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Rodrigues da Cunha Gianotti, André; Hatem de Souza, Maria José; Marinho Pereira, Israel; Mendonça Machado, Evandro Luiz; Duarte Vieira, Artur; Rodrigues Magalhães, Mariana

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SOIL AND PHYTOSOCIOLOGICAL CHARACTERIZATION OF AN AREA WITH PREDOMINANCE OF ARNICA (*Lychnophora pohlii* Sch. Bip.)[1]

André Rodrigues da Cunha Gianotti[2], Maria José Hatem de Souza[3], Israel Marinho Pereira[4], Evandro Luiz Mendonça Machado[4], Artur Duarte Vieira[5] & Mariana Rodrigues Magalhães[5]

SUMMARY

Lychnophora pohlii **Sch. Bip. (Asteraceae), known as "Arnica mineira", is widely used in folk medicine and very abundant in the altitude vegetation of rocky grassland. The aim of this work was to study the density of this species and its relationship with soil parameters in rocky grassland in Diamantina, in the Upper Jequitinhonha region, Minas Gerais. Ten contiguous 20 x 50 m plots were marked (total sampled area 10,000 m²) on the campus Juscelino Kubitschek of the Federal University of Jequitinhonha and Mucuri Valleys (UFVJM). The plants in these plots were evaluated for frequency, dominance and density. The relationship between the density of this species with nine soil physical and chemical properties was analyzed by means of canonical correspondence analysis (CCA). The highest plant abundance (I) of the species *Lychnophora pohlii* Sch. Bip. was found in the vegetation sampling areas: plot 6 with 255 plants, plot 7 with 173, plot 8 with 189, plot 9 with 159, and plot 1 with 151 plants. In these areas, the floristic soil characteristics were similar, resulting in spatial proximity in the ACC diagrams. The density of *Lychnophora pohlii* was higher in plots with higher pH, P-rem and base saturation, the variables most strongly correlated with the first axis of canonical correspondence analysis.**

Index terms: rocky grassland, savanna, forest soils, canonical correspondence analysis.

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[2] Agronomist, Master of Science in Forestry, Dept. of Forest Engineering, Faculdade de Ciências Agrárias, UFVJM. Praça Dom Joaquim, 100, Centro. CEP 39100-000 Diamantina (MG). E-mail: andre-rcg@hotmail.com

[3] Agricultural engineer, Professor Doctor, Dept. of Agronomy, UFVJM. Rua da Glória, 187. Centro. CEP 39100-000 Diamantina (MG). E-mail: mariahatem@yahoo.com.br

[4] Forest Engineer, Prof. Doctor, Dept. of Forest Engineering, FCA/UFVJM. E-mail: imarinhopereira@gmail.com, machadoelm@gmail.com

[5] Undergraduate student in Forest Engineering, Dept. of Forest Engineering, Faculdade de Ciências Agrárias, UFVJM. E-mail: arthur.duartevieira@gmail.com

RESUMO: *CARACTERIZAÇÃO FITOSSOCIOLÓGICA E EDÁFICA EM UMA ÁREA DE MONODOMINÂNCIA DE ARNICA (*Lychnophora pohlii *Sch. Bip.)*

A espécie Lychnophora pohlii *Sch. Bip.(Asteraceae), conhecida como "Arnica mineira", é uma planta largamente utilizada na medicina popular e muito abundante na vegetação de campo rupestre de altitude. Nesse contexto, este trabalho teve como objetivo estudar a densidade dessa espécie e sua relação entre os parâmetros do solo em uma área de campo rupestre em Diamantina, região do Alto Jequitinhonha, Minas Gerais. Foram alocadas 10 plotas contíguas de 20 x 50 m, totalizando uma amostragem de 10.000 m², localizadas dentro do Campus Juscelino Kubitschek da Universidade Federal dos Vales do Jequitinhonha e Mucuri (UFVJM). Nessas plotas, os indivíduos foram avaliados quanto à frequência, dominância e densidade. Estudou-se a relação da densidade dessa espécie com nove atributos químicos e físicos do solo por meio da análise de correspondência canônica (ACC). A maior abundância de indivíduos (I) da espécie* Lychnophora pohlii *Sch. Bip. foi verificada nas plotas de amostragem da vegetação de número 6, com 255 indivíduos; 7, com 173; 8, com 189; 9, com 159; e 1, com 151. Verificaram-se nessas plotas características florísticas e do solo semelhantes, resultando em uma proximidade espacial quando representadas nos diagramas da ACC. Maiores densidades da espécie* Lychnophora pohlii *Sch. Bip. foram encontradas em plotas com os maiores valores de pH, P-rem e saturação por bases, variáveis essas mais fortemente correlacionadas pelo primeiro eixo da análise de correspondência canônica.*

Termos de indexação: campo rupestre, savana, solos florestais, análise de correspondência canônica.

INTRODUCTION

The vegetation physiognomies of the cerrado are distributed across plateaus of up to 1,300 m asl, and rocky grassland and altitude grassland are found in the higher regions (Rodrigues & Carvalho, 2001). Both have particular soil characteristics, being composed of rock outcrops, and a peculiar species composition, including endemic species and species groups, e.g. "candeias", which are evergreen neotropical savanna trees (Diniz et al., 2010). The cerrado flora has an endemism level of 44 % (Klink & Machado, 2005) and several of its species have a high medicinal value, but are threatened with extinction (Mendonça & Lins, 2000).

An example of medicinal use is the genus *Lychnophora* sp., popularly known as "Arnica mineira" (Semir, 1991). Some arnica species grow on grasslands on quartzite outcrops (rocky grassland) in Minas Gerais, and are widely used in the treatment of injuries, bruises or contusions and of lesions by insect bites (Souza et al., 2003). Due to its widespread use in folk medicine, the pressure of extractivism on arnica, as on other species of the genus, has become extremely strong. It is therefore currently listed in the category of plants threatened with extinction (SBB, 1992). Soil parameters can determine the population structure of plants in the cerrado, considered one of the "hotspots" of global biodiversity (Matikosano et al., 2008). In this sense, studies that relate the population structure of arnica with soil parameters could underlie the selection of naturally appropriate locations for reforestation and planting of this species.

In this context, the purpose of this study was to analyze the relationships between properties of the soil and the population distribution of arnica (*Lychnophora pohlii* Sch. Bip.) in an area of rocky grassland vegetation where this species is monodominant.

MATERIAL AND METHODS

The study was conducted in Diamantina, Minas Gerais, in the southern region of Espinhaço Meridional. The soils in the study area are mostly sandy, generally with low moisture retention capacity, interspersed with large rock outcrops (Abreu et al., 2005). The area is part of the *Campus* JK (Juscelino Kubitschek), of the Federal University of the Jequitinhonha and Mucuri Valleys (UFVJM), latitude 18º 10' S, longitude 43º 30' W, 1,387 m asl. The climate is Cwb, according to the Köppen classification, i.e., tropical altitude with summer rains and cool summers (Cupolillo, 2008). In more detail, according to the climatic classification elaborated by Nimer (1989) for Diamantina, the climate domain is tropical, subdomain moderately hot and moderately humid, with climatic variety, of four-five dry months (IBGE, 1977). The vegetation of the region is predominantly rocky Cerrado and rocky grassland, of which the latter is the vegetation environment of this study. The soils were classified as sandy, according to the Brazilian System of Soil Classification - SiBCS (Embrapa, 2006).

The plots for the analysis of vegetation and soil were distributed at representatives locations of the growth conditions of *Lychnophora pohlii* Sch. Bip., based on visual criteria of the soil cover density of the species. The phytosociology was assessed in a sampling 1.0-ha block of vegetation-covered soil, which was divided into contiguous subplots of 1,000 m^2 (20 x 50 m) (Figure 1). As suggested for soil sampling by Ribeiro et al. (1999), six single samples were collected (layer 0-20 cm), to form one composite sample per plot. All soil samples were labeled, packed in plastic bags and separated for physical and chemical analysis, after being air-dried, ground and sieved (2 mm).

The soil particle size was analyzed (for coarse sand, fine sand, silt, and clay fractions), according to Embrapa (1997). The water pH was measured at a ratio of 1:2.5 (v/v) soil: solution. The organic matter (OM) content was determined by the Walkley-Black method (1934). Exchangeable Ca^{2+}, Mg^{2+} and Al^{3+} were extracted by 1. 0 mol L^{-1} KCl and the Ca^{2+} and Mg^{2+} in the extract determined by titration with 0.01 mol_c L^{-1} EDTA and the Al^{3+} content by titration with 0.025 mol L^{-1} NaOH, as described by Silva et al. (1999). The nutrients P, K, Zn, Fe, Mn, and Cu were extracted by Mehlich-1 and B extracted in hot water, and the concentration determined by

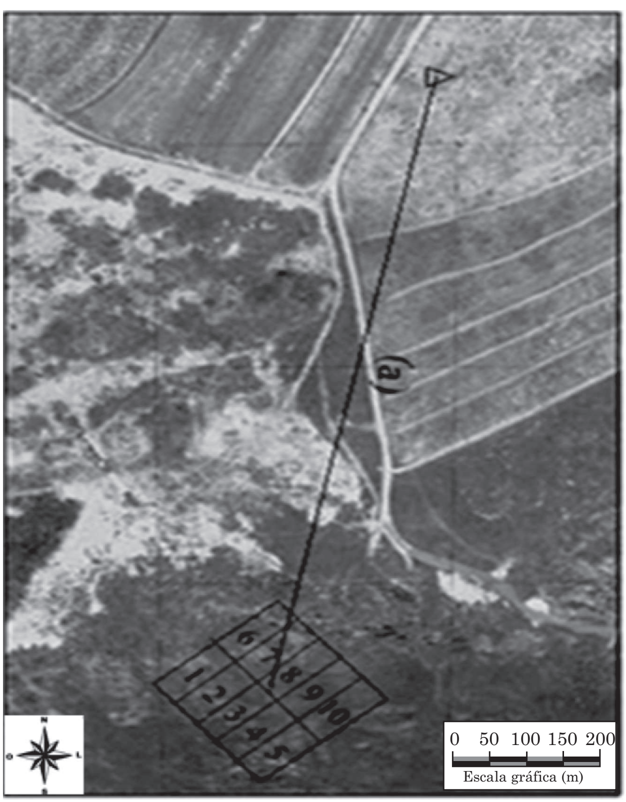

Figure 1. Google Earth image of the study area (18º 10' S and 43º 30' W) and the distribution of the 10 sampled plots in a 1-ha area, at a distance of 488 m (a) from the weather station Juscelino Kubitschek (▲).

spectrophotometry (Silva et al., 1999). The potential acidity (H+Al) was determined by extraction with 0.5 mol L^{-1} calcium acetate at pH 7.0 and alkaline titration (Silva et al., 1999). The sum of bases (SB), effective cation exchange capacity - CEC (t), aluminum saturation (m), and base saturation (V) were calculated, respectively, by the expressions: SB = (K^+ + Ca^{2+} + Mg^{2+}); t = SB + Al^{3+}; m = 100 x Al/t; V = 100 x SB/SB + (H+Al) (Alvarez V. et al., 1999).

In the rocky grassland, we surveyed all living plants with circumference at ground level (CGL) ≥ 3.0 cm, which included mostly shrub vegetation. For each plant, the species name, CGL and total height were recorded. To describe the community structure of the environments, the following phytosociological parameters were calculated for the plant species and families: relative density, frequency and dominance, as well as the importance value index (Mueller-Dombois & Ellenberg, 1974).

Partly, the plants identified in the field were known species, studied and inventoried in specimens in the herbarium Jeanini Felfili of the Federal University of the Jequitinhonha and Mucuri Valleys. From the remaining unidentified plants in the field, botanical material was sampled for later identification based on literature (Silva Junior et al., 2005), and for comparison with herbarium specimens of the institution. Non-woody species as of the family Velloziaceae were excluded from analysis for standardization of the stratum.

The distribution of species abundance was related with soil variables, by ordination by canonical correspondence analysis (CCA). It was assumed that variations in vegetation in terms of species abundance are strongly linked to environmental variables. Initially, the matrix of environmental variables per plot included 21 soil variables. After a preliminary analysis, 13 of these variables were eliminated due to low correlations (<0.4 with axes 1 and 2).

For the processing of CCA we used program PC-ORD, version 4.14 for Windows (McCune & Mefford, 1999) to produce an ordination with several axes, in which plots and species distribution are represented by triangles, while the environmental variables are represented by the respective names, indicating the direction of the maximum gradient (vector length proportional to the correlation of the variable with the axes). To enhance visualization, the ordering graph was separated in two diagrams, one with the ordering of the plots associated with the environmental variables and the other with the ranking of species abundances *Lychnophora pohlii* Sch. Bip., represented by the triangle (plot) size (the larger the triangle, the higher the number of plants).

In a rocky grassland gradient, we calculated the Pearson correlation coefficients between soil variables and the three ordination axes of the canonical correspondence analysis to verify the relationship between the variables.

RESULTS AND DISCUSSION

In the rocky grassland area under study, 19 woody species of 12 families and 16 genera were sampled (Table 1). The number of species of the families (in decreasing order) were Asteraceae (4 species) Malpighiaceae (2), Myrsinaceae (2), Melastomataceae (2), Rubiaceae (1), Erythroxylaceae (1), Clusiaceae (1), Fabaceae (1), Marcgraviaceae (1), Myrtaceae (1), Lythraceae (1), Clusiaceae (1), and Araliaceae (1). In terms of family occurrence, Asteraceae was best represented, and 90.34 % of the plants of this family were *Lychnophora pohlii* Sch.Bip. (Table 1).

High-altitude dwarf forests, such as arnica forests, can be considered conglomerate rocky grassland in transition to the montane Cerrado itself (Oliveira-Filho & Fluminhan-Filho, 1999). The degree of local endemism is an important criterion to determine areas of conservation and should be investigated in studies on regional flora. The genus *Lychnophora* sp. (Asteraceae) is restricted to rocky grassland areas (Nakajima & Romero, 1999). The species with highest importance value (IV) (in descending order) were *Lychnophora pohlii* Sch. Bip. *Eremanthus glomerulatus, Palicourea rigida, Byrsonima* sp, and *Eremanthus incanus*. Together, these five species represented 84.03 % of the total IV, 96.57 % of the total density, while *Lychnophora pohlii* Sch. Bip. alone accounted for 89.49 % of the relative dominance (Table 1). Consequently, the family with highest abundance was Asteraceae, accounting for 94.29 % of the total plant density. The species with the highest densities were *Lychnophora pohlii* Sch. Bip. *Eremanthus glomerulatus, Palicourea rigida, Byrsonima* sp. *Eremanthus incanus*, which represented 26.31 % of all species. With a very high number of plants, *Lychnophora pohlii* Sch. Bip. was the only species with a frequency of 100 %.

The Brazilian Institute of Geography and Statistics (IBGE, 2004) defines basal area as a phytosociological parameter used to indicate the dominant species in a community. The basal area is estimated by measuring the stem circumference or diameter and by the non-specific formulas used in this study. The parameters related to phytosociology (Table 1) were measured in a total of 1,460 plants, on a total basal area of 2.48 m^2 ha^{-1}, of which, only for the species *Lychnophora pohlii* Sch. Bip., 1,319 plants were assessed on 2.19 m^2 ha^{-1}. Similar values were reported by Diniz et al. (2010), in a study on rocky grassland in Lavras, Minas Gerais, with a density of 2,000 plants ha^{-1} of *Lychnophora pinaster*. This number was slightly higher than in this work, since no minimum diameter was used as inclusion criterion.

Table 1. Phytosociological parameters of the species sampled on 10,000 m^2 rocky grassland in the Municipality of Diamantina, in the Upper Jequitinhonha region, Minas Gerais, Brazil, in descending order: importance value (IV), number of plants (NP), relative density (RD), relative dominance (RDo), and relative frequency (RF)

Family	Specie	NP	RD	RDo	RF	IV
		unid	%			
Asteraceae	*Lychnophora pohlii* Sch. Bip.	1319	90.34	89.49	17.24	65.69
Asteraceae	*Eremanthus glomerulatus* Less.	49	3.36	2.82	10.34	5.51
Rubiaceae	*Palicourea rígida* Kunth	12	0.82	0.56	12.07	4.48
Malpighiaceae	*Byrsonima sp.*	18	1.23	1.38	10.34	4.32
Asteraceae	*Eremanthus incanus* (Less.) Less.	12	0.82	0.91	10.34	4.03
Erythroxylaceae	*Erythroxylum suberosum* A.St.-Hil.	9	0.62	1.1	5.17	2.3
Clusiaceae	*Kielmeyera lathrophyton* Saddi	8	0.55	0.82	5.17	2.18
Malpighiaceae	*Byrsonima crassa* Nied.	8	0.55	0.3	5.17	2.01
Fabaceae faboideae	*Dalbergia miscolobium* Benth.	4	0.27	0.22	5.17	1.89
Asteraceae	Asteraceae1	4	0.27	0.54	3.45	1.42
Myrsinaceae	*Myrsine sp.*	5	0.34	0.68	1.72	0.92
Marcgraviaceae	*Norantea sp.*	2	0.14	0.56	1.72	0.81
Myrtaceae	*Myrtaceae sp.*	2	0.14	0.21	1.72	0.69
Lythraceae	*Lafoensia vandelliana* Cham. & Schltdl.	2	0.14	0.13	1.72	0.66
Clusiaceae	*Clusia criuva* Cambess.	2	0.14	0.08	1.72	0.65
Melastomataceae	*Tibouchina candolleana* (Mart. ex DC.) Cogn.	1	0.07	0.04	1.72	0.61
Araliaceae	*Schefflera macrocarpa* (Cham. & Schltdl.) Frodin	1	0.07	0.05	1.72	0.61
Myrsinaceae	*Myrsine guianensis* (Aubl.) Kuntze	1	0.07	0.04	1.72	0.61
Melastomataceae	*Lavoisiera sp.*	1	0.07	0.05	1.72	0.61

The results of the canonical correspondence analysis (CCA) for the distribution of *Lychnophora pohlii* Sch. Bip. and the highest abundance values are shown in the diagrams of figure 2.

The number of plants of each plot was: 151 (P01), 129 (P02), 106 (P03), 78 (P04), 29 (P05), 255 (P06), 173 (P07), 189 (P08), 140 (P09), and 69 (P10). Density analysis (Figure 2) showed highest species abundance of *Lychnophora pohlii* Sch. Bip., corresponding to a central position on the left of the diagram, with most plants (255) in plot 6.

Abundance of *Lychnophora pohlii* Sch. Bip was observed at sampling of other plots (P07 - 173 plants, P08 - 189 plants, P09 - 159 plants and P01 - 151), indicating a decreasing trend of density in the eastern part of the diagram (P010 - 69 plants, P04 - 78 and P05 - 29 plants).

Miranda et al. (2007) commented that density expresses the ability of a plant species to colonize the environment. Asexual reproduction by budding can influence the structure of plant populations, as for example the distribution pattern of the species studied (Raven et al., 2001). As observed by Souza et al. (2003), the axillary buds of *Lychnophora pinaster* Mart are regenerative. Vegetative propagation may therefore be one of the factors responsible for the abundance of this plant observed in this study.

The ACC produced low eigenvalues (0.28, 0.25 and 0.18, respectively, for ordination axes 1, 2 and 3) indicated the existence of short gradients, i.e., most species can be found throughout the entire gradient, varying mostly in abundance (Ter Braak, 1987). The eigenvalue is the relative weight of each axis, explaining the total variance (Santos et al., 2000). The three axes accounted for 25.3, 22.7, and 16.1 % of the total variance (cumulative total of 64.2 %), indicating little remaining unexplained variance. These values suggest that the environmental measures were apparently sufficient to explain most of the environment-related variation in species abundance. This indicates the existence of microenvironments favorable for the establishment of the species *Lychnophora pohlii* Sch. Bip., corroborating the results of species abundance and population size structure (Figure 2), although low values of variance percentage for species abundance are common in vegetation data and have no influence on the significance of the species/environment ratio (Ter Braak, 1988).

In fact, Monte Carlo permutation tests indicated that species abundance and environmental variables were significantly correlated ($p<0.01$ for the first two axes).

The environmental variables with strongest internal correlations ($r > 0.6$) with the first axis, (Table 2) were (in decreasing order) H+Al ($r = 0.845$), organic matter ($r = 0.811$), P-rem ($r = 0.802$), clay ($r = 0.719$), pH ($r = 0.711$), and base saturation ($r = 0.623$). For the second axis, the variables with strongest internal correlations ($r > 0.3$) were (in decreasing order) effective CEC ($r = 0.445$), clay ($r = 0.330$), and H+Al ($r = 0.324$). The two ordination axes distinguished the soil subgroups very clearly, concentrating the plots with most *Lychnophora pohlii* Sch. Bip. plants (1, 2, 3, 6, 7, 8, and 9) in the western quadrant, corresponding to a central position on the left of the diagram (Figure 2); the values of P-rem, base saturation, pH and coarse sand were highest in this region, and values of H+Al, organic matter (OM) and clay were lowest.

This showed that the most limiting factors to the occurrence of *Lychnophora pohlii* Sch. Bip. are high

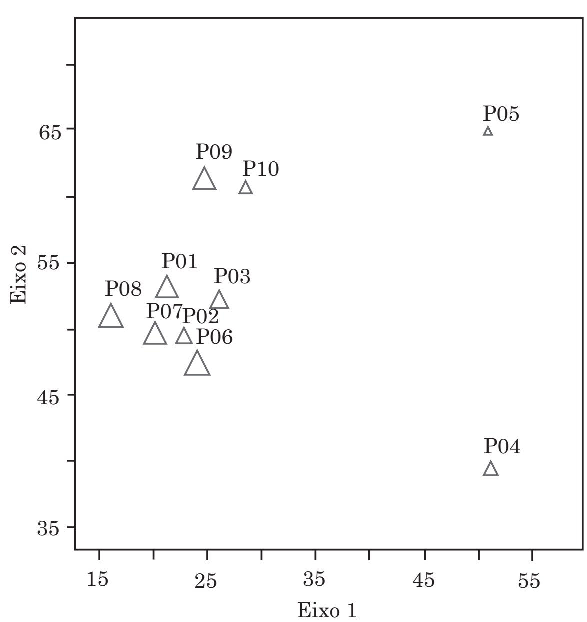

Figure 2. Inter-relationship between the distribution of study environments and species *Lychnophora pohlii* Sch. Bip with highest abundance values in the total sample. P01 - P10 represent the 10 sampled plots and the size of the triangles is proportional to the number of plants.

Table 2. Pearson correlation coefficients between the soil variables and three ordination axes of the canonical correspondence analysis for a gradient of rocky grassland, Diamantina-MG

Soil variable	Axis 1	Axis 2	Axis 3
pH	-0.711	-0.059	-0.038
H+Al	0.845	0.324	0.32
(t)	0.588	0.445	-0.289
V	-0.623	-0.119	0.08
OM	0.811	0.075	0.43
P-rem	-0.802	-0.222	-0.492
Coarse sand	-0.525	0.242	-0.482
Fine sand	0.339	-0.157	0.392
Clay	0.719	-0.33	0.482

H+Al, OM and clay contents as well as low levels of coarse sand and base saturation.

Restrictive soil conditions are reflected in the southeast and northeast quadrant (bottom and top right of the diagram, respectively), where plots 4 and 5 are concentrated, respectively, both with fewest *Lychnophora pohlii* Sch. Bip. plants (Figure 2).

Low *Lychnophora* pohlli Sch Bip. densities were found in the plots 4 and 5, with highest OM contents (1.79 and 2.3 dag kg^{-1}, respectively) (Figure 3). The soil in these plots is highly acidic, pH lowest and H+Al highest. According to Moreira & Siqueira (2002), the high acidity can contribute to the reduction of microbial activity, OM mineralization and nutrient availability. This is most likely the reason for the reduced density of *Lychnophora pohlii* Sch. Bip, since there were no significant correlations between soil Ca and Mg with density. On the other hand, the P levels in the soil of our study were very low (Table 1) and P was certainly the limiting nutrient for the occurrence of *Lychnophora pohlii* Sch. Bip. in soils with higher levels of OM and clay. These results agree with those of Oliveira Junior et al. (2005) and Oliveira Junior et al. (2006).

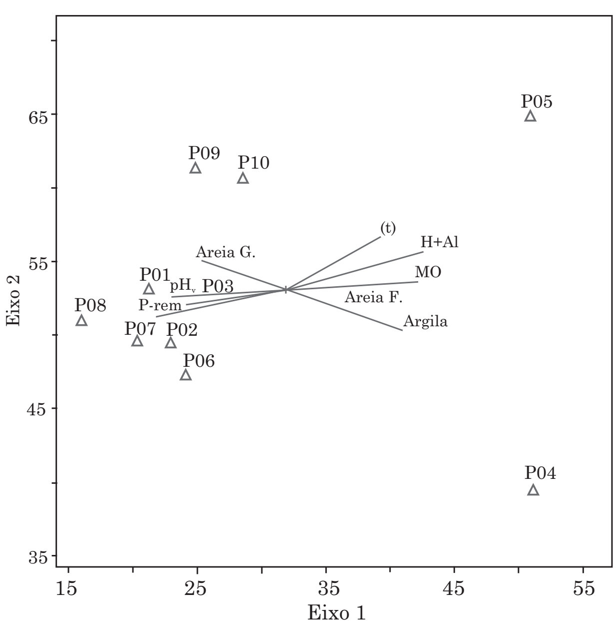

Figure 3. Ordination axis produced by canonical correspondence analysis of the 10 plots sampled in rocky grassland vegetation; inter-relationships between the distribution of study environments and environmental soil variables.

CONCLUSIONS

1. The species *Lychnophora pohlii* Sch. Bip. (Asteraceae) has the highest number of plants, relative density, relative dominance, and relative frequency in the area of Diamantina, Minas Gerais region of Espinhaço Meridional. The frequency of these plants was highest in soil with high pH, P-rem and base saturation, which are variables strongly correlated by the ACC.

2. The occurrence of the species *Lychnophora pohlii* Sch. Bip. is ensured by an environmental adaptation strategy, consisting in the ability of the species to grow in micro-environments that are favorable for its establishment.

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