 2005). PCE constitutes one of the most

relevant areas for conservation of the Atlantic forest, as it shelters many endemic species from different groups of organisms (Prance 1982; Roda *et al.* 2011; Roberto *et al.* 2017).

Besides all genera from group VI (*Araeococcus*, *Billbergia*, *Canistrum*, *Cryptanthus*, *Lymania*, *Neoregelia* and *Pseudananas*), 73 out of 108 analyzed species (67,6%) have records restricted to ECAF. Although some of these taxa have distributions extending South of São Francisco River, 27 species are endemic to this part of the PCE, of which about 81% are evaluated here as Vulnerable (*Canistrum pickelii* and *Cryptanthus zonatus*), Endangered (13 spp.) and Critically Endangered (six spp.). Among those, *Hohenbergia aechmeoides* Leme and *Vriesea zonata* Leme & J.A.Siqueira are also endemic to the PCE (Leme & Siqueira 2006; Leme *et al.* 2010). Their risk of extinction was evaluated in our study but due to limited number of records, as they are known only from their type material, such categorization may still be controversial. This is a worrying reality for many taxa endemic to the study area in our dataset, as only 13 of the 34 (38,2 %) species have over 10 records available and as stressed by Siqueira-Filho & Silva (2006) the number of potentially threatened species from the Atlantic forest of Northeastern Brazil is largely underestimated.

Although all high-altitude wet forests in the semiarid Northeast have been treated as single biogeographic unit (Silva & Casteletti 2005), the fragments of Northern Ceará (NCB) are evidenced here as an area of endemism different from those from Paraíba, Pernambuco and Alagoas, in ECAF. PAE analysis performed for tree species by Santos *et al.* (2007) showed similar results, where the Baturité massif (CE) appeared well apart from all other southern eastern high-altitude forests and clustered with sites from the Amazon and coastal Pernambuco. Interestingly, studies using amphibians from *brejos de altitude* have suggested that such areas might have different evolutionary history (Carnaval & Bates 2007; Castro *et al.* 2019).

Inside ECAF, our coarser analysis with PAE reflects almost the whole extension of PCE, the finer analysis uncovers subregions of the PCE, notably in the coast of Alagoas (Figure 7A: D), in coastal Pernambuco to Rio Grande do Norte (Figure 7A: F), the inner high-altitude forests of Alagoas, Pernambuco and Paraíba (Figure 7A: G), as well as adjacent relevant areas of Caatinga (Figure 7A: E). On the other hand, NCB corroborates to the biologic relevance of forest fragments in Northern Ceará, now with evidence also from the Bromeliaceae.

Areas of endemism are hierarchical and, as shown here, very often smaller units are contained inside larger ones (Crother & Murray 2011). As many species were evidenced here as microendemic and should be considered in conservation planning, finer analyses are particularly useful as they can target to target small important areas and help to ensure conservation locally.

Conclusion

In this study, we used a traditional approach with species occurrence data from herbarium specimens to analyze distribution, richness and collection intensity, as well the application of the parsimony principle to identify areas of endemism (PAE) with a descriptive approach (*sensu* Escalante 2011). Patterns of genera distribution presented here show a strong relation with precipitation, with most genera restricted towards areas of higher humidity with only a few distributed in the semi-arid habitats of Caatinga. Not surprisingly, the areas with higher number of genera are congruent with areas of high species richness and collecting intensity. However, it is important to consider that this result may reflect historical bias as the existence of traditional research on botany, herbaria and conservation units. The areas of endemism evidenced are also mostly associated with coastal or high-altitude fragments of rainforests with high relevance for

conservation, especially due to the occurrence of threatened and endemic bromeliad species. The fact that *brejos* in Northern Ceará differ from those in Borborema plateau also should bring more attention to the unique bromeliad diversity of these regions.

Acknowledgments

We are thankful to CAPES and Graduate Program in Systematics and Evolution, for the ECT's M. Sc. Scholarship. We thank Ana Clara Davi and Matheus Mendes for helping in the data cleaning process.

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TABLE 1. List of Bromeliaceae genera occurring in the study area. REC: records count in our dataset; SPP: number of species in our dataset; GG: groups of genera with similar distribution patterns.

GENERA	REC	SPP	GG
<i>Aechmea</i> Ruiz & Pav.	548	23	I
<i>Ananas</i> Mill.	26	3	III
<i>Araeococcus</i> Brogn.	12	2	V
<i>Billbergia</i> Thunberg	31	2	V
<i>Bromelia</i> L.	118	3	I
<i>Canistrum</i> E.Morren	76	4	V
<i>Catopsis</i> Griseb.	14	2	III
<i>Cryptanthus</i> Otto. & A.Dietr.	106	6	V
<i>Dyckia</i> Schult. & Schult.f.	14	1	II
<i>Encholirium</i> Mart. ex Schult. & Schult.f.	80	3	II
<i>Guzmania</i> Ruiz & Pav.	68	3	III
<i>Hohenbergia</i> Schult. & Schult.f.	200	7	I
<i>Lymania</i> Read	8	1	V
<i>Neoglaziovia</i> Mez	46	1	II
<i>Neoregelia</i> L.B.Sm.	3	1	V
<i>Orthophytum</i> Beer	98	5	II
<i>Pitcairnia</i> L'Hér.	5	1	IV
<i>Pseudananas</i> Hassl. Ex Harms	2	1	V
<i>Racinaea</i> M.A.Spencer & L.B.Sm.	30	1	III
<i>Tillandsia</i> L.	938	18	I
<i>Vriesea</i> Lindl.	132	15	III
<i>Wallisia</i> E.Morren	2	1	IV
<i>Wittmackia</i> Mez	114	6	III

TABLE 2: List of Bromeliaceae species distributed in the Northeastern Caatinga and Coastal drainages ecoregion. REC: number of records; END: endemic to the study area; OCC: occurrence in the study area by state; AE = areas of endemism evidenced in the present study.

TAXA	REC	THREAT CATEGORY			END	OCC	AE
		This study	MMA (2014)	Martinelli & Moraes (2013)			
<i>Aechmea aquilega</i> (Salisb.) Griseb.	76	LC or NT	–	–	–	AL, CE, PB, PE, RN	–
<i>Aechmea atrovittata</i> Leme & J.A.Siqueira	3	EN	–	–	YES	AL	ECAF
<i>Aechmea bromeliifolia</i> (Rudge) Baker	25	LC or NT	–	LC	–	CE, PB	–
<i>Aechmea castelnavii</i> Baker	4	EN	–	–	–	CE	–
<i>Aechmea catendensis</i> J.A.Siqueira & Leme	7	EN	–	–	YES	AL, PE	ECAF
<i>Aechmea cephaloides</i> J.A.Siqueira & Leme	8	EN	–	–	YES	PE	ECAF
<i>Aechmea chrysocoma</i> Baker	8	EN	–	–	YES	PE, PB	ECAF
<i>Aechmea costantinii</i> (Mez) L.B.Sm.	64	LC or NT	–	–	YES	AL, PB, PE	ECAF
<i>Aechmea emmerichiae</i> Leme	10	CR	–	–	YES	PB	ECAF
<i>Aechmea eurycorymbus</i> Harms	7	VU	–	NT	–	AL, PB, PE	–
<i>Aechmea fulgens</i> Brongn.	61	LC or NT	–	–	–	AL, PB, PE	–
<i>Aechmea guainumbiorum</i> J.A.Siqueira & Leme	4	CR	–	–	YES	PE	ECAF
<i>Aechmea gustavoi</i> J.A.Siqueira & Leme	3	CR	CR	CR	–	PE	–
<i>Aechmea lactifera</i> Leme & J.A.Siqueira	3	EN	–	–	YES	AL, PE	ECAF
<i>Aechmea leptantha</i> (Harms) Leme & J.A.Siqueira	113	LC or NT	–	–	–	AL, CE, PB, PE	–
<i>Aechmea mertensii</i> (Meyer) Schult. & Schult.f.	49	LC or NT	–	–	–	AL, PB, PE, RN	–
<i>Aechmea mulfordii</i> L.B.Sm.	5	EN	–	–	–	PB, PE	–
<i>Aechmea multiflora</i> L.B.Sm.	3	EN	–	–	–	AL	–
<i>Aechmea muricata</i> (Arruda) L.B.Sm.	29	LC or NT	EN	EN	YES	AL, PB, PE, RN	ECAF
<i>Aechmea nudicaulis</i> (L.) Griseb.	12	VU	–	LC	–	PB, PE	–
<i>Aechmea serragrandensis</i> Leme & J.A.Siqueira	8	EN	–	–	YES	AL, PE	ECAF
<i>Aechmea tomentosa</i> Mez	42	LC or NT	–	–	–	AL, PE	–
<i>Aechmea werdermannii</i> Harms	4	EN	EN	EM	–	PB, PE	–

<i>Ananas ananassoides</i> (Baker) L.B.Sm.	15	LC or NT	–	–	–	AL, CE, PB, PE, RN	–
<i>Ananas bracteatus</i> (Lindl.) Schult. & Schult. f.	3	EN	–	–	–	CE, PE	–
<i>Ananas comosus</i> (L.) Merril	8	VU	–	–	–	CE, PB, PE	–
<i>Araeococcus chlorocarpus</i> (Wawra) Leme & J.A.Siqueira	5	EN	–	–	–	AL, PE	–
<i>Billbergia morelii</i> Brongn.	29	LC or NT	–	–	–	AL, PB, PE	–
<i>Billbergia portearia</i> Brongn. ex Beer	2	CR	–	–	–	PE	–
<i>Bromelia auriculata</i> L.B.Sm.	5	EN	–	–	–	CE	–
<i>Bromelia aff. karatas</i> L.	57	LC or NT	–	–	–	AL, CE, PB, PE, RN	–
<i>Bromelia laciniosa</i> Mart. ex Schult. & Schult.f.	56	LC or NT	–	–	–	CE, PB, PE, RN	–
<i>Canistrum alagoanum</i> Leme & J.A.Siqueira	10	VU	EN	EN	YES	AL	ECAF
<i>Canistrum aurantiacum</i> E.Morren	48	LC or NT	EN	EN	YES	AL, PE	ECAF
<i>Canistrum improcerum</i> Leme & J.A.Siqueira	3	CR	–	–	YES	AL	ECAF
<i>Canistrum pickelii</i> (A.Lima & L.B.Sm.) Leme & J.A.Siqueira	15	VU	VU	–	YES	AL, PE	ECAF
<i>Catopsis berteroniana</i> (Schult. & Schult. f.) Mez	4	EN	–	–	–	AL, PE	–
<i>Catopsis sessiliflora</i> (Ruiz & Pav.) Mez	10	VU	–	–	–	AL, CE, PE	–
<i>Cryptanthus alagoanus</i> Leme & J.A.Siqueira	11	VU	–	–	–	AL, PB, PE	–
<i>Cryptanthus bahianus</i> L.B.Sm.	19	LC or NT	–	–	–	PE, PB	–
<i>Cryptanthus diana</i> Leme	22	LC or NT	–	–	YES	AL, PE	ECAF
<i>Cryptanthus felixii</i> J.A.Siqueira & Leme	3	EN	–	–	YES	AL, PE	ECAF
<i>Cryptanthus reptans</i> Leme & J.A.Siqueira	5	CR	–	–	YES	PE	ECAF
<i>Cryptanthus zonatus</i> (Vis.) Vis.	46	LC or NT	VU	VU	YES	AL, PB, PE, RN	ECAF
<i>Dyckia limae</i> L.B.Sm.	5	EN	–	–	–	PB, PE	–
<i>Dyckia pernambucana</i> L.B.Sm.	9	EN	–	–	–	PB, PE	–
<i>Encholirium erectiflorum</i> L.B.Sm.	2	EN	–	–	–	CE, PE	–
<i>Encholirium spectabile</i> Mart. ex Schult. & Schult.f.	73	LC or NT	–	–	–	CE, PB, PE, RN	–
<i>Guzmania lingulata</i> (L.) Mez	31	VU	–	–	–	CE, PE	–
<i>Guzmania monostachia</i> (L.) Rusby ex Mez	28	VU	VU	VU	–	CE	–

<i>Guzmania sanguinea</i> (André) André ex Mez	9	EN	EN	EN	–	CE	–
<i>Hohenbergia aechmeoides</i> Leme	1	CR	–	–	YES	PB	ECAF
<i>Hohenbergia blanchetii</i> (Baker) Mez	7	VU	–	–	–	AL, PE	–
<i>Hohenbergia cattingae</i> Ule	48	LC or NT	–	–	–	AL, PB, PE, RN	–
<i>Hohenbergia horrida</i> Harms	9	VU	–	–	–	PB, PE, RN	–
<i>Hohenbergia ramageana</i> Mez	39	LC or NT	–	–	–	AL, PB, PE, RN	–
<i>Hohenbergia ridleyi</i> (Baker) Mez	89	LC or NT	–	–	–	AL, PB, PE, RN	–
<i>Hohenbergia stellata</i> Schult. & Schult.f.	7	EN	–	–	–	PE, AL	–
<i>Lymania smithii</i> Read	8	EN	–	–	–	PE, AL	–
<i>Neoglaziovia variegata</i> (Arruda) Mez	46	LC or NT	–	–	–	AL, CE, PB, PE, RN	–
<i>Neoregelia pernambucana</i> Leme & J.A.Siqueira	3	EN	EN	EN	YES	AL, PE	ECAF
<i>Orthophytum atalaiense</i> J.A.Siqueira & Leme	3	CR	–	–	YES	AL	ECAF
<i>Orthophytum cearense</i> Leme & F.Monteiro	4	EN	–	–	YES	CE	–
<i>Orthophytum disjunctum</i> L.B.Sm.	79	LC or NT	–	–	–	AL, PB, PE, RN	–
<i>Orthophytum jabrense</i> Baracho & J.A.Siqueira	11	EN	–	–	YES	PB	ECAF
<i>Orthophytum triunfense</i> J.A.Siqueira & Leme	1	CR	–	–	–	PB	–
<i>Pitcairnia limae</i> L.B.Sm.	5	EN	CR	CR	YES	CE	NCB
<i>Pseudananas sagenarius</i> (Arruda) Camargo	2	EN	–	–	–	PE	–
<i>Racinaea spiculosa</i> (Griseb.) M.A.Spencer & L.B.Sm.	30	LC or NT	–	LC	–	AL, CE, PE	–
<i>Tillandsia bulbosa</i> Hook.f.	59	LC or NT	–	–	–	AL, PB, PE, RN	–
<i>Tillandsia chapeuensis</i> Rauh	14	LC or NT	–	–	–	AL, PE	–
<i>Tillandsia gardneri</i> Lindl.	62	LC or NT	–	LC	–	AL, CE, PB, PE, RN	–
<i>Tillandsia geminiflora</i> Brongn.	11	VU	–	LC	–	PB, PE	–
<i>Tillandsia juncea</i> (Ruiz & Pav.) Poir.	29	LC or NT	–	–	–	AL, CE, PB, PE	–
<i>Tillandsia kegeliana</i> Mez	7	VU	–	–	–	AL, PB, PE	–
<i>Tillandsia loliacea</i> Mart. ex Schult. & Schult.f.	101	LC or NT	–	–	–	CE, PB, PE, RN	–
<i>Tillandsia paraensis</i> Mez	20	LC or NT	–	–	–	AL, PB, PE, RN	–
<i>Tillandsia paraibensis</i> R.A. Pontes	6	EN	–	–	YES	PB, RN	ECAF

<i>Tillandsia pohliana</i> Mez	12	VU	—	—	—	CE, PE	—
<i>Tillandsia polystachia</i> (L.) L.	64	LC or NT	—	—	—	AL, CE, PB, PE, RN	—
<i>Tillandsia recurvata</i> (L.) L.	201	LC or NT	—	—	—	AL, CE, PB, PE, RN	—
<i>Tillandsia streptocarpa</i> Baker	103	LC or NT	—	LC	—	CE, PB, PE, RN	—
<i>Tillandsia stricta</i> Sol.	56	LC or NT	—	—	—	AL, CE, PB, PE, RN	—
<i>Tillandsia tenuifolia</i> L.	99	LC or NT	—	LC	—	AL, CE, PB, PE, RN	—
<i>Tillandsia tricholepis</i> Baker	18	LC or NT	—	LC	—	CE, PB, PE, RN	—
<i>Tillandsia usneoides</i> (L.) L.	76	LC or NT	—	LC	—	AL, CE, PB, PE, RN	—
<i>Vriesea barbosae</i> J.A.Siqueira & Leme	3	CR	—	—	YES	PE	ECAF
<i>Vriesea baturitensis</i> Versieux & Tomaz	27	EN	—	—	YES	CE	NCB
<i>Vriesea carmenae</i> R.Moura & A.F.Costa	15	EN	—	—	YES	CE	NCB
<i>Vriesea cearensis</i> L.B.Sm.	12	EN	EN	EN	YES	CE	NCB
<i>Vriesea ensiformis</i> (Vell.) BECAF	4	EN	—	—	—	PE	—
<i>Vriesea flammea</i> L.B.Sm.	1	CR	—	LC	—	PE	—
<i>Vriesea freicanecana</i> J.A.Siqueira & Leme	5	EN	—	—	YES	PE	ECAF
<i>Vriesea friburgensis</i> Mez	2	EN	—	—	—	PE	—
<i>Vriesea gigantea</i> Gaudich.	3	EN	—	LC	—	PE	—
<i>Vriesea limae</i> L.B.Sm.	9	EN	—	—	YES	AL, PE	ECAF
<i>Vriesea procera</i> (Mart. ex Schult.f.) Wittm.	33	LC or NT	—	LC	—	AL, PB, PE	—
<i>Vriesea rodigasiana</i> E.Morren	4	EN	—	LC	—	PE	—
<i>Vriesea scalaris</i> E.Morren	8	EN	—	LC	—	PE	—
<i>Vriesea wawraea</i> Antoine	5	EN	EN	EN	—	PE	—
<i>Vriesea zonata</i> Leme & J.A.Siqueira	1	CR	—	—	YES	AL	ECAF
<i>Wallisia anceps</i> (Lodd.) Barfuss & W.Till	2	EN	—	—	—	CE	—
<i>Wittmackia froesii</i> (L.B.Sm.) Aguirre-Santoro	5	EN	—	—	—	AL, PE	—
<i>Wittmackia lingulatoides</i> (Leme & H. Luther) Aguirre-Santoro	2	EN	—	—	—	PB, PE	—

<i>Wittmackia maranguapensis</i> (Leme & Scharf) Aguirre-Santoro	13	EN	–	–	YES	CE	NCB
<i>Wittmackia patentissima</i> (Mart. ex Schult. & Schult.f.) Mez	88	LC or NT	–	–	–	AL, PB, PE, RN	–
<i>Wittmackia pernambucensis</i> (J.A.Siqueira & Leme) Aguirre-Santoro	5	EN	–	–	YES	AL, PE	ECAF
<i>Wittmackia sulbahianensis</i> (Leme, Amorim, J.A.Siqueira) Aguirre-Santoro	1	CR	–	–	–	AL	–

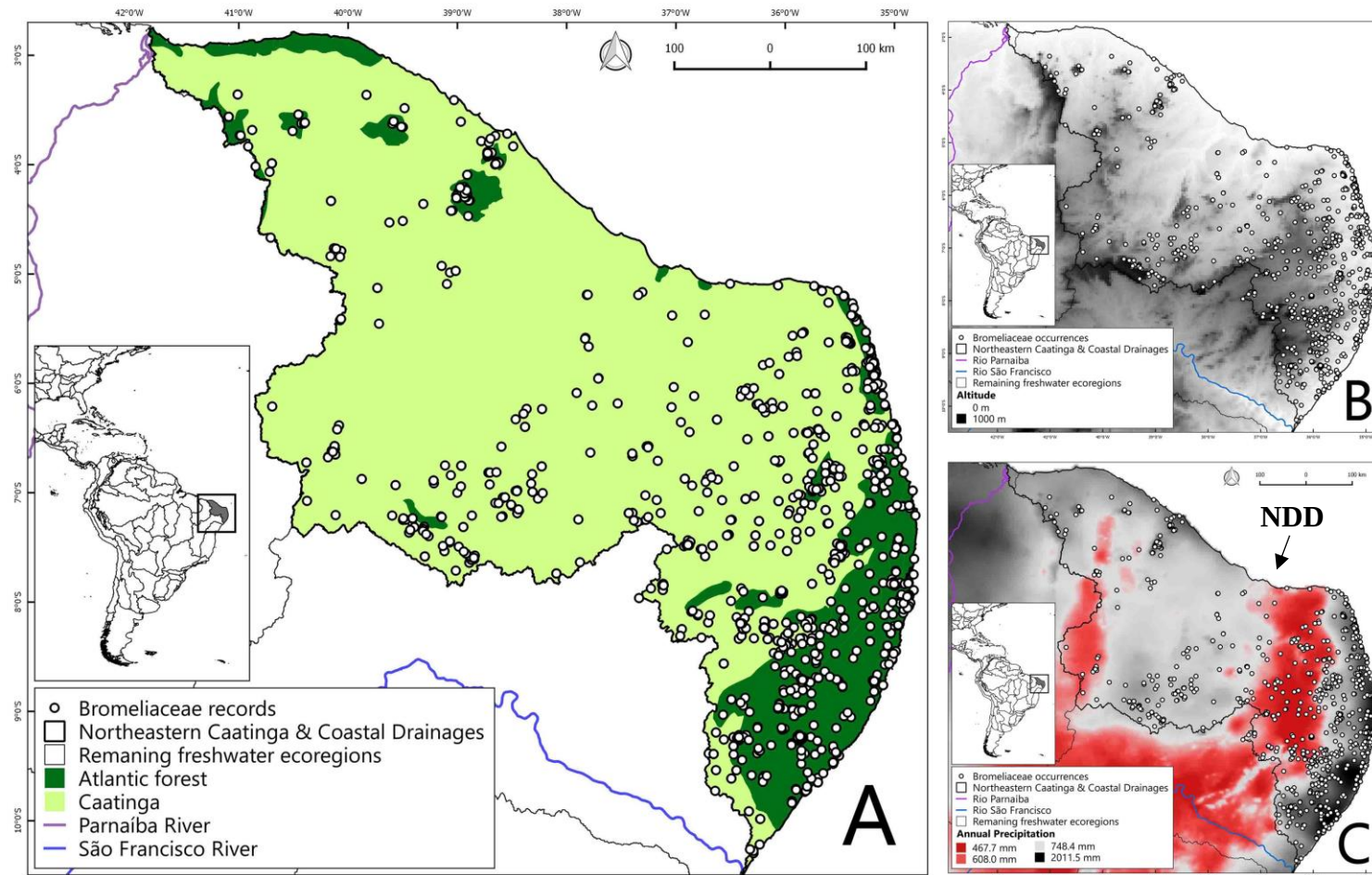


FIGURE 1. Distribution of Bromeliaceae in the Northeastern Caatinga and Coastal drainages ecoregion. Records are overlapped with **A.** vegetation, **B.** altitude and **C.** mean annual temperature (black arrow indicate the Northern Dry Diagonal, NDD).

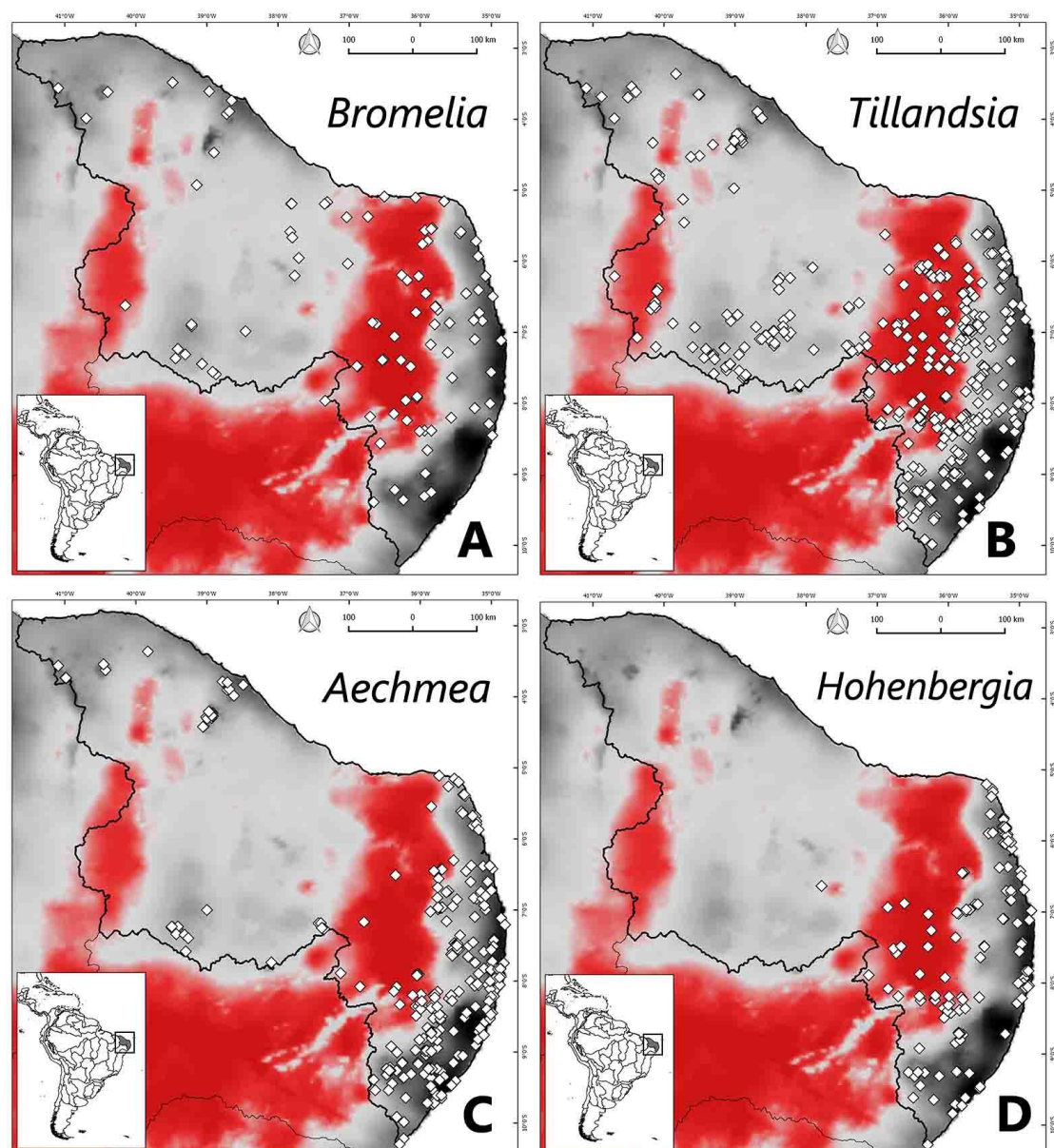


FIGURE 2. Group of genera with distribution pattern I overlapped with annual precipitation in the Northeastern Caatinga and Coastal drainages ecoregion. **A.** *Bromelia*, **B.** *Tillandsia*, **C.** *Aechmea*, **D.** *Hohenbergia*.

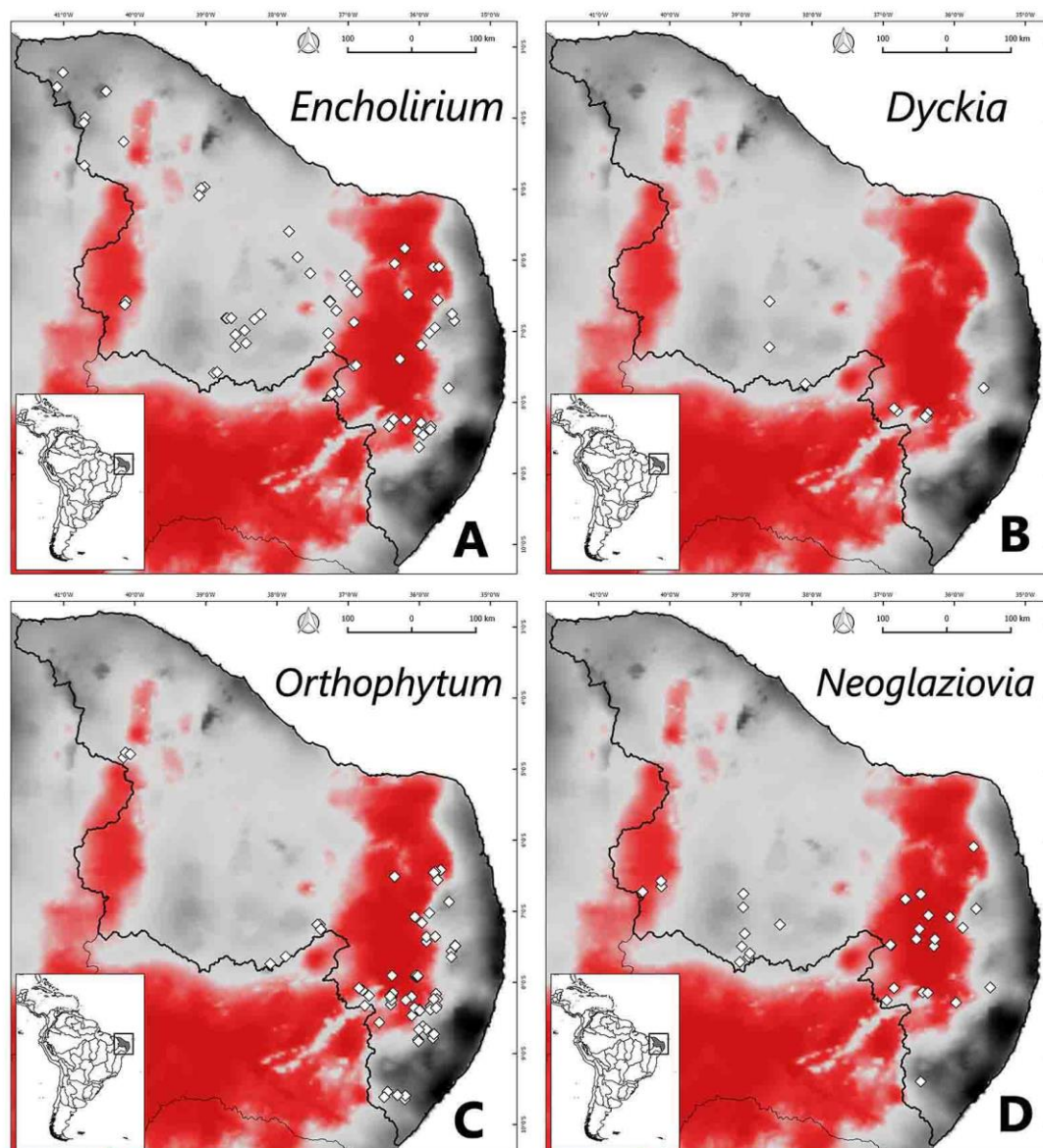


FIGURE 3. Group of genera with distribution pattern II overlapped with annual precipitation in the Northeastern Caatinga and Coastal drainages ecoregion. **A.** *Encholirium*, **B.** *Dyckia*, **C.** *Orthophytum*, **D.** *Neoglaziovia*.

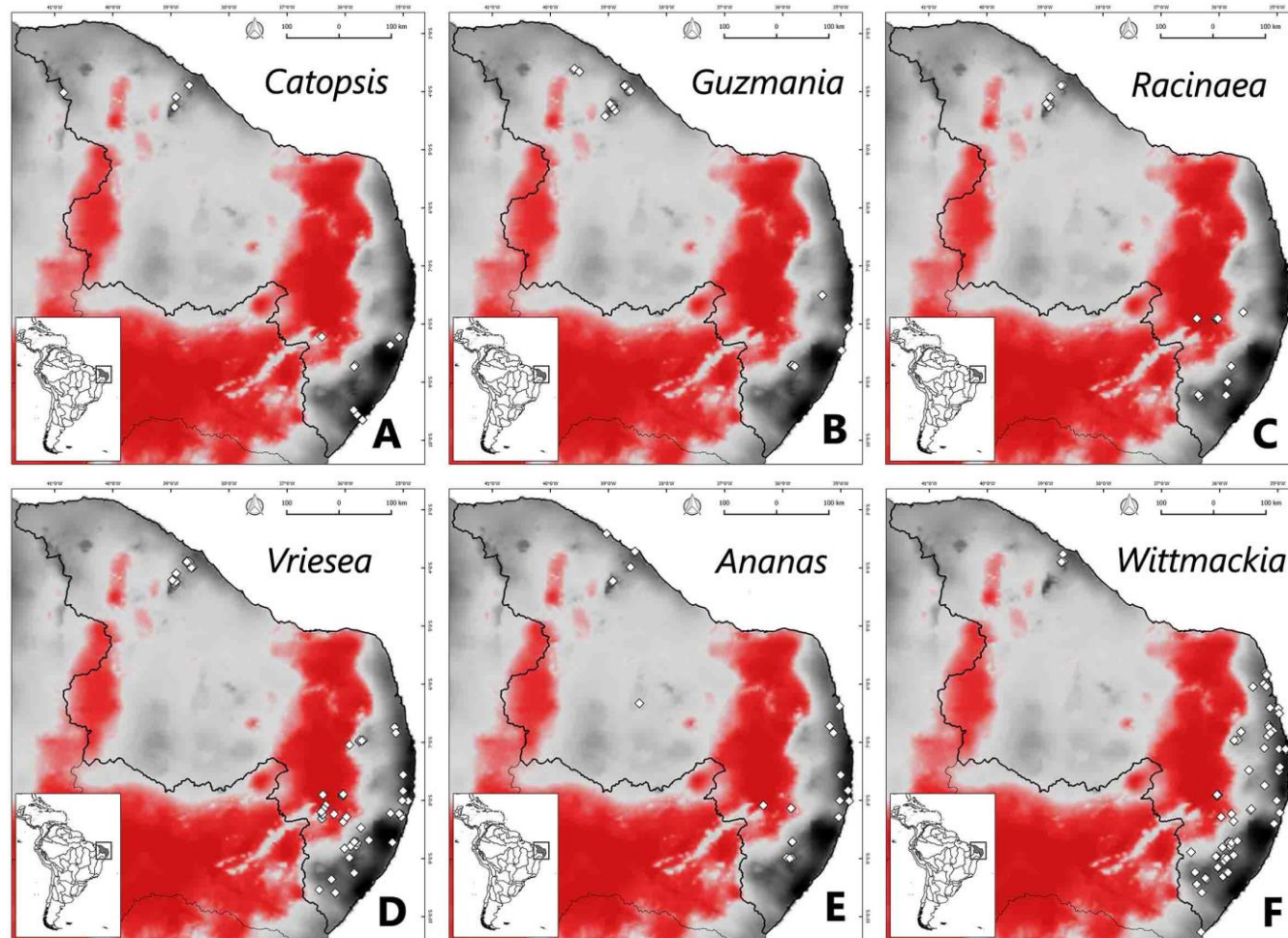


FIGURE 4. Group of Bromeliaceae genera with distribution pattern III overlapped with annual precipitation in the Northeastern Caatinga and Coastal drainages ecoregion. **A.** *Catopsis*, **B.** *Guzmania*, **C.** *Racinaea*, **D.** *Vriesea*, **E.** *Ananas*, **F.** *Wittmackia*.

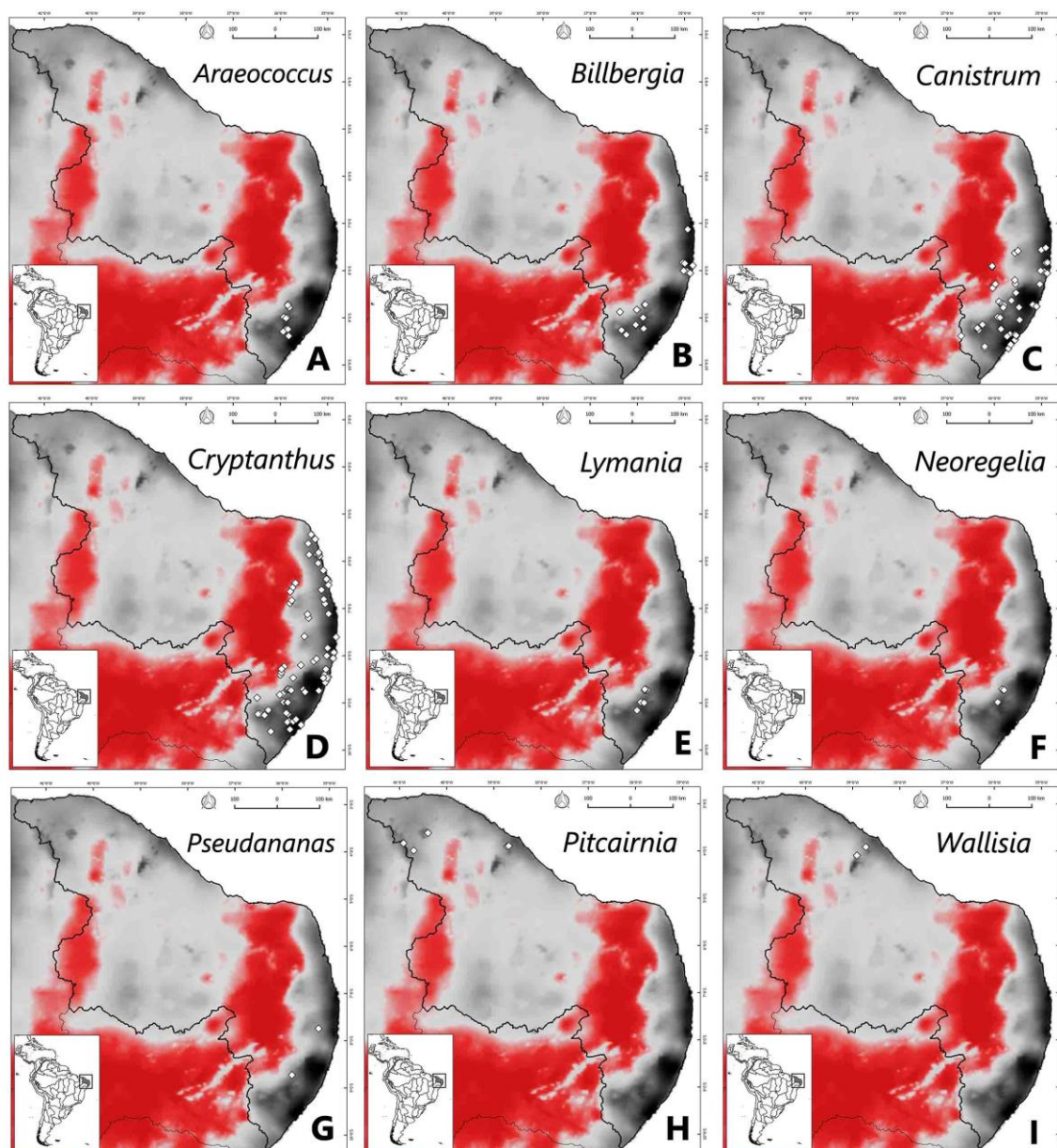


FIGURE 5. Groups of Bromeliaceae genera overlapped with annual precipitation in the Northeastern Caatinga and Coastal drainages ecoregion. **A–G.** Distribution pattern IV: **A.** *Araeococcus*, **B.** *Billbergia*, **C.** *Canistrum*, **D.** *Cryptanthus*, **E.** *Lymania*, **F.** *Neoregelia*, **G.** *Pseudananas*. **H–I.** Distribution pattern V: **H.** *Pitcairnia*, **I.** *Wallisia*.

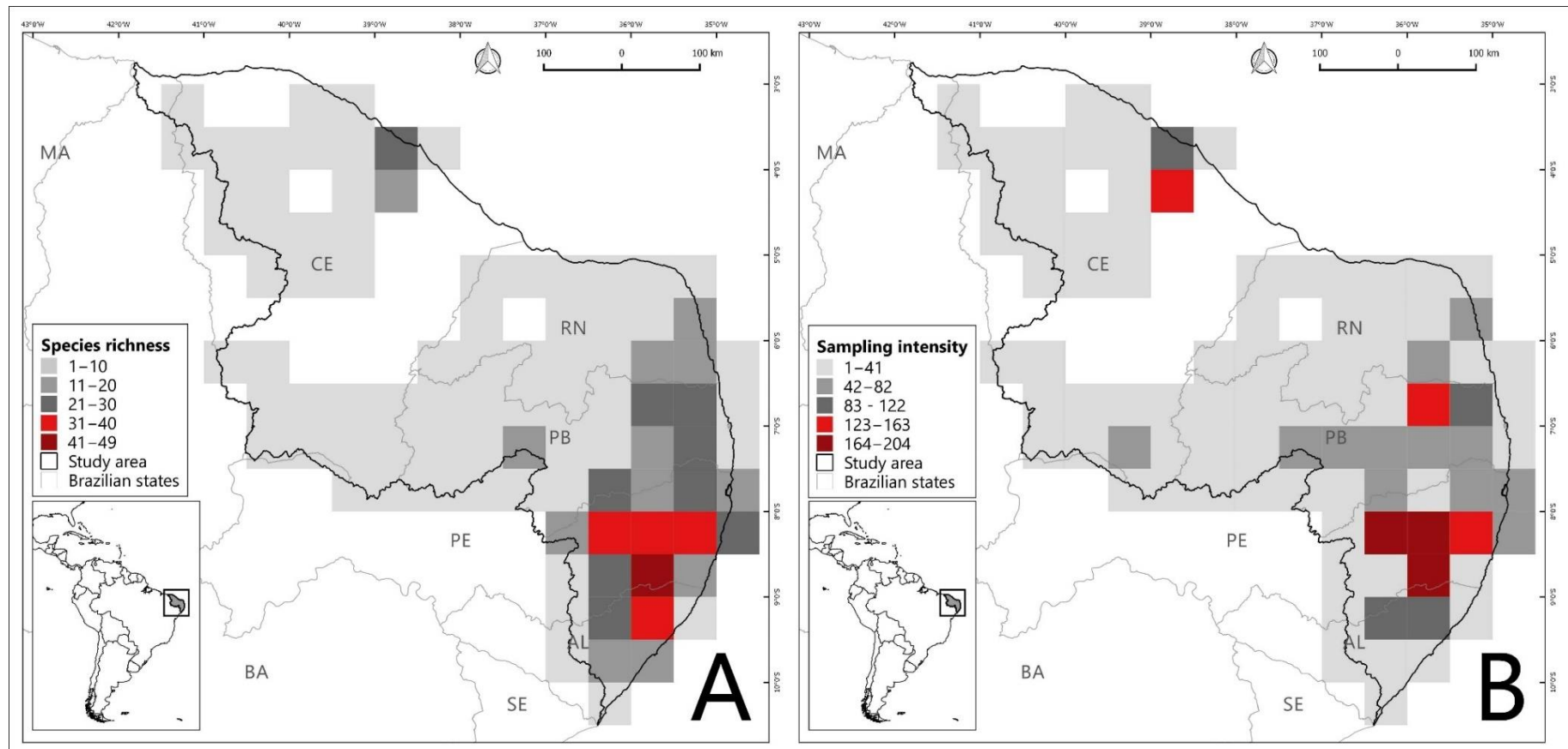


FIGURE 6. Bromeliaceae in the Northeastern Caatinga and Coastal drainages ecoregion. **A.** Species richness in $0.5^{\circ} \times 0.5^{\circ}$ cells: light gray (1–10 spp.), medium gray (11–20 spp.), dark gray (21–30 spp.), bright red (31–40 spp.) and dark red (21–49 spp.). **B.** Collection density in $0.5^{\circ} \times 0.5^{\circ}$ cells: light gray (1–41 records), medium gray (42–32 records), dark gray (83–122 records), bright red (123–163 records) and dark red (164–204 records).

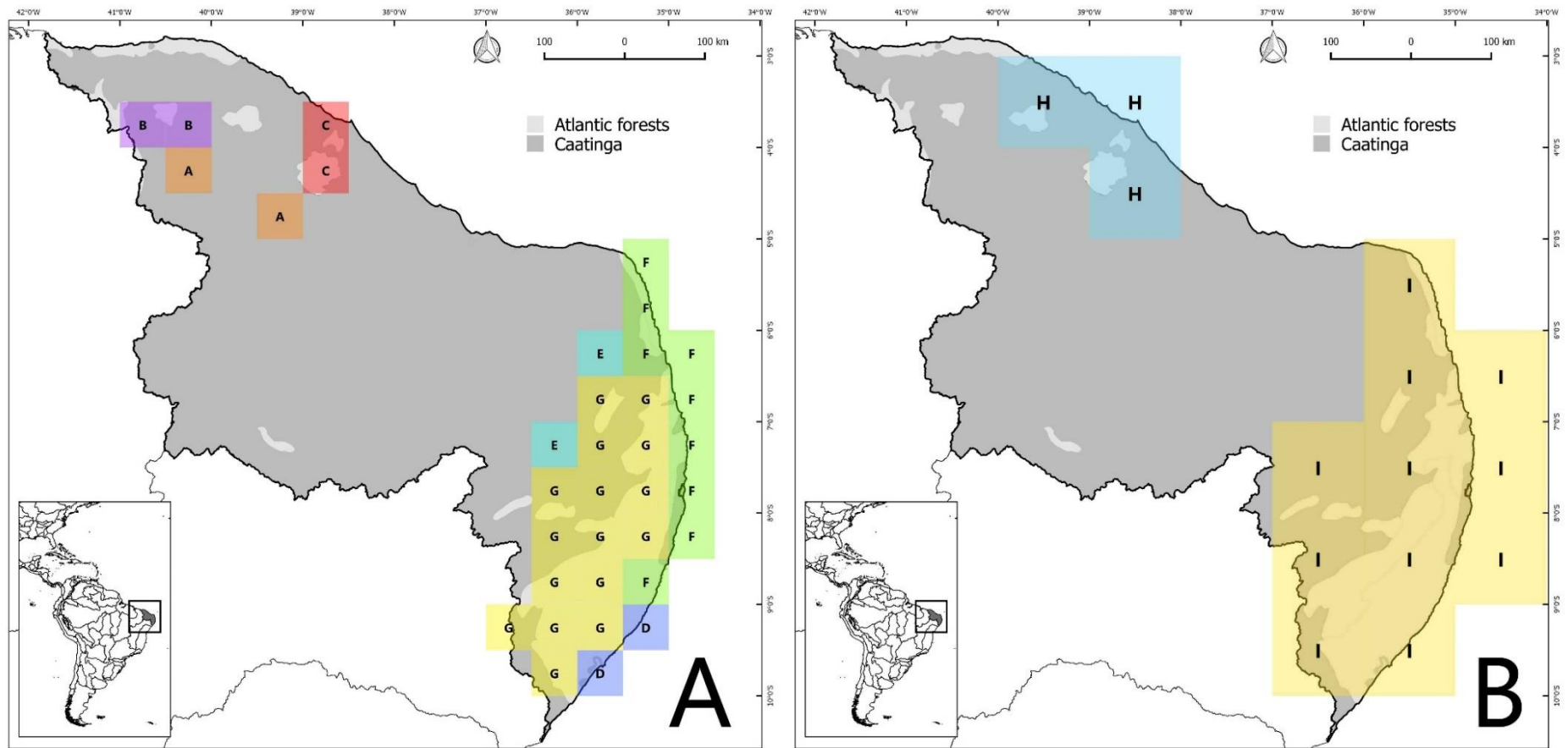


FIGURE 7. Areas of endemism of Bromeliaceae in the Northeastern Caatinga and Coastal drainages ecoregion recovered with Parsimony Analysis of Endemism. **A.** areas of endemism at 0.5° scale. **B.** areas of endemism at 1° scale.

CONSIDERAÇÕES FINAIS

O tratamento taxonômico de Bromeliaceae para o Rio Grande do Norte e o *checklist* desta família no Ceará apresentados aqui representam mais um passo à frente na construção das Floras destes estados. Além disso, a informação contida aqui pode contribuir para melhor entender a variação morfológica de Bromeliaceae, os problemas taxonômicos que precisam ser mais investigados, bem como a sua distribuição no extremo Nordeste do Brasil. Além disso, com as novas ocorrências evidenciadas neste trabalho, reforçamos a noção de que os estados do Ceará e Rio Grande do Norte possuem sua riqueza subestimada. Foi possível também mostrar que análises biogeográficas tradicionais, *i.e.* utilizando apenas dados de herbário, ainda são extremamente úteis para a pesquisa em biodiversidade com o objetivo de descobrir e explicar padrões de distribuição e endemismo de espécies e assim contribuir com a conservação dos grupos de interesse. E no que toca a conversação da flora, é alarmante perceber que espécies descobertas e publicadas recentemente já possuem algum nível de ameaça de extinção. A riqueza e endemismo de Bromeliaceae na área de estudo como um todo estão ligados a fragmentos de floresta úmida ou regiões de altitude elevada, que devem ser considerados áreas prioritárias para a conservação do grupo, mas que também podem representar forte viés de coleta naquelas áreas e precisam ser investigados mais a fundo. Por fim, o fato de brejos de altitude do Ceará representarem áreas de endemismo diferentes daquela composta pelos brejos da Paraíba, Pernambuco e Alagoas deve trazer mais atenção a flora única daquela região.

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ANEXO – Normas do Periódico *Phytotaxa*

Phytotaxa - Information for authors

Aim and scope

Phytotaxa is a peer-reviewed, international journal for rapid publication of high quality papers on any aspect of systematic and taxonomic botany, with a preference for large taxonomic works such as monographs, floras, revisions and evolutionary studies and descriptions of new taxa. *Phytotaxa* covers all groups covered by the International Code for Botanical Nomenclature, ICBN (fungi, lichens, algae, diatoms, mosses, liverworts, hornworts, and vascular plants), both living and fossil. *Phytotaxa* was founded in 2009 as botanical sister journal to *Zootaxa*. It has a large editorial board, who are running this journal on a voluntary basis, and it is published by Magnolia Press (Auckland, New Zealand). It is also indexed by SCIE, JCR and Biosis.

All types of taxonomic, floristic and phytogeographic papers are considered, including theoretical papers and methodology, systematics and phylogeny, monographs, revisions and reviews, catalogues, biographies and bibliographies, history of botanical explorations, identification guides, floras, analyses of characters, phylogenetic studies and phytogeography, descriptions of taxa, typification and nomenclatural papers. Monographs and other long manuscripts (of 60 printed pages or more) can be published as books, which will receive an ISBN number as well as being part of the *Phytotaxa* series.

Checklists and vegetation surveys are only included when the data provided in the checklist or survey are analysed and discussed. Data in checklists should be interpreted to make the study relevant for the international botanical community. Range extensions of single species are generally not considered for publication, although exceptions may be possible. Please contact the chief editor before submitting such articles.

Open Access publishing is strongly encouraged for authors who have funding to do so. For those without grants/funds, accepted manuscripts will be published, but access will be secured for subscribers only. All manuscripts will be subjected to peer review by two or more anonymous reviewers before acceptance. *Phytotaxa* aims to publish each paper within two months after the acceptance by the editors. To make this possible, authors are advised to follow the following guidelines carefully and to consult the most recent issues of *Phytotaxa*. Therefore, when preparing your manuscript, please follow this guide carefully. During our first years, its format has varied somewhat, but we are now aiming for more uniformity.

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The most recent version of the ICBN should be applied (until 2011, this is the Vienna Code, 2006, after which the Melbourne Code will take precedence). Author(s) of taxon names (from the rank of genus or below) must be provided when the scientific name of any plant species is first mentioned with the year of publication. These are cited as a full reference and should be included in the reference list.

Type of Manuscripts

Based on their length, three categories of papers are considered:

1) Research article

Research articles are significant papers of four or more printed pages reporting original research. Papers between 4 and 59 printed pages are published in multi-paper issues of ca. 60 pages. Monographs (60 or more pages) are individually issued and bound and will receive ISBN numbers as well as being part of the *Phytotaxa* series.

Phytotaxa encourages large comprehensive taxonomic works. There is no upper limit on the length of manuscripts, although authors are advised to break monographs of over 1000 pages into multi-volume contributions simply because books over 1000 pages are difficult to bind and too heavy to carry.

Short papers on species of economic, environmental or phylogenetic importance may be accepted at the discretion of editors, who will generally encourage and advise authors to add value to the paper by providing more information (e.g. key to species of the genus, biological information, ecology, etc.). Papers of 4 or 5 pages accepted for publication may be shortened for publication in the Correspondence section.

2) Correspondence

Manuscripts of one to four pages are welcome. We can publish these fairly rapidly because they are useful to fill blank pages in multi-paper issues. *Phytotaxa* publishes the following six types of correspondence:

- ☐ 1. Opinions and views on current issues of interests to systematic botanists.
- ☐ 2. Commentaries on or additions/corrections to papers previously published in *Phytotaxa* or elsewhere.
- ☐ 3. Obituaries of botanists.
- ☐ 4. Taxonomic/nomenclatural notes.
- ☐ 5. Book reviews meant to introduce readers to new or noteworthy taxonomic works (interested authors/publishers are advised to contact the editor before submitting books for review; editors then prepare the book review or invite colleagues to write the review; unsolicited reviews are not usually published).
- ☐ 6. Short papers converted from manuscripts submitted as research articles but too short to qualify as such.

These short contributions should generally have no more than 20 references (exceptions may be considered), and the total length should not exceed four printed pages. Neither an abstract nor a list of key words is needed; major headings (Introduction, Material and Methods, etc.) should not be used, except for new taxon headings and References. A typical correspondence should consist of (1) a short and

concise title, (2) author name, affiliation, address and e-mail address, (3) a series of paragraphs being the main text, and (4) a list of references (if any). The first or last paragraph may be a short summary.

Commentaries on published papers are intended for scholarly exchange of different views or interpretations of published data and should not contain personal attack; note that authors of the papers concerned may be invited to reply to comments on their papers.

3) Monographs, floras and other articles of more than 60 printed pages

Appear in book-form with their own ISBN number. They may be different from the standard formatting when the author provides reasonable arguments for doing so. Please consult the editor in such cases.

Special issues

Special issues with collected papers on a selected topic in the scope of the journal are also published. Potential guest editors should send a proposal to the chief editor for approval and instructions. Although guest editors for special issues are responsible for organizing the peer review of papers in these issues, they must follow the style of *Phytotaxa* (as laid out in this author guide) and peer review procedures. If any papers by the guest editors are to be included in the special issue, these papers must be handled by editors/colleagues other than the editor(s) involved. Special issues must be 60 or more pages. Funding may be required to offset part of the production costs. Author payment for Open Access is strongly encouraged. Reprints can be ordered for the entire issue or for individual papers.

Preparation of manuscripts

General

Please read the guidelines below and additionally consult a recent article published in *Phytotaxa* and follow the style therein.

Language. The article has to be written in British or American English throughout the manuscript. Authors whose native language is not English are encouraged to ask colleagues familiar with the field of research and fluent in English (preferably a native speaker) to correct the language in the manuscript before submission. An article may be returned to the author without review if the language is not of an acceptable standard.

The author is also responsible for the correct usage of other languages, be it a Latin diagnosis or an abstract in a foreign language. The grammar of texts in foreign languages needs to be checked by the author before submission, and again after review if the English from which it is translated (e.g. an abstract) has changed. Latin scholars who are consulted for the correcting of diagnoses should be acknowledged.

Metric measures should be used. Please use the common font Times New Roman, 12 pt and as little formatting as possible (apply only **bold** and *italics* where necessary and indent paragraphs except the first). Special symbols can be used but need to be

carefully checked by the author at proof stage, because they may be altered due to incompatibility of files.

Hyphens ‘-’ are used to link words such as personal names, topographical names, some prefixes and compound adjectives that could otherwise be confused (examples: well-established, 5-sided, Kingston-upon-Thames, Kingdon-Ward, co-operation, etc.).

En-dash or en-rule ‘—’ (a dash the length of the letter ‘n’) should be used for ranges or spans. In the context of *Phytotaxa* it is mainly used for ranges of numbers, most frequently size ranges, elevational ranges, dates and page numbers (e.g. 500–1000 m, 1–3 May, 1976–1977, figs 5–7). Remember also to apply them in the reference section for ranges of volumes, years and pages. The en-dash is also used in name associations (e.g. a Federal–State agreement) and in phenology (e.g. flowering May–September).

Em-dash or em-rule ‘—’ (the length of the letter ‘m’) is used infrequently; they are used for breaks in the text or subject. In contrast to parentheses an em-dash can be used alone; e.g. “What could these results mean—that John discovered the meaning of life?” Em-dashes are also used after a subheading, for instance:

“Type:—BRAZIL . Paraná: Ponta Grossa, Furnas Gêmeas, remnant *Araucaria* forest below large sandstone cliff, 25.145°S, 049.958°W, 950–1000 m, 16 February 2008, *Christenhusz et al.* 4790 (holotype SP!, isotypes K!, MBM, NY!, P!, TI, TUR!, UC!, UPCB).”

Exclamation mark ‘!’ is used to indicate after the herbarium acronym to indicate that this voucher specimen has been seen by the author (see above).

Multiplication or times sign ‘×’. The multiplication sign × is not to be confused with the letter x. It should always be used in hybrid taxa (e.g. *Equisetum* × *schaaffneri*) and in measurements of length and width (of leaves or petals, for example), for example: “leaves 1.0–4.2 × 0.4–0.8 cm”.

Dashes and hyphens should not be spaced. Please feel free to copy these symbols from this author guide and paste them into your manuscript. Using the correct symbols will speed up the editing process. Editors may return the manuscript to the author if dashes, hyphens and multiplication signs are not correctly used.

Italicisation. Generic names and all ranks below are italicised. Book and journal titles are also in italics, as well as diagnoses in Latin and Latin abbreviations (such as *sp. nov.*, *comb. nov.*, *nom. illeg.*, *et al.*). “subsp.”, “ser.”, “var.”, “cv.” and “f.” (for forma or filius) are not italicised, nor are names above the rank of genus. The abbreviation “ssp.” should be avoided and replaced by “subsp.” (for subspecies) to prevent confusion with the abbreviation spp. (= species in plural). As a general rule abbreviations are discouraged.

Abbreviations of certain words are standardised: ca. = circa, m = meter, cm = centimeter, dbh = diameter at breast height, elev. = elevation (altitude is not used for heights of land surfaces above sea level; altitude is used for heights above the earth surface, e.g. of an airplane), *sp. nov.* = new species, *comb. nov.* = new combination, *gen.*

nov. = new genus, *subsp.* = subspecies, *sect.* = section, *pers. comm.* = personal communication, etc. Herbarium acronyms follow *Index Herbariorum* <http://sweetgum.nybg.org/ih/>

Citation of author names

Author abbreviations are seldom used (generally only for basionym authors and new taxa proposed in the manuscript); they are generally cited fully in the references. This means that the name is not abbreviated but the surname is written in full, followed in brackets by the year of publication, a colon, and the page number of the page where the name was published. This is treated as a normal citation, and thus the full article in which the species was published has to be cited in the references. (Include full title of the article, full journal title and full page range.) This is obligatory for all taxonomic articles and articles in which fewer than 30 taxa are mentioned. In articles that deal with a larger number of species (such as ecological or phylogenetic studies or checklists) this is not encouraged because it is impractical. If uncertain, please contact an editor about this matter.

Author abbreviations (strictly following IPNI) are only used in larger monographs and checklists, but even in these articles names in introductions and running text are properly cited in the references. Taxon author names should be cited only once, when the taxon/species first appears in the text. *Phytotaxa* aims to have all taxonomic sources cited included in the reference section. Citation of species authors is as follows:

- *Hymenophyllopsis asplenoides* A.C.Sm. in Gleason (1931: 302). Smith is abbreviated here because it is published in Gleason, which is the proper article to cite.
- *Cyathea asplenoides* (A.C.Sm.) Christenhusz (2009: 39). Smith is abbreviated here because the basionym is already given above.
- *Cyathea gibbosa* (Klotzsch 1844: 542) Domin (1929: 262). Both the basionym and new combination are cited because the basionym is not given above.

In the references:

Christenhusz, M.J.M. (2009) New combinations and an overview of *Cyathea* subg. *Hymenophyllopsis* (Cyatheaceae). *Phytotaxa* 1: 37–42.

Domin, C. (1929) *Pteridophyta*. České Akademie, Prague. 276 pp.

Gleason, H.A. (1931) Botanical results of the Tyler-Duida expedition. *Bulletin of the Torrey Botanical Club* 58: 227–344.

Klotzsch, J.F. (1844) Beiträge zu einer Flora der Äquinoctial-Gegenden der neuen Welt, Filices. *Linnaea* 18: 525–556.

Deposition of voucher specimens and GenBank numbers

Authors of new taxa are required to deposit type specimens in national or international public museums or collections, preferably ones listed in the *Index Herbariorum* that are provided with a corresponding acronym.

Authors are also advised to request registration numbers of deposited sequences in GenBank in advance of the submission of papers to avoid unnecessary delay of publication. Descriptions of species can also be linked to other sources such as the *Encyclopedia of Life*. For fungi MycoBank numbers need to be provided.

Some countries (e.g. Australia, Brazil, Peru) require that primary type specimens (holotypes) be deposited in collections in the country of origin; authors are advised to take this into consideration.

Geography and elevation

Please apply the word ‘elevation’ when dealing with geological features. ‘Altitude’ is here defined as the distance above the surface of the Earth, whereas ‘elevation’ applies to the height of an earth surface above sea level.

For country names (always capitalised in specimen citations) and provinces (followed by a colon), the standard spellings in English followed by the UN apply (e.g. Kyrgyzstan not Kirghizia, Madagascar not Malagasy Republic etc.). For a standard list of countries and areas see: <http://unstats.un.org/unsd/methods/m49/m49alpha.htm>. Exceptions may be discussed with the editor.

Title

The title should be concise and informative and should cover the content of the article. No author names of taxa are given in the title. Family names should always be included. The higher taxa containing the taxa dealt with in the paper (when appropriate) should be indicated in parentheses, example: **A taxonomic revision of the genus *Aa* (Cranichidae, Orchidoideae, Orchidaceae).**

Names and affiliations of article author(s)

Names of all authors must be given below the title and should be typed in upper case (e.g. ADAM J. SMITH, BRIAN SMITH & CAROL SMITH). Inclusion of all major contributors to the work should be considered.

Below the names, the address(es) of professional affiliation for each author should be given in *italics* each starting on a separate line. E-mail address(es) should be provided if available. Affiliation addresses are linked to the author names by numbers in superscript and are provided in corresponding order.

Abstract

The abstract should cover concisely contents of the paper and should be phrased such that additional key words are not necessary. Any new names or new nomenclatural acts proposed in the article should be mentioned. No taxon author names are to be included

in the abstract. Introductory information should not be included in the abstract, neither should be the citation of references.

Abstracts in other languages using the Latin alphabet may also be included in addition to English and should be a direct translation of the English abstract. The spelling and grammar of these abstracts in other languages is the responsibility of the author. An abstract in another language should be corrected if there are any changes in the English abstract during the editorial process.

Key words

Key words may be given when the abstract does not already cover these. The key words may not include words that are already in the title, and they should be given in alphabetical sequence.

Abstracts and key words are not included in short Communications.

Introduction

The introduction should place the study in context, and it should provide recent or historical background relevant to the study. This information should not be included in the abstract. Author names of a taxon should be cited only once, when the taxon/species first appears in the text.

Material & Methods

Materials and methodology used in empirical studies should be concisely provided. Herbaria consulted can be listed here, if not done so in the Acknowledgements. Field work should be highlighted. Floras and other taxonomic works consulted to identify the plant material involved in a study should be cited.

Results

The results section should only present the results of the study. Do not mix results and discussion. Combined Results/Discussion sections are discouraged. Citations of other literature are not normally permitted in the Results section.

Discussion

Discuss your results and place these in the context of the introduction.

Conclusion

The conclusion should state what the scientific contribution of your study is (ask yourself the question: ‘What can we learn from this study and how do the results help us to understand the questions asked in the introduction and discussion?’). It is helpful for other researchers to point out further studies that may be needed in the future.

Taxonomy

A taxonomy section should start with each taxon in bold italics. Abbreviations of authors of new species should be given (following IPNI, not bold), and these should be followed by the correct designation (in italics, not bold, e.g. *comb. nov.*, *nom. nov.*, *spec. nov.*, *stat. nov.*, etc.). When species are not newly described, the author names should be followed by the year and page of publication (and the full article should be included in the references).

All new taxa need to be accompanied by short diagnoses in English or Latin that describe the new taxa. If you prefer Latin, please make sure the language is used correctly. The editors will generally not correct your Latin diagnoses. A specimen needs to be designated as its type (following the ICBN), and the holotype must have been studied by the author of the species. It is encouraged that, when possible, the holotype is deposited in the country of origin, and that two or isotypes are deposited in major herbaria where the specimens will be available for public study.

Taxonomic descriptions should be organised describing the plants from below to above and from outside towards the inner parts. Of course, this is different for each taxon and can thus follow a variable. Subsections of descriptions can be highlighted using italics. Additional data (e.g. distribution, ecology, etymology, etc.) may follow. Often these are subheaded by ‘:—’ (m-dash).

Specimens are cited as follows:

COUNTRY. Province: Locality, elevation, coordinates, date (day month (in full) year), *Collector number* (herbarium acronym in upper case). All specimens studied should be cited. Lectotypes, neotypes and epitypes should always be followed by the reference where they are designated, for example:

Lectotype (designated by Smith 2000/designated here):—FINLAND .
Uusimaa: Helsinki, Kaisaniemi Park, 27 April 1976, *Virtanen* 22 (H!).

Keys

Identification keys should be dichotomous, and the leads should (preferably) be opposite to each other in meaning so that the species can be easily distinguished. Please do not format the key; provide it in the following simple layout:

1. Bracts longer than pedicels; filaments with 1 acute lobe at apex on either side of anther ... *Ornithogalum nutans*

- Bracts shorter than pedicels; filaments without apical lobes on anther ... 2.

2. Inflorescence corymbose; tepals longer than 14 mm ... *Ornithogalum angustifolium*

- Inflorescence racemose; tepals shorter than 14 mm ... *Ornithogalum pyrenaicum*

Acknowledgements

The format for the Acknowledgements is variable, and anyone can be thanked for their contribution. Please consider co-authorship for people that contributed to the study in a major way, especially contributors of specimens or laboratory work.

References

All literature cited in the text (including full articles of taxon authors) should be included. Please check this carefully before submission because errors are common. References should be cited in the text as Smith (1999), Smith & Jones (2000) or Smith *et al.* (2001), the latter when there are three or more authors, or alternatively in a parenthesis (Adams 2000, Smith & Jones 2000, Jones 2001, Smith *et al.* 2001). The citation of floras, revisions and monographs used to identify the collections on which the study is based is strongly encouraged.

Please include DOI for papers that have these. This facilitates linking to papers that have online versions.

Journal article: Author, A. & Author, B.C. (YEAR) Title of the paper. *Title of the journal in full in italics* volume: x–y. For example:

Christenhusz, M.J.M., Zhang, X.-C. & Schneider, H. (2011) Linear sequence of extant families and genera of lycophytes and ferns. *Phytotaxa* 19: 7–54.

Book chapter: Author, A. & Author, B.C. (YEAR) Title of the chapter. *In:* Author, A., Author, B.C. & Author, D. (Eds.) *Title of book in italics*. Publisher name, City, pp. x–y. For example:

Schneider, H., Kreier, H.-P., Janssen, T., Otto, E., Muth, H. & Heinrichs, J. (2010) Key innovations versus key opportunities: identifying causes of rapid radiations in derived ferns. *In:* Glaubrecht, M. (Ed.) *Evolution in action*. Springer, Berlin, pp. 61–76.

Book: Author, A. & Author, B.C. (YEAR) *Title of book in italics*. Publisher name, location, xyz pp. For example:

Copeland, E.B. (1947) *Genera filicum*. Chronica Botanica, Waltham, Massachusetts, 247 pp.

Internet source: Author, A. (YEAR) *Title of website, database or other resources*, Publisher name and location (if indicated), number of pages (if known). Available from: <http://xxx.xxx.xxx/> (Date of access). For example:

IUCN (2010) *The IUCN red list of threatened species*, version 2010.4. IUCN Red List Unit, Cambridge U.K. Available from: <http://www.iucnredlist.org/> (accessed: 19 May 2011).

Dissertations resulting from graduate studies and non-serial proceedings of conferences/symposia are to be treated as books and cited as such. Articles not cited in the manuscript should not be included in the References section.

Figures and Tables

Legends of figures and tables should be listed after the list of references within the same file of the manuscript. Legends for tables and figures should start with **TABLE** or **FIGURE** followed by its number and a full stop. Illustrators and photographers should be mentioned in the figure legend, and if the illustrator is not one of the authors he/she should also be acknowledged. All figures and tables need to be referred to in the text.

Example:

FIGURE 1. Distribution map of *Psilotum nudum* in the Caribbean region.

When preparing illustrations, authors should bear in mind that the journal has a matter size of 25 cm by 17 cm and is printed on A4 paper. For species illustrations, line drawings are preferred, although good quality black and white or colour photographs are also acceptable. See a guide [here](#) for detailed information on preparing plates for publication; this guide was prepared by Dr Daniel Geiger for *Zootaxa*, but it applies equally to *Phytotaxa*.

Line drawings must be scanned at 600 to 1200 dpi as line art (bitmap, =1 bit); they must NOT be scanned as 8 bit or full colour images. Pictures and line drawings should be saved as TIFF files. In some cases PDF or DOC files are acceptable. JPG is not an accepted format. Do not scan line drawings as JPG files because this creates blurry or pixellated images. Sufficient resolution should be provided, but it is up to the author to do so. Low resolution figures can only be printed at a small size.

Tables, if any, should be provided at the end of the manuscript. Please use the table function in your word processor to build tables such that the cells, rows and columns remain aligned when font size and width of the table are changed. Please do not use the tab key or space bar to type tables.

Submission

All manuscripts should be sent by online submission facility

*** Older versions of IE (Internet Explorer 9.0 or earlier) may not be compatible with the new online submission system. A latest version of IE or similar browser (ie. Chrome, Mozilla Firefox and etc.) is more preferable.**

More author information for Biotaxa.org submission system, please click [here](#). For tutorials please click [here](#).

Please follow the above guidelines in detail and check if your manuscript has been prepared according to the style and format of the journal. When you submit your manuscript, it will be more expedient for the review process if you provide the names of three or more potential reviewers with their email addresses.

For legal purposes it should be noted that upon submitting an article the authors agree to the following:

- 1) All authors agree to its submission and the corresponding author has been authorised by co-authors
- 2) This article has not been published before and is not concurrently being considered for publication elsewhere (including another editor of *Phytotaxa*)
- 3) This article does not violate any copyright or other personal proprietary right of any person or entity, and it contains no abusive, defamatory, obscene or fraudulent or any other statements that are unlawful in any way.

If the manuscript submitted does not follow this guideline, it will not be processed.

For manuscripts with numerous illustrations, which might be saved as separate TIFF or JPG files, it will be easier and more efficient for the purpose of review and for the subject editors and reviewers to have the figures converted into one larger PDF (Portable Document Format) file, instead of requiring the subject editor to save many files, cutting and copying these into a string of messages/files to the reviewers. You should retain the original figures in a higher resolution format for the final production of the accepted paper. For the text, PDF file along with original DOC files are preferred. The advantage of submitting an RTF file for the text part of the manuscript is that the reviewers can amend the manuscript electronically. If you cannot prepare PDF files, then submit text in RTF and the figures in TIF (line drawing scanned at 600 dpi and half tone at 300 dpi; please use LZW compression, if you can, to reduce the size of e-files for easy transmission); if halftone TIFF files are too big (exceeding 2 MB), then submit them in jpeg. See [here](#) for detailed information on preparing plates for publication.

Authors of accepted papers will be asked to submit an electronic version of the manuscript so that the publisher does not need to re-key or scan the manuscript. At this stage, the text part of the manuscript must be submitted as DOC (MS Word) files and figures as TIF files.

In submitting the final version of revised manuscript to editors, authors are asked to provide the following information to aid typesetting and indexing of the manuscript:

- 1) Corresponding author name and e-mail
- 2) Author last name and running title (<60 characters; to be used in footer)
- 3) Number of plates and cited references
- 4) Higher level taxon (i.e. taxon section in *Phytotaxa* website in which the article should be filed) and number of new taxa described in the paper

Authors need to complete and return an Assignment of Copyright form when a paper is accepted for publication. Authors from institutions that do not allow transfer of copyrights to publishers (e.g. government institutions such as USDA, CSIRO) should attach a copyright waiver or similar document.

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When a manuscript is received by the Editor, he/she will have it reviewed by at least two peers qualified to evaluate the manuscript. The editor normally asks the reviewers to complete the review within one month. However, the reviewing process may take longer, depending on the length of the manuscript and reviewers' responses.

Journal Production and Publication

Once the manuscript is accepted by your subject editor, final files, produced according to the requirements above, will be forwarded by your subject editor to the managing editor, who will liaise with the copy editor, author and printer to ensure that the article is published without unnecessary delay. Normally the proof will be sent to the author for checking one to three weeks after the final files are accepted. The paper will usually be published within two weeks (for larger papers it may take longer) once the corrections to the proof are received.

Page charge and colour plates. There is no mandatory page charge for publishing in *Phytotaxa*. Publication of colour figures/photographs in online editions are also free of charge (print version in black and white). If colour plates in the print edition are desired, authors will be asked to contribute the full cost. Current rates: 300 USD for the first colour page and 200 USD for each additional colour page.

Open access. *Phytotaxa* endorses open access publication of taxonomic information. Authors who have funds to publish are strongly encouraged to pay a fee of 20 US\$ per printed page to give free online access of their papers to all readers at the *Phytotaxa* site or their own site. Open access papers are read by many more people and can be expected to have higher citation rates.

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Printed copies of each paper/monograph in the form of the regular reprint can also be produced by the Publisher for purchase by authors, with a discount based on the number of copies ordered; quotes for price will be provided when proofs are returned.

References

- Angiosperm Phylogeny Group [APG III] (2009) An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. *Botanical Journal of the Linnean Society* 161: 105–121. DOI: 10.1111/j.1095-8339.2009.00996.x(see also <http://mapress.com/phytotaxa/content/2011/f/pt00019p134.pdf>)
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