Over the hills and far away: New plant records for the Guayana Shield in Brazil

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Abstract. The Guayana Shield is one of the oldest geological formations in South America, ranging from southern Colombia, Venezuela, and the Guianas to the extreme north of the Brazilian states of Amazonas and Roraima. Because of its ancient origin and isolation from other mountain ranges in South America, it harbors a rich flora with high levels of endemism. Recent expeditions to remote areas in the Brazilian portion of the Guayana Shield generated many new herbarium collections. Through these efforts, we report the first records for Brazil of 57 species and infraspecific taxa of vascular plants. In most cases, the taxa are narrowly distributed and were previously known from nearby populations in other countries. In other cases, however, the new Brazilian records expand considerably the known geographical distributions of the taxa.

Key Words: Amazon, geographic distribution, pantepui, tepui, vascular plants.

Resumo. O Escudo das Guianas é uma das formações geológicas mais antigas da América do Sul, que vai desde sul da Colômbia, Venezuela e as Guianas ao extremo norte dos estados brasileiros do Amazonas e Roraima. Devido a sua origem antiga e isolada de outras cadeias de montanhas da América do Sul, abriga uma rica flora com altos níveis de endemismo. Expedições recentes para áreas remotas na porção brasileira do Escudo das Guianas geraram novas coleções de herbário. Através destes esforços, relatamos os primeiros registros para o Brasil de 57 espécies e táxons infraespecíficos de plantas vasculares. Na maioria dos casos, os táxons eram previamente conhecidos a partir de populações próximas em países vizinhos. Em outros casos, porém, os novos registros brasileiros expandem consideravelmente as distribuições geográficas conhecidas dos táxons.

The Guayana Shield is drained to the south and west by the Negro and Orinoco Rivers, and also defines the northern limits of the Amazon basin, covering an area of around 1,000,000 km^2 in northern South America (Berry & Riina, 2005), including South America's highest extra-Andean mountains. Most of this territory is located in Venezuela, with outlying areas extending into Brazil, Colombia, and the Guianas (Huber, 1988). Characterized by magnificent table mountains known as tepuis (Huber, 1988), this landscape served as the backdrop for Sir Arthur Conan

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Doyle's fictional Lost World, a mysterious land, home to a long-lost civilization (Conan Doyle, 1912). Locally, the mountains are worshipped as sacred by indigenous tribes (Berry et al., 1995a), who believe they house powerful gods and ancestral spirits. Geographical and biological factors define the tepuis of the Guayana Shield as a distinct biogeographic province known as Pantepui (Huber, 1987). The region is an important center of diversity for Neotropical flora, and its extremely ancient and isolated terrain has promoted vicariance and radiation resulting in an unique set of relictual endemic plant species (Givnish et al., 2000; Rull & Nogué, 2007).

Although the first major botanical explorations in the tepuis, the expeditions of Alexander von Humboldt and Aimé Bonpland (Humboldt & Bonpland, 1826) and Robert Schomburgk (Schomburgk, 1840a, b), occurred in the nineteenth century, the great breakthrough in documenting the Guayanan flora began in the 1950s, when Julian Steyermark and Bassett Maguire undertook numerous expeditions in the region and conceived of the Guayana Shield Program (see Maguire, 1945, 1955, 1970; Steyermark, 1974; Steyermark & Dunsterville, 1980; Huber et al., 1984), with the ultimate goal of cataloguing the entire flora of the Venezuelan tepuis and surrounding lowlands. Ongoing for several decades afterwards, the Guyana Shield Program culminated in the publication of the Flora of the Venezuelan Guyana (Berry et al., 1995b, 1997, 1998, 1999, 2001b, 2003, 2004, 2005), which treated 2447 species of vascular plants for the Pantepui province, of which 42% are endemic, with up to 25% of the species restricted to single mountains (Berry & Riina, 2005).

Unfortunately these efforts paid relatively little attention to the Brazilian portion of the Guiana Shield, and vast collecting gaps within this region and within the Brazilian Amazon have been documented (e.g., Hopkins, 2007, Milliken 2010). Such gaps may account for diversity estimates for the Brazilian Amazon that are lower than those for some other biomes (BFG, 2015). For example, the Brazilian Atlantic Forest has been estimated to host 16,000 vascular plant species, more than 5000 more than the total for the Brazilian Amazon, although the former covers a much smaller area (Forzza et al., 2012; BFG, 2015; Prado et al., 2015).

In order to expand our knowledge of the Amazonian flora, we carried out field expeditions to remote areas in the Amazon as part of a comprehensive project called "Montanhas da Amazônia" (Coelho et al., 2015). These expeditions were focused on the Brazilian portion of the Guayana Shield, one of the least explored areas in the Amazon Basin (Martinelli, 2007).

As a result of these efforts, we present here new records for Brazil that add significantly to knowledge not only of the Brazilian flora but also of the species endemic to the tepuis.

Materials and methods

Five expeditions were carried out between September 2011 and November 2014 to three mountain ranges: Serra do Aracá (Parque Estadual da Serra do Aracá, 900–1700 m elevation) and Pico da Neblina (Parque Nacional do Pico da Neblina, 2000–3010 m elevation) in the Brazilian state of Amazonas, and Monte Caburaí (Parque Nacional do Monte Roraima, 1300–1400 m elevation) in Roraima state (Fig. 1). All specimens were deposited in the RB herbarium and duplicates were sent to CEPEC, INPA, MIRR, MG, NY, UFRR and UPCB, when available.

Most of the species were identified using the Flora of the Venezuelan Guayana (Berry et al., 1995b, 1997, 1998, 1999, 2001b, 2003, 2004). The putative names were then checked using herbarium specimens for comparison, mainly from F, INPA, MG, MO and NY, including the types whenever possible.

New occurrences recorded here also include species represented by samples already collected but until now unidentified or misidentified or that, for some other reason, had not been included in the List of Species of the Brazilian Flora (2014). Some species whose presence in Brazil was considered likely (i.e. their presence in Brazil was suggested in the Flora of the Venezuelan Guayana) have now been confirmed and therefore are listed in this work.

Results

Fifty-seven species and infra-specific taxa that were not included in the List of Species of the Brazilian Flora (2014) are reported here for the first time from Brazil (Appendix). These new records (Fig. 2) represent 51 genera and 26 families. Four genera —*Viburnum* (Adoxaceae), *Steyerbromelia* (Bromeliaceae), *Disterigma* and *Notopora*

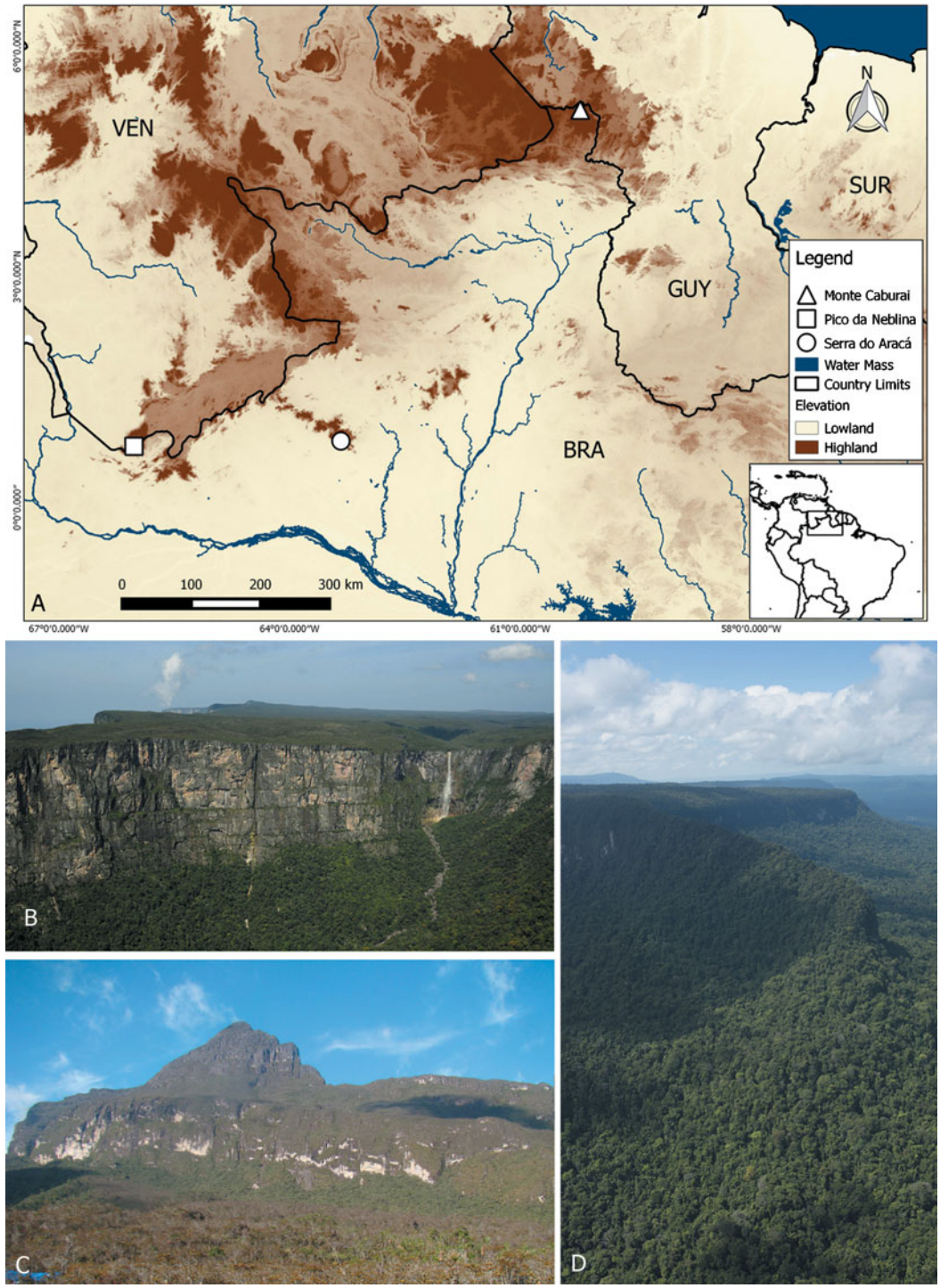

Fig 1. Overview of the Tepui region. **A.** Map showing the mountains where new plant records for Brazil were found. **B.** Serra do Aracá. **C.** Pico da Neblina. **D.** Monte Caburai. Photos by Ricardo Azoury.

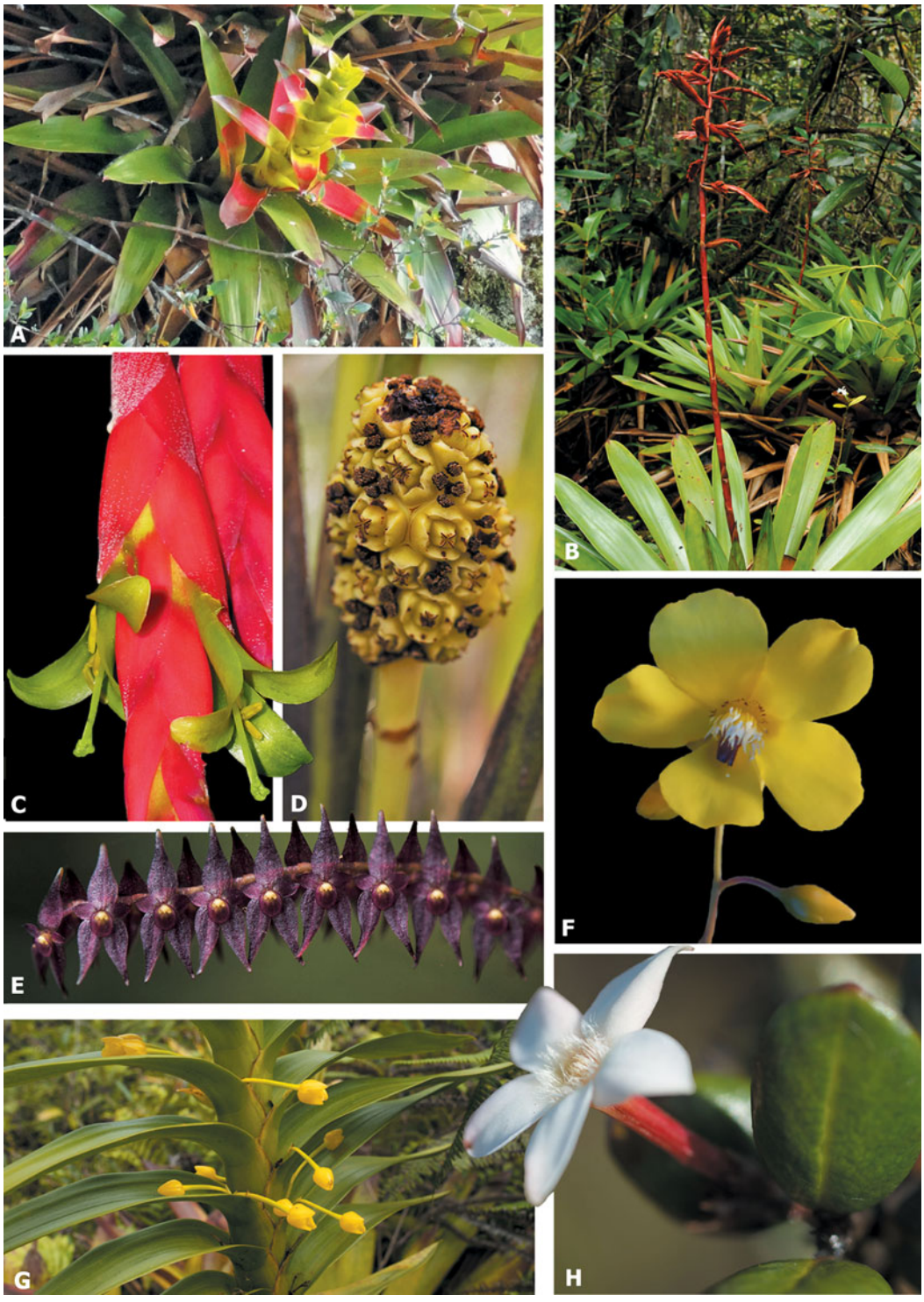

Fig. 2. Selected images of species newly recorded for the Brazilian Guayana. **A.** *Guzmania squarrosa*. **B.** *Vriesea duidae*. **C.** *Vriesea incurva*. **D.** *Stelestylis stylaris*. **E.** *Lepanthopsis vinacea*. **F.** *Poecilandra pumila*. **G.** *Maxillaria aurea*. **H.** *Chalepophyllum guianense*. (Photos: A, C by R. G. Barbosa-Silva; B, D, E, G, H by Ricardo Azoury; F by Marcus Nadruz Coelho).

(Ericaceae) — are newly reported for Brazil. A fifth genus, *Centronia* (Melastomataceae), was cited in the List of Species of the Brazilian Flora (Chiavegatto, 2014), but the vouchers for the two species listed were found to belong to species of *Graffenrieda*. Thus, the current report for *Centronia neblinae* Wurdack is the first valid record of the genus from Brazil. Although its first report for Brazil was based on a specimen collected during the project, *Monochaetum bonplandii* (Humb. & Bonpl.) Naudin is not listed in Appendix 1 because it was included in the List of Species of the Brazilian Flora (2014).

Four other species reported by Prance and Johson (1992) for the Serra do Aracá but not included in the List of Species of the Brazilian Flora (2014) were brought to our attention [*Ilex retusa* Klotzsch, *Cybianthus cardonae* G. Agostini, *Notopleura crassa* (Benth.) C. M. Taylor and *Ruizterania ferruginea* (Steyerm.) Marc.-Berti].

Our collection of *Eccremis coarctata* (Ruiz & Pav.) Baker from the Pico da Neblina (*Forzza 7248*) was the basis for including the species (and the family Xanthorrhoeaceae) in the List of Species of the Brazilian Flora (2014). Subsequently, a collection of the species made in 1984 (*Gentry & Stein 46699*) and referenced by Wurdack and Door (2009) under Hemerocallidaceae came to our notice. This prompted us to find an even older specimen of the same species collected at Pico 31 de Março in 1977 (*Rodrigues 9918*) that had been incorrectly determined as an *Orthrosanthes* (Iridaceae).

Discussion

Most studies related to the highland flora of Brazil have focused on the Atlantic Forest, Cerrado and Caatinga biomes (e.g. Giulietti et al., 1987; Pirani et al., 1994, 2003, 2015; Stannard, 1995; Safford & Martinelli, 2000; Zappi et al., 2003; Borges et al., 2010; Iganci et al., 2011; Forzza et al., 2013). The only floristic survey in the Amazonian highlands of Brazil was that of Prance and Johnson (1992) in the Serra do Aracá, and floristic inventories in the surrounding lowlands are also essentially lacking (Hopkins, 2007; Zappi et al., 2006). The shortage of such studies explains the extensive number of new records recently discovered, especially for those taxa that are known from the Pantepui province in the neighbouring countries (Berry et al., 1995b, 1997, 1998, 1999, 2001b, 2003, 2004, 2005), and suggests that certainly there are many species still waiting to be discovered in the area.

Expeditions in the Amazonian highlands are logistically complex and expensive, and this has hindered the exploration of the region (Coelho et al., 2015). The shortage of plant taxonomists based locally in Northern Brazil slows down the processes needed to improve the knowledge of the regional flora, as does the low number of complete floristic surveys in the Brazilian Amazon. This neglect is by no means restricted to this biome's highlands (Hopkins, 2007; Zappi et al. 2006).

Approximately half of the new records made here belong to Melastomataceae, Bromeliaceae, and ferns and lycophytes, groups that had specialists involved in at least some of the expeditions that form the base of this research. This result supports previous studies that have shown that the presence of taxonomic specialists in the field improves the sampling of groups in which they specialize (Medeiros et al., 2014). It also suggests that botanists specializing in other taxonomic groups that are prominent in the region should be included in future collecting trips.

Another source of new records for the Guayana Highlands are changing identifications on previously collected specimens. Recent examples include *Graffenrieda laevicarpa* Michelang. & R. Goldenb. (Michelangeli & Goldenberg, 2014), and *Styrax prancei* P. W. Fritsch (Fritsch, 2015), both first collected at the Serra do Aracá in 1984, and *Phyllanthus aracaensis* G. L. Webster ex Secco & A. Rosário (Secco & Rosário, 2015), collected in 1978.

Biogeographic patterns —The new records made on the Serra do Aracá, the southernmost and one of the most isolated tepuis of the Guayana Shield, expand considerably the known geographic ranges of some taxa. It is noteworthy that all new records of ferns and lycophytes, spore-bearing plants capable of long-distance dispersal, are from the Serra do Aracá.

In contrast, most of the new records from Pico da Neblina are of taxa that were already known from nearby populations on the Venezuelan side of the same mountain. These records are no less significant, however, as they represent important additions to the Brazilian flora and are mostly of narrowly distributed endemics of conservation concern for the Brazilian government. Anecdotal evidence suggests that our knowledge of the flora

of this single mountain is still very incomplete. For example, of the 51 species of Melastomataceae known to occur above 800 m on Pico de Neblina (Berry, 2001b), 21 of them have yet to be recorded from the Brazilian side of the mountain.

Conclusion.—The new records presented here represent not only a significant increase in knowledge of the Brazilian flora, but also constitute valuable information that is relevant for the management and conservation of plant diversity in the national and state parks where the expeditions took place. Many of the taxa recorded have highly restricted ranges globally, as well as very localized occurrences within Brazil, thus our data will contribute importantly toward the realization of the 2020 targets of the Global Strategy for Plant Conservation (CDB 2010), such as Target 1, the preparation of a flora for the whole country and Target 2, assessing all threatened species. It is noteworthy that these new records are a result of only five expeditions within a limited timeframe, during which approximately 1300 collections of vascular plants were made above 900 m elevation.

Finally, we suggest that the collection curve is still ascending, and that many more species are yet to be discovered in the Amazon, still the least well-known biome in Brazil (Hopkins, 2007; Forzza et al., 2012; BFG, 2015). According to Medeiros et al. (2014), even after many years of organized collecting in Acre, one of every six identifications of new collections constitutes a new record for the state. In the Xingu region of Mato Grosso, Zappi et al. (2006) reported an average of one new state record per ten collections gathered. In the current project, to date we have found approximately one new record per seven species identified. Therefore, we estimate that another five expeditions in the Brazilian Guayana Shield, including specialists on diverse plant families not yet targeted by the project (e.g., Orchidaceae, Asteraceae, Rubiaceae, Cyperaceae, Clusiceae and Xyridaceae), will add a similar number of new records as listed here.

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Appendix 1

List of new occurrences for Brazil. [MC=Monte Caburaí; PN=Pico da Neblina; SA=Serra do Aracá; country acronyms follow ISO 3166-1 (1997).]

FAMILY / SPECIES	VOUCHER	BRAZILIAN COLLLECTION SITE	PREVIOUSLY KNOWN DISTRIBUTION
FERNS AND LYCOPHYTES			
Cyatheaceae			
Cyathea lechleri Mett.	*Prance 29134*; *Forzza 6666*	SA	COL, VEN, ECU, PER, BOL (Smith, 1995; Lehnert, 2011)
Dryopteridaceae			
Arachniodes ochropteroides (Baker) Lellinger	*Labiak 5642*	SA	JAM, PAN, COL, VEN, GUY, SUR (Smith, 1995)
Gleicheniaceae			
Dicranopteris schomburgkiana (J. W. Sturm) C. V. Morton	*Martinelii 17233*	SA	VEN (Smith, 1995)
Lindsaeaceae			
Lindsaea klotzschiana Moritz ex Ettingsh.	*Forzza 6593*	SA	GTM, CRI, PAN, COL, VEN (Smith, 1995)
Lindsaea pendula Klotzsch	*Prance 29025*; *Tavares 37*	SA	VEN, GUY, SUR (Smith, 1995)
Lycopodiaceae			
Phlegmariurus myrsinites (Lam.) B. Øllg.	*Tavares 146*	SA	MEX, Central America, COL, VEN, GUY, ECU, PER (Smith, 1995)
Pteridaceae			
Eriosorus flexuosus (Humb. & Bonpl.) Copel. *var. flexuosus*	*Moraes 259*	PN	MEX, Central America, COL, VEN, ECU, PER, BOL (Smith, 1995)
Schizaeaceae			
Schizaea sprucei Hook.	*Labiak 5680*	SA	COL; VEN (Smith, 1995)
Selaginellaceae			
Selaginella anaclasta Alston ex Crabbe & Jermy	*Labiak 5639*	SA	VEN (Smith, 1995)
ANGIOSPERMS			
Adoxaceae			
Viburnum tinoides var. *roraimense* (Killip & A. C. Sm.) Steyerm.	*Prance 29188*	SA	VEN, GUY (Ramírez & Berry, 1998)

Appendix 1 Continued

FAMILY / SPECIES	VOUCHER	BRAZILIAN COLLLECTION SITE	PREVIOUSLY KNOWN DISTRIBUTION
Apocynaceae			
Aspidosperma neblinae Monach.	*Forzza 7283*	PN	VEN (Morillo, 1995a)
Ditassa bolivarensis (R. W. Holm) Morillo	*Nadruz 2879; Forzza 8194*	MC	VEN (Morillo, 1997)
Mandevilla benthamii (A. DC.) K. Schum.	*Martinelli 18387*; *Forzza 8225*	MC	VEN, GUY (Morillo, 1995b)
Asteraceae			
Glossarion rhodanthum Maguire & Wurdack	*Forzza 7173*	PN	VEN (Pruski, 1997)
Lepidaploa imeriensis (V. M. Badillo) Pruski	*Forzza 7194*	PN	VEN (Pruski, 1997)
Mikania neblinensis Aristeg.	*Forzza 7155*; *Martinelli 17803*	PN	VEN (Pruski, 1997)
Bonnetiaceae			
Bonnetia rubicunda (Sastre) A. L. Weitzman & P. F. Stevens	*Martinelli 18447*	MC	VEN, GUY (Weitzman, 2005)
Bromeliaceae			
Brocchinia acuminata L. B. Sm.	*Martinelli 18443*	MC	COL, VEN (Holst, 1997)
Brocchinia reducta Baker	*Forzza 8185*; *Martinelli 18427*	MC	VEN, GUY (Holst, 1997)
Guzmania squarrosa (Mez & Sodiro) L. B. Sm. & Pittendr.	*Martinelli 17087*	SA	COL, VEN, GUY, ECU, PER (Morillo & Briceño, 2010)
Guzmania sphaeroidea (André) André ex Mez	*Forzza 7993*	SA	COL, VEN, GUY, ECU, PER (Holst, 1997)
Racinaea tetrantha var. *caribaea* (L. B. Sm.) M. A. Spencer & L. B. Sm.	*Forzza 7132; Martinelli 17769, 17777, 17827*	PN	HTI, CRI, VEN, CUB (Holst, 1997)
Steyerbromelia plowmanii (L. B. Sm., Steyerm. & H. Rob.) B. Holst	*Martinelli 17813*	PN	VEN (Holst, 1997)
Tillandsia confinis L. B. Sm.	*Forzza 7135*; *Martinelli 17783*, *17807*	PN	COL, VEN, GUY PER, ECU, BOL (Holst, 1997)
Vriesea duidae (L. B. Sm.) Gouda	*Martinelli 17223*; *Forzza 7133*	SA, PN	VEN, GUY (Holst, 1997)
Vriesea incurva (Griseb.) Read	*Martinelli 17812*	PN	HTI, DOM, JAM, CRI, PAN, COL, VEN, BOL, ECU, PER (Morillo & Briceño, 2010)
Cunoniaceae			
Weinmannia fagaroides Kunth	*Moraes 238*	PN	VEM, CRI, COL, GUY, ECU, PER (Bradford & Berry, 1998)
Cyclanthaceae			
Stelestylis stylaris (Gleason) Harling	*Forzza 8149*	MC	VEN, GUY (Eriksson, 1998)
Elaeocarpaceae			
Sloanea crassifolia Earle Sm.	*Martinelli 18403*	MC	VEN, GUY (Smith & Steyermark, 1998; Funk et al., 2007)
Ericaceae			
Disterigma humboldtii (Klotzsch) Nied.	*Martinelli 17800*; *Forzza 7265*	PN	MEX, GTM, CRI, PAN, COL, VEN, GUY, ECU (Luteyn, 1998; Luteyn & Wilbur, 2005)
Notopora schomburgkii Hook.f.	*Forzza 8250*	MC	VEN, GUY (Luteyn, 1998)
Fabaceae			
Dicymbe fraterna R. S. Cowan	*Forzza 8269*	MC	VEN, GUY, SUR (Cowan & Berry, 1998)

Appendix 1 Continued

FAMILY / SPECIES	VOUCHER	BRAZILIAN COLLLECTION SITE	PREVIOUSLY KNOWN DISTRIBUTION
Gentianaceae			
Macrocarpaea neblinae Maguire & Steyerm.	*Forzza 7276*	PN	VEN (Struwe, 1999a)
Tapeinostemon longiflorum Maguire & Steyerm. var. *longiflorum*	*Forzza 7159*; *Martinelli 17776*; *Nadruz 2705*	PN	VEN (Struwe, 1999b)
Melastomataceae			
Centronia neblinae Wurdack	*Nadruz 2716*	PN	VEN (Berry, 2001a)
Graffenrieda fruticosa Wurdack	*Martinelli 17789*; *Moraes 258*; *Forzza 7246*; *Nadruz 2702*, *2717*	PN	VEN (Gröger, 2001)
Graffenrieda reticulata Wurdack	*Forzza 7150*, *7268*; *Martinelli 17828*; *Nadruz 2712*	PN	VEN (Gröger, 2001)
Macrocentrum brevipedicellatum Wurdack	*Nadruz 2890*	MC	VEN, GUY (Wurdack et al., 1993; Berry et al., 2001a)
Macrocentrum minus Gleason	*Nadruz 2869*	MC	VEN, GUY (Wurdack et al., 1993; Berry et al., 2001a)
Maieta neblinensis Wurdack	*Maguire 60428*; *Silva 60845*, *60854*; *60876*	PN	Species previously mentioned for the Brazilian side of PN (Luckana, 2001) but overlooked in the List of Species of the Brazilian Flora (Michelangeli, 2014).
Meriania sclerophylla Triana	*Forzza 8151*; *Martinelli 18444*; *Nadruz 2871*	MC	VEN (Luckana & Berry, 2001)
Miconia roraimensis Ule	*Forzza 7188*; *Nadruz 2700*, *2710*, *2711*	PN	VEN, GUY (Berry, 2001b)
Tibouchina fraterna N. E. Br. subsp. *fraterna*	*Forzza 8248*	MC	VEN, GUY (Berry, 2001c)
Tococa tepuiensis subsp. *glabrata* Wurdack	*Forzza 7262*	PN	VEN (Michelangeli, 2001)
Ochnaceae			
Poecilandra pumila Steyerm.	*Nadruz 2854*	MC	VEN, GUY (Sastre, 2003; Funk et al., 2007)
Tyleria spectabilis Maguire & Wurdack	*Martinelli 17766*	PN	VEN (Sastre, 2003)
Orchidaceae			
Epidendrum durum Lindl.	*Forzza 6571*	SA	VEN, GUY (Carnevali & Ramírez-Morillo, 2003a; Funk et al., 2007)
Lepanthopsis vinacea C. Schweinf.	*Forzza 8266*	MC	VEN (Carnevali & Ramírez-Morillo, 2003b; Funk et al., 2007)
Maxillaria aurea (Poepp. & Endl.) L. O. Williams	*Forzza 7263*	PN	COL, VEN, GUY, ECU, PER, BOL (Carnevali & Ramírez-Morillo, 2003c)
Pentaphylacaceae			
Ternstroemia pungens Gleason	*Forzza 8152, Martinelli 18390*	MC	VEM, SUR (Berry & Weitzman, 2004)
Phyllanthaceae			
Phyllanthus majus Steyerm.	*Forzza 8205*	MC	VEN, GUY (Webster, 1999)
Rapateaceae			
Stegolepis neblinensis Maguire	*Forzza 7169*; *Martinelli 17764*	PN	VEN (Berry, 2004)
Rubiaceae			
Chalepophyllum guyanense Hook.f.	*Nadruz 2861*	MC	VEN, GUY (Govaerts, 2015)

Appendix 1 Continued

FAMILY / SPECIES	VOUCHER	BRAZILIAN COLLLECTION SITE	PREVIOUSLY KNOWN DISTRIBUTION
Ixora intropilosa Steyerm.	*Nadruz 2878*	MC	VEN, GUY (Govaerts, 2015)
Notopleura aligera (Steyerm.) C. M. Taylor	*Martnelli 18421*; *Forzza 8190*	MC	VEN, GUY (Govaerts, 2015)
Pagamea capitata Benth. subsp. *capitata*	*Forzza 8166*, *8278*	MC	VEN, GUY, SUR, GUF (Govaerts, 2015)
Psychotria crocochlamys Sandwith	*Forzza 8188*; *Martinelli 18438*; *Nadruz 2865*, *2893*	MC	VEN, GUY (Govaerts, 2015)