Composition and conservation of Orchidaceae on an inselberg in the Brazilian Atlantic Forest and floristic relationships with areas of Eastern Brazil

Alexandre Soares Pessanha[1], Luiz Menini Neto[2,3*], Rafaela Campostrini Forzza[4] & Marcelo Trindade Nascimento[1]

1. Herbário do Centro de Biociências e Biotecnologia, Laboratório de Ciências Ambientais, Universidade Estadual do Norte Fluminense Darcy Ribeiro, Av. Alberto Lamego 2000, Pq. Califórnia, 28013-602, Campos dos Goytacazes, RJ, Brasil; orquidealex@yahoo.com.br, mtn@uenf.br
2. Centro de Ensino Superior de Juiz de Fora, Campus Arnaldo Janssen, Luz Interior 345, Santa Luzia, 36030-776, Juiz de Fora, MG, Brasil; menini.neto@gmail.com
3. Departamento de Botânica, Instituto de Ciências Biológicas, Universidade Federal de Juiz de Fora, 36036-900, Martelos, Juiz de Fora, MG, Brasil.
4. Jardim Botânico do Rio de Janeiro, Pacheco Leão 915, Jardim Botânico, 22460-030, Rio de Janeiro, RJ, Brasil; rafaela@jbrj.gov.br

* Correspondence

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Abstract: The Brazilian Atlantic Forest presents high levels of richness and endemism of several taxonomic groups. Within this forest, the Orchidaceae may be highlighted as the richest family of Angiosperms found there, and is highly threatened due to collection and habitat destruction. The inselbergs of the Brazilian Atlantic Forest are mostly unknown regarding their floristic composition, but the available information points to occurrence of endemic species, with adaptations to survive to this dry environment. The objectives of this study were to conduct a floristic survey of the Orchidaceae species on the Maciço do Itaoca, an inselberg located in the Northern region of the State of Rio de Janeiro, make a comparative analysis with other sites in Eastern Brazil, and discuss the geographic distribution, floristic relationships and conservation status of the orchid species present on the inselbergs. The floristic composition of the study area was compared with 24 other locations in Eastern Brazil (of which 13 are inselbergs) and the influence of the types of surrounding vegetation on the composition of the Orchidaceae flora on the inselbergs. On Maciço do Itaoca we recorded 18 species from 17 genera: *Brasiliorchis picta*, *Brassavola tuberculata*, *Campylocentrum robustum*; *C. sellowii*, *Catasetum luridum*, *Cattleya guttata*, *Cyclopogon congestus*, *Cyrtopodium glutiniferum*, *Leptotes bicolor*, *Lophiaris pumila*, *Miltonia moreliana, Oeceoclades maculata*, *Phymatochilum brasiliense*, *Prescottia plantaginifolia*, *Pseudolaelia vellozicola*, *Sarcoglottis fasciculata*, *Sophronitis cernua*. and *Vanilla chamissonis*. The highest floristic similarity was with the Pedra da Botelha (0.43), an inselberg located in the North of Espírito Santo. This result is probably due to the similarity in altitude and distance from the coast in both areas despite the geographical distance between them. Apparently, little influence is exerted by the types of surrounding vegetation on the composition of the flora of inselbergs, due to their unique environmental characteristics which exert a strong selection pressure on plants that are adapted to survive on these inselbergs. The threats observed to the species on this inselberg are the same as for other inselbergs and include the collection of ornamental species, fire and quarrying. Specifically for the Maciço do Itaoca, a possibility for conservation may be the annexation of this area to the Desengano State Park, an important conservation area in the Northern of the State of Rio de Janeiro. Rev. Biol. Trop. 62 (2): 829-841. Epub 2014 June 01.

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The high levels of richness and endemism of all organisms occurring in the Brazilian Atlantic Forest, along with devastation and pressure that it has suffered for over 500 years after European occupation, culminated in the extreme reduction of its area and earned it the status of a global biodiversity hotspot (Myers, Mittermeier, Mittermeier, Fonseca & Kent, 2000; Mittermeier et al., 2004). The species richness observed in the Brazilian Atlantic Forest is, in general, due to strong latitudinal, altitudinal and internalization gradients which result in a large number of ecosystems, both forest and grassland (Stehmann et al., 2009).

Although forest physiognomies are prominent in the Brazilian Atlantic Forest (Stehmann et al., 2009), inselbergs also deserve attention. Inselbergs are defined as crystalline rock outcrops isolated and detached from the surrounding landscape and are often found in the tropics (Barthlott, Gröger & Porembski, 1993). They are effectively islands with distinct vegetation compared to the adjacent physiognomy and harbor plant species with adaptations to survive seasonal droughts. Although they do not have the same richness as forests, they often harbor many endemic species, especially in Southeastern Brazil (Porembski, 2007).

Among the studies on the flora of the Brazilian Atlantic Forest inselbergs, those done by Porembski, Martinelli, Ohlemüller and Barthlott (1998) and Meirelles, Pivello & Joly (1999) can be highlighted, along with some other regional floristic and ecological surveys (Caiafa & Silva, 2005; Oliveira & Godoy, 2007; Pifano et al., 2007; Barros, 2008; Esgario, Fontana & Silva, 2009). Some studies also conducted in inselbergs of Eastern Brazil, but located in the Caatinga (Northeastern Brazil), can be cited (França, Melo & Santos, 1997; França et al., 2005; França, Melo & Miranda, 2006; Araújo, Oliveira & Lima-Verde, 2008; Porto, Almeida, Pessoa, Trovão & Felix, 2008; Gomes & Alves, 2009; 2010).

Brazil stands out for its richness in Orchidaceae with over 2 430 recorded species (Barros, Vinhos, Rodrigues, Barberena & Fraga, 2010; Barros et al., 2012), 1 424 of which occur in the Brazilian Atlantic Forest, the phytogeographic region with the highest species richness of orchids in the country (Barros, Rodrigues & Batista, 2009; Barros et al., 2012). Although specific studies of Orchidaceae on inselbergs are rare those conducted by Miranda & Oliveira (1983), Almeida, Felix, Andrade & Felix (2007), Cunha & Forzza (2007) and Saddi (2008) can be cited.

In the few studies comparing the floristic relationships between the inselbergs of Brazilian Atlantic Forest or in other phytogeographic domains, such as the Caatinga, it seems that, in general, similarity between them is low, as found by Meirelles et al. (1999) studying the flora of eight sites in Rio de Janeiro, and Saddi (2008) analyzing the Orchidaceae composition of seven inselbergs of Rio de Janeiro, Espírito Santo (Brazilian Atlantic Forest) and Paraíba (Caatinga). Gomes & Alves (2009) investigated the floristic similarity of inselbergs and other physiognomies of Caatinga in Northeast Brazil and found greater similarity between them than with the vegetation that surrounded the outcrops. It is noteworthy to highlight the need of more studies in order to support initiatives for conservation of these outcrops as well as biogeographic studies to elucidate the floristic relationships among these inselbergs. Thus, the objectives of this study were to: 1) compare the floristic similarity of Orchidaceae on the Maciço do Itaoca, an inselberg located in the Northern region of the State of Rio de Janeiro to other granitic inselbergs in Eastern Brazil based on the species of Orchidaceae; 2) assess whether the Orchidaceae flora on inselbergs in Southeastern Brazil is more similar to each other or if it is influenced by other physiognomies in the surrounding Brazilian Atlantic Forest, 3) provide support for the conservation of the Maciço do Itaoca.

MATERIAL AND METHODS

Study area: The Maciço do Itaoca is an inselberg located in the district of Ibitioca (21º48' S - 41º26' W), near the highway BR-101, about 20km from the center of the

city of Campos dos Goytacazes in the Northern region of the state of Rio de Janeiro. It is approximately 300ha in size, with altitudinal range between 8 and 420m.a.s.l. It consists of two interconnected areas known locally as Morro do Rato, covered mainly by fragments of semideciduous seasonal forest and Morro do Macaco, with bare rock outcrops and patches of rupicolous vegetation harboring species of Bromeliaceae, Cactaceae, Orchidaceae and Velloziaceae, mosses and lichens (Dan, Aguiar & Nascimento, 2009; Aguiar & Gaglianone, 2011).

Currently, the Maciço do Itaoca is a common tourist destination, especially for extreme sports such as mountain biking and hang gliding. Due to its easy access, uncontrolled visitation endangers species of ornamental interest due to the pressure of collecting plants, especially Bromeliaceae, Gesneriaceae, and Orchidaceae. The immediate surrounding area is occupied by sugar cane plantations and near the Southwestern and Northeastern ends of the inselberg, there are several sites used for extraction of gravel and ornamental rocks (Alves, Barroso, Ramos & Pacheco, 2003).

Field work and laboratory: The floristic survey was carried out using the free walking survey methodology (Filgueiras, Nogueira, Brochado & Guala, 1994) during monthly expeditions between 2007 and 2009. These surveys sought to cover the largest possible area using five previously marked trails as well as new tracks opened during the survey. Voucher specimens were collected, pressed and had their relevant data recorded in the field, dried and subsequently cataloged and deposited in the Herbarium of the State University of Norte Fluminense Darcy Ribeiro (UENF), according to methods presented in Fidalgo & Bononi, 1984.

Information on the geographical distribution for each species found was obtained from the data base of the list of flora of Brazil (available in http://floradobrasil.jbrj.gov.br/2012).

Similarity analysis: The matrix for the similarity analysis was constructed using 500 species from 25 areas of the Eastern states of Brazil. Among the sites, 14 were composed primarily of inselbergs, 10 of which were located in the Brazilian Atlantic Forest and distributed in the Southeastern states of Rio de Janeiro, Espírito Santo, Minas Gerais and São Paulo, and four in the Atlantic or the Caatinga Domain in the Northeastern states, Bahia, Pernambuco, Paraíba. The remaining 11 were composed of different types of vegetation (such as seasonal semideciduous forest, evergreen forest, sandbanks, marsh, rocky fields and/or high altitude fields) within the Atlantic Forest and distributed in Southeastern Brazil (Table 1).

Only taxa identified to the species level were used in these analyses and those identified with "cf." or "aff." were discarded. We calculated the similarity using the Sorensen index and the UPGMA clustering algorithm. The cophenetic correlation was calculated in order to test the fit between the matrices and the resulting dendrograms. A Principal Coordinate Analysis (PCoA) using the species matrix was also performed to assess the existence of groups based on floristic similarities. The software PAST v2.17 (Hammer, Harper & Ryan, 2001) was used to make these analyses.

RESULTS

On the Maciço do Itaoca we recorded 18 orchid species belonging to 17 genera. Nine species presented an exclusive epiphytic habit, three being terrestrial, one rupicolous and five species presented two life forms (Table 2).

Among the species recorded on the Maciço do Itaoca, 11 (61%) occur only on the Morro do Rato, while three (17%) were unique to Morro do Macaco and four species were located in both areas. Five patterns of geographic distribution were established for the Orchidaceae species in the study area (transcontinental distribution (Americas and Africa); widely distributed in South America; Atlantic Forest, endemic to Brazil; Atlantic Forest in Brazil and Argentina and/or Paraguay; Atlantic Forest and other phytogeographical domains in Brazil), with 44% of the species belonging to

TABLE 1
List of locations used in the similarity analysis

Acronym	Locality	N	Coordinates	Altitude (m)	Reference
MIt*	Maciço do Itaoca - RJ	18	21º47'S - 41º27'W	40-420	Present study
PGav*	Pedra da Gávea, P.N. Tijuca - RJ	22	22º59'S - 43º17'W	601-842	Saddi (2008)
PNMP*	P.N.M. da Prainha - RJ	25	23º01'S - 43º30'W	0-456	Cunha & Forzza (2007)
PEST*	P.E. da Serra da Tiririca - RJ	27	22º48'S - 42º57'W	0-412	Barros (2008)
PA*	Pão de Açúcar - RJ	17	22º56'S - 43º09'W	0-395	Miranda & Oliveira (1983)**
PNI	P.N. Itatiaia - RJ/MG	158	22º30'S - 44º35'W	650-2 780	JABOT
PBot*	Pedra da Botelha - ES	14	18º26'S - 40º21'W	150-522	Bis (pers. comm.)
AltM*	Alto Misterioso - ES	25	19º48'S - 40º46'W	850-1 143	Esgario et al. (2009)
EBSL	E.B. Santa Lúcia - ES	160	19º56'S - 40º36'W	600-900	Romagna (pers. comm.)
PESB*	P.E. da Serra do Brigadeiro - MG	12	20º42'S - 42º28'W	1 722	Caiafa and Silva (2005)
IJF*	Inselbergs de Juiz de Fora - MG	12			
	- Morro do Imperador		21º45'S - 43º21'W	800-923	Pifano et al. (2007)
	- A.P.A. Santo Cristo		21º41'S - 43º18'W	850-1 000	Menini Neto (pers. comm.)
SN	Serra Negra - MG	109	21º58'S - 43º53'W	900-1 690	Abreu, Menini Neto & Konno (2011)
RBRG	R.B. Represa do Grama - MG	28	21º25'S - 49º20'W	750	Menini Neto, Almeida & Forzza (2004)
PEI	P.E. do Ibitipoca - MG	118	21º40'S - 43º52'W	1 000-1 784	Menini Neto, Alves, Barros & Forzza (2007)
PNC	P.N. Caparaó - MG/ES	86	20º20'S - 41º45'W	1 300-2 890	Leoni (1997)
MF*	Morro do Forno - SP	4	21º02'S - 47º19'W	800-900	Oliveira and Godoy (2007)
PNMFAM	P.N.M. Francisco Afonso de Mello - SP	67	23º28'S - 46º09'W	807-1 141	Rodrigues (2008)
NC	Núcleo Curucutu (P.E. Serra do Mar) - SP	25	23º59'S - 46º44'W	750-850	Garcia & Pirani (2005)
PEIC	P.E. Ilha do Cardoso - SP	139	25º10'S - 47º59'W	0-800	Romanini & Barros (2007)
EEJI	E.E. Juréia-Itatins - SP	70	24º18'S - 47º30'W	0-1 240	Catharino & Barros (2004)
SJ	Serra do Japi - SP	125	23º15'S - 43º65'W	700-1 300	Pansarin & Pansarin (2008)
IPB*	Inselbergs da Paraíba - PB	9			Almeida et al. (2007)
	- Lagoa de Pedra (mun. Esperança)		7º00'S - 35º53'W	699	
	- Pedra de Santo Antônio (mun. Fagundes)		7º20'S - 35º47'W	730	
	- Fazenda Santa Helena (mun. Serraria)		6º49'S - 35º38'W	562	
PAB*	Pedra Antônio Bezerra - PE	10	8º20'S - 35º50'W	713-835	Gomes & Alves (2009)
IBA*	Inselbergs do Brejo de Agrestina - PE	13			Gomes & Alves (2010)
	- Pedra da Guariba		8º22'S - 35º50'W	620	
	- Pedra Cabeça de Velho		8º23'S - 36º00'W	740	
IM*	Inselbergs de Milagres - BA	5			França et al. (1997)
	- Morro das Tocas		12º43'S - 39º42'W	280-410	
	- Morro do Agenor		12º42'S - 39º46'W	310-430	

*Inselbergs from Eastern Brazil. The others represent locations with different vegetation types occurring in the Atlantic Forest in Southeastern Brazil. **Database listing complemented by the Herbarium of the Botanical Garden of Rio de Janeiro (JABOT) because the published study took into account only rupicolous species of Orchidaceae. N - number of species. A.P.A. - Environmental Protection Area, E.E. - Ecological Station, PE - State Park, PN - National Park, P.N.M. - Municipal Natural Park, RB - Biological Reserve. Acronyms of Brazilian states: BA - Bahia, ES - Espírito Santo, MG - Minas Gerais, PE - Pernambuco, PB - Paraíba, RJ - Rio de Janeiro, SP - São Paulo.

TABLE 2
Orchidaceae recorded on the Maciço do Itaoca, Campos dos Goytacazes, Rio de Janeiro, Brazil

Species	Substrate preference	Presence		Patterns of geographic distribution	Voucher specimens
		Morro do Rato	Morro do Macaco		
Brasiliorchis picta (Hook.) R.B.Singer, S.Koehler & Carnevali	E	Common	Absent	D4	3 077
Brassavola tuberculata Hook. *	E/R	Rare	Common	D5	5 769
Campylocentrum robustum Cogn.	E	Rare	Absent	D5	5 774
Campylocentrum sellowii (Rchb. f.) Rolfe	E	Rare	Absent	D5	5 782
Catasetum luridum (Link) Lindl. *	E	Rare	Rare	D5	3 076
Cattleya guttata Lindl.	E/R	Common	Absent	D3	3 091
Cyclopogon congestus (Vell.) Hoehne	T	Common	Absent	D4	5 772
Cyrtopodium glutiniferum Raddi	R	Absent	Common	D3	5 786
Leptotes bicolor Lindl.	E	Rare	Absent	D2	5 763
Lophiaris pumila (Lindl.) Braem	E	Rare	Absent	D2	3 075
Miltonia moreliana A.Rich.	E	Rare	Absent	D3	3 078
Oeceoclades maculata (Lindl.) Lindl.	T	Common	Absent	D1	3 086
Phymatochilum brasiliense Christenson	E	Rare	Absent	D3	3 074
Prescottia plantaginifolia Lindl.	T/R	Absent	Common	D5	3 090
Pseudolaelia vellozicola (Hoehne) Porto & Brade	E	Absent	Common	D5	3 082
Sarcoglottis fasciculata (Vell.) Schltr.	T	Rare	Absent	D4	5 777
Sophronitis cernua Lindl. *	E/R	Common	Rare	D5	5 765
Vanilla chamissonis Klotzsch *	E/R	Common	Rare	D5	5 764

*Species that occur on two both parts of the Maciço do Itaoca, Morro do Rato and Morro do Macaco. Habits: E = Epiphyte R = Rupícolous, T = Terrestrial. Patterns of geographic distribution: D1 - transcontinental distribution (Americas and Africa); D2 - widely distributed in South America; D3 - Atlantic Forest, endemic to Brazil, D4 - Atlantic Forest in Brazil and Argentina and / or Paraguay; D5 - Brazilian Atlantic Forest and other phytogeographical domains in Brazil. The voucher refers to the first specimen collected in the study area and all deposited in the Herbarium UENF.

the Atlantic Forest pattern and other areas in Brazil (Table 2).

The dendrogram obtained in the similarity analysis (Fig. 1) showed the formation of two large groups. Group 1 was divided into two subgroups: the first (A) consisted of four inselbergs, two in Minas Gerais, one in Espírito Santo and one in São Paulo, and the second (B) was formed by all the 11 areas with different types of vegetation of the Atlantic Domain in the four states of the Southeastern region of Brazil. Group 2 was also composed of two subgroups, subgroup C comprised solely of inselbergs of the Atlantic Domain in the Southeast (Rio de Janeiro and Espírito Santo) and D formed by the four inselbergs in the Northeastern region of Brazil. The cophenetic correlation obtained was 0.9107, indicating little distortion between the matrix and the dendrogram. The Maciço do Itaoca was placed in subgroup C, having the highest similarity (0.44) with the Pedra da Botelha, inselberg located in the municipality of Boa Esperança in the North of Espírito Santo.

The eigenvalues and the percentage of variance explained for the first three ordination axes obtained by PCoA were 1.80, and 18%, 1.17 (12%) and 0.79 (8%), respectively. This ordination segregated distinct clusters of sites (Fig. 2) that were coincident with the main groups found by the cluster analysis, with a clear distinction between inselbergs and non

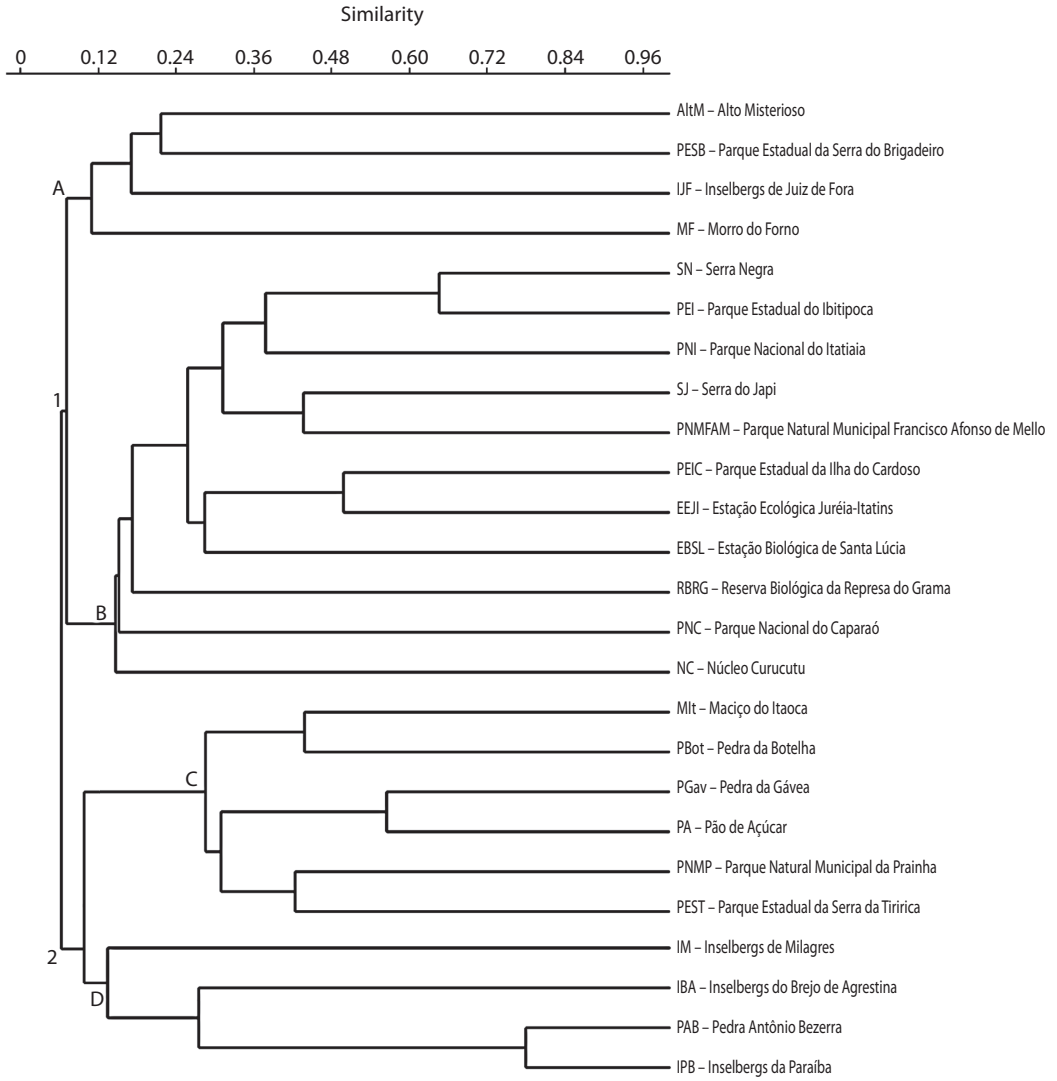

Fig. 1. Dendrogram (Sorensen index) obtained for the analysis of 525 species of orchids and 25 areas in Eastern Brazil (Table 1): AltM – Alto Misterioso; PESB – Parque Estadual da Serra do Brigadeiro; IJF – Inselbergs de Juiz de Fora; MF – Morro do Forno; SN – Serra Negra; PEI – Parque Estadual do Ibitipoca; PNI – Parque Nacional do Itatiaia; SJ – Serra do Japi; PNMFAM – Parque Natural Municipal Francisco Afonso de Mello; PEIC – Parque Estadual da Ilha do Cardoso; EEJI – Estação Ecológica Juréia-Itatins; EBSL – Estação Biológica de Santa Lúcia; RBRG – Reserva Biológica da Represa do Grama; PNC – Parque Nacional do Caparaó; NC – Núcleo Curucutu; MIt – Maciço do Itaoca; PBot – Pedra da Botelha; PGav – Pedra da Gávea; PA – Pão de Açúcar; PNMP – Parque Natural Municipal da Prainha; PEST – Parque Estadual da Serra da Tiririca; IM – Inselbergs de Milagres; IBA – Inselbergs do Brejo de Agrestina; PAB – Pedra Antônio Bezerra; IPB – Inselbergs da Paraíba. Cophenetic correlation = 0.9107. *Inselbergs from Eastern Brazil. The others represent locations with different vegetation types occurring in the Atlantic Forest in southeastern Brazil.

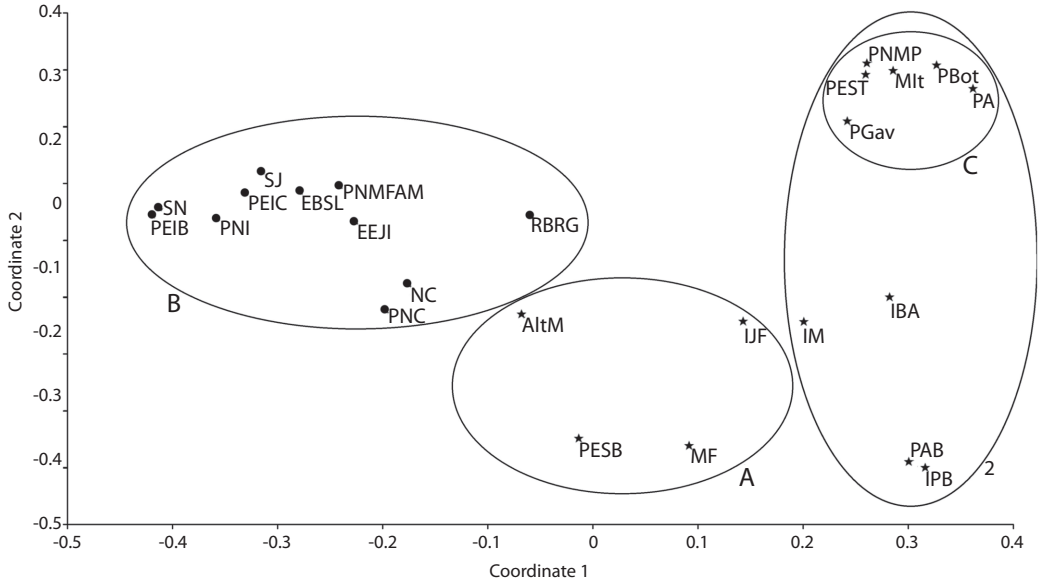

Fig. 2. Principal Coordinates Analysis of 525 species of orchids and 25 areas in Eastern Brazil (Table 1): AltM – Alto Misterioso; PESB – Parque Estadual da Serra do Brigadeiro; IJF – Inselbergs de Juiz de Fora; MF – Morro do Forno; SN – Serra Negra; PEI – Parque Estadual do Ibitipoca; PNI – Parque Nacional do Itatiaia; SJ – Serra do Japi; PNMFAM – Parque Natural Municipal Francisco Afonso de Mello; PEIC – Parque Estadual da Ilha do Cardoso; EEJI – Estação Ecológica Juréia-Itatins; EBSL – Estação Biológica de Santa Lúcia; RBRG – Reserva Biológica da Represa do Grama; PNC – Parque Nacional do Caparaó; NC – Núcleo Curucutu; MIt – Maciço do Itaoca; PBot – Pedra da Botelha; PGav – Pedra da Gávea; PA – Pão de Açúcar; PNMP – Parque Natural Municipal da Prainha; PEST – Parque Estadual da Serra da Tiririca; IM – Inselbergs de Milagres; IBA – Inselbergs do Brejo de Agrestina; PAB – Pedra Antônio Bezerra; IPB – Inselbergs da Paraíba. ★ Inselbergs from Eastern Brazil; ● locations with different vegetation types occurring in the Atlantic Forest in Southeastern Brazil. The letters and numbers outside the ellipses correspond to branches obtained in the cluster analysis (Fig. 1).

inselbergs sites. The Maciço do Itaoca, as found in the dendrogram (Fig. 1) formed a subgroup with other inselbergs from the Southeast Brazil (Rio de Janeiro and Espírito Santo) (C).

Seven of the species recorded in this study did not appear in any of the other 13 inselberg areas used in the comparative analysis: *Brasiliorchis picta*, *Campylocentrum sellowii*, *Cyclopogon congestus*, *Leptotes bicolor*, *Miltonia moreliana*, *Phymatochilum brasiliense* and *Pseudolaelia vellozicola*. When compared to inselbergs in the state of Rio de Janeiro, this number rises to eight, with the inclusion of *Vanilla chamissonis*.

On the other hand, four species occurring on the Maciço do Itaoca were found on at least six other inselbergs in the Eastern region of Brazil, among the 13 used in the similarity analysis. *Brassavola tuberculata* was the most often cited species, recorded at eight sites, while *Oeceoclades maculata* and *Prescottia plantaginifolia* were each reported at seven locations and *Cyrtopodium glutiniferum* was cited at six locations. When the Maciço do Itaoca was compared with other areas of the state of Rio de Janeiro, *B. tuberculata* and *P. plantaginifolia* were cited for all five inselbergs while *C. glutiniferum, O. maculata* and *Sophronitis cernua* were recorded at four.

The comparison of the Orchidaceae species of the Maçico do Itaoca with the other 11 areas with different vegetation types in the Atlantic Domain of the Southeastern region of Brazil showed that only *Phymatochilum brasiliense* and *Pseudolaelia vellozicola* were not mentioned at any other location.

DISCUSSION

The species richness of Orchidaceae recorded on the Maciço do Itaoca can be considered intermediate when compared with inselbergs of Eastern Brazil, with slightly fewer species than other inselbergs in the state of Rio de Janeiro: for example, PNMP (Cunha & Forzza, 2007), PEST (Barros, 2008) and PGav (Saddi, 2008). However, it was richer than inselbergs in other states in the Southeast region such as in Minas Gerais (Caiafa & Silva, 2005), São Paulo (Oliveira & Godoy, 2007), Espírito Santo (Bis, personal communication), and the Northeast region such as Bahia (França et al., 1997), Paraíba (Almeida et al., 2007) and Pernambuco (Gomes & Alves, 2009; 2010). However, these comparisons should be interpreted with caution due to factors such as inselberg size, habitat heterogeneity, and isolation, that may affect species diversity on inselbergs (Porembski, 2007).

Due to environmental characteristics inherent on inselbergs, the occurrence of a greater percentage of rupicolous orchid species is common when compared with epiphytes and terrestrials, as observed in studies of Miranda & Oliveira (1983) and Saddi (2008). However, on the Maciço do Itaoca, the epiphytic life form was predominant due to the occurrence of forest fragments in this area, especially on the Morro do Rato, since only *Brassavola tuberculata* and *Pseudolaelia vellozicola* were observed as epiphytes on *Vellozia plicata* Mart. (Velloziaceae) on the rocky outcrop. Similarly, in the study of Cunha & Forzza (2007) conducted in an environmental mosaic of interspersed forest fragments and inselbergs, epiphytic species were also more numerous than rupicolous. On the other hand, Werneck & Espírito Santo (2002) found low diversity of epiphytes in a study of vascular epiphytic flora on *Vellozia piresiana* L.B.Sm., in *campo rupestre* vegetation in Minas Gerais State (which presents environmental features similar to inselbergs), due to the low number of available phorophytes and inadequate environmental conditions for this life form. So, those epiphytic species found in the rock outcrops of Maciço do Itaoca are the real specialists in this type of environment.

Only 30% of the species of Orchidaceae on the Maçico do Itaoca were found on the Morro do Rato and Morro do Macaco, although with different frequencies. This result is especially interesting due to the fact that the two areas have very different structural characteristics, such as the presence of rocky outcrops, presence/absence of woody vegetation, microclimate (temperature and humidity). This fact corroborates the observations of Cunha & Forzza (2007) and Barros (2008) in studies conducted in areas with the presence of a forest physiognomy and rocky outcrops, reinforcing the existence of strong habitat specificity peculiar to many species of Orchidaceae (Hoehne, 1949; Pabst & Dungs, 1975).

In terms of habitat specificity and vegetative habit, we can cite *Pseudolaelia vellozicola* that is found only on rock outcrops as an epiphyte on *Vellozia plicata* on the Maciço do Itaoca and does not occur on any nearby shrub or tree, though these species also serve as phorophytes for other Orchidaceae. This pattern can be observed in most species of *Pseudolaelia* (Menini Neto, 2011) and a similar specificity has been reported for *Zygopetalum maxillare* Lodd., whose individuals occur almost exclusively as epiphytes on stems of tree ferns especially of the genera *Alsophila* and *Cyathea* (Cyatheaceae), and *Dicksonia* (Dicksoniaceae) (Hoehne, 1949).

The species distribution records show that seven are endemic to the Brazilian Atlantic Forest and only three are widely distributed in South America (*Oeceoclades maculata* can be found in Central America and Africa as well, *Leptotes bicolor* and *Lophiaris pumila*). The other species can be found also in other phytogeographic domains such as the Caatinga and Cerrado (Barros et al., 2009; 2010; 2012).

The clear formation of two distinct groups by both cluster and PCoA analyses suggests strong divergence in floristic composition among the Orchidaceae on inselbergs from Eastern Brazil. Most of the inselbergs analyzed appeared in group 2, consisting of two

subgroups C (consisting of all locations of Rio de Janeiro and only one in Espírito Santo) and D (inselbergs found in the Northeastern Brazil). This differentiation between inselbergs in the Southeast and Northeast regions of Brazil suggests the influence of latitude, altitude or the presence of barriers to the migration of species, since in general the environmental conditions found on inselbergs are similar, regardless of the phytogeographical domain in which they occur (Porembski, 2007). Another factor that must be considered includes the stochastic colonization events, which may also be responsible by the floristic differentiation between the inselberg communities as highlighted by Porembski & Barthlott (2000).

The position of the Maciço do Itaoca in subgroup C, showing greater similarity to Pedra da Botelha, located in Northern Espírito Santo than with other closer inselbergs in the state of Rio de Janeiro also is worthy of note. The environmental characteristics of these two inselbergs probably are influenced by the combination of distance from the coast (about 45km and 70km for MIt and PBot, respectively) and similar altitudes (40-420m at MIt and in PBot 150-520m), possibly allowing their flora to present greater similarity. The four inselbergs in the state of Rio de Janeiro present in the other branch of the subgroup C (PGav, PA, PNMP and PEST) are situated nearer the ocean and are subject to different climatic conditions, which may influence the occurrence of different species, because of the habitat specificity of many orchid species.

The separation of groups by distance from the coast and altitude can also be observed in the formation of subgroup A, in which other Southeastern inselbergs appear grouped together compared to inselbergs in subgroup C. All four areas of this subgroup are at altitudes above 800m, and generally much further from the coast than the other inselbergs. The importance of elevation as a condition for the distribution of plant species was also cited by Oliveira-Filho & Carvalho (1993), van den Berg & Oliveira-Filho (2000) and Menini Neto, Forzza & Zappi (2009) for other plant communities in Brazil.

The influence of different surrounding types of vegetation on the composition of the flora of the Orchidaceae on inselbergs seems to be small, but the degradation of contiguous forests does not allow more detailed conclusions. Although the 11 areas with different vegetation types occurring in the Southeast subgroup B form a group, along with four inselbergs in subgroup A, the similarity between A and B is extremely low (ca. 0.05). The observed similarity between classes 1 and 2 (the latter joining the other analyzed inselbergs) is even lower. Similar results were observed in a study conducted in Northeastern Brazil by Gomes & Alves (2009), who found low similarity among inselbergs, Caatinga and surrounding areas, suggesting their reduced influence on the floristic composition of the inselbergs.

The results of this study confirm the peculiar environmental and floristic composition of inselbergs and that these sites are largely independent of the matrix of surrounding vegetation, since they represent isolated islands with distinct microclimate and vegetation strongly adapted to the seasonal drought that is typical of these rocky outcrops (Barthlott et al., 1993; Porembski, 2007). They also confirm the conclusions of Fiaschi & Pirani (2009) that the heterogeneity of habitats in the Brazilian Atlantic Forest probably played an important role in the diversification and endemism of its flora, especially on inselbergs, which are common in Southeastern Brazil (Porembski, 2007).

The composition and reduced similarity of the flora of inselbergs, independent of surrounding vegetation, reinforces the need of special conservation efforts of each outcrop, due to degradation of their environment.

Although none of the Orchidaceae found on the Maciço do Itaoca are cited in the list of endangered species in Brazil (Ministério do Meio Ambiente, 2008), the occurrence of some species of ornamental interest should be highlighted especially due to collection pressure by visitors, due to ease of access and lack of official protection. These species include *Cattleya*

guttata, *Miltonia moreliana* and *Phymatochilum brasiliense*, all endemic to the Atlantic Domain in Brazil, reinforcing the importance of establishing protected areas in this region. *Phymatochilum brasiliense*, despite its relatively wide distribution, from Pernambuco to São Paulo, is apparently a very rare species with few records in herbarium collections.

Pseudolaelia vellozicola is another species worth mentioning. Although it does not suffer collection pressure and is the species in the genus with the widest geographical distribution, there are only two records from the State of Rio de Janeiro, being more frequent on the coast and in the highlands of the state of Espírito Santo. The population of the Maciço do Itaoca along with another recorded in Casimiro de Abreu, also in the state of Rio de Janeiro, represent the Southern distribution limit of this species (Menini Neto, 2011). As noted by this author, the location of this population, at the Southern limit of the species, is also reflected in a considerable genetic differentiation relative to populations occurring in Bahia, Espírito Santo and Minas Gerais, a fact that should also be taken into account for effective conservation. The isolated nature of inselbergs probably contributed to this genetic differentiation, as this may hinder gene flow between populations, also reinforcing the importance of conservation of these unique vegetation islands Porembski (2007).

Collection pressure is generally responsible for the destruction of the vegetation on inselbergs because the target species are restricted to some families of more ornamental interest, such as Bromeliaceae, Gesneriaceae, and Orchidaceae. However, quarrying is one of the most damaging activities to the inselbergs because it puts at risk not only the species, but the very environment in which they occur (Porembski, 2007). This threat is also present in the Maciço do Itaoca where two granite mining areas are present on the edges of this inselberg.

Although the natural occurrence of fire due to lightning is occasional on inselbergs, fires caused by anthropogenic activities have been largely responsible for the degradation of the vegetation in these environments both in Brazil and in inselbergs around the world (Meirelles et al., 1999; Burke, 2003). Fires are recurrent on the Maciço do Itaoca, due to the periodic burning of adjacent sugar cane plantations as part of management of this type of culture (personal observation). Besides the direct impact on the plants during the fires, Meirelles et al. (1999) noted that even the shallow soil, which occurs in patches on the outcrops, can be completely removed after burning during the occurrence of heavy rains, leaving bare rock. Even if this does not occur, the patches of soil can be rapidly colonized by exotic species, such as *Melinis minutiflora* Beauv. (Poaceae). This species can eliminate native species from this environment, because its aggressive growth.

Also, the conservation of orchid species in the Maciço do Itaoca is important because the flowers are generally pollinated by euglossine bees (Apidae, Euglossina) and this area is considered to be a regional refuge to these pollinator insects (Aguiar & Gaglianone, 2011).

Dan et al. (2009) indicated the species of the flora that are endemic and/or rare in the Brazilian Atlantic Forest and that have been recorded from the Maciço do Itaoca. These include *Begonia ibitiocensis* E. L. Jacques & Mamede (Begoniaceae), *Cryptanthus delicatus* Leme (Bromeliaceae), *Sinningia pusilla* (Mart.) Baill., *Sinningia* sp. nov. (Gesneriaceae). A proposed annexation of the Maciço do Itaoca to the Desengano State Park (PED) has been discussed within the scientific community and the management of the PED, the State Environmental Institute (INEA) and this would be an opportunity to establish an effective monitoring program in the area in an attempt to protect this unique type of environment with highly adapted vegetation and frequent occurrence of endemic species.

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RESUMEN

Composición y conservación de Orchidaceae en un *inselberg* en el bosque Atlántico brasileño y sus relaciones florísticas con áreas del este de Brazil. La Mata Atlántica brasileña presenta altos niveles de riqueza y endemismo de varios grupos taxonómicos. Los inselbergs de la Mata Atlántica de Brasil son, en su mayoría, desconocidos en cuanto a su composición florística. Los objetivos de este estudio fueron hacer un análisis comparativo de las especies de Orchidaceae en el Macizo de Itaoca, un inselberg ubicado en la región norte del Estado de Río de Janeiro, con otros sitios en el este de Brasil, y discutir la distribución geográfica, las relaciones florísticas y el estado de conservación de las especies de orquídeas presentes en los inselbergs. La composición florística de la zona de estudio se comparó con otras 24 localidades en el este de Brasil (13 de las cuales son inselbergs) y la influencia de los tipos de vegetación aledaña en la composición de la flora de Orchidaceae en los inselbergs. En Macizo de Itaoca registramos 18 especies de 17 géneros. La mayor similitud florística fue con la Pedra da Botelha (0,43), en Espírito Santo. Al parecer, los tipos de vegetación aledaña ejercen poca influencia sobre la flora de los inselbergs.

Palabras clave: biogeografía, similitud florística, Maciço do Itaoca, Estado de Río de Janeiro, afloramiento rocoso.

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