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ECOSYSTEMS

Distribution patterns, endemism, richness and diversity of Convolvulaceae in the Espinhaço Range, Brazil

JOILSON V. ALVES & MARIA TERESA BURIL

Abstract: The Espinhaço Range is known for its unique plant diversity and richness of endemic species. We identified the distribution patterns, areas of endemism, floristic similarity, and the areas of richness and diversity of Convolvulaceae within the Espinhaço Range by analyzing a database of approximately 2600 occurrence records. One hundred and eighty-four taxa were categorized into one of four distribution patterns: continuous, disjunct, centered in the Bahia sector, and centered in the Minas Gerais sector. Nineteen Convolvulaceae species are endemic to Espinhaço Range. Endemic species had all of the different distribution patterns. Parsimony analysis of endemism indicated two main centers of endemism for the family: one in the Minas Gerais sector, on the Diamantina Plateau, and another in the Bahia sector, in the Chapada Diamantina. The floristic similarity, richness, and diversity analyses evidenced a principal group in each portion, mainly concentrated in the Chapada Diamantina, and secondarily in the Iron Quadrangle. Such studies are important both for understanding biodiversity and for decision-making in public conservation policies.

Key words: Biogeography, *Campos Rupestre*s, *Jitirana*, Morning Glory.

INTRODUCTION

Understanding the spatial patterns of biodiversity and the processes that may determine them, represent goals that have been pursued for many years in biogeographic studies (Hawkins 2001). Endemism, richness, diversity, and floristic compositions are important aspects that can reveal biogeographic patterns (Conceição & Giulietti 2002, Hawkins et al. 2003, Willig & Bloch 2006, Kamino et al. 2008).

The Espinhaço Range (ER) (Figure 1) in central-eastern Brazil is the second largest mountain range in the country, in terms of its length, with its northern and southern boundaries extending to the municipalities of Jacobina (Bahia State) and Ouro Branco (Minas Gerais State) respectively. The Espinhaço Range consists of two main sectors: the Bahia sector (ERBA) and the Minas Gerais sector (ERMG), which are separated by a central lowland discontinuity. Its geomorphological characteristics led Harley (1988) to propose that the discontinuity acts as a geographic barrier between the ERBA and ERMG, with those low lands separating the northern and southern sectors by approximately 300 km (Rapini et al. 2008, Rando & Pirani 2011).

The average altitude of the ER is between 700 and 1,200m, and the dominant phytophysiognomy is the *Campos Rupestres* (rocky grassland/savanna, sensu Oliveira-Filho 2009) above 900m (Giulietti & Pirani 1988, Harley 1995, Giulietti et al. 1997, Gontijo 2008, Rapini et al. 2002, Giulietti et al. 2005). The floristic composition of the ER is also strongly influenced

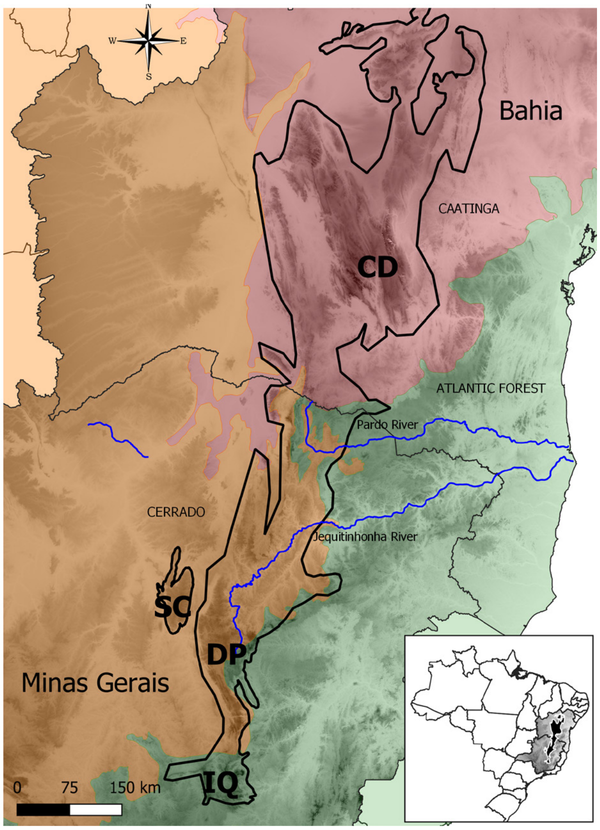

Figure 1. Location map of the Espinhaço Range extending north-south in the states of Bahia (BA) and Minas Gerais (MG). (CD = Chapada Diamantina; DP = Diamantina Plateau; SC = Serra do Cabral; IQ = Iron Quadrangle).

by three bordering domains - the Atlantic Forest, Cerrado and Caatinga (Harley 1995).

The Minas Gerais sector includes both the Serra do Cabral mountains (which are geographically separated from the Espinhaço Supergroup but belong to the same lithostratigraphic unit) (Cruz et al. 2018) and the Iron Quadrangle, which has a distinct geological origin from the Supergroup (Renger et al. 1994, Almeida-Abreu 1995, Saadi 1995, Knauer 2007, Gontijo 2008). Both of those ER sectors are considered a single unit in terms of biological similarity (Giulietti & Pirani 1988, Giulietti et al. 1997, Rapini et al. 2002, Vasconcelos 2011, Echternacht et al. 2011).

Despite representing less than 1% of the area of Brazil, the ER is recognized as an important center of endemism, richness, and species diversity for several plant groups, such as Asclepiadoideae (Apocynaceae) (Rapini et al. 2002, Bitencourt & Rapini 2013), *Syngonanthus* Ruhland (Eriocaulaceae) (Costa et al. 2008), *Chamaecrista* (L.) Moench (Fabaceae) (Rando & Pirani 2011), and *Jacquemontia* Choisy (Convolvulaceae) (Buril et al. 2014).

The Convolvulaceae family is monophyletic (Stefanovic et al. 2002, 2003, APG 2016), and comprises species having economic, medicinal, ornamental, and ecological importance (Austin & Secco 1988, Mohanraj & Sivasankar 2014, Lourenço et al. 2020). Its distribution is cosmopolitan, although with greater diversity in tropical regions (Stefanovic et al. 2002, 2003, Staples 2021) with many endemic genera (Staples & Brummitt 2007). It is represented globally by approximately 2,000 species (Staples 2021, Buril et al. 2014), with approximately 400 recorded in Brazil; 193 of those are endemic (Simão-Bianchini et al. 2020).

Despite being a family with relevant diversity and endemism in Brazil, and its species having important ecosystem functions, detailed information concerning its spatial occupation is still lacking. We therefore addressed the following questions: (1) What are the patterns of spatial distribution observed for species of Convolvulaceae in the Espinhaço Range? (2) Where are the areas of endemism, richness, and diversity of the family there? (3) Are the floristic compositions of Convolvulaceae between the two ER sectors distinct or similar?

MATERIALS AND METHODS

Geographical coordinates were compiled from the Reflora Virtual Herbarium (http://floradobrasil.jbrj.gov.br/) and from CRIA–Species Link (http://

www.splink.org.br/). Records of Convolvulaceae in municipalities with territory partially or completely within the polygon corresponding to the Espinhaço Range were searched. Specimens with imprecise locations (e.g. “Minas Gerais”, “Bahia”, “Brazil”), vouchers without collector numbers and duplicates were discarded. Non-georeferenced samples, when possible, were adjusted to the location indicated in the specimens or to the respective municipal coordinates. Geographical distribution maps were created in the QGis 3.14 program for analysis of distribution patterns. The nomenclature of the species follows the digital databases The International Plant Names Index (https://www.ipni.org/) and Tropicos (https://www.tropicos.org/home). Dubious identifications not confirmed by experts were discarded.

Richness and diversity analyzes were conducted employing the DIVA-GIS program (Hijmans et al. 2001) using the Jackknife 2 estimator and the Shannon index respectively. The centers of endemism were identified using Parsimony Analysis of Endemism (PAE), considering only those grid cells with three or more endemic species. A presence/absence matrix (Table I) was constructed in Mesquite version 3.16. and conducted to WinClada/Nona (Goloboff 1999, Nixon 2002) for parsimony analysis, following the procedure described by Usama (2018). The grid cells with records of Convolvulaceae were subjected to a cluster analysis in the PAST version 2.17c program to determine the floristic similarities between the two sectors, based on the Dice–Sorensen similarity coefficient (Hammer et al. 2013). The above analyzes were all conducted in 0.5º x 0.5º grid cells.

RESULTS

Using the parameters described above, we obtained a database with 2,691 records of 184 taxa (almost 50% of the Convolvulaceae species recorded for Brazil) distributed among 17 genera. Nineteen Convolvulaceae species are endemic from the Espinhaço Range. Four categories were established to represent the distribution patterns of the studied taxa: disjunct between Bahia and Minas Gerais sector, continuous in the ER, centered in the Bahia sector of the ER (species without records in the Minas Gerais sector), and centered in the Minas Gerais sector (species without records in the Bahia sector). The genera with the highest number of species were *Ipomoea*, *Evolvulus,* and *Jacquemontia*, as expected, with 58, 56 and 40 species respectively. Thirty-five species have continuous distribution patterns, of which only one is endemic to the ER.

Table I. Presence and absence matrix of Convolvulaceae species from the Espinhaço Range.

Endemic species	Area1	Area2	Area3	Area4	Area5
I. rupestris	1	1	1	1	1
J. diamantinensis	1	1	0	0	1
J. decipiens	1	1	0	0	1
E. brevifolius	1	0	1	0	1
D. repens	0	0	0	0	0
J. ochracea	0	0	0	0	1
J. lasioclados	0	0	0	0	1
J. revoluta	0	0	0	0	0
J. macrocalyx	0	0	0	0	0
I. chapadensis	1	1	0	0	0
E. altissimus	1	1	1	0	0
E. harleyi	1	1	1	0	0
E. jacobinus var. *ramosus*	1	0	0	0	0
I. ana-mariae	1	1	1	0	0
I. serrana	1	1	1	0	0
J. breviacuminata	0	0	0	0	0
J. grisea	0	1	1	1	0
J. staplesii	1	1	1	1	0
J. robertsoniana	1	1	1	0	0

Thirty-seven species have disjunct distributions, of which three are endemic species. Sixty-two species have distribution patterns centered in the Bahia sector (ERBA), of which 11 are endemic; 50 species are centered in the Minas Gerais sector (ERMG), of which four are endemic to the ER (Table II).

Distribution patterns

Species with continuous patterns are distributed over almost the entire extent of the Espinhaço Range (Figure 2a), although some have wide distributions in the Bahia sector, with few occurrences in the Minas Gerais sector (where they have been recorded only at the northern extent of the ERMG). The opposite situation is also observed. Some species are widely distributed throughout the Minas Gerais sector, with few records extending beyond the southern extent of the Bahia sector. *Ipomoea rupestris* Sim.-Bianch. & Pirani is the only endemic species of the ER demonstrating a continuous pattern.

Approximately 20% of the species analyzed evidenced disjunct distributions between the ERBA and the ERMG (Figure 2b). The species in the Bahia sector are mostly concentrated in the Chapada Diamantina mountain range, while in the Minas Gerais sector the species are mostly distributed in the Diamantina Plateau and Iron Quadrangle.

Approximately 27% of the species analyzed show distribution patterns centered on the ERMG (Figure 2c), with those being recorded mainly in the Diamantina Plateau and Iron Quadrangle (and most of them with few known populations). *Distimake repens* (D.F.Austin & Staples) Petrongari & Sim.-Bianch, *Jacquemontia lasioclados* (Choisy) O'Donell, *J. ochracea* Sim.-Bianch. & Pirani, and *J. revoluta* Sim.-Bianch. are endemic to the Minas Gerais sector. The Bahia sector of the ER harbored the largest number of the species analyzed, with 63 species showing distribution patterns centered on the ERBA (Figure 2d), ten of which are endemic.

Areas of endemism

Five candidate grid cells for areas of endemism (those with three or more endemic species) were used for Parsimony Analysis of Endemism – PAE. These grid cells resulted in a parsimonious tree with 20 steps, a consistency index (Ci) of 0.75, and a retention index (Ri) of 0.75. The PAE evidenced two main clades (Figure 3): the Chapada Diamantina clade, which appears as the main center of endemism (grid cells 1, 2, 3 and 4) and the Diamantina Plateau clade, which appears as a secondary center of endemism (grid cell 5).

Richness, diversity, and floristic similarity

The areas with the greatest richness and diversity of Convolvulaceae are concentrated mainly in the Chapada Diamantina, and secondarily in the Iron Quadrangle (Figure 4a-b). Different from other groups studied in the ER, such as Asclepiadoideae (Bitencourt & Rapini 2013), Convolvulaceae has been more intensively sampled in the ERBA, with the greatest efforts concentrated in the Chapada Diamantina – with those efforts decreasing towards the center of the ER. In the ERMG, the areas that have experienced the most intensive sampling efforts are the Diamantina Plateau, Serra do Cipó, and the Iron Quadrangle.

Cluster analysis, considering all species of Convolvulaceae in the ER, evidenced the formation of two main groups depending on the geographical locations of the areas: a group in ERBA comprising 23 grid cells and another in ERMG comprising 10 grid cells. The grid cells of each portion showed low similarity to each other, evidencing the heterogeneity of the regions (Figure 5). Some isolated situations occur, however, with some grid cells in the Minas Gerais sector being more similar to some grid cells in the Bahia sector.

Table II. **Distribution patterns of Convolvulaceae species in the Espinhaço Range.**

Distribution pattern of Convolvulaceae species in the Espinhaço Range					
Species	**Widely**		**Centered**		**E**
	C	**D**	**ERBA**	**ERMG**	
Aniseia martinicensis (Jacq.) Choisy		x			
A. martinicensis var. *ambigua* Hallier f.			x		
Bonamia agrostopolis (Vell.) Hallier f.	x				
B. burchellii (Choisy) Hallier f.			x		
B. sphaerocephala (Dammer) Ooststr.		x			
Camonea umbellata (L.) A.R. Simões & Staples	x				
Cuscuta corniculata Engelm.			x		
C. crenatifolius Ruiz & Pav.				x	
C. incurvata Progel				x	
C. indecora Choisy				x	
C. insquamata Yunck.			x		
C. lanulosus D.F. Austin	x				
C. partita Choisy		x			
C. racemosa Mart.		x			
C. racemosa var. *miniata* (Mart.) Engelm.				x	
C. tinctoria Mart.				x	
C. umbellata Kunth				x	
Daustinia montana (Moric.) Buril & A.R. Simões			x		
Dichondra macrocalyx Meisn.			x		
Distimake aegyptius (L.) A.R.Simões & Staples	x				
D. cissoides (Lam.) A.R.Simões & Staples	x				
D. contorquens (Choisy) A.R. Simões & Staples				x	
D. digitatus (Spreng.) A.R. Simões & Staples	x				
D. flagellaris (Choisy) A.R. Simões & Staples		x			
D. hirsutus (O'Donell) Petrongari & Sim.-Bianch.				x	
D. macrocalyx (Ruiz & Pav.) A.R. Simões & Staples	x				
D. maragniensis (Choisy) Petrongari & Sim.-Bianch.				x	
D. repens (D.F. Austin & Staples) Petrongari & Sim.-Bianch.				x	x
D. tomentosus (Choisy) Petrongari & Sim.-Bianch				x	
Evolvulus alsinoides (L.) L.				x	
E. altissimus C.V. da Silva & Sim.-Bianch.			x		x

Table II. Continuation.

Distribution pattern of Convolvulaceae species in the Espinhaço Range					
Species	**Widely**		**Centered**		**E**
	C	**D**	**ERBA**	**ERMG**	
E. anagalloides Meisn.			x		
E. argyreus Choisy.			x		
E. aurigenius Mart.				x	
E. brevifolius (Meisn.) Ooststr.		x			x
E. chamaepitys Mart.			x		
E. chrysotrichos Meisn.				x	
E. comosus Ooststr.			x		
E. cordatus Moric.			x		
E. daphnoides Moric.			x		
E. diosmoides Mart.		x			
E. echioides Moric.		x			
E. elaeagnifolius Dammer		x			
E. elegans Moric.	x				
E. ericifolius Mart. ex Schrank			x		
E. filipes Mart.	x				
E. flexuosus Helwig			x		
E. frankenioides Moric.			x		
E. fuscus Meisn.				x	
E. glaziovii Dammer		x			
E. glomeratus Nees & Mart.	x				
E. gnaphalioides Moric.		x			
E. goyazensis Dammer				x	
E. gypsophiloides Moric.		x			
E. harleyi C.V. da Silva & Sim.-Bianch.			x		x
E. helichrysoides Moric.	x				
E. jacobinus Moric.	x				
E. jacobinus var. *ramosus* Ooststr.			x		x
E. kramerioides Mart.				x	
E. latifolius Ker Gawl.	x				
E. linarioides Meisn.		x			
E. linoides Moric.	x				

Table II. Continuation.

Distribution pattern of Convolvulaceae species in the Espinhaço Range					
Species	**Widely**		**Centered**		**E**
	C	**D**	**ERBA**	**ERMG**	
E. lithospermoides Mart.		x			
E. lithospermoides var. *martii* Sim.-Bianch.	x				
E. luetzelburgii Helwig			x		
E. macroblepharis Mart.				x	
E. niveus Mart.			x		
E. nummularius (L.) L.	x				
E. passerinoides Meisn.		x			
E. phyllanthoides Moric.			x		
E. pohlii Meisn.			x		
E. pterocaulon Moric.	x				
E. pterygophyllus Mart.	x				
E. pusillus Choisy			x		
E. rufus A. St.-Hil.				x	
E. saxifragus Mart.	x				
E. scoparioides Mart.	x				
E. sericeus Sw.		x			
E. serpylloides Meisn.			x		
E. speciosus Moric.			x		
E. stellariifolius Ooststr.			x		
E. thymiflorus Choisy				x	
E. vimineus Ooststr.		x			
E. lagopodioides Meisn.				x	
Ipomoea acanthocarpa (Choisy) Aschers. & Schweinf.			x		
I. acutisepala O'Donell				x	
I. alba L.		x			
I. amnicola Morong			x		
I. ana-mariae L.V. Vasconcelos & Sim.-Bianch.			x		x
I. aprica House				x	
I. argentea Meisn.				x	
I. asarifolia (Desr.) Roem. & Schult.			x		
I. bahiensis Willd. ex Roem. & Schult.			x		

Table II. Continuation.

Distribution pattern of Convolvulaceae species in the Espinhaço Range					
Species	**Widely**		**Centered**		**E**
	C	**D**	**ERBA**	**ERMG**	
I. batatoides Choisy.		x			
I. blanchetii Choisy			x		
I. brasiliana (Choisy) Meisn.			x		
I. cairica (L.) Sweet				x	
I. campestris Meisn.				x	
I. carnea subsp. *fistulosa* (Mart. ex Choisy) D.F. Austin		x			
I. chapadensis J.R.I. Wood & L.V. Vasconcelos			x		x
I. cynanchifolia Meisn.		x			
I. decipiens Dammer			x		
I. delphinioides Choisy				x	
I. echinocalyx Meisn.				x	
I. eriocalyx (Mart. ex Choisy) Meisn.				x	
I. granulosa Chodat & Hassl.				x	
I. hederifolia L.	x				
I. hirsutissima Gardner				x	
I. horsfalliae Hook.		x			
I. incarnata (Vahl) Choisy		x			
I. indica (Burm.) Merr.		x			
I. langsdorffii Choisy				x	
I. longeramosa Choisy			x		
I. longibracteolata Sim.-Bianch. & J.R.I. Wood.			x		
I. longistaminea O'Donell			x		
I. marcellia Meisn.			x		
I. maurandioides Meisn.		x			
I. nil (L.) Roth.	x				
I. parasitica (Kunth) G.Don				x	
I. pintoi O'Donell			x		
I. procumbens Mart. & Choisy	x				
I. procurrens Meisn.				x	
I. purpurea (L.) Roth.		x			
I. quamoclit L.		x			

Table II. Continuation.

Distribution pattern of Convolvulaceae species in the Espinhaço Range					
Species	**Widely**		**Centered**		**E**
	C	**D**	**ERBA**	**ERMG**	
I. ramosissima (Poir.) Choisy	x				
I. regnellii Meisn.		x			
I. rosea Choisy		x			
I. rupestris Sim.-Bianch. & Pirani	x				x
I. saopaulista O'Donell				x	
I. sericophylla Meisn.			x		
I. sericosepala J.R.I.Wood & Scotland	x				
I. serrana Sim-Bianch. & L.V.Vasconcelos			x		x
I. setosa Ker Gawl.			x		
I. squamisepala O'Donell				x	
I. squamosa Choisy			x		
I. subalata Hassl.			x		
I. subincana (Choisy) Meisn.			x		
I. syringifolia Meisn.				x	
I. tricolor Cav.				x	
I. triloba L.	x				
I. verbasciformis (Meisn.) O'Donell				x	
Iseia luxurians (Moric.) O'Donell				x	
Jacquemontia aequisepala M. Pastore & Sim-Bianch.			x		
J. bahiensis O'Donell			x		
J. blanchetii Moric.	x				
J. bracteosa Meisn.				x	
J. breviacuminata (Mart. ex Choisy) Buril			x		x
J. chrysanthera Buril	x				
J. corymbulosa Benth.			x		
J. decipiens Ooststr.		x			x
J. densiflora (Meisn.) Hallier f.			x		
J. diamantinensis Buril		x			x
J. estrellensis Krapov.	x				
J. evolvuloides (Moric.) Meisn.	x				
J. ferruginea Choisy		x			

Table II. Continuation.

Distribution pattern of Convolvulaceae species in the Espinhaço Range					
Species	**Widely**		**Centered**		**E**
	C	**D**	**ERBA**	**ERMG**	
J. glabrescens (Meisn.) M. Pastore & Sim.-Bianch.				x	
J. glaucescens Choisy		x			
J. gracillima (Choisy) Hallier f.			x		
J. grisea Buril			x		x
J. heterantha (Nees & Mart.) Hallier f.		x			
J. heterotricha O'Donell				x	
J. lasioclados (Choisy) O'Donell				x	x
J. linarioides Meisn.				x	
J. macrocalyx Buril			x		x
J. martii Choisy		x			
J. multiflora Hallier f.			x		
J. nodiflora (Desr.) G.Don.	x				
J. ochracea Sim.-Bianch. & Pirani				x	x
J. pentanthos (Jacq.) G.Don.	x				
J. prostrata Choisy				x	
J. revoluta Sim.-Bianch.				x	x
J. robertsoniana Buril & Sim.-Bianch.			x		x
J. rufa (Choisy) Hallier f.				x	
J. saxicola L.B.Sm.			x		
J. sphaerocephala Meisn.				x	
J. sphaerostigma (Cav.) Rusby	x				
J. staplesii Buril			x		x
J. tamnifolia (L.) Griseb.			x		
J. unilateralis (Roem. & Schult.) O'Donell			x		
J. velutina Choisy		x			
Keraunea brasiliensis Cheek & Sim.-Bianch.			x		
Odonellia eriocephala (Moric.) K.R. Robertson		x			
Operculina macrocarpa (L.) Urb.	x				
Turbina abutiloides (Kunth) O'Donell			x		

Continuous distribution pattern (C). Disjoint distribution pattern (D). Distribution pattern centered in Bahia portion (ERBA). Distribution pattern centered in the Minas Gerais portion (ERMG). Endemic species of the Espinhaço Range (E).

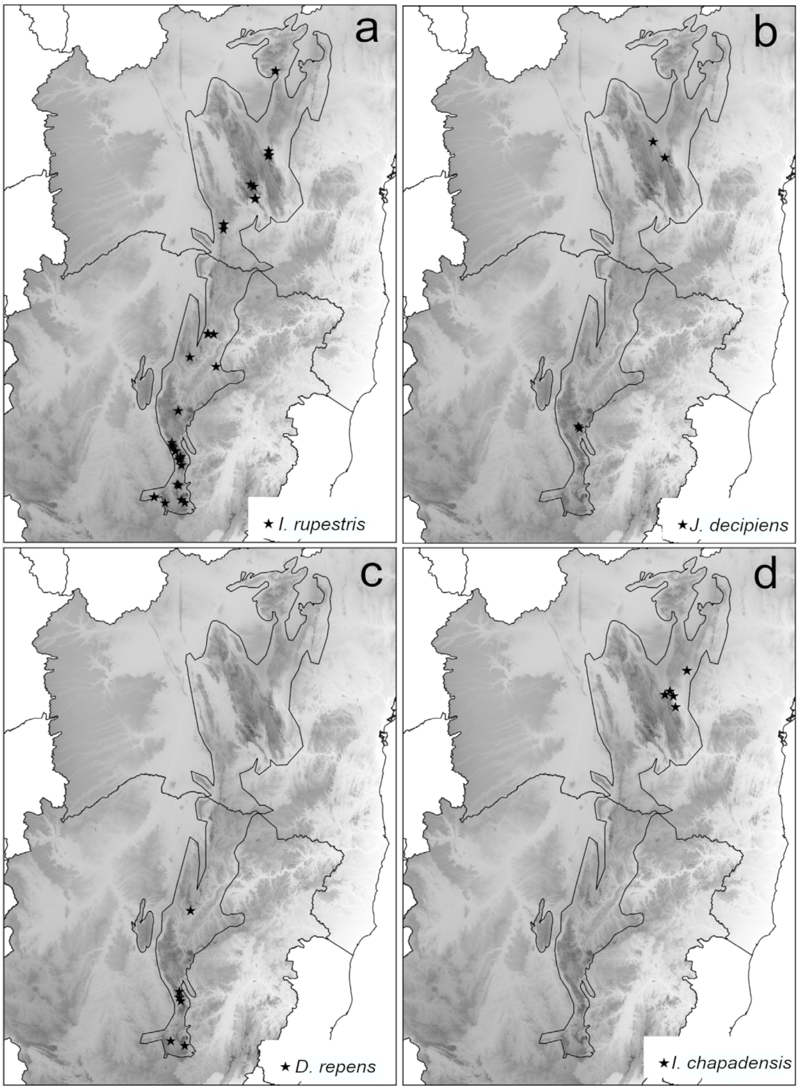

Figure 2. Examples of Convolvulaceae species representing all four distribution patterns found throughout the Espinhaço Range (a) Continuous distribution pattern (b) Disjoint distribution pattern (c) Distribution pattern centered on the Minas Gerais portion (ERMG) (d) Distribution pattern centered on the Bahia portion (ERBA).

DISCUSSION

Distribution

Species from different angiosperm families commonly show continuous distribution patterns in the ER (Kamino et al. 2008). Some authors have suggest that this pattern is favored by the high humidity and high elevations found there (Harley 1995, Kamino et al. 2008), although the dispersal capacity and niche occupation of each species must also be taken into account (Giannini et al. 2012). The low number of species shared between Serra do Cabral and the rest of the ER (and particularly with ERMG) is probably related to the geographic separation between those two areas, as well as phytogeographic and climatic differences (Kamino et al. 2008) and their distinct substrates (Conceição & Pirani 2007).

Harley (1988) proposed that the lowlands between the two sectors represent a geographic barrier to the dispersal of many species – which could help explain the distribution of several Convolvulaceae species. Rando & Pirani (2011) noted that the gap separating the two sectors of the ER would have made it impossible in the past for species of the genus *Chamaecrista* (Fabaceae) to migrate between the two sectors,

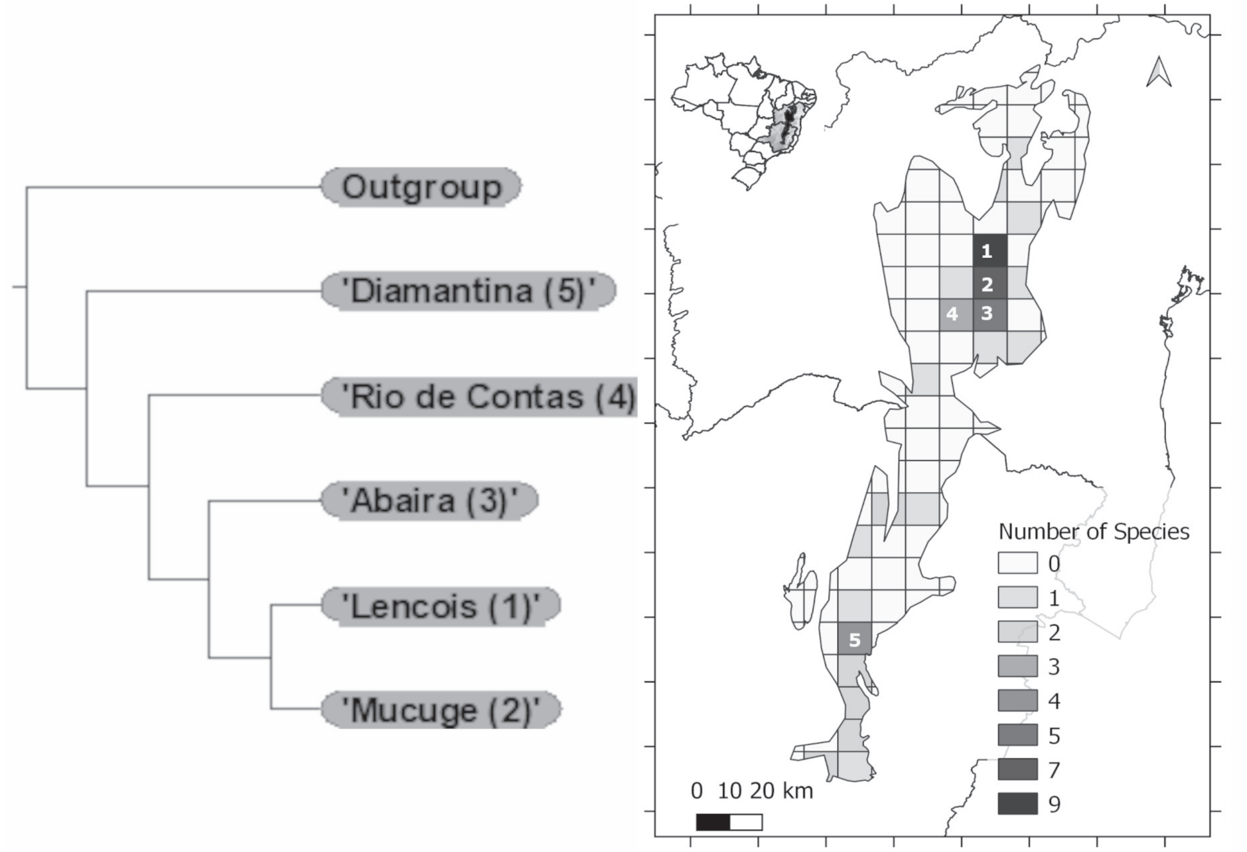

Figure 3. Parsimony Analysis of Endemism of Convolvulaceae species in the Espinhaço Range showing two main centers of endemism: one in Chapada Diamantina (grid cells 1 to 4) and another in Diamantina Plateau (grid cell 5). The numerical grid cells are partially equivalent to the territories of the municipalities of Lençóis, Mucugê, Abaíra, Rio de Contas (ERBA) and Diamantina (ERMG).

although more in depth phylogeographic studies will be needed to determine the origin of the ancestors of the Convolvulaceae in the ER and the historical events that culminated in the distribution patterns described here.

In addition to the gap between the two sectors of the ER, we suggest two more barriers that could have driven the disjoint distributions of many Convolvulaceae species there: the ecotone between the two ER sectors of the Caatinga, Cerrado, and Atlantic Forest domains, and the hydrographic basin complex there composed of the Pardo and Jequitinhonha rivers. That gap in the Espinhaço Range near the border between the states of Bahia and Minas Gerais is an area of low elevation where Cerrado, Caatinga and Atlantic Forest vegetation overlap and constitute an ecological barrier (Wiens et al. 1985, Milan & Moro 2016, Magura et al. 2017). The Jequitinhonha River valley is the divisor of many mountains in the Minas Gerais sector (Giulietti & Pirani 1988), as are the Verde Grande and Pardo rivers on the border between the states of Bahia and Minas Gerais. Those three rivers, together with the ecotone gap between the ERBA and ERMG, act as barriers to species movements between the two Espinhaço sectors. This pattern was also observed by Rando & Pirani (2011) in some species of the genus *Chamaecrista* (Fabaceae).

Both the distribution patterns centered in Bahia and those centered in Minas Gerais

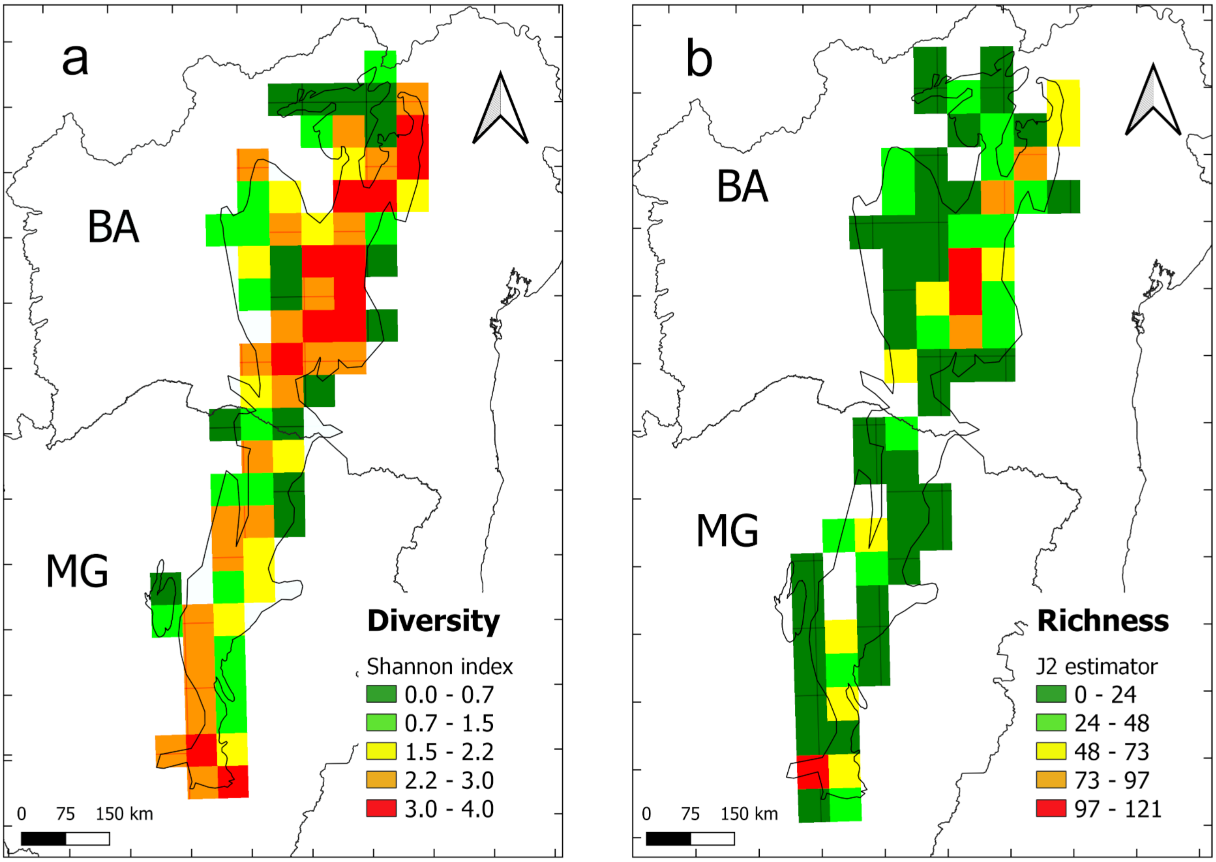

Figure 4. Maps of diversity and richness of Convolvulaceae in the Espinhaço Range. (a) Species diversity is concentrated mainly in the Bahia portion (Chapada Diamantina) and secondarily in the extreme south of the ER (Iron Quadrangle). (b) Jackknife2 estimator pointed out that species richness is also mostly concentrated in the Chapada Diamantina.

are poorly documented in the literature, and are usually associated with endemic species: Rapini et al. (2002) point out several species of Apocynaceae with exclusive occurrences in the ERMG; Rando & Pirani (2011) reported the existence of such exclusive patterns among endemic species of Fabaceae. These patterns may be directly related to geomorphological and environmental distinctions and the influences exerted mainly by the Caatinga domain in the ERBA and the Cerrado domain in the ERMG, which determine species distribution preferences (Harley 1988, Rapini et al. 2002, Azevedo & Berg 2007, Kamino et al. 2008).

Endemism

Many studies have documented the Chapada Diamantina and the Diamantina Plateau as areas of endemism of different plant groups. Echternacht et al. (2011) highlighted 10 areas of endemism in the Minas Gerais sector of the ER, including the Diamantina Plateau. Bitencourt & Rapini (2013) investigated Asclepiadoideae throughout the Espinhaço Range and identified five main centers of endemism, including the Diamantina Plateau and the Chapada Diamantina. Buril et al. (2014) highlighted these two areas as centers of endemism for the genus *Jacquemontia*. The concentrations of endemic species in both the Chapada Diamantina and Plateau Diamantina has probably occurred

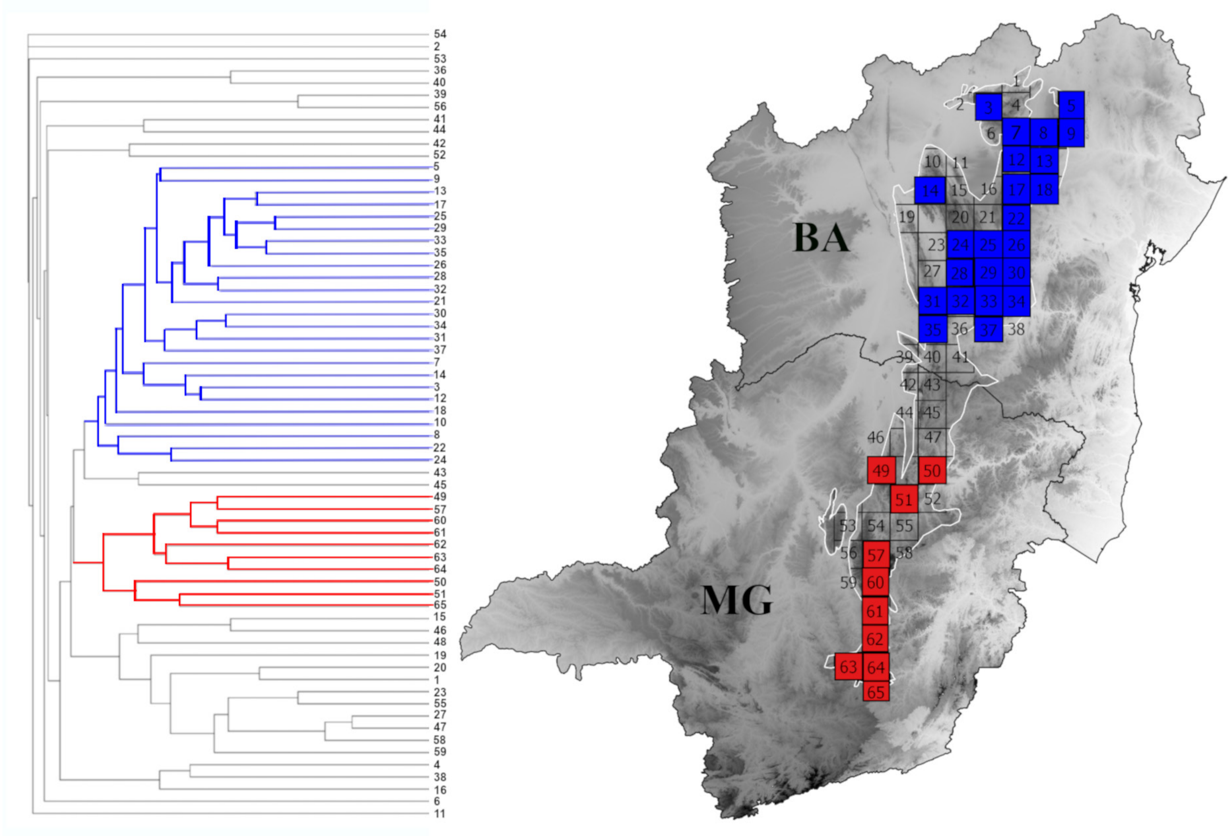

Figure 5. Floristic similarity of Convolvulaceae in the Espinhaço Range. The cluster analysis showed two main groups: one in the Bahia portion (blue squares) and another in the Minas region (red squares). This floristic similarity pattern is depending on the geographic location of the squares and apparently occurs to the detriment of climatic influences surrounding domains in the ER.

due to long evolutionary processes in those areas (Silva et al. 2008) reflecting their unique geomorphological and climatic conditions (Giulietti & Pirani 1988, Giulietti et al. 1997, Kamino et al. 2008).

Although many endemic species are distributed throughout the Espinhaço Range, few of them are shared between the two sectors (Giulietti & Pirani 1988, Giulietti et al. 1997, Rapini et al. 2002, 2008, Bitencourt & Rapini 2013). While sharing among Convolvulaceae is observed with *I. rupestris* Sim.-Bianch. & Pirani (continuous distribution) and *J. decipiens* Ooststr., *J. diamantinensis* Buril, and *E. brevifolius* (Meisn.) Ooststr. (disjoint distributions). *E. harleyi* C.V. da Silva & Sim.-Bianch., *E. jacobinus* var. *ramosus* Ooststr., *J. breviacuminata* (Mart. ex Choisy) Buril, *J. grisea* Buril, *J. macrocalyx* Buril, *J. revoluta* Sim.-Bianch. *J. staplesii* Buril are considered microendemic, as they occur in less than five locations within the same phytogeographic unit (as suggested by Buril et al. 2014). All endemic Convolvulaceae species from the ER have records in protected conservation areas, emphasizing the roles of such areas in protecting the genetic heritage from progressive anthropogenic degradation.

Barbosa et al. (2015) pointed out that the ER may contain areas that can be considered current microrefuges harboring many microendemic species. Refuges in the Espinhaço Range emerged during tertiary and quaternary climatic fluctuations, and enabled the subsequent expansion and isolation of several species (Zappi

2008). Those refuges are mainly represented by the *Campos Rupestres* vegetation (Rapini et al. 2008, Bitencourt & Rapini 2013). Due to ongoing climate change, however, it is estimated that by the end of this century 97% of all angiosperm microendemic species in ER refuges will be at risk of extinction (Bitencourt et al. 2016).

Diversity and richness

Rapini et al. (2008) pointed out that the diversity of plant groups in the ER is a result of diversification processes that occurred because of spatial heterogeneity, extreme environmental conditions, and climatic variations during the Pleistocene. The high richness of Convolvulaceae observed in the Iron Quadrangle may be related to (among other factors) its distinct substrates and the frequent association of its species with disturbed environments (Barreto 1949, Orzari et al. 2013, Moura & Morim 2015). Many of those species contribute to primary successional processes, and are therefore very beneficial to the recuperation of degraded areas (Moura & Morim 2015). The Iron Quadrangle, located in the extreme southern end of the ER, is historically known for the extraction of mineral resources and for its disturbed landscape (Azevedo et al. 2012). But despite those high levels of disturbance, Harley (1995) and Giulietti et al. (1997) identified the Iron Quadrangle as an area of great floristic diversity in South America.

The high richness and diversity observed in the Chapada Diamantina is seen in many plant groups (Conceição & Pirani 2007). The substrate types are different between the two sectors in the ER, and even distinct in some areas of the same sector (Conceição & Pirani 2007, Rapini et al. 2008). Barreto (1949) considered that one of the main determinants for species richness is variations in the types of substrates – which influence floristic composition. Many plant groups within the ERMG, the Diamantina Plateau, Serra do Cipó, and the mountains of the Iron Quadrangle have been intensively surveyed, such as Asclepiadoideae (Bitencourt & Rapini 2013).

Floristic similarity

The floristic similarity in Convolvulaceae that depended on the geographic locations of the grid cells surveyed, was also reported by Bitencourt & Rapini (2013) for Asclepiadoideae species, with the formation of two groups, one in each sector of the ER. The floristic composition of the ER apparently reflects extreme climatic influences linked to the Caatinga domain in the Bahia sector, and the Cerrado in the Minas Gerais sector, in addition to historical biogeographic events and current ecological interactions (Almeida et al. 2004, Echternacht et al. 2011, Bitencourt & Rapini 2013, Cruz et al. 2018).

The low floristic similarity of Convolvulaceae between both sectors of the Espinhaço Range seems to be a common observation for other groups, even in nearby areas (Zappi et al 2003, Conceição & Pirani 2005, Azevedo & Berg 2007, Rapini et al. 2008). Some authors have suggested that the low observed floristic similarity probably reflects microclimatic, topographical, geomorphological, and substrate heterogeneity (Conceição & Giulietti 2002, Conceição & Pirani 2005, Rapini et al. 2008).

CONCLUSIONS

One hundred and eighty-six taxa and nineteen Convolvulaceae species endemic from ER were recognized. The species were categorized in four distribution patterns. The Chapada Diamantina and Diamantina Plateau are endemic areas in the ER. The richness and the diversity are mainly in the Chapada Diamantina and Iron Quadrangle, following the Diamantina Plateau. Both sectors have distinct floristic similarity.

The results confirm the Espinhaço Range as a center of endemism, richness and diversity to Convolvulaceae. We wish to stress here the importance of expanding public conservation policies to the Espinhaço Range, as a regional center of endemism, richness, and diversity not only for Convolvulaceae but also for many groups of the fauna and flora, as it experienced evolutionary processes that culminated in a unique diversity of species. The richness and diversity of Convolvulaceae observed in the Iron Quadrangle indicates the adaptation of some lineages to anthropically impacted environments, and more studies will be needed to better understand both the origin of that group in the ER as well as the diversification of species adapted to disturbed environments.

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JOILSON V. ALVES
https://orcid.org/0000-0002-8308-3563

MARIA TERESA BURIL
https://orcid.org/0000-0001-9615-2057

Programa de Pós-Graduação em Biodiversidade, Universidade
Federal Rural de Pernambuco, Laboratório de Sistemática
Integrativa, Departamento de Biologia, Rua Dom Manoel
de Medeiros, s/n, Dois Irmãos, 52171-900 Recife, PE, Brazil

Correspondence to: **Joilson Viana Alves**
E-mail: j.vianaalves@hotmail.com

Author contributions

JVA conducted the research, made the analysis, figures, maps, tables and wrote the manuscript; MTB supervised the research project and revised the text. All authors read and approved the final manuscript.