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BIOLOGY

Ecogeography of *Lippia rotundifolia* Cham. in Minas Gerais, Brazil

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ABSTRACT: *Lippia rotundifolia is a specie native to the Brazilian Cerrado, endemic to the Cadeia do Espinhaço mountain range. Due to the limited information about the species, the present study aimed to characterize the ecogeography, climate conditions and physical and chemical characteristics of the soil of Lippia rotundifolia in the state of Minas Gerais, Brazil. Thirteen sites were ecogeographically characterized: Parque Estadual Veredas do Peruaçu; Gigante; Rio do Peixe; AEP of Olhos D'água; Joaquim Felício; Parque Estadual do Rio Preto; São Gonçalo do Rio das Pedras; Rio Tigre; RPPN Brumas do Espinhaço; Lapinha; Poço Bonito; Abóboras; and Parque Estadual de Serra Nova. Environments belonged to Cerrado and Caatinga biomes, specifically in rocky and altitude fields. The species occurs at altitudes between 691-1311m, with precipitation between 700 to 1600mm and average temperature between 14.5 to 24°C. In these vegetation types, the soils were sandy, hyper dystrophic and highly toxic with a low cation exchange capacity. These characteristics make the species undemanding with regard to edaphoclimatic and ecogeographic factors.*
Key words: *genetic resources, characterization, ecogeography, Lippia rotundifolia.*

Ecogeografia de *Lippia rotundifolia* Cham. *(Verbenaceae)* em Minas Gerais, Brasil

RESUMO: *Lippia rotundifolia é uma espécie nativa do Cerrado e endêmica da Cadeia do Espinhaço. Devido a poucas informações acerca da espécie, objetivou-se caracterizar as condições ecogeográficas e edafoclimáticas bem como os atributos físico-químicos do solo da Lippia rotundifolia no estado de Minas Gerais, Brasil. Realizou-se o levantamento ecogeográfico em 13 locais (Parque Estadual Veredas do Peruaçu, Gigante, Rio do Peixe, APA de Olhos d'Água, Joaquim Felício, Parque Estadual do Rio Preto, São Gonçalo do Rio das Pedras, Rio Tigre, RPPN Brumas do Espinhaço, Lapinha, Poço Bonito, Abóboras e Parque Estadual de Serra Nova). Os resultados identificaram os ambientes pertencentes aos biomas Cerrado e Caatinga especificamente nos campos rupestres e de altitude. A espécie ocorre entre as altitudes de 691 a 1311 metros, precipitação entre 700 a 1600 milímetros e temperatura média variando entre 14,5 a 24 graus. Nestas fitofisionomias os solos apresentam textura arenosa, são hiperdistrófico, altamente tóxico com baixa capacidade de troca de cátions, que faz a espécie ser pouco exigente quanto aos fatores edafoclimáticos e ecogeográficos.*
Palavras-chave: *recursos genéticos, caracterização, ecogeografia, Lippia rotundifolia.*

INTRODUCTION

Rocky fields are one of the vegetation types of the Brazilian Cerrado and are characterized by altitudes above 800m, xeromorphysm and the presence of rocky outcrops (RAPINI et al., 2008). The Cadeia do espinhaço (BFG, 2015) presents rocky fields and its species composition is predominately of the family Verbenaceae. Most of the endemic species at these altitudes belong to the genus *Lippia* Linn., the second largest genus in the Verbenaceae family. *Lippia rotundifolia* Cham., one of the endemic species of rocky fields (CARVALHO et al., 2012), is known as chá-de-pedestre. It is a shrub with upright stalks, alternate leaves, coriaceous and pink-lilac inflorescences, which has a fragile physiognomy and low resilience (SALIMENA & SILVA, 2009).

The species produces an essential oil whose main components are β-myrcene, farnesol, limonene and myrcenal. Pharmacological tests have indicated that the species has antibacterial activity (LEITÃO, 2008). Studies such as these are useful in

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the development of genetic improvement programs, since native aromatic species produce chemical compounds with high biological activity, giving them great economic potential (LEITÃO, 2008).

In order to develop any conservation program for native medicinal flora, it is necessary to conduct characterization studies of the different places of occurrence in order to understand the population dynamics of each species in relation to ecogeographic factors (PARRA-QUIJANO, 2012). Ecogeographic studies showed that species such as *Varronia curassavica Jacq. Boraginaceae* are generalist in regards to ecogeographic and edaphoclimatic factors (MENDES et al., 2015) and that *Lippia sidoides* Cham. occurs naturally in poor and acidic soils (MELO, 2012). This type of information is important for developing conservation strategies for plant genetic resources. Thus, the present study aimed to characterize the ecogeographic and climate conditions, in regards to the degree of anthropism, burns, climate (altitude, precipitation, temperature) and e physico-chemical characteristics of the soil, of *Lippia rotundifolia* in Minas Gerais, Brazil.

MATERIALS AND METHODS

The study was conducted from August 2014 to May 2015 in the mesoregions Norte, Vale Jequitinhonha, Central, Metropolitana and Campo das Vertentes in Minas Gerais State. The first two are part of the so-called drought polygon, and the third is in Serra do Cabral, which is a watershed between the tributaries of the São Francisco river with trail, wood and rocky outcrop ecotone. The fourth mesoregion is located in Serra do Cipó and has a high-altitude tropical climate. It is also considered to be the geomorphological threshold of Brazil. The last one, Campo das Vertentes, is a watershed of the Brazilian plateau and also has a high-altitude tropical climate, in addition to being the coldest mesoregion of the state. All these mesoregions encompass the Cadeia do Espinhaço, which presents vegetation types of rocky fields with herbaceous shrubs and trees, sclerophyllous and evergreen vegetation and many springs.

Thirteen sites with natural occurrence of *Lippia rotundifolia* were selected. The environments were located by means of hiking in the *Cadeia do espinhaço*. Geographical orientation for proper access to the sites was based on the reference of the *Melastomataceaes* species *fasciculata Microlicia Mart. Ex Naudin* (PAMG58103), *Lavoisiera imbricata* (Thunb.) DC. (PAMG58104), *Cambessedesia espora* (A. St.-Hil. Ex. Bonpl.) DC. (PAMG58105) and *Microlicia serpyllifolia* D. Don (PAMG58106), the species Asteraceae *Pseudobrickellia brasiliensis* (Spreng.) R.M.King &H. Rob. (PAMG 58102) and by consulting the information bank of INCT - Virtual Herbarium of Flora and Fungi. The occurrence sites were identified by GPS (Global Positioning System) Oregon 550 Garmin®, which determined the geographical coordinates (latitude, longitude and altitude). From these coordinates, a thematic chart was created with the points of occurrence of the species in the five mesoregions (Table 1).

The data for the preparation of the chart were extracted from the vector files made available by IBGE (2015), which were imported into SIRGAS 2000 (Geocentric Reference System for the Americas) whose EPSG code was 31983 with Datum projection in UTM zone 23s. In order to classify the environments of occurrence of the species, the biome, vegetation type, mean annual rainfall and mean annual temperature were identified using thematic letters made available by IBGE (2015).

For soil chemical analysis, samples were taken in each place of occurrence at 0-20cm of depth using a Dutch auger. Five auger samples were taken per site in order to form each composite sample. Chemical analyses were performed at the Soil Laboratory of the Institute of Agricultural Sciences, Universidade Federal de Minas Gerais Montes Claros, Minas Gerais state. Analytical determination was obtained according to extraction and determination margins proposed by CFSEMG (1999). Soils were classified according to the Brazilian Soil Classification System (SANTOS et al., 2013).

Chemical and granulometric analysis data of the occurrence sites of the species were submitted to principal component analysis (PCA). Variables were first submitted to Pearson correlation analysis (r) ($P \leq 0.5$) in order to verify whether they had the minimum correlation to justify their use in the data matrix. The retention of PCA axes to be interpreted was obtained by reducing the data set in linear combinations, which generated scores around 80% of the total variation. This enabled the identification of the most relevant chemical properties in the discrimination of the different sites of occurrence. From the correlation matrix generated, it was then possible to generate groups based on their measurements. This analysis was performed using the statistical software Ntsys-pc 2.1 (ROHLF, 2000).

RESULTS AND DISCUSSION

The 13 environments located within the five mesoregions of Minas Gerais state are distributed into two biomes, where 92% is located in the Cerrado and

Table 1 - Location and characterization of 13 sites of natural occurrence of *Lippia rotundifolia* Cham.

Code	Mesoregion	Site	Coordinates		Soil class	Altitude (m)	Precipitation (mm)	Temperature (C°)	Exsic record
			Latitude	Longitude					
N	PVP	PE Veredas do Peruaçu	-14°55´24´´S-14°55´24´´S	-44°38´21´´W	LVAd	729	700	22 - 24	PAMG 58090
	GIG	Gigante	-16°35´24´´S-16°35´24´´S	-42°55´30´´W	AR	726	1200 - 1500	21 - 24	PAMG 58097
	RPE	Rio do Peixe	-16°52´36´´S-16°52´36´´S	-43°28´56´´W	AR	722	1000 - 1200	21 - 24	PAMG 58094
	ODA	APP Olhos D'água	-17°26´10´´S-17°26´10´´S	-43°37´12´´W	AR	691	1000 - 1200	21 - 24	PAMG 58096
	ABO	Comunida de Abóboras	-16°56´87´´S-16°56´87´´S	-43°55´76´´W	RLd	700	1000 - 1200	22 - 24	PAMG 58095
	SNO	PE Serra Nova	-15°6,92´´S	-42°44.034´W	AR	790	700	21 - 24	PAMG 58096
C	JFE	Joaquim Felício	-17°44´24´´S-17°44´24´´S	-44°11´41´´W	RLd	1010	1200 - 1500	21 - 24	PAMG 58093
VJ	PRP	PE do Rio Preto	-18°06´09´´S-18°06´09´´S	-43°20´18´´W	AR	901	1200 - 1500	18 - 19	PAMG 58091
	SGS	São Gonçalo do Rio das Pedras	-18°25´51´´S-18°25´51´´S	-43°28´56´´W	AR	1020	1200- >1500	14,5 - 21	ESAL 28086
	RTI	Rio Tigre	-18°33´59´´S-18°33´59´´S	-43°49´40´´W	RLd	1020	1200- >1500	19 - 21	PAMG 58092
M	RBE	RPPN Brumas do Espinhaço	-19°03´04´´S-19°03´04´´S	-43°42´34´´W	RLd	1311	1600	19 - 21	PAMG 58098
	SRI	Santana do Riacho	-19°16´47´´S-19°16´47´´S	-43°37´12´´W	RLd	756	1600	19 - 21	PAMG 58099
CV	PBO	PEc Quedas do Rio Bonito	-21°20´07´´S-21°20´07´´S	-44°58´55´´W	AR	1092	- 1500	19 - 21	ESAL 28086

N = Northern Mesoregion. C= Central Mineira Mesoregion, VJ= Vale Jequitinhonha Mesoregion M= Metropolitana Mesoregion CV= Campo das Vertentes Mesoregion PE= State Park; APP= Area of Environmental Preservation; RPPN= Private Reserve of Natural Heritage; PEc= Ecological Park TM = Mean annual temperature. LVAd = Dystrophic Yellow Red Latosol; AR = Rocky Outcrop; RLd = Dystrophic litholic neosol Source: IBGE (2015).

8% in the Caatinga (Figure 1). Among this distribution, 36.36% are in the ecotone area and 63.64% occur in rocky fields. Altitudes varied between 691 and 1311 meters (m). Mean annual rainfall ranged from dry (700mm) to very wet (1600mm) and mean annual temperatures ranged between 14.5 and 24°C (Table 1).

The species occurs preferentially in altitude environments and near water courses, which is a specific feature of the plant for rocky environments. This species also occurs in altitude environments with varied rainfall, in which the lowest rainfall occurred in PVP and SNO with 729 and 790m. The lowest altitude was in ODA with 691 meters, with similar rainfall index for the other sites of the northern mesoregion, which varied between 1000 and 1500mm. However, the highest rate occurred in sites with 600m of difference between them, with altitudes between 756 and 1311m SRI in RBE (Table 1).

The thermal gradient, altitude, and temperature were not determinant factors for the occurrence of the species within the studied vegetation types. In the Vale Jequitinhonha mesoregion, in PRP, the median altitude was 901m and the temperature was below 19°C. In Serra do Cipó, in SRI and RBE, the temperatures were the same, which was between 19 and 21°C, although the altitudes were different, with 756 and 1311m, respectively. The explanation for this variation lies in the hilly topography since these last two ecotypes are geographically close and belong to the same mesoregion (Table 1). For the northern mesoregion there was no difference in altitude. Regarding precipitation, the lowest recorded in PVP and SNO corresponded to the highest temperatures, between 21 and 24ºC. This difference is due to the transition area between the Cerrado and Caatinga, whose soil and climatic characteristics are semi-arid.

The phenotype stage of the species varies among the places of occurrence, where PRP RTI, JFE, ODA and GIG presented young individuals, whereas PBO, RBE, SRI, SGS, RPE and PVP presented adults. This is due to environmental conditions in which the species is found since its phenological cycle oscillates depending on the availability of resources necessary for its establishment (COLLEVATTI et al., 2010).

Unfavorable environmental conditions included fires and the use of native vegetation for grazing. This last event was observed at the SRI site, where the species was located in an area of secondary vegetation with the presence of cattle. Although, the environment is conducive to the occurrence of the species because it is located on a river bed, the trampling of the animals in the area prevents the establishment of individuals in this area (ALVES et al., 2009). Notably, the GIG, JFE and PVP sites presented occurrence of fire. In GIG, all individuals were in the physiological process of regrowth. In the ecotone (JFE and PVP sites), the individuals in the first one were in a succession process with all young individuals, while in the second the impact of fire was more critical. Explanation for the occurrence of the species in this type of environment is the fact that the plant has a well-developed root system, where xylophones grow shoots after events such as fires, which are features of pioneer colonizing species of anthropogenic environments (ALVES & SILVA, 2011).

However, climate, degree of anthropism and fire are frequent characteristics in nature, where the establishment of the species in temporal space is distinct in each place in which reestablishment depends on environmental conditions. Following this logic, the species under study is considered a model for metapopulation. In this dynamic, each area has the same possibility of extinction and recolonization (LEVINS, 1969; ALVES & SILVA, 2011).

Soils were grouped into three classes, in which 8% of the sites (PVP) occur in typical acric red yellow latosol, 54% (LGA, EPR, ODA, PRP, SGS, SNO and PBO) occur in rocky outcrops and 38% (JFE, RTI, RBE, ABO and SRI) in a litholic neosol (Table 1). Among the rocky fields of high altitude, rocky outcrops and cliffs, 92.30% of sites occur in rocky environments with shallow and stony soils (Figure 1a and Table 1), which confirms the specificity of the plant for these environments (RIBEIRO & FREITAS, 2010).

Using principal component analysis (PCA) and discriminant analysis, the physical and chemical soil properties summarized the physical and chemical variables in the first two principal components (PC). These were retained for interpretation with accumulated eigenvalues at 88.79% of variance for all variables. The first component explained 64.03% of the variability for all samples. The attributes with the highest factorial load in the first component were pH in water, exchangeable acidity (EA), base sum (BS), effective cation exchange capacity (t), saturation by aluminum (m) and sand, with scores varying between 0.933 to 0.984. The second component explained 24.76% of variability. Attributes that contributed to the explanation of this component were the remaining phosphorus (Prem) and organic matter (OM), with negative scores between -0.694 and -0.645 (Table 2).

The first principal component (PC1) showed clear separation of the physical and chemical properties of the soil, in which the 13 sites of occurrence presented hyper dystrophic and aluminum soils with base saturation (V) of less than 35% and for aluminum (m) ranged from 60% in PBO to 85% in ODA (Figure 1b). The low value of V suggested high adsorption of Al^{3+} and H^{+} as well as low amounts of basic cations adsorbed in the soil colloids. This saturation refers to the potential acidity (H + Al), which presented a high negative correlation (Table 2, Figure 1b). This variable

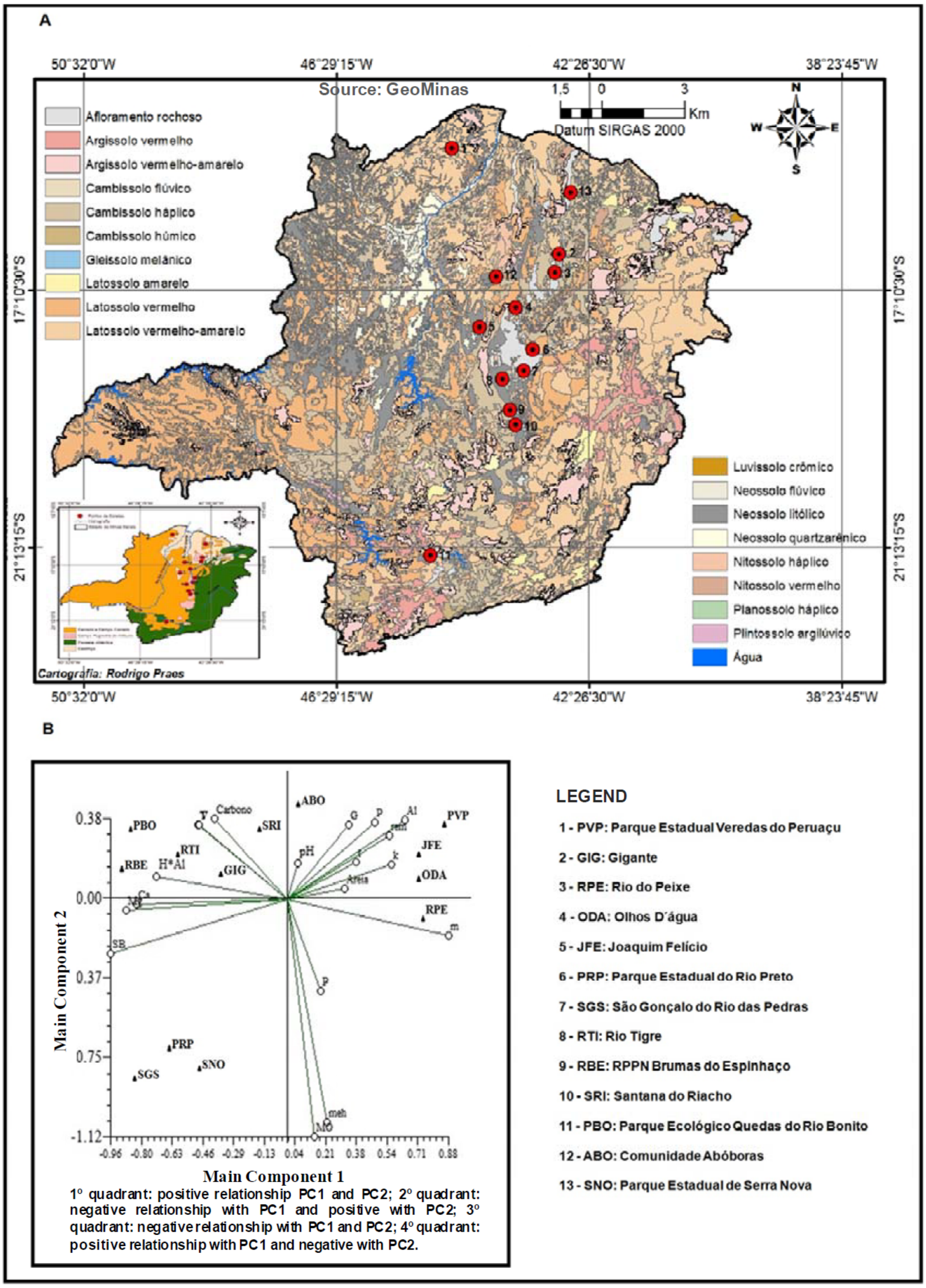

Figure 1 - a: Soil classification map and b: two-dimensional space projection of the two main components obtained from the similarity matrix of the chemical and physical soil attributes of 13 sites of occurrence of *Lippia rotundifolia* in Minas Gerais, Brazil. Source Data: GEOMINAS.

contributed to the grouping of the collection sites according to the similarity between the environments.

The collection sites were divided into two groups. The lower plane of the axis presented soils

Table 2 - Chemical and physical soil attributes with the eigenvalues of the main components of the 13 *Lippia rotundifolia* collection sites in Minas Gerais. Brazil.

Components of variance		-------------------------Soil rates------------------------	
		PC 1	PC 2
Variability (%)		64.03	4.76
Accumulated variability (%)		64.03	8.79
Variables	Mean±DP	Factor load	
pH in H_2O	4.47±0.82	0.984	0.003
Phosphorus (Remaining mg L^{-1})	32.65±1.08	0.555	-0.726
Potassium (k in mg dm^{-3})	20±11.48	0.890	0.190
Calcium	0.23±0.04	-0.807	-0.051
Magnesium	0.1083±0.02	-0.876	-0.087
Exchangeable acidity (Al cmolc dm^{-3})	1.30±0.4	0.933	0.093
Potential acidity (H + Al in cmolc dm^{-3})	7.93±3.4	-0.891	-0.017
Base sum (SB in cmolc dm^{-3})	0.39±0.26	-0.982	-0.026
Effective CTC (t cmolc dm^{-3})	1.69±0.45	0.972	-0.067
Saturation by aluminum (m in%)	75.42±2.56	0.975	-0.004
CTC at pH 7.0 (T in cmolc dm^{-3})	6.28±2.26	-0.861	-0.152
Saturation per base (V in%)	7.08±3.6	-0.868	-0.054
Organic Matter (MO in dag kg^{-1})	3.63±1.33	0.449	-0.645
Organic Carbon (C in dag kg^{-1})	2.11±0.77	-0.654	0.084
Coarse sand (g kg^{-1} <X2 />)	28.11±19.21	0.981	0.529
Fine sand (dag kg^{-1})	54.56±20.64	0.646	0.12
Silt (dag kg^{-1})	10±8.05	0.19	0.24
Clay (dag kg^{-1})	7.33±3.65	-0.34	-0.38

*SD = Standard Deviation; PC = Principal component.

with potential acidity of 9.0 and 9.83cmolc dm^{-3} and very low pH in water. The upper plane presented soils with potential acidity between 2.37 and 5.9cmolc dm^{-3} and low pH (Figure 1). The lowest intra-group distance was observed for PRP, SGS and SNO soils because they presented very high alkalinity, of 8.75, 9.0 and 12.98cmolc dm^{-3}, respectively, with sandy texture, and higher content of organic matter and were well drained. The proximity between RTI, RBE, SRI and PBO is due to the fact that they coexist in rocky and altitude field environments in addition to presenting the same climatic conditions. The ODA and RPE environments presented neutral reaction and moderate alkalinity (6.81 and 7.79cmolc dm^{-3}).

Environments with alkaline soils (RPE, SGS) and lower plane of the axis presented the largest individuals with heights over 2 meters and well-developed stems. The smallest individuals occurred in environments with acid soils (GIG, JFE, PVP, SRI, RTI, PBO and RBE), which make up 54% of the sites. Heights of these individuals did not exceed 1.5m. This confirms that fire and dystrophism act as one of the selective factors of the Cerrado species (PINHEIRO & MONTEIRO, 2010).

A strong positive potassium correlation (K) with sand in PC1 was confirmed in the first quadrant of spatial analysis (Figure 1b), showing a strong relationship with coarse sand, which was more mobile in relation to the other two elements, calcium (Ca) and magnesium (Mg) in the third quadrant of PC1 (Table 2, Figure 1b). For the second principal component (PC2), there was a strong negative relation between the two variables (MO and Prem) in the intense adsorption of phosphorus (P) as a function of the low organic matter contents in 58% of the sampled sites (Table 2, Figure 1b) (PEREIRA et al., 2010). This result corroborated the hypothesis that species of this genus are well adapted in nutrient-poor environments with high acidity (MELO, 2012).

However, the main components analysis confirmed the physicochemical characteristics common to all environments regarding hyperdystrophy, toxicity and the low effective capacity of cation exchange. Results about edophoclimatic and ecogeographic conditions as well as the degree of anthropism occurring at sites of *Lippia rotundifolia* show this species to be a well-adapted ecotype, since it is not considered under threat of extinction and its wide occurrence corresponds to a characteristic of the genus (SALIMENA & SILVA, 2009).

CONCLUSION

The species has a wide distribution and varied density. It does not present any ecogeographic constraint; however, each site of occurrence has specific characteristics within a dynamic metapopulation. The species has a preference for environments near water courses and higher altitudes.

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