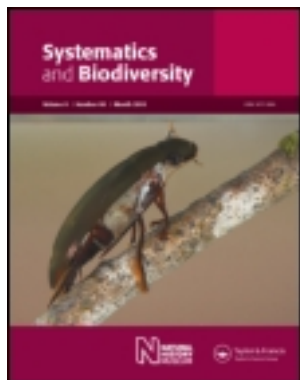


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Research Article

The major diversity centre for Neotropical Turneraceae

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The Neotropical country where the Turneraceae are best represented is Brazil; 82% of the American species are native, and 73% of them are endemic to this country. The most diverse states are Bahia, Minas Gerais and Goiás. Within this area the diversity – in terms of number of species – was analysed at a level of one degree square, taking into account the phytogeographic domains (biomes) recognized in Brazil. The distribution of endemic and rare species was also explored. The major centre of diversity is located in the Chapada Diamantina, Bahia, inside the biome ‘Caatinga’, but there are hotspots in Minas Gerais and Goiás, within the biome ‘Cerrado’. The biome with highest number of endemic species is the ‘Cerrado’, followed by the ‘Caatinga’.

Key words: Amazônia, Brazil, Caatinga, campo rupestre, Cerrado, endemic species, Mata Atlântica, native species, *Piriqueta*, rare species, restinga, *Turnera*

Introduction

Turneraceae is a family of ten genera and about 220 species, distributed from North to South America and in Africa including Madagascar and the Mascarene Islands (Arbo, 2007). It is represented in America by four genera: *Adenoea*, monospecific, endemic to Cuba (Arbo, 1977); *Erblichia*, with one species in Mexico and Central America and four in Madagascar (Arbo, 1979); *Piriqueta*, with 44 American species and one in South Africa (Arbo, 1995); and *Turnera* with 140 American species and two in Africa, which was reviewed in four contributions (Arbo, 1997, 2000, 2005, 2008).

Without any doubt, the neotropical country with the greatest richness in Turneraceae is Brazil, with 155 native species belonging to two genera: *Piriqueta* and *Turnera*. When the revision of *Piriqueta* was published, the mountainous region of Bahia was proposed as the generic centre of variation (Arbo, 1995: fig. 20). During the revision of the different series of *Turnera*, it became clear that the states with greater diversity are Bahia, Goiás (including the Federal District) and Minas Gerais.

Some time ago, a contribution was prepared for the project ‘Plantas raras do Brasil’ (Giulietti *et al.*, 2009). Rare plants were defined as species with a known distri-

bution less than 10 000 km². It turned out that Turneraceae was the family with the highest proportion of rare species in Brazil (60%). Unfortunately, it was not possible to include in that work the series *Leiocarpae*, which is the largest of the genus *Turnera*. In this contribution the whole genus is covered, as well as many new collections, so the present list of rare species shows some differences.

The aim of this paper was to analyse the distribution of *Piriqueta* and *Turnera* in order to find out which is their major centre of diversity in Brazil, taking into account the phytogeographic domains or biomes (IBGE, 2004) present in the country (Fig. 1). The distribution of endemic and rare species is also considered.

Materials and methods

The analyses were based on herbarium material and field collections. The Brazilian exsiccata of 99 herbaria (American and European) were studied: about 4200 samples of *Turnera* and 1400 of *Piriqueta*. Field trips were made in Bahia, Goiás, Espírito Santo, Minas Gerais, Pernambuco and Rio Grande do Sul.

Each herbarium specimen was geo-referenced, in order to make distribution maps. These were overlapped with the phytogeographic domains (biomes) recognized in Brazil (IBGE, 2004). The biomes and the biogeographic regions devised by Morrone (2001) are similar, except

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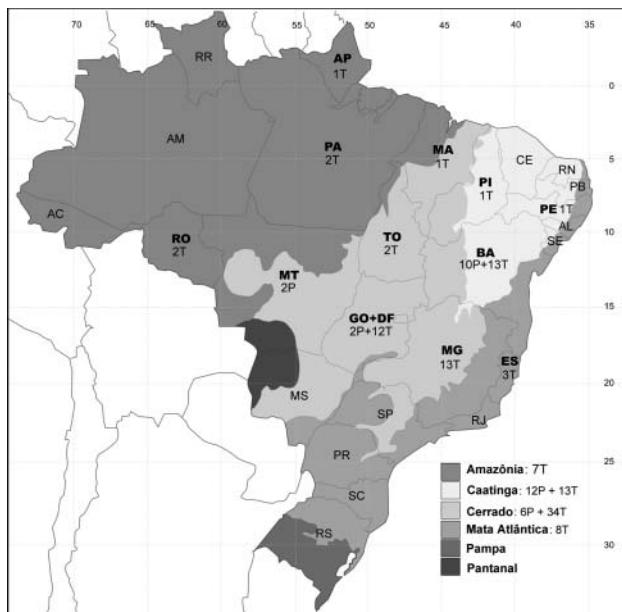


Fig. 1. Brazilian Biota and number of species of Turneraceae endemic to each state and biome. P: *Piriqueta*; T: *Turnera*.

for the following main differences: (1) the Southwestern part of the Amazonian subregion (Morrone, 2001) corresponds to the Brazilian biome 'Pantanal', in the states Mato Grosso and Mato Grosso do Sul; (2) the Chaquean subregion of Morrone matches with the Brazilian biomes 'Caatinga' (Northeast section), 'Cerrado' (central section) and 'Pampa' (Southeast end, part of the state Rio Grande do Sul). In this paper, the maps are based upon the Brazilian biomes.

The species diversity, in terms of number of species, was plotted at a level of one degree square (d.sq.). This task was made for each genus and species, within the area bounded by latitudes 5°–24°S and longitudes 35°–54°W. This area was selected because earlier studies showed that it is the most diverse for Brazilian Turneraceae.

Separate maps were prepared for the rare species, identified according to the definition of Giulietti *et al.* (2009), in order to be consistent with the previous work. Some species are confined to a single degree square; other distributions cross lines of latitude or longitude or show linear outline, but the area is up to 10 000 km².

A Principal Components Analysis (PCA) was performed to analyse the interdependence of metric variables and find a best graphical representation of data variability in a table of *n* observations and *p* columns or variables. The PCA tries to find a new set of uncorrelated variables (components) with minimal loss of information, to explain the structure of variation in the ranks of the data table.

Response variables were number of species of *Piriqueta* and *Turnera* present in each degree square. Classification criteria were latitude, longitude, maximum and minimum

altitude of each square. The altitude was determined with the *Brazil in the International Chart of the World on the Millionth Scale* (IBGE, 1972).

The following abbreviations are used: Degree square: d.sq.; Mean altitude: m.alt. The Brazilian states are abridged with their usual two-letter acronyms: Acre – AC; Alagoas – AL; Amapá – AP; Amazonas – AM; Bahia – BA; Ceará – CE; Distrito Federal – DF; Espírito Santo – ES; Goiás – GO; Maranhão – MA; Mato Grosso – MT; Mato Grosso do Sul – MS; Minas Gerais – MG; Pará – PA; Paraíba – PB; Paraná – PR; Pernambuco – PE; Piauí – PI; Rio de Janeiro – RJ; Rio Grande do Norte – RN; Rio Grande do Sul – RS; Rondônia – RO; Roraima – RR; Santa Catarina – SC; São Paulo – SP; Sergipe – SE; Tocantins – TO.

Results

Turneraceae are found in every state of Brazil. *Piriqueta* has 37 native species, 25 of them being endemic (68%). *Turnera* is ordered in 11 series (Arbo, 2008), established upon morphological and cytological data, all of them with taxa endemic to Brazil. In fact, whole groups of *Turnera* are endemic to Brazil, like the small series *Papilliferae*, *Sessilifoliae* and *Conciliatae* and the subseries *Umbilicatae*. The series *Anomalae*, *Capitatae* and *Microphyllae* are not endemic to Brazil, but all their species are native to this country (Table 1). At present, 118 Brazilian native species are recognized, of which 85 are endemic (73%) (Forzza *et al.*, 2010).

The states with larger number of native species are BA: 59, MG: 53 and GO: 44 (Table 1). Some endemic species have wide areas, embracing two or more states, while many are endemic to certain states: BA: 23; GO + DF: 14; MG: 13; ES: 3; MT, PA, RO and TO: 2; AP, MA, PE, and PI: 1 (Fig. 1).

In addition, there are some endemic taxa at subspecific level. *Piriqueta guianensis* subsp. *elongata* is endemic to NE Brazil, whereas the typical subspecies grows in RR and Guyana. *P. tamberlikii* subsp. *rotundifolia* is endemic to MG, while the typical subspecies occurs in mid-west Brazil and Paraguay. *T. blanchetiana* var. *blanchetiana* is endemic to NE Brazil, whilst var. *subspicata* Urb. lives in MS and Paraguay. *T. hindsiana* subsp. *brachyantha* was collected in MA, BA and MG, whereas the typical subspecies is endemic to Ecuador. *T. pumilea* var. *pumilea* has a wide distribution in the Neotropics, but var. *piauhyensis* is endemic to NE Brazil.

The phytogeographic links observed within the distribution of endemic taxa at subspecific level are of particular interest; Harley (1995) pointed out that similar cases have been cited in many families.

Among the species of Turneraceae endemic to Brazil, there are many which are also endemic to certain biomes. It is noteworthy to point out that the species of *Piriqueta* are endemic only to 'Caatinga' or 'Cerrado', while *Turnera*

Table 1. Number of native, endemic and rare species according to the present taxonomic structure of the genera for Brazil and most diverse states. Endemic groups ▲; groups with all species native ■.

| Genera | # spp | native/endemic | | | | | | | rare spp. |
|------------------------|-------|----------------|-------|-------|-------|------|------|------|-----------|
| | | Brazil | BA | MG | GO+DF | PI | MT | PA | |
| <i>Piriqueta</i> | 45 | 37/25 | 21/10 | 10/0 | 11/2 | 9/0 | 9/2 | 4/0 | 14 |
| <i>Turnera</i> | 142 | 118/85 | 38/13 | 43/13 | 33/13 | 15/1 | 13/0 | 16/2 | 42 |
| Series or Subseries | | | | | | | | | |
| <i>Annulares</i> | 4 | 3/1 | 1/0 | — | 1/0 | — | 1/0 | 2/0 | — |
| <i>Anomala</i> ■ | 14 | 14/13 | 5/1 | 1/0 | — | 2/0 | 1/0 | 2/2 | 7 |
| <i>Capitata</i> ■ | 10 | 10/8 | 3/3 | 3/2 | — | — | — | — | 6 |
| <i>Conciliata</i> ▲ | 1 | 1/1 | — | — | — | — | — | — | 1 |
| <i>Leiocarpae</i> | 56 | 49/38 | 11/3 | 22/5 | 26/11 | 5/1 | 5/0 | 3/0 | 19 |
| <i>Microphyllae</i> ■ | 5 | 5/4 | 4/1 | 3/1 | — | 2/0 | — | — | 2 |
| <i>Papilliferae</i> ▲ | 2 | 2/2 | 2/1 | 1/0 | — | 1/0 | — | — | 1 |
| <i>Salicifoliae</i> | 12 | 9/4 | 1/0 | 4/2 | 1/0 | — | 2/0 | 3/0 | 3 |
| <i>Sessilifoliae</i> ▲ | 2 | 2/2 | — | 2/2 | — | — | — | — | 1 |
| <i>Stenodictyae</i> | 9 | 5/1 | — | — | — | — | 1/0 | 3/0 | — |
| <i>Turnera</i> | 19 | 10/3 | 6/0 | 10/0 | 3/0 | 4/0 | 3/0 | 3/0 | — |
| <i>-Umbilicatae</i> ▲ | 8 | 8/8 | 5/4 | 2/1 | 3/2 | 4/0 | — | — | 2 |

shows species endemic to four biomes. The highest number of endemisms is found in the biome ‘Cerrado’, the next is ‘Caatinga’, followed by ‘Mata Atlântica’; the last is ‘Amazônia’. There are no species endemic to ‘Pantanal’ or ‘Pampa’ (Fig. 1 and Table 2).

Species diversity

The area analysed, 5°–24°S and 35°–54°W, includes the most diverse states: BA, GO and MG, as well as TO and the states on the Atlantic coast: RN, PB, PE, AL, SE, ES and RJ. All the biomes with endemic species are represented in this area: ‘Amazônia’, ‘Cerrado’, ‘Caatinga’ and ‘Mata Atlântica’. *Piriqueta* and all the series of the genus *Turnera*

are found within this zone. The data show that in each d.sq. 0–12 species of *Piriqueta* and 0–15 species of *Turnera* may be found.

The greatest diversity is found in the d.sq. 13°S 41°W (BA) with 12 species of *Piriqueta* and 15 species of *Turnera*. The following towns: Piatã, Abaira, Mucugê, Jussiape, Rio de Contas, Barra da Estiva, Livramento do Brumado, Ituaçu and Contendas do Sincorá are located there. The highest mountains of NE Brazil, Pico do Barbado (2033 m) and Pico das Almas (1850 m) are situated in this d.sq.

The contiguous d.sq. North 12°S 41°W where Palmeiras, Lençóis and Andaraí are located, holds nine species of *Piriqueta* and 12 of *Turnera* (Fig. 2). The National Park Chapada Diamantina is enclosed within these two squares.

Table 2. Brazilian Turneraceae, species endemic to each biome. Rare species: ♣.

| Biomes | | |
|----------------|------|---|
| name | #spp | Turneraceae endemic to each biome (among species endemic to Brazil) |
| Amazônia | 14 | 7: <i>T. amapaensis</i> ♣, <i>T. amazonica</i> , <i>T. discors</i> ♣, <i>T. kuhlmanniana</i> ♣, <i>T. laciniata</i> , <i>T. tapajoensis</i> ♣, <i>T. urbanii</i> |
| Caatinga | 51 | 25: <i>P. abairana</i> ♣, <i>P. asperifolia</i> , <i>P. assuruensis</i> ♣, <i>P. carnea</i> ♣, <i>P. dentata</i> ♣, <i>P. douradina</i> ♣, <i>P. flammea</i> ♣, <i>P. nanuzae</i> ♣, <i>P. plicata</i> , <i>P. revoluta</i> ♣, <i>P. scabrida</i> ♣, <i>P. sulfurea</i> , <i>T. asymmetrica</i> ♣, <i>T. caatingana</i> ♣, <i>T. chrysocephala</i> , <i>T. harleyii</i> , <i>T. hebeptala</i> , <i>T. involucrata</i> ♣, <i>T. jobertii</i> ♣, <i>T. joelii</i> , <i>T. leptosperma</i> , <i>T. simulans</i> , <i>T. stachydifolia</i> , <i>T. stenophylla</i> ♣, <i>T. uleana</i> |
| Cerrado | 75 | 40: <i>P. araguaiana</i> ♣, <i>P. breviseminata</i> , <i>P. caiapoensis</i> ♣, <i>P. cristobaliae</i> ♣, <i>P. emasensis</i> ♣, <i>P. lourteigiae</i> ♣, <i>T. angelicae</i> ♣, <i>T. arcuata</i> , <i>T. cipoensis</i> ♣, <i>T. clauseniana</i> ♣, <i>T. coccinea</i> ♣, <i>T. collotricha</i> ♣, <i>T. coriacea</i> ♣, <i>T. crulsii</i> ♣, <i>T. diamantinae</i> ♣, <i>T. elliptica</i> ♣, <i>T. emendata</i> , <i>T. fissifolia</i> ♣, <i>T. foliosa</i> ♣, <i>T. gardneriana</i> ♣, <i>T. glabrata</i> ♣, <i>T. gouveiana</i> ♣, <i>T. humilis</i> ♣, <i>T. ignota</i> ♣, <i>T. incana</i> , <i>T. iterata</i> ♣, <i>T. lamiifolia</i> , <i>T. lanceolata</i> , <i>T. paradoxa</i> ♣, <i>T. patens</i> , <i>T. pinifolia</i> ♣, <i>T. pohliana</i> , <i>T. princeps</i> ♣, <i>T. purpurascens</i> , <i>T. reginae</i> ♣, <i>T. revoluta</i> ♣, <i>T. riedeliana</i> ♣, <i>T. rosulata</i> ♣, <i>T. tenuicaulis</i> , <i>T. vallii</i> ♣, <i>T. vicaria</i> ♣ |
| Mata Atlântica | 38 | 8: <i>T. albicans</i> ♣, <i>T. hatschbachii</i> ♣, <i>T. lucida</i> , <i>T. maracasana</i> ♣, <i>T. marmorata</i> ♣, <i>T. pernambucensis</i> ♣, <i>T. rubrobracteata</i> ♣, <i>T. sancta</i> ♣ |

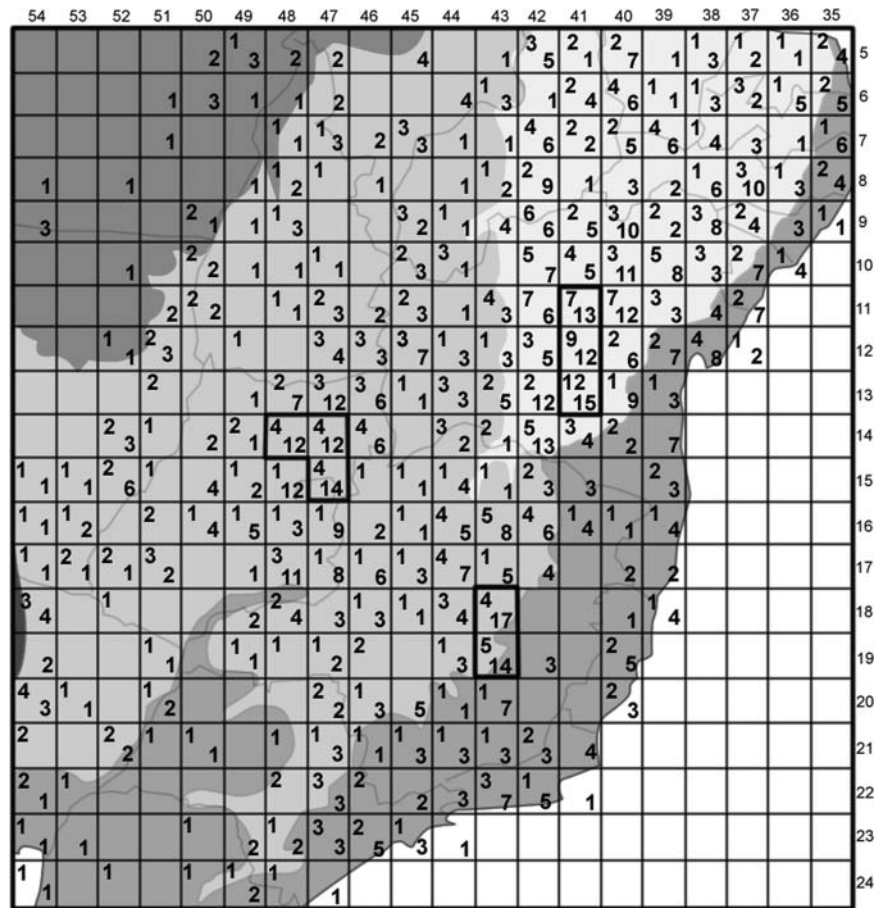


Fig. 2. Diversity per degree square. Number of species of *Piriqueta* (above-left) and *Turnera* (below-right). Biomes represented as in Fig. 1.

The next d.sq. North 11°S 41°W, where Morro do Chapéu is placed, shows 20 species. In the contiguous square East 11°S 40°W where Jacobina is situated, there are 19 species (Fig. 2). The m.alt. of the last squares is 700 m or above.

The major diversity in MG is found in the Cadeia do Espinhaço range, with peaks over 2000 m high. The d.sq. with most species – four of *Piriqueta* and 17 of *Turnera* – is 18°S 43°W (Diamantina, Gouveia, Serro and Congonhas do Norte; m.alt. 969 m). The next d.sq. South 19°S 43°W (Lagoa Santa, Morro do Pilar, Jaboticatubas, Santana do Riacho and Serra do Cipó; m.alt. 852 m) shows five species of *Piriqueta* and 14 species of *Turnera* (Fig. 2).

The most diverse d.sq.s of GO are located in the Brazilian Planalto. The d.sq. 15°S 47°W (m.alt. 900 m) where the DF is situated shows 18 species. In the next d.sq. North 14°S 47°W (m.alt. 925 m) the Chapada dos Veadeiros, Alto Paraíso de Goiás and São João da Aliança are placed; Niquelandia and Colinas are located in the contiguous square West 14°S 48°W (m.alt. 700 m). These d.sq.s show four species of *Piriqueta* and 12 species of *Turnera* each

(Fig. 2). In the d.sq. 15°S 48°W, where the Serra dos Pirineus is situated, there are also 12 species of *Turnera* (Fig. 2).

The places of BA with highest diversity belong to the biome 'Caatinga', while in MG and GO they belong to the biome 'Cerrado' (Fig. 2). A list of the species found in the most diverse d.sq. for each state is provided in Appendix 1 (see supplementary material, which is available on the Supplementary Content tab of the article's online page at <http://dx.doi.org/10.1080/14772000.2011.603382>).

PCA analysis

Response variable is associated with latitude and longitude, this behaviour is shown in the biplots resulting from PCA. No behaviour pattern of number of species of *Piriqueta* and *Turnera* related to d.sq. maximum and minimum altitudes was found. However, the mean altitude of all the d.sq. with 14 or more species is between 700 and 1216 m.

Figure 3 shows the result of a PCA analysis exploring the association between number of species of *Piriqueta*

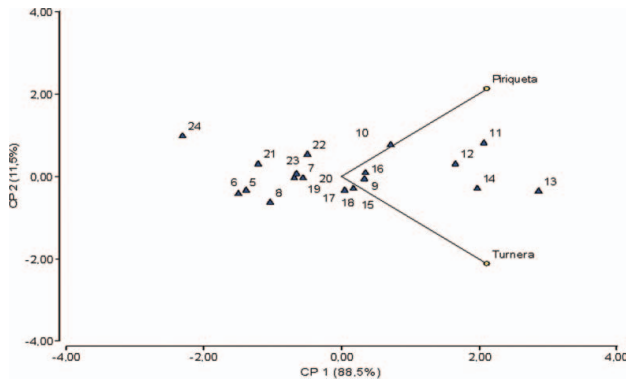


Fig. 3. Number of species of *Piriqueta* and *Turnera* per degree square in relation with latitude.

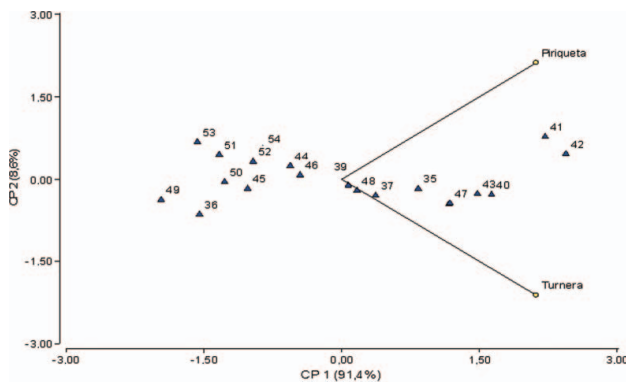


Fig. 4. Number of species of *Piriqueta* and *Turnera* per degree square in relation with longitude.

and *Turnera* per d.sq. in relation to latitude. It shows an association between latitude and number of species of each genus, greater in latitudes 11, 12, 13 and 14.

Figure 4 shows the result of a PCA analysis exploring the association between number of species of *Piriqueta* and *Turnera* per d.sq. in relation to longitude. It displays an association between longitude and number of species of each genus, greater in longitudes 40, 41, 42 and 43.

Rare species

There are 14 Brazilian species of *Piriqueta* which meet the definition of rare plants. *P. asperifolia* was listed as a rare plant in Giulietti *et al.* (2009); at present the known area of this species exceeds 10 000 km², so it should no longer be considered as rare.

Five species are found within the biome 'Cerrado'; *P. lourteigiae* and *P. cristobaliae* are native to MT, *P. araguaiana* to TO and two species to GO. The others are native to BA in the 'Caatinga', eight of them occur in the Chapada Diamantina (Fig. 5, Table 2).

Within *Turnera*, 42 species fall into the range of rare species. They belong to nine of 11 series of the genus (Figs 6 and 8, Table 2). They are absent in series *Annulares* and *Stenodyctiae*. Subseries *Turnera* does not have rare species,

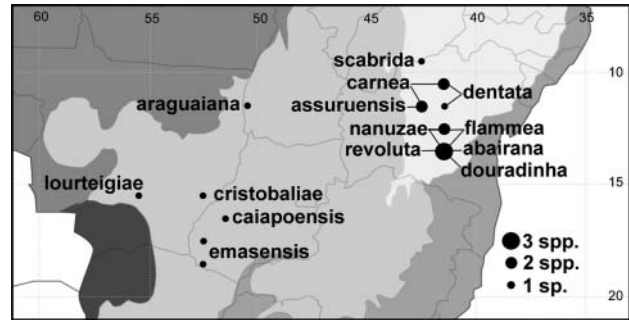


Fig. 5. Distribution of rare species of *Piriqueta*.

but there are two in subseries *Umbilicatae*. Series *Leiocarpae* was not fully considered in Giulietti *et al.* (2009); it shows 49 Brazilian species (Table 1) of which 19 are rare (Fig. 8). The present proportion of rare species within the native Turneraceae is 51%.

There are also some infraspecific taxa that can be defined as rare plants, for instance *P. sarae* var. *glabrescens* is known only by the type specimen from MG, whereas the var. *sarae* lives in the Chapada Diamantina, BA. *T. luetzelburgii* var. *luetzelburgii*, is known only from Pico das Almas, BA, but the var. *dubia* has been collected in BA and MG. *T. dasytricha* var. *crinita* was collected only in two localities of PI, while the typical variety grows in MT, MS and Bolivia.

The rare species of *Turnera* found in 'Amazônia' belong to two series, the ones found in 'Caatinga' and 'Cerrado' pertain to six groups. Seven rare species belonging to three series occur in 'Mata Atlântica';

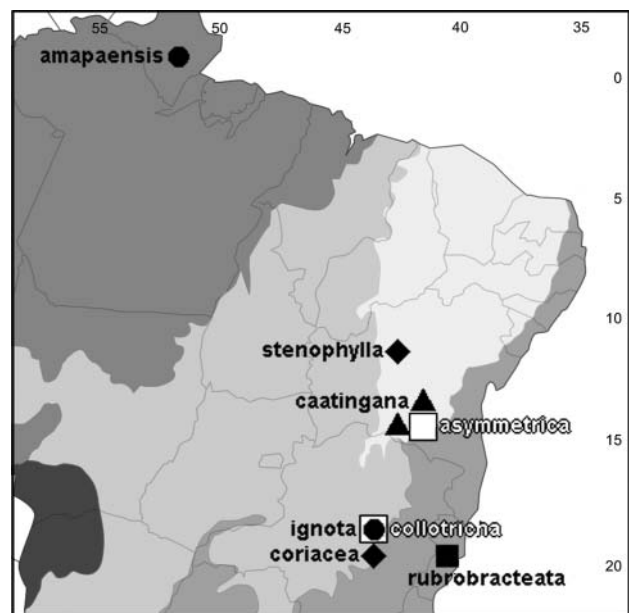


Fig. 6. Distribution of rare species of *Turnera*: Series *Conciliatae* ■, *Microphyllae* □, *Papilliferae* ▲, *Salicifoliae* ●, *Turnera* subseries *Umbilicatae* ◆.

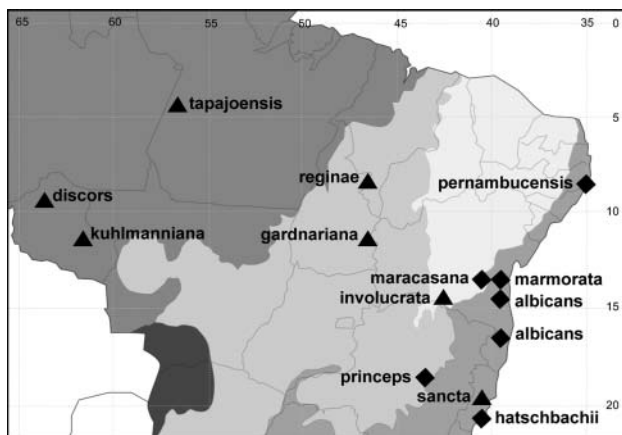


Fig. 7. Distribution of rare species of *Turnera*: Series *Anomala* ▲, *Capitatae* ◆.

T. albicans and *T. marmorata* (*Capitatae*) are typical of the 'restinga' forest, which is in great danger (Figs 6 and 7, Table 2). Within series *Leiocarpae* all the rare species belong to the biomes 'Cerrado' and 'Caatinga' (Fig. 8). *T. harleyi* and *T. urbanii* are excluded because their present known area is over 10 000 km².

Some rare species are isolated, but many are gathered in the areas of major diversity (Fig. 9). In the d.sq. 13°S 41°W of Chapada Diamantina (BA) there are five species of *Piriqueta* (Fig. 5) and one of *Turnera* (Fig. 6). Other species are found in the neighbouring squares (Figs 6–7).

Six rare species of *Turnera* (Fig. 9) belonging to five series (Figs 6–8) live in the d.sq. 18°S 43°W, Cadeia do Espinhaço (MG). There are three rare species in the next d.sq. 19°S 43°W (MG), where Serra do Cipó is located (Fig. 9).

In GO three species of series *Leiocarpae* live in the d.sq. 15°S 47°W, and four in the next d.sq. 15°S 48°W where the Serra dos Pirineus is located (Fig. 9).

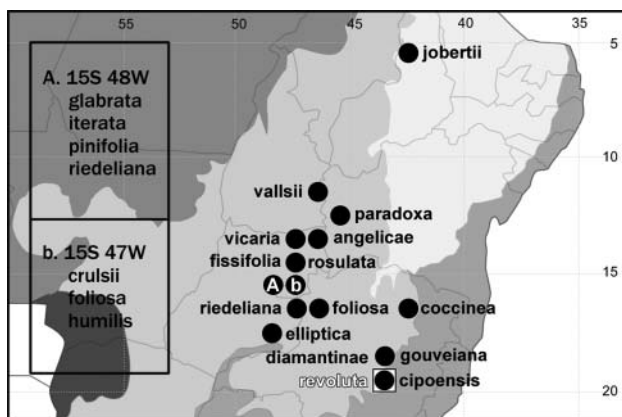


Fig. 8. Distribution of rare species of *Turnera*: Series *Leiocarpae* ●, *Sessilifoliae* □.

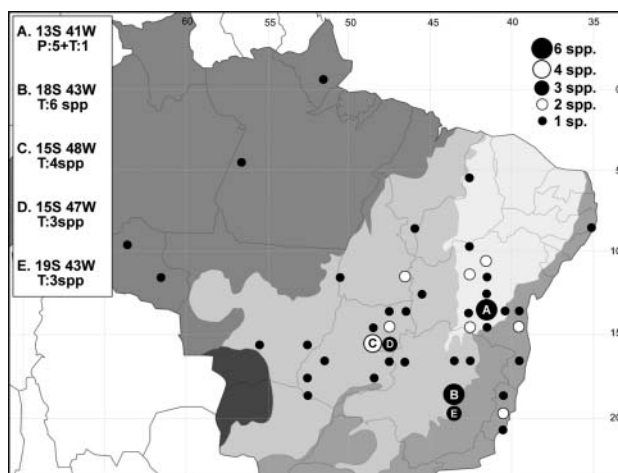


Fig. 9. Assemblage of rare species of *Turneraceae* in Brazil. P: *Piriqueta*; T: *Turnera*.

Discussion

According to the PCA analysis, there is an association between the number of species per d.sq. with latitudes 11–14°S and longitudes 40–43°W. The Chapada Diamantina is located exactly within the intersection of both stripes.

The d.sq. 13°S 41°W with the highest diversity: 27 species of *Turneraceae*, and the next two squares North with 21–20 species lie in the Chapada Diamantina. The contiguous d.sq. 11°S 40°W shows 19 species. Most d.sq. with 16–21 species in MG and GO lie within the indicated stripes of latitude or longitude. The exception is the d.sq. 15°S 47°W with 18 species.

It is important to recall that the data obtained about diversity may reflect at least to some extent the number of collections made. The richest d.sq. has been the subject of very intensive collecting and several local flora treatments. Figure 2 shows some d.sq. in BA, MG and GO where no *Turneraceae* have been collected, while in the surrounding squares there are several species registered. This suggests that if new collections were to be made in those areas, some taxa will probably be found.

Several species are known only from one or two samples, indicating that collections are missing. In some cases only the type specimen is known, collected more than a century ago, as in *P. scabrata* (Ule in 1907), *T. clauseniana* (Clausen in 1840), *T. elliptica* (Pohl in 1818), *T. gardneriana* (Gardner in 1839), *T. pernambucensis* (Gardner in 1837). *T. ignota* was known only by the holotype, collected by Saint Hilaire in MG (1816–1821), the second specimen was collected in 2000.

Other species are represented by several or many samples, all collected within an amazingly restricted range. For instance, the samples of *T. simulans* (91) were gathered just in two d.sq.; *T. marmorata* is known by 19 samples from

two d.sq.; all the specimens known of *T. coriacea* (22) were picked in only one d.sq.

Since the *Piriqueta* monograph was published (Arbo, 1995), hundreds of specimens have been collected. The data obtained confirm that BA is the most diverse state for this genus: 21 native species (Table 1), the largest number of endemic species (Fig. 1), up to 12 species in one d.sq. (Fig. 2). Interestingly, nine of 14 rare species of the genus occur in this state; all the d.sq. with more than one rare species are located in the Chapada Diamantina, in the biome 'Caatinga' (Fig. 5).

With respect to *Turnera*: eight of 11 series of the genus are represented in BA and MG, and each state holds 13 endemic species; series *Sessilifoliae* is endemic to MG (Table 1). The highest number of native species is found in MG, followed by BA. Up to 18 species live in one d.sq. in MG and 15 in BA (Fig. 2). In GO there are 33 native species and the proportion of endemic species is also high (Fig. 1).

The Chaquean subregion of Morrone (2001) was proposed as the ancestral area for *Turnera* (Arbo & Espert, 2009). This subregion matches with the biomes 'Caatinga' and 'Cerrado'.

The examination of the present distribution of *Turnera* endemic species suggests that the diversification of *Microphyllae*, *Papilliferae* and *Umbilicatae* took place in the 'Caatinga' and that of *Sessilifoliae* in the 'Cerrado'. At present series *Leiocarpae* and series *Turnera* have a very wide distribution area, but an important share of their diversification occurred both in 'Cerrado' and 'Caatinga'. Some groups diversified mostly in 'Amazônia' (*Anomaleae*, *Stenodictyae* and *Annulares*) and 'Mata Atlântica' (*Capitatae* and *Conciliatae*).

Many species growing in 'cerrado' vegetation show adaptations to fire (Simon *et al.*, 2009). Several species of Turneraceae (for instance *P. aurea*, *T. crulsii*, *T. emendata*, *T. iterata*, *T. longiflora*, *T. opifera*, *T. purpurascens*) have xylopodia or rhizomes. Although their shoots do not have any protection against fire, their phenology is specialized: they are among the first species to produce new sprouts after burning. Furthermore they flower precociously, when the shoots are only a few centimetres high.

Conclusion

From the taxonomic point of view BA and MG are the most diverse states for Turneraceae: *Piriqueta* and eight out of 11 series of *Turnera* are represented (Table 1) in each one.

BA is the most diverse state in terms of number of native and endemic species: there are 59 native species of which 23 are endemic to the state (Fig. 1). MG has 53 native species and 13 endemic to the state, but *Piriqueta* is not represented among the latter. There are 44 native species in GO + DF, counting two endemic ones of *Piriqueta* and 12 of *Turnera*.

The distribution of rare species proves that Bahia has the top number: nine of *Piriqueta* (Fig. 5) and eight of *Turnera* (Figs 6–8). There are 14 in GO, two of *Piriqueta* and 12 of *Turnera*. In MG there are nine rare species of *Turnera*, none of *Piriqueta*.

Within the area plotted, the major species diversity centre is the Chapada Diamantina. There are three d.sq. with 20 or more species, the d.sq. 13°S 41°W shows the record number of species (Fig. 2) and the maximum number of rare species per d.sq. (Fig. 9).

Biodiversity is intimately related to landscape evolution through all kinds of geological and physiographic change (Heads, 2004). The presence of mountain ranges determines per se a great ecological variability; probably the towering diversification of the family at the Chapada Diamantina is related with its physiographic heterogeneity. The variability in altitude and types of soil is wide, and precipitation is not evenly distributed. Some places on the East side of the Chapada have high annual rainfall, a mean of 1200 mm, while in other localities it is around 750 mm (Parrini *et al.*, 1999). The interaction of these factors is responsible for the extensive scope of vegetation types. Turneraceae are found frequently in 'caatinga' and 'cerrado', but they live also in gallery forest and montane humid or dry forests like 'mata do cipó' and 'carrasco'. Above 900 m.alt., many species are found in 'campo rupestre' and 'campos gerais'.

The biome with highest number of endemic species is the 'Cerrado' (Table 2). In this biome are located GO and a great portion of MG (Fig. 1). The most diverse spots of MG (Fig. 2) show concurrently the greatest number of rare species per d.sq. (Fig. 9). In GO the most diverse spots (Fig. 2) are contiguous to the d.sq. where most rare species are found (Fig. 9).

These spots of MG and GO are also located in montane areas, with elevated m.alt., between 700–970 m. Again, the range of vegetation types is broad: 'cerrado', 'campo', 'campo cerrado', 'cerradão', gallery forest and at higher altitudes 'campo rupestre'.

This work is useful to point out the d.sq. where collections are missing. In MG the d.sq. 18°S 43°W shows the top number of species – it is odd that not one has been found in the contiguous d.sq. East.

Some rare species of Turneraceae are found in national parks, but there are many rare species living in places where there is no protection, such as the ones of the biome Mata Atlântica. Hopefully, the identification of the rare species will contribute to the selection and setting up of new protected areas.

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References

- ARBO, M.M. 1977. *Adenaea*, nuevo género americano de Turneraceae. *Hickenia* **1**, 87–91.
- ARBO, M.M. 1979. Revisión del género *Erblichia* (Turneraceae). *Adansonia* sér. 2, **18**, 459–482.
- ARBO, M.M. 1995. Turneraceae Parte I. *Piriqueta*. *Flora Neotropica*, *Monograph* **67**, 156 pp., 59 figs.
- ARBO, M.M. 1997. Estudios sistemáticos en *Turnera* (Turneraceae). I. Series *Salicifoliae* y *Stenodictyae*. *Bonplandia* **9**, 151–208.
- ARBO, M.M. 2000. Estudios sistemáticos en *Turnera* (Turneraceae). II. Series *Annulares*, *Capitatae*, *Microphyllae* y *Papilliferae*. *Bonplandia* **10**, 1–82.
- ARBO, M.M. 2005. Estudios sistemáticos en *Turnera* (Turneraceae). III. Series *Anomala* y *Turnera*. *Bonplandia* **14**, 115–318.
- ARBO, M.M. 2007. Turneraceae. In: KUBITZKI K., Ed., *The Families and Genera of Vascular Plants*. Springer, Berlin, Vol. IX, pp. 458–466.
- ARBO, M.M. 2008. Estudios sistemáticos en *Turnera* (Turneraceae). IV. Series *Leiocarpae*, *Sessilifoliae* y *Conciliatae*. *Bonplandia* **17**, 107–334.
- ARBO, M.M. & ESPERT, S.M. 2009. Morphology, phylogeny and biogeography of *Turnera* (Turneraceae). *Taxon* **58**, 457–467.
- FORZZA, R.C. ET AL. 2010. *Catálogo de plantas e fungos do Brasil*. Turneraceae. Vol. 2: 1655–1661. Jardim Botânico do Rio de Janeiro. <http://floradobrasil.jbrj.gov.br/2010/> (accessed 4 July 2011).
- GIULIETTI, A.M., RAPINI, A., ANDRADE, M.J.G. DE, QUEIROZ, L.P. DE & SILVA, J.M.C. DA. 2009. *Plantas raras do Brasil*. Conservação Internacional (CI-Brasil) & Universidade Estadual de Feira de Santana. Belo Horizonte. 495 pp.
- HARLEY, R.M. 1995. Introduction. In: STANNARD, B.L., Ed., *Flora of the Pico das Almas, Chapada Diamantina, Bahia, Brazil*. Royal Botanic Gardens, Kew, pp. 1–42.
- HEADS, M. 2004. What is a node? *Journal of Biogeography* **31**, 1883–1891.
- IBGE (Instituto Brasileiro de Geografia, Fundação IBGE, Ministério do Planejamento e Coordenação Geral). 1972. Carta do Brasil ao Milionésimo: Brazil in the International Chart of the World on the Millionth Scale.
- IBGE (Instituto Brasileiro de Geografia e Estatística). 2004. Mapa de Biomas e de Vegetação. http://www.ibge.gov.br/home/presidencia/noticias/noticia_visualiza.php?id_noticia=169 (accessed 4 July 2011).
- MORRONE, J.J. 2001. *Biogeografía de América Latina y el Caribe*. M & T-Manuales y Tesis SEA, Zaragoza.
- PARRINI, R., RAPOSO, M.A., PACHECO J.F., CARVALHÃES, A.M.P., Melo JÚNIOR, T.A., FONSECA, P.F.M. & MINNS, J. 1999. Birds of the Chapada Diamantina, Bahia, Brazil. *Cotinga* **11**, 86–95.
- SIMON, M.F., GREYER, R., QUEIROZ, L.P. DE, SKEMA, C., PENNINGTON, R.T. & HUGHES C.E. 2009. Recent assembly of the Cerrado, a neotropical plant diversity hotspot, by in situ evolution of adaptations to fire. *Proceedings of the National Academy of Sciences USA* **106**, 20359–20364.

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