An Acad Bras Cienc (2020) 92(2): e20190017 DOI 10.1590/0001-3765202020190017
Anais da Academia Brasileira de Ciências | *Annals of the Brazilian Academy of Sciences*
Printed ISSN 0001-3765 I Online ISSN 1678-2690
www.scielo.br/aabc | www.fb.com/aabcjournal

BIOLOGICAL SCIENCES

Solanaceae diversity in South America and its distribution in Argentina

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Abstract: Solanaceae is one of the most diverse families in the Americas, particularly in Argentina where it represents the fourth family in terms of species number. Although checklists for most South American countries have been published, some are outdated and there has been no analysis of Solanaceae diversity at country level. We present an updated summary of Solanaceae diversity in South America, an analysis of its distribution in Argentina, and preliminary conservation assessments for all species endemic to Argentina. Regression analyses were used for evaluating the ratio between taxa/area and endemic/total species, multivariate ordering methods were used to analyze the relationships between Argentine ecoregions, and the IUCN criteria were applied for conservation assessments. Results show that Solanaceae comprises 1611 species in South America. The highest diversity is in Peru, which, together with Ecuador, possesses more diversity than expected for the area; Chile and Brazil have the greatest percentage of endemic species. In Argentina, the Chaco ecoregion hosts the highest number of taxa, but largest number of endemic species is found in the Monte ecoregion. According to the IUCN criteria, 28 endemic species from Argentina are considered threatened. We discuss South American countries and Argentine ecoregions in terms of conservation priorities.

Key words: Argentina, conservation status, distribution, ecoregion, endemic species, South America.

INTRODUCTION

The Solanaceae family includes 98 genera and approximately 2800 species (Dupin et al. 2017). It is distributed in all continents except Antarctica, with a preference for warm to tropical zones, from sea level to heights up to 5000 m and it inhabits many heterogeneous environments (Barboza 2013). It includes small annual herbs (e.g. *Leptoglossis* Benth.) up to trees taller than 15 m (e.g. *Duckeodendron* Kuhlm.) (Hunziker 2001) and it is well-known for its diverse reproductive structures (Knapp 2010) as well as its varied chemical compounds (Eich 2008). The Solanaceae species are very valuable to man mainly as food (*Solanum tuberosum* L., potato; *Solanum lycopersicum* L., tomato; *Solanum melongena* L., aubergine; *Capsicum annuum* L., bird pepper), ornamentals (species of *Petunia* Juss., *Schizanthus* Ruiz & Pav., *Salpiglossis* Ruiz & Pav., *Browallia* L., *Brugmansia* Pers.) and for their medicinal, poisonous or psychotropic effects (*Nicotiana tabacum* L., tobacco; *Atropa belladonna* L., belladonna; *Mandragora officinarum* L., mandrake; *Hyoscyamus niger* L., henbane; *Datura stramonium* L., thorn apple; *Cestrum parqui* L'Her., duraznillo negro). Likewise, many taxa are used in biological studies as model organisms for experimentation e.g.: *Nicotiana* spp., *Solanum* spp., *Petunia* spp., *Datura* spp. (Gebhardt 2016).

Solanaceae is among the 12 most diverse families in the Americas, the genus *Solanum* L. being the sixth in the number of species (Ulloa Ulloa et al. 2017), while South America represents both the ancestral area and the actual centre of diversity of the family (Olmstead 2013, Dupin et al. 2017). Argentina presents a vast richness of species; in fact, Solanaceae is the fourth family by number of species after Asteraceae (1502 spp.), Poaceae (1170) and Fabaceae (760), and is represented by 319 species (Barboza 2013, Del Vitto & Petenatti 2015).

Currently, species lists of vascular plants in Argentina (Zuloaga et al. 1999) and the South American Southern Cone (Zuloaga & Belgrano 2015) already exist. Nevertheless, neither an in-depth analysis of Solanaceae diversity nor preliminary conservation assessments applying the IUCN criteria for all species endemic to Argentina, have yet to be carried out.

The aims of this paper are: (i) to present an updated summary of the diversity of Solanaceae in South America and Argentina, related to its distribution, (ii) to assess the conservation status of all endemic species from Argentina and to identify the priority areas for planning regional conservation management in the country.

MATERIALS AND METHODS

Solanaceae diversity in South America

All South American countries were included in the diversity analysis. The species lists were compiled from floras and catalogues of the different countries (D'Arcy et al. 1993, 2007, Short et al. 1999, Ulloa Ulloa et al. 2004, Rodríguez et al. 2006, Hokche et al. 2008, Zuloaga et al. 2008, Knapp et al. 2011, Barboza 2013, Nee 2014, Orozco et al. 2015, Rodriguez et al. 2018, Flora do Brasil 2019a) and monographs of the genera when available. All taxonomic novelties up to April 2019 were included based on a web search with specific keywords (Solanaceae "new combination", "new record", "new species", "sp. nov." and "updated list", https://scholar.google.com). Doubtful data were cross-checked against the databases Solanaceae Source (2019) and POWO (2019), and in all cases the final decision for species inclusion was based on specimens properly identified by Solanaceae specialists.

Linear regression analysis was used to determine the taxa-area ratio and the endemic species-species richness ratio for each country and the Guianas (French Guiana, Guyana and Suriname). When necessary, data were log-transformed to meet the assumptions of regression analysis. InfoStat v. 2016 (Di Rienzo et al. 2016) software was used to perform all the statistical analysis.

Solanaceae diversity and distribution in Argentina

Diversity and distribution of Solanaceae in Argentina was analysed according to the ecological systems proposed by Josse et al. (2003) and modified by Zuloaga & Belgrano (2015). Eight ecoregions were considered: South Central Dry Andes, Atlantic Forest, Chaco, Monte, Wet Temperate Pacific, Pampas, Patagonia, and Yungas (Fig. 1).

Data from Documenta Florae Australis (2019) and GBIF (2019) databases were included in the analysis, complemented with information from specimen labels of the main herbaria of Argentina {BA, BAB, CORD, LIL, MERL, SI [Thiers continuously updated]} and monographs when available, i.e., *Fabiana* Ruiz & Pav. (Barboza & Hunziker 1993), *Jaborosa* Juss. (Barboza & Hunziker 1987), *Lycium* L. (Bernardello 1986), *Sclerophylax* Miers (Di Fulvio 1961), *Solanum* (Knapp 2013, Spooner et al. 2016, Knapp et al. 2017). When the identification of some specimens or their distributions were doubtful, Solanaceae experts were consulted.

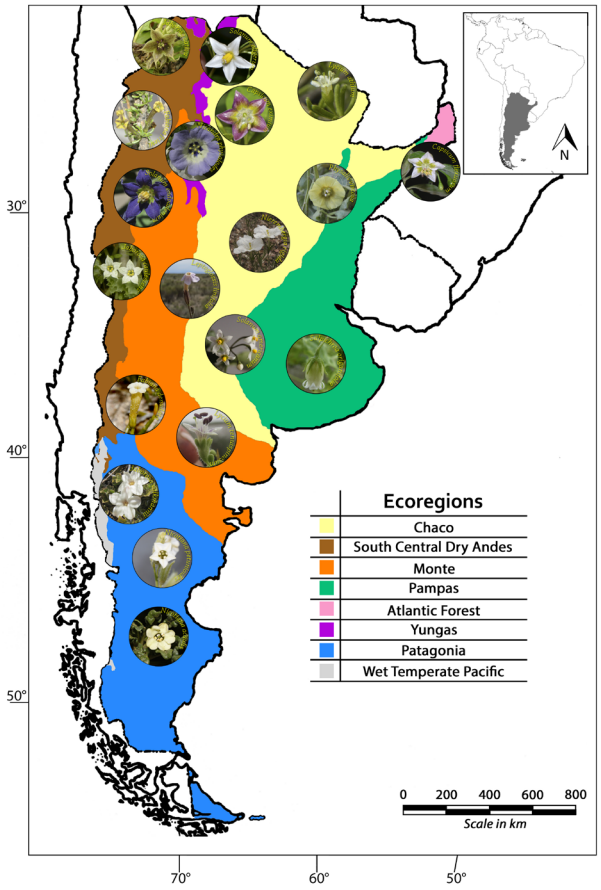

Figure 1. Ecoregions of Argentina (modified from Zuloaga & Belgrano 2015). Photographs of typical Solanaceae species from each ecoregion are included.

The relationships between ecoregions were explored using principal coordinates analysis (PCoA) and a minimum spanning tree (MST). Jaccard's similarity index (S) was calculated for the binary data of presence of taxa with the transformation $(1\text{-}S_{ij})^{1/2}$.

Conservation status assessment of Argentine endemic species

The distribution for each endemic species was plotted using QGIS 2.8 (QGIS Development Team 2018) and was based on georeferenced data of all the herbarium collections studied. Conservation status was assessed using the IUCN criteria version 3.1 (IUCN 2012, IUCN Standards and Petitions Subcommittee 2017), considering only the extent of occurrence (EOO) since the area of occupancy (AOO) is very sensitive to georeferencing bias associated with few or no georeferenced collections, and collecting effort (Särkinen et al. 2018, Knapp et al. 2019). Geospatial Conservation Assessment Tool (GeoCAT) was used (Bachman et al. 2011).

RESULTS

Solanaceae diversity in South America

The number of Solanaceae species in South America accounted is 1611 (1595 native and 16 introduced species; Table SI - Supplementary Material). The number of genera is 62 (61 native and one introduced, *Datura* L.) and the 10 most speciose genera are: *Solanum*, *Cestrum* L., *Nolana* L.f., *Jaltomata* Schltdl., *Lycianthes* (Dunal) Hassl., *Deprea* Raf., *Nicotiana* L., *Iochroma* Benth., *Lycium*, and *Capsicum* L. (Fig. 2; Table SII - Supplementary Material). Analysis of species richness across South American countries shows that Peru has the highest number of genera, species as well as endemic species (Table I, Table SIII -Supplementary Material) while Uruguay and the Guianas have the lowest numbers. Paraguay and the Guianas have only one endemic species (*Cestrum hassleri* Francey and *Solanum costatum* M.Nee, respectively). Chile, Peru and Brazil are the countries with the greatest percentage of endemic species (almost 50%).

The relationship between the number of genera, species or endemics and the area of the countries was significantly positive ($p \leq 0.05$; R^2=0.36, R^2=0.44, R^2=0.45, respectively) (Fig. 3a-c). Ecuador and Peru show higher values than expected according to their areas in all cases and inversely, the Guianas and Paraguay (only for the case of endemics and area) show lower values than expected for their areas.

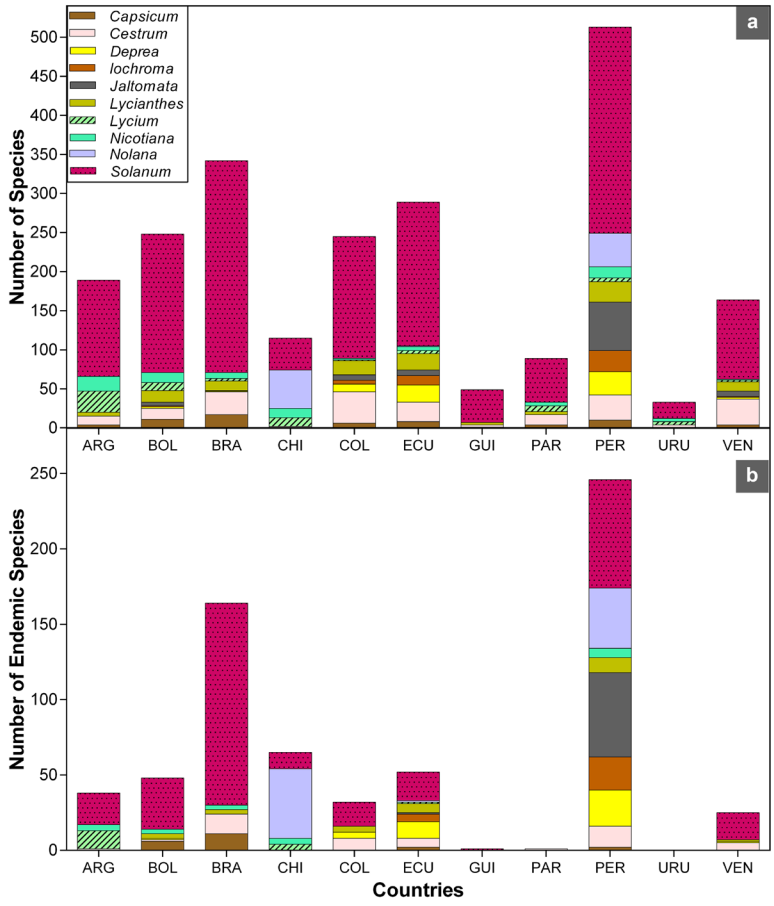

Figure 2. Distribution of Solanaceae in South American countries. a. The 10 most speciose genera. b. The 10 most endemic speciose genera. Abbreviations: ARG (Argentina), BOL (Bolivia), BRA (Brazil), CHI (Chile), COL (Colombia), ECU (Ecuador), GUI (The Guianas), PAR (Paraguay), PER (Peru), URU (Uruguay), VEN (Venezuela).

Species richness was positively related to endemics (R^2=0.80, p <0.01), so the countries with a larger number of species also possess a larger number of endemic species (Fig. 3d). Chile and Brazil present a larger number of endemics than expected from the total number of species; inversely, Bolivia, Colombia, and Ecuador possess a smaller number.

Solanaceae diversity and distribution in Argentina

Argentine Solanaceae in numbers

Argentina has 338 specific and infraspecific taxa, distributed in 34 genera and 319 species of which 83 are endemics (Fig. 4a). Regarding their distribution status, almost all species are native to Argentina, except for seven species (Fig. 4b). *Lycium barbarum* L., from Asia, is the only extra-American species. The other introduced species are American: *Datura ferox* L., *D. inoxia* Mill., *D. stramonium* L. and *Solanum rostratum* Dunal from North America, and *Brugmansia suaveolens* (Willd.) Sweet and *Solanum capsicoides* All. from Brazil.

A total of 38% of the genera (13) is represented by only one species from which *Pantacantha* Speg. is the sole monotypic genus restricted to Argentina (Fig. 4c). Contrarily, the genus with the largest number of species is *Solanum*, also being the one that contributes with the most endemics in the country. Considering the genera with more than three species, those with the greatest proportion of endemics are

Table I. Species diversity of Solanaceae in South America. Number of genera, species and endemics is provided for each country and the Guianas (French Guiana, Guyana and Suriname).

Countries	Genera	Species	Endemic (%)	Area (km²)
Peru	41	631	295 (47)	1,279,996
Brazil	35	479	223 (47)	8,358,140
Ecuador	32	370	66 (18)	276,841
Colombia	31	335	49 (15)	1,038,700
Bolivia	36	322	53 (16)	1,083,301
Argentina	34	319	83 (26)	2,736,690
Venezuela	30	215	31 (14)	882,050
Chile	22	173	85 (49)	743,812
Paraguay	21	119	1 (1)	397,302
The Guianas	12	69	1 (1)	436,383
Uruguay	17	67	2 (3)	175,015

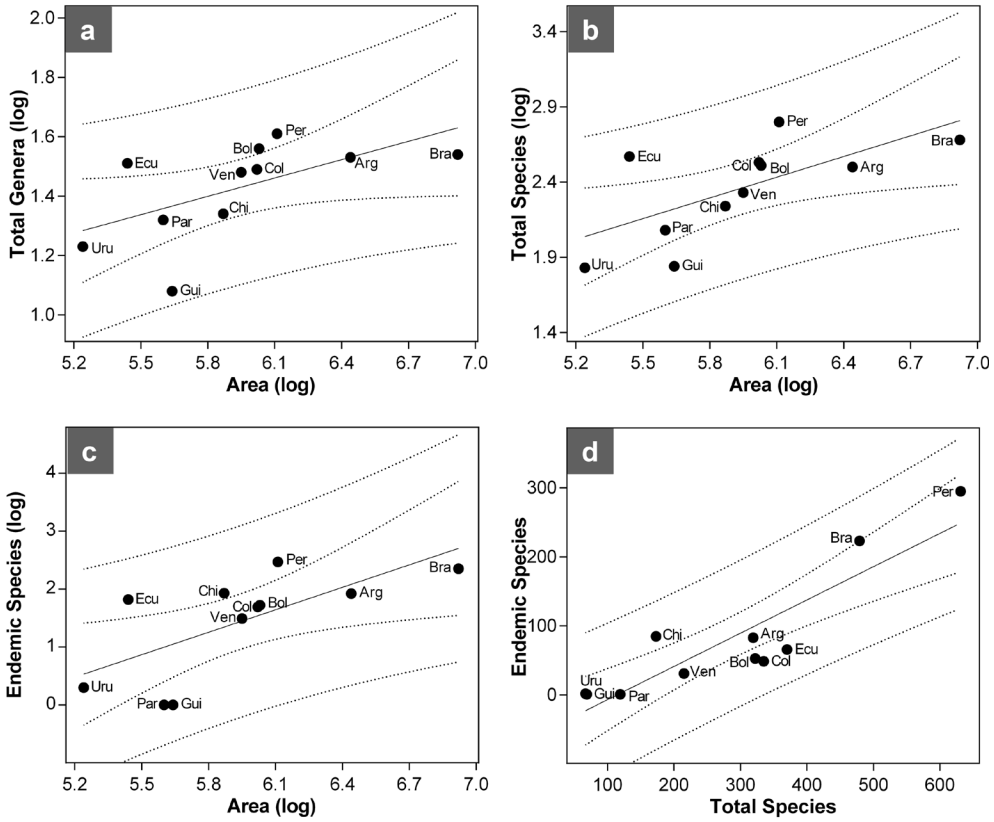

Figure 3. Solanaceae in South America: relationships between the number of taxa and the countries area, and between endemic species and total species. a. Number of genera and area. b. Number of species and area. c. Number of endemic species and area. d. Number of endemic species and total number of species for different countries. Abbreviations: Arg (Argentina), Bol (Bolivia), Bra (Brazil), Chi (Chile), Col (Colombia), Ecu (Ecuador), Gui (The Guianas), Par (Paraguay), Per (Peru), Uru (Uruguay), Ven (Venezuela).

a

Genera	Total spp	Endemic spp (%)	Total taxa	Endemic taxa (%)
Athenaea	1	0 (0)	1	0 (0)
Benthamiella	12	8 (67)	12	8 (67)
Bouchetia	1	0 (0)	1	0 (0)
Brugmansia	1	0 (0)	1	0 (0)
Brunfelsia	3	0 (0)	3	0 (0)
Calibrachoa	12	1 (8)	12	1 (8)
Capsicum	4	0 (0)	4	0 (0)
Cestrum	11	1 (9)	11	1 (9)
Combera	1	0 (0)	1	0 (0)
Datura	3	0 (0)	3	0 (0)
Dunalia	1	0 (0)	1	0 (0)
Eriolarynx	3	2 (67)	3	2 (67)
Exodeconus	1	0 (0)	1	0 (0)
Fabiana	10	5 (50)	10	5 (50)
Jaborosa	21	10 (48)	22	10 (45)
Leptoglossis	1	1 (100)	1	1 (100)
Lycianthes	5	0 (0)	5	0 (0)
Lycium	27	12 (44)	36	17 (47)
Melananthus	1	0 (0)	1	0 (0)
Nicandra	1	0 (0)	1	0 (0)
Nicotiana	19	4 (21)	20	5 (25)
Nierembergia	15	3 (20)	20	7 (35)
Pantacantha	1	1 (100)	1	1 (100)
Petunia	7	1 (14)	9	1 (11)
Physalis	7	1 (14)	8	1 (13)
Reyesia	1	0 (0)	1	0 (0)
Salpichroa	4	0 (0)	4	0 (0)
Salpiglossis	1	0 (0)	1	0 (0)
Schizanthus	2	0 (0)	2	0 (0)
Schwenckia	2	0 (0)	2	0 (0)
Sclerophylax	14	12 (86)	14	12 (86)
Sessea	2	0 (0)	2	0 (0)
Solanum	123	21 (17)	123	21 (17)
Vassobia	1	0 (0)	1	0 (0)
Total	319	83 (26)	338	93 (28)

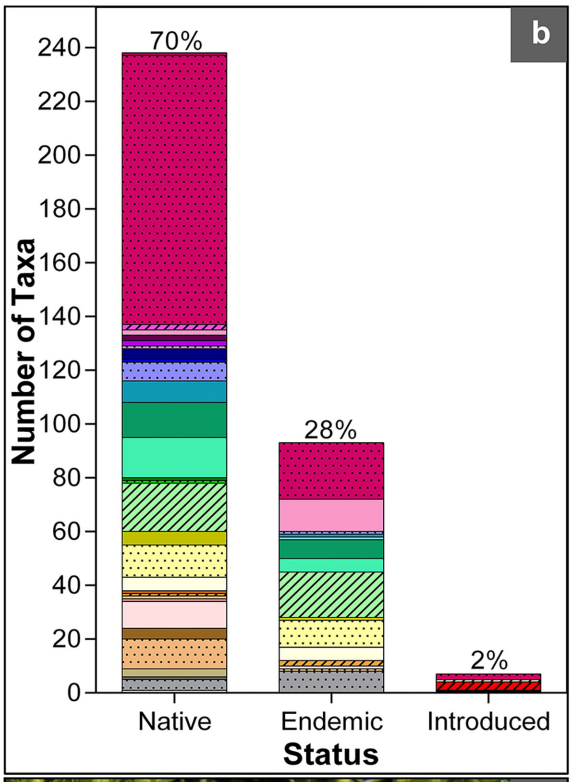

Figure 4. Solanaceae diversity in Argentina. a. Number of species, specific and infraspecific taxa, and endemics in each genus (taxa means: specific and infraspecific taxa). b. Number of specific and infraspecific taxa versus distribution status. c. *Pantacantha*, the only endemic monotypic genus in Argentina.

Sclerophylax with 86% and *Benthamiella* Speg. with 67% (Fig. 4a).

Argentine Solanaceae in ecoregions

Solanum and *Lycium* are present in all Argentine ecoregions; *Nicotiana, Nierembergia* Ruiz & Pav., *Cestrum* and *Physalis* L. also inhabit nearly all ecoregions, except for the Wet Temperate Pacific; *Exodeconus* Raf., *Reyesia* Gay and *Salpiglossis* are exclusive to the Andes, *Athenaea* Sendtn. and *Brugmansia* to the Atlantic Forest, *Eriolarynx* (Hunz.) Hunz. to Yungas and *Melananthus* Walp. to the Chaco. *Benthamiella* is a Chilean-Argentine Patagonian endemic genus. The ecoregions with the greatest richness of genera are the Chaco (with 65% of the genera i.e., 22 genera) and Yungas (62% i.e., 21 genera), followed by The Andes (20 genera), Monte (19 genera), Atlantic Forest and Pampas (18 genera), whereas Patagonia (44% i.e., 15 genera) and Wet Temperate Pacific (6% i.e., 2 genera) have the lowest richness.

The Chaco is the ecoregion with the highest number of specific and infraspecific taxa (121), followed by the Andes (111), Pampas (109), Monte (94), Yungas (90), Atlantic Forest (74), Patagonia (59) and Wet Temperate Pacific (5) (Fig. 5a). Introduced species are found in all regions but Wet Temperate Pacific.

The Argentine endemic specific and infraspecific taxa are recorded in six ecoregions: Monte (37), Andes (34), Chaco (29), Patagonia (29), Yungas (16), and Pampas (5) (Fig. 5b).

The analysis of the similarities and differences of Solanaceae between ecoregions showed that about 60% of the total variation is related to the number of genera, where Atlantic Forest, Pampas, Chaco and Yungas constitute a group on the lower left side of the biplot (Fig. 6a) with Monte related to them. When considering the total specific and infraspecific taxa, 40% of the total variability between ecoregions could be explained, and in this way Atlantic Forest, Pampas, Chaco, and Yungas are separated from the remaining regions (Fig. 6b), and the Pacific region being isolated from the rest. Regarding endemics (Fig. 6c), Monte and the Andes are the most similar ecoregions, sharing a high number of specific and infraspecific endemic taxa.

Conservation status assessment of Argentine endemic species

Using the IUCN criteria, we consider that 34% (28) of the 83 endemic species belong to threatened categories (Fig. 7); being 9 Critically Endangered (CR), 6 Endangered (EN), and 13 Vulnerable (VU). Six species are considered as Near Threatened (NT) while 2 are Data Deficient (DD) (Fig. 8). The remaining species (47) were evaluated as Least Concern (LC).

DISCUSSION

The spatial patterns in species richness of Solanaceae in the South American countries agree with the species-area relationships found by Cowling & Samways (1994) and Gaston (2000). Brazil, the most extensive country, is also the most diverse in its vascular flora as well as the one with the greatest proportion of endemics (Ulloa Ulloa et al. 2017). Peru and Ecuador present higher Solanaceae diversity than expected. According to our results, Peru is the country with the greatest diversity including genera, total species and endemic species. *Solanum*, *Jaltomata* and *Nolana* are the most speciose genera in Peru (Knapp et al. 2006), and Peru specially holds the greater number of potato (Spooner et al. 2016) and tomato species in the world (Peralta et al. 2008). On the other hand, *Solanum, Cestrum* and *Deprea* are the most speciose genera in Ecuador (see Table SIII).

In addition, Chile and Brazil have a high proportion of Solanaceae endemic species; they

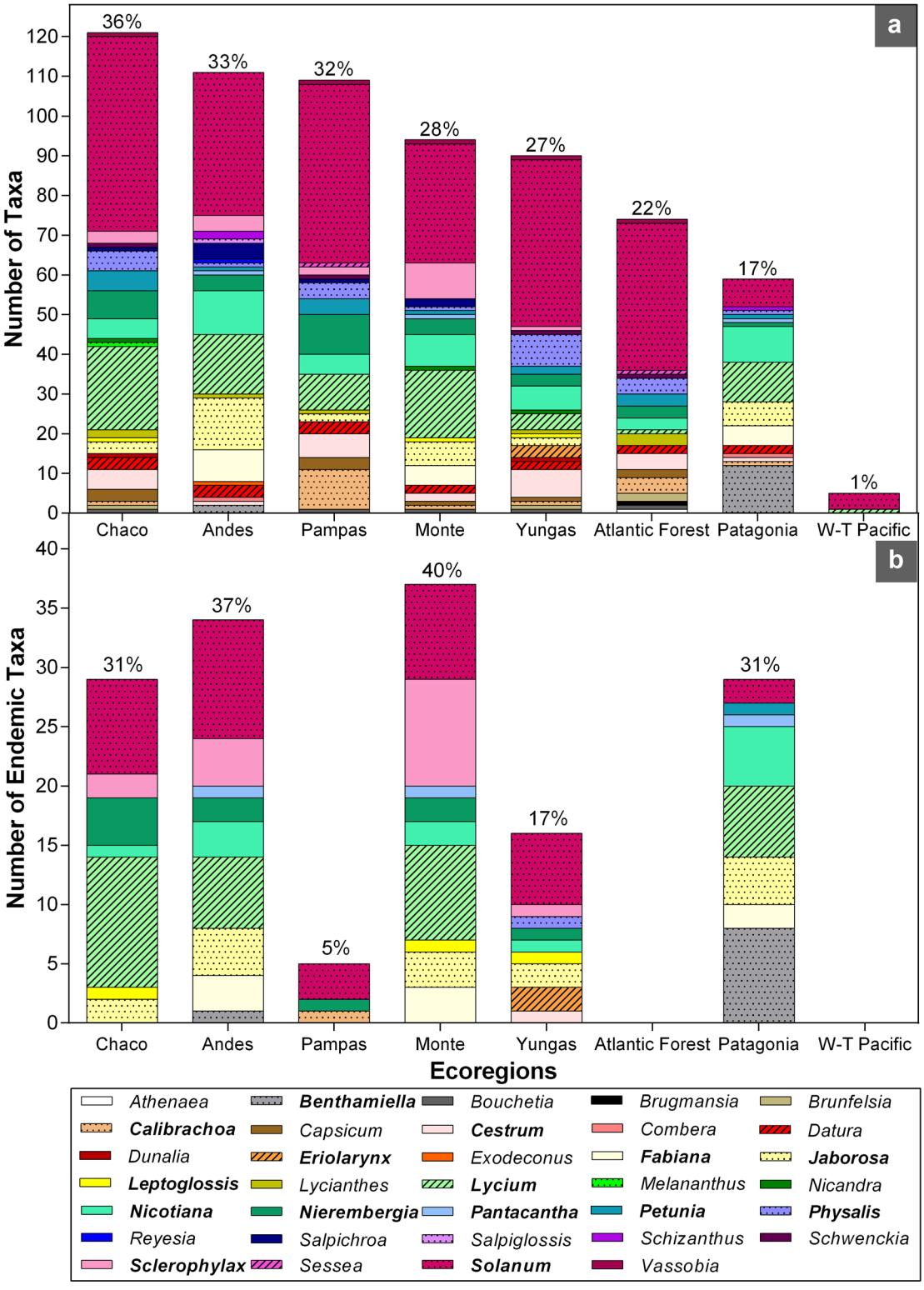

Figure 5. Solanaceae diversity in Argentine ecoregions. a. Total number of specific and infraspecific taxa in each ecoregion. Percentage relative to the total Argentine specific and infraspecific taxa are expressed. b. Number of Argentine endemic specific and infraspecific taxa in each ecoregion. Percentage relative to the total Argentine endemic specific and infraspecific taxa are expressed.

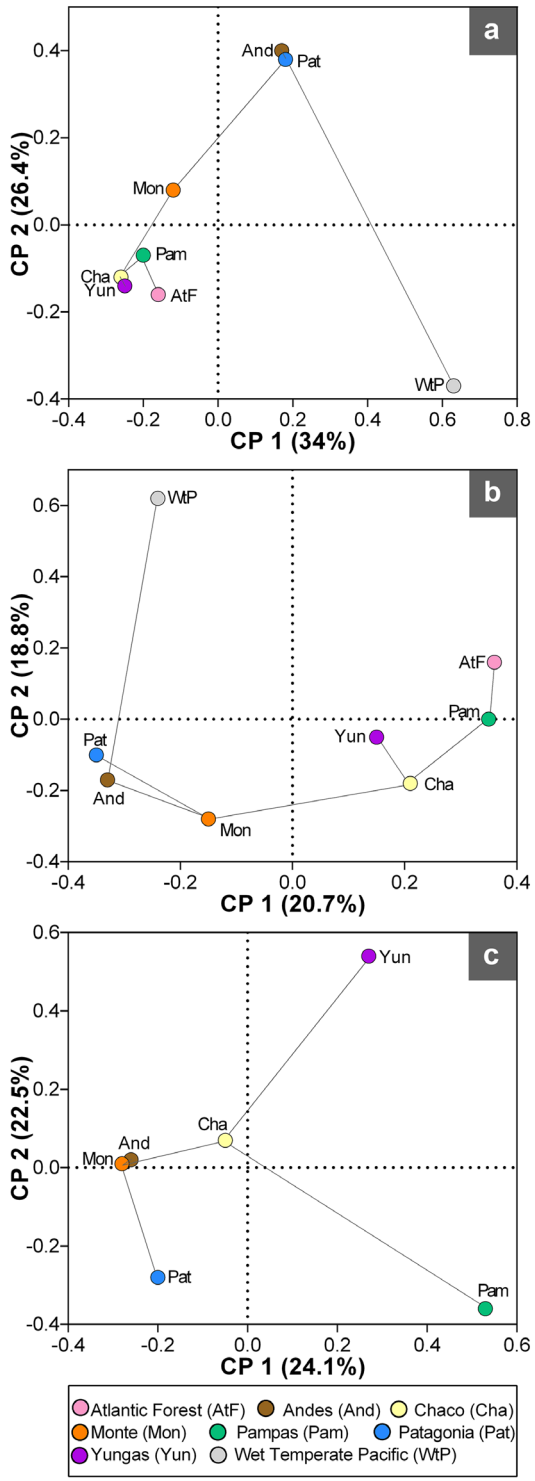

Figure 6. PCoA dispersion diagrams of Solanaceae species richness of Argentina (see Methods for details). a. Total genera (34). b. Total specific and infraspecific taxa (338). c. Total endemic specific and infraspecific taxa (93).

even have endemic genera such as *Vestia* Willd. and *Latua* Phil. in Chile, and *Duckeodendron*, *Dyssochroma* Miers, *Heteranthia* Nees & Mart. and *Metternichia* J.C.Mikan in Brazil. Both countries have also a high percentage of endemic species considering all vascular plants: 55% for Brazil (Flora do Brasil 2019b) and almost 40% for Chile (Rodriguez et al. 2018).

The non South American countries, Costa Rica and Mexico, have the highest biodiversity indexes in the world (Grayum et al. 2004, Villaseñor 2016); specifically, Mexico has a great Solanaceae diversity, with 34 genera and 381 species (Martínez et al. 2017), while in Costa Rica the number is lower (23 genera and 180 species) (Bohs 2015). Thus, the amount of these taxa for each country match with what is expected according to their areas, as happens in several South American countries (e.g., Argentina, Brazil, Colombia, Venezuela) tested in this paper.

Regarding Argentina, our inventory contributed to the increase of number of species compared to Barboza (2013) adding one species (i.e., 319), while the number of specific and infraspecific taxa reminded at 338. *Solanum rostratum* is the new introduced species (Del Vitto & Petenatti 2015). Beyond the numbers, it should be noted that there were some changes in the taxonomy and distribution: *Solanum chamaesarachidium* Bitter and *Solanum excisirhombeum* Bitter are now considered synonyms of *Solanum weddellii* Phil. and *Solanum grandidentatum* Phil (Solanaceae Source 2019), respectively; *Salpichroa ramosissima* Miers was excluded from the Argentinean flora, *Salpichroa tristis* var. *lehmanni* (Dammer) Keel is now considered at specific level (i.e., *Salpichroa lehmannii* Dammer) (Gonzáles et al. 2018); and the genus *Iochroma* does not grow in Argentina anymore since *Iochroma australe* Griseb has been

Critically Endangered (CR)	
Benthamiella azorelloides Speg.	B2ab(iv)
Benthamiella chubutensis A. Soriano	B2ab(iv)
Calibrachoa longistyla Stehmann & Greppi	B1ab(iii)
Eriolarynx iochromoides (Hunz.) Hunz.	C2a(i)
Jaborosa ameghinoi (Speg.) Macloskie & Dusén	B1ab(iv);D
Lycium ciliatum x cestroides Hieron.	B1ab(iii,v)
Lycium ciliatum x elongatum Bernardello	B1ab(iii)
Solanum concarense Hunz.	B1ab(iii)
Solanum pedersenii Cabrera	B2ab(iii)

Endangered (EN)	
Benthamiella sorianoi S. Arroyo	B1ab(v)
Nierembergia tucumanensis Millán	D
Physalis victoriana J.M. Toledo	B1ab(iii)
Sclerophylax difulvioi Del Vitto & Peten.	D
Solanum homalospermum Chiarini	B1ab(iii)
Solanum profusum C.V. Morton	B1ab(iii)

Vulnerable (VU)	
Benthamiella graminifolia Skottsb.	D1
Benthamiella skottsbergii A. Soriano	D1
Benthamiella spegazziniana A. Soriano	D1
Cestrum kunthii Francey	B1ab(iii,iv)
Jaborosa cabrerae Barboza	D1
Jaborosa kurtzii Hunz. & Barboza	B2ab(iv)
Jaborosa odonelliana Hunz.	B1ab(iii)
Jaborosa oxipetala Speg.	B1ab(iii,iv)
Lycium athium Bernardello	D2
Nierembergia tandilensis (Kuntze) Cabrera	D2
Sclerophylax cuyanus Di Fulvio	B1ab(iii)
Solanum mortonii Hunz.	D2
Solanum x rechei Hawkes & Hjert.	D2

Near Threatened (NT)	
Eriolarynx lorentzii (Dammer) Hunz.	Population size near 2,000 mature individuals *
Lycium elongatum x cestroides Hieron.	The taxon is declining and severely fragmented, but has an EOO of 23,375 km²
Sclerophylax cocuccii Di Fulvio	Population size near 2,000 mature individuals *
Solanum glandulosipilosum Bitter	The taxon is declining and occurs at not many more than 10 locations, but has an EOO higher than 20,000 km²
Solanum salamancae Hunz. & Barboza	Population size near 2,000 mature individuals *
Solanum x brucheri Correll	Population size near 2,000 mature individuals *

Least Concern (LC)	
Benthamiella longifolia Speg.	*Pantacantha ameghinoi* Speg.
Benthamiella pycnophylloides Speg.	*Petunia patagonica* (Speg.) Millán
Fabiana foliosa (Speg.) S.C. Arroyo	*Sclerophylax adnatifolia* Di Fulvio
Fabiana friesii Dammer	*Sclerophylax arnottii* Miers
Fabiana nana (Speg.) S.C. Arroyo	*Sclerophylax caducifructus* Di Fulvio
Fabiana peckii Niederl.	*Sclerophylax cynocrambe* (Griseb.) Griseb.
Fabiana punensis S.C. Arroyo	*Sclerophylax hunzikeri* Di Fulvio
Jaborosa bergii Hieron.	*Sclerophylax kurtzii* Di Fulvio
Jaborosa lanigera (Phil.) Hunz. & Barboza	*Sclerophylax ruiz-lealii* Di Fulvio
Jaborosa leucotricha (Speg.) Hunz.	*Sclerophylax tenuicaulis* Di Fulvio
Jaborosa sativa (Miers) Hunz. & Barboza	*Sclerophylax trispermus* Di Fulvio
Leptoglossis linifolia (Miers) Griseb.	*Solanum annuum* C.V. Morton
Lycium ameghinoi Speg.	*Solanum delitescens* C.V. Morton
Lycium elongatum Miers	*Solanum euacanthum* Phil.
Lycium fuscum Miers	*Solanum hastatilobum* Bitter
Lycium gilliesianum Miers	*Solanum juvenale* Thell.
Lycium infaustum Miers	*Solanum kurtzianum* Bitter & Wittm.
Lycium repens Speg.	*Solanum neorossii* Hawkes & Hjert.
Lycium schreiteri F.A. Barkley	*Solanum pygmaeum* Cav.
Nicotiana acaulis Speg.	*Solanum reductum* C.V. Morton
Nicotiana ameghinoi Speg.	*Solanum venturii* Hawkes & Hjert.
Nicotiana noctiflora Hook.	*Solanum vernei* Bitter & Wittm.
Nicotiana spegazzinii Millán	*Solanum x aemulans* Bitter & Wittm.
Nierembergia veitchii Hook.	

Data Deficient (DD)	
Jaborosa chubutensis Barboza & Hunz. (Fig. 8a)	Known exclusively for the type material from Chubut province.
Lycium pubitubum C.L. Hitchc. (Fig. 8b)	Known exclusively by three specimens from Santa Cruz province, without precise location data.

Figure 7. Conservation status of Solanaceae species endemic to Argentina. The IUCN criteria used for classification are indicated. Asterisk (*) indicates that the best estimates of population size is 2,000 mature individuals, but this estimate is very uncertain, and as low as 1,000 mature individuals cannot be ruled out.

recently transferred to *Eriolarynx* (*Eriolarynx australis* (Griseb.) J.M.H. Shaw) (Shaw 2018).

The Yungas and Atlantic Forest are the ecoregions of greatest total species richness of vascular plants (Grossi et al. 2012, Zuloaga & Belgrano 2015). However, for Solanaceae, the Chaco is the ecoregion with the largest number of genera, and specific and infraspecific taxa. For endemics, Monte is the ecoregion with the largest number of endemic specific and infraspecific taxa of Solanaceae, coinciding with southern South America total endemic vascular plants (Zuloaga & Belgrano 2015). The Andes and Patagonia, important ecoregions for total endemic vascular species, particularly the Poaceae and Asteraceae (Katinas et al. 2007, Biganzoli & Zuloaga 2015), are also main centres for endemics Solanaceae (see Fig. 5b).

Although in this work environmental aspects were not included in the diversity analyses, some general remarks could be outlined. Some genera appear to have specific habitat or bioclimatic preferences in their distribution in South America. Many of the species of *Calibrachoa* Cerv. have a very limited geographical distribution and, although some have overlapping

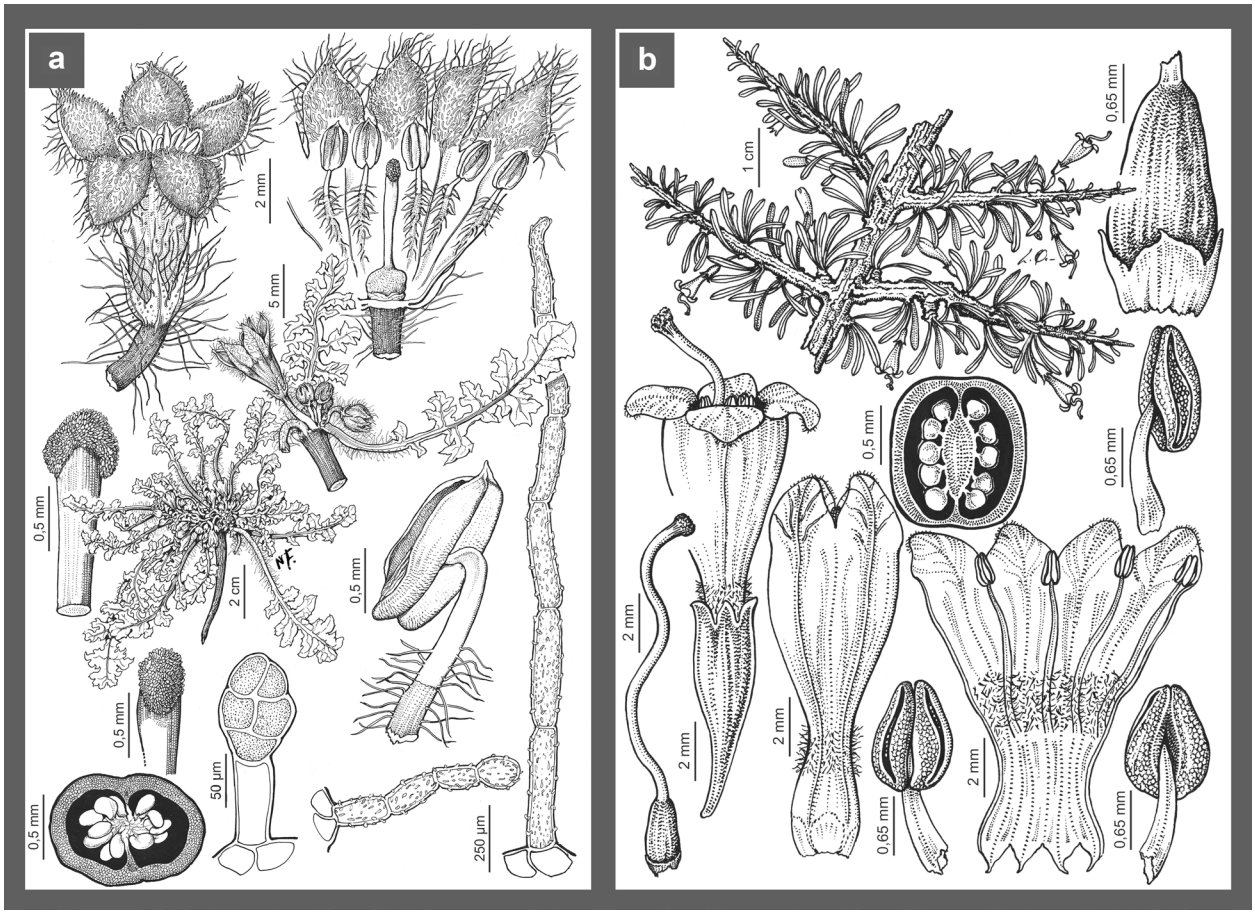

Figure 8. Data Deficient species from Argentina. a. ***Jaborosa chubutensis*** (taken from Barboza & Hunziker 1987). b. ***Lycium pubitubum*** (taken from Bernardello 1986).

occurrence areas, they generally occupy different environments, characterized by different types of soils in general with acid pH (Greppi et al. 2013). *Solanum* diversity patterns have been widely explored showing higher species richness in mountains, and hence high diversity in Andean countries (e.g. Särkinen et al. 2015). *Nolana* species are largely restricted to fog-dependent desert *lomas* formations of coastal Peru and Chile (Dillon et al. 2009). Four endemic Brazilian genera live in restricted areas: *Dyssochroma* inhabits exclusively in the Atlantic Forest, *Heteranthia* and *Metternichia* grow in the Caatinga and Atlantic Forest while *Duckeodendron* is from Amazonia (Flora do Brasil 2019a). Finally, genera of the tribe Benthamielleae (Hunz.) Hunz. are typical of Patagonia, where *Pantacantha* is mostly an orophilous genus (Hunziker 2001, Barboza GE & Cantero JJ, personal communication).

Among the native species growing in Argentina, some of them have small or infrequent populations or there are no recent collections; these are: *Calibrachoa pubescens* (Spreng.) Stehmann, *Cestrum bracteatum* Link & Otto, *C. reflexum* Sendtn., *Exodeconus integrifolius* (Phil.) Axelius, *Lycium cyathiforme* C.L. Hitchc., *Melananthus multiflorus* Carvalho, *Salpiglossis sinuata* Ruiz & Pav., *Schizanthus hookeri* Gillies ex Graham, *Sessea vestioides* (Schltdl.) Hunz., *S. regnellii* Taub., *Solanum furcatum* Dunal, *S. grandidentatum* Phil., *S. toldense* Matesevach & Barboza and *S. turneroides* Chodat (Barboza

2013). Mostly these species seem to be locally rare or really discrete, and therefore hard to find. One example is the endemic *Jaborosa ameghinoi* (Speg.) Macloskie & Dusén, rediscovered by González et al. (2017) after more than a century since the original collection, which was probably overlooked many times because it loses its aerial parts and stays under the soil during most of the year, as happens in other Patagonian species (e.g., as other *Jaborosa* species or *Fabiana nana* (Speg.) S.C. Arroyo; Barboza GE, personal communication). We recommend carrying out further sampling efforts that could improve the knowledge of species' geographic distribution which is essential for conservation planning and forecasting (Elith et al. 2006). In relation to the introduced Solanaceae species in Argentina, the Asiatic *Lycium barbarum* is cultivated in Santa Cruz province where it could escape from gardens (Bernardello 2013). Usually, the North American species of *Datura* (*D. ferox*, *D. inoxia* and *D. stramonium*) grow as weeds and ruderals, mainly *D. ferox* which is an important noxious plant in summer crop fields (Fernández et al. 2016). Up to now, the Brazilian *Brugmansia suaveolens* (Hay 2014, Dupin 2017) has been collected infrequently at different sites in NE Argentina (Misiones) (Documenta Florae Australis 2019) and *Solanum capsicoides* is cultivated as ornamental (Chiarini 2013). One population of the North American *Solanum rostratum* was recently found in central western Argentina (San Luis Province) as a ruderal (Del Vitto & Petenatti 2015) and no other record has been cited.

Only a few species of Solanaceae were previously assigned to IUCN categories in Argentina; *Physalis victoriana* J.M. Toledo was considered as Endangered (EN) by Toledo (2013) and *Solanum pygmaeum* Cav. as Least Concern (LC) by Särkinen et al. (2018), in coincidence with our proposal. In another case, Delucchi (2006) suggests a local categorization for plants of Buenos Aires, categorizing the endemic *Nierembergia tandilensis* (Kuntze) Cabrera as Critically Endangered (CR); however, we propose to reformulate its status as Vulnerable (VU) at global scale. A constant update of the conservation status of the species is necessary, since population changes can happen (IUCN 2017). Furthermore, efforts to recollect the two endemics with Data Deficient (DD), *Jaborosa chubutensis* Barboza & Hunz. and *Lycium pubitubum* C.L. Hitchc., only known by their type collections (Bernardello 1986, Barboza & Hunziker 1987), are needed.

Land use change, mainly deforestation, causes environmental impacts such as biodiversity loss in South America (De Sy et al. 2015). The expansion of the agricultural frontier has promoted deforestation in tropics. Brazil, Argentina and Paraguay are the three countries with the largest loss of tree cover during 1982-2016, and Argentina alone lost an area of 113,000 km^2 (25%) during these years (Song et al. 2018). In Argentina, during the 20^{th} century and especially in more recent decades, the lowland landscape occupied by Chaco and Espinal forests has been transformed into an agricultural system at high deforestation rates (Boletta et al. 2006). In the mountain area of the same regions, fire, grazing and the recent advance of exotic woody species have transformed the landscape into a complex mosaic of degraded native forests, monospecific stands of woody exotics, shrublands and grasslands (Cabido et al. 2018). In relation to these changes in land use, it is alarming that many of the taxa proposed here as threatened are only found in the margins of cultivated areas, increasing the risk of loss of their populations as a consequence of habitat changes (i.e., *Solanum concarense* Hunz.). Godoy-Bürki et al. (2014) showed that in north-western (NW) Argentina, most protected areas are concentrated in the

ecoregion with the highest diversity, the humid Yungas region, but the endemics are mainly found in the arid NW Argentina ecoregions. They also considered that the current reserve system in NW Argentina is ineffective. In our case, most of Solanaceae endemics grow in the Monte and Andes arid ecoregions also pointing out the need for choosing new priority areas for conservation as it has already been stated by Barboza et al. (2016). No formal program has been yet established for conservation of the endemic flora in Argentina. Only a preliminary data base (PlanEAr 2019) for endemic species was generated recently, which is not updated nor based on IUCN criteria.

In Argentina, scientific research has been historically supported by public funds and the national state usually defines research priority areas and programs (Bekerman 2016). In this sense, the Red List of vascular plants in Argentina should be a priority issue in the near future.

CONCLUSIONS

South America has a great diversity of Solanaceae which represents approximately 60% of the Solanaceae diversity at the global scale and it is extremely variable between South American countries. Peru and Brazil host the highest diversity and the highest number of endemic species of Solanaceae, so its conservation should be a priority issue considering its biological and economic importance.

In Argentina, Chaco is the most diverse ecoregion for Solanaceae while Monte and Andes have the highest number of endemic species. Furthermore, the conservation status assessment revealed that 34% of the endemic species of Solanaceae belongs to threatened categories. No formal conservation program exists for Argentine vascular plants. We propose the Monte and Andes ecoregions as priority areas for conservation and an urgent agenda for the Chaco ecoregion where land use changes have dramatically destroyed the natural habitats where a high percentage of endemic Solanaceae grow.

Acknowledgments

The authors thanks to curators and staff of the Argentine herbaria for their disposition to provide information of the Solanaceae collections; to G. Bernardello, F. Chiarini, A.A. Cocucci, R. Deanna, L. Giacomin, M. Matesevach, and A. Romanutti for specifying either the identification or the distribution and the abundance of the populations of some species; to R. Deanna for *Nierembergia rigida* and *Physalis viscosa* photographs; and to the anonymous reviewers for constructive suggestions to improve the manuscript. V.P. thanks the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) for the doctoral fellowship. This study was funded by the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)-Argentina (PIP number 11220170100147CO), Secretaría de Ciencia y Tecnología (SECyT)-UNC (Res. 411-18, Universidad Nacional de Córdoba, Argentina) and SECyT-UNRC (Res. Rec. 130/2017, Universidad Nacional de Río Cuarto, Argentina).

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SUPPLEMENTARY MATERIAL

Table SI, Table SII, Table SIII.

How to cite

PALCHETTI MV, CANTERO JJ & BARBOZA GE. 2020. Solanaceae diversity in South America and its distribution in Argentina. An Acad Bras Cienc 92: e20190017. DOI 10.1590/0001-3765202020190017.

Manuscript received on January 7, 2019;
accepted for publication on October 14, 2019

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MVP reviewed literature, analyzed and interpreted the data, prepared and wrote the manuscript; GEB checked the identification of the specimens; GEB & JJC reviewed the manuscript and were responsible for the study conception and design, and funds acquisition. All authors discussed the results, critically revised the manuscript and approved the final version.

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