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Ecologia da nidificação de formigas cortadeiras em Campos Naturais de Altitude, sul do Brasil

Ant nesting ecology of leaf-cutter ants in altitude natural fields, southern Brazil

Ecología de anidación de las hormigas cortadoras de hojas en los campos naturales de altitud, sur de Brasil

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Alexandre Giesel
ORCID: https://orcid.org/0000-0002-9569-015X
Federal University of Technology, Brazil
E-mail: alexandregiesel@gmail.com
Pedro Boff
ORCID: https://orcid.org/0000-0002-9041-5503
Santa Catarina Agricultural Research and Rural Extension Company Lages, Brasil
E-mail: boff.pedro@yahoo.com.br
Mari Inês Carissimi Boff
ORCID: https://orcid.org/0000-0003-1700-8837
State University of Santa Catarina, Brasil
E-mail: mari.boff@udesc.br
Patricia Fernandes
ORCID: https://orcid.org/0000-0002-0981-5930
Federal University of Technology, Brazil
E-mail: patriciaf@utfpr.edu.br

Resumo

Este trabalho teve por objetivo estudar os aspectos ecológicos do processo de nidificação realizado por formigas cortadeiras dos gêneros *Atta* e *Acromyrmex*, na Microrregião de Campos de Lages, Brasil. Em cada município foram estabelecidos 4 locais de observação equidistantes, cada ponto representou um formigueiro, num total de 72 formigueiros. Todos os formigueiros de cortadeiras amostrados foram georreferenciados e medidos em relação a sua superfície. Coleta de amostras de solo foram realizadas em três pontos a 1,5 m de cada formigueiro, na profundidade de 10 a 20 cm. Posteriormente realizada a caracterização ambiental e definição da arquitetura de cada formigueiro. Os teores de argila influenciaram o

processo de seleção de locais de nidificação de formigas da espécie *Atta* ssp., e os teores de Al e valores de pH do solo, influenciaram no processo de nidificação de formigas *Acromyrmex* ssp. Formigueiros de *Acromyrmex* spp. localizaram-se em altitudes superiores em relação aos formigueiros de *Atta* ssp. Formigueiros de *Atta* ssp. apresentaram forma irregular, são aparentes e preferencialmente localizados em bordas de fragmentos vegetativos. Formigueiros de *Acromyrmex* spp. apresentaram forma circular, são aparentes, e preferencialmente localizados em áreas de bordas de fragmentos florestais.
Palavras-chave: Comportamento; Saúvas; Quenquéns; Formigueiros; Campos de Altitude.

Abstract

This work aimed to study the ecological aspects of the nesting process carried out by *Atta* and *Acromyrmex* leaf-cutter ants in the Campos de Lages Microregion, Brazil. In each municipality 4 equidistant observation sites were established, each point representing an anthill, for a total of 72 anthills. All cutter anthill's sampled were georeferenced and measured in relation to their surface. Soil samples were collected at three points at 1.5 m from each anthill, at a depth of 10 to 20 cm. Subsequently, the environmental characterization and definition of the architecture of each anthill were performed. The clay contents influenced the selection process of ant nesting sites of the species *Atta* ssp., and the Al contents and pH values of the soil influenced the nesting process of *Acromyrmex* ssp. ants. The *Acromyrmex* spp. anthills were located at higher altitudes than the *Atta* ssp. anthills. Regarding *Atta* ssp. anthill's have a rough shape, are apparent and preferably located on the edges of vegetative fragments. *Acromyrmex* spp. anthill's have a circular shape, are apparent, and preferably located in areas on the edges of forest fragments.
Keywords: Behaviour; Sauvas; Quenquens; Anthills; Altitude fields.

Resumen

Este trabajo tenía como objetivo estudiar los aspectos ecológicos del proceso de anidación llevado a cabo por las hormigas cortadoras de hojas Atta y Acromyrmex en la Microrregión de Campos de Lages, Brasil. En cada municipio se establecieron 4 sitios de observación equidistantes, cada uno de los cuales representaba un hormiguero, para un total de 72 hormigueros. Todos los hormigueros cortadores muestreados fueron georeferenciados y medidos en relación con su superficie. Las muestras de suelo se recogieron en tres puntos a 1,5 m de cada hormiguero, a una profundidad de 10 a 20 cm. Posteriormente, se realizó la caracterización ambiental y la definición de la arquitectura de cada hormiguero. El contenido de arcilla influyó en el proceso de selección de los sitios de anidación de las hormigas de la especie *Atta* ssp., y el contenido de Al y los valores de pH del suelo influyeron en el proceso de anidación de las hormigas *Acromyrmex* ssp. Los hormigueros de *Acromyrmex* ssp. se encontraban a mayor altura que los hormigueros de *Atta* ssp. Los hormigueros *Atta* ssp. tienen una forma áspera, son aparentes y están situados preferentemente en los bordes de los fragmentos vegetativos. Los hormigueros *Acromyrmex* spp. tienen una forma circular, son aparentes y están ubicados preferentemente en áreas en los bordes de los fragmentos de bosque.

Palabras clave: Comportamiento; Sauvas; Quenquens; Hormigueros; Campos de altitud.

1. Introduction

In the south of Brazil there are unique formations called altitude fields or fields above the mountain range (Martins et al., 2011). In these fields there is a great diversity of plants and animals, which gives them as important centers of endemism of the world's neo-tropical flora and fauna, with a high rate of endemism, being higher than that found in many Atlantic forest (Radaeski et al., 2011).

The regions composed of Natural Altitude Fields differ from the remnants of Atlantic Forest with araucaria trees and mixed ombrophilous forest (Alvares et al. 2013), since they present discrepant topographic, soil and climate conditions and typical vegetation (Medeiros 2005), which can influence the nesting process of leaf-cutter ants.

The majority of the leaf-cutter ants belong to the *Atta* and *Acromyrmex* genera with wide distribution in the American continent (Mantragolo et al., 2010), from the northern United States (40° "N") to the southern tip of Argentina, Patagonia region (41° "S") (Rabeling et al., 2007). The leaf-cutter ants are eusocial insects with foraging habits in native plant species, but their activity intensifies in agricultural crops, thus becoming pest insects of economic importance (Borror & Delong, 2011). Its relevance as an insect-pest for agriculture is related to its habit of foraging plants to cultivate its fungus symbiont, its real food source, mainly for queens and young forms (Peternelli, 2009). Despite various damages they can cause in agriculture, leaf-cutting ants play a particular ecological role in natural ecosystems and even in agro-ecosystems (Wells et al., 2017), as they provide various ecological services, such as secondary seed dispersal, dormancy breakage of various plant species, in addition to promoting the revitalization of soils through the process of redevelopment, resulting in physical improvements and increased fertility (Peternelli, 2009).

Their anthills are considered superior to termite, bee or wasp nests (Spadoni et al., 2015), which can be located in several habitats, from rotten trunks, wall holes or situated above or below ground, often difficult to see in the environment or totally exposed in open field (Verza et al., 2020). In relation to their behavior, leaf-cutter ants show differences between genera, species and even within the species itself, when they inhabit different environments within the same region (Giesel et al., 2013).

The ants differ between genera and species of leaf-cutter ants, varying their architecture, which can be complex formed by numerous chambers, occupying extensive areas as in the case of ants of the genus *Atta*, or more simply formed by a single chamber with a single exit hole, as occurs in some species of the genus *Acromyrmex* (Verza et al., 2020). The external appearance of the anthill's also presents variations between *Atta* and *Acromyrmex* genera and within the species that compose them (Verza et al., 2020).

In this way, the anthill's can be formed simply by deposition of earth from their excavations, or have a complex composition, with a diversified appearance formed by mixing plant remains such as straw, sticks and leaves with earth. According to Farji-Brener et al. (2016), the leaf-cutter ants are adapted to various environments, ranging from native forests to areas of intensive agricultural use, thus showing the influence of environmental factors in the ecological nesting process performed by leaf-cutter ants.

In recent years the altitude fields have been threatened by the expansion of agriculture, through the occupation of spaces by the introduction of reforestation, annual crops and orchards, thus changing the composition of biodiversity and its ecological relationships (Rezende et al., 2018). In this process of anthropization of environments, many species are replaced by others by the process of ecological facilitation, especially those with opportunistic characteristics, such as some species of leaf-cutter ants.

Thus, this work aimed to study and describe ecological aspects of the nesting process carried out by *Atta* and *Acromyrmex* cutter ants in Campos de altitude de Lages, Santa Catarina, Brazil.

2. Methodology

a) Place of study

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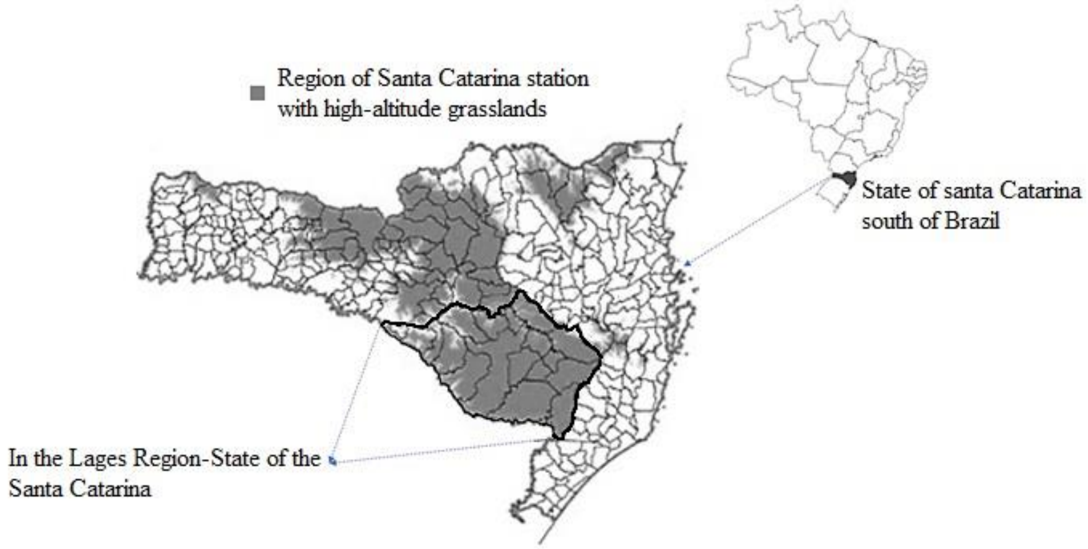
The survey was conducted from August 2010 to December 2011, in the Microregion of Campos de Lages, SC, composed of 18 municipalities and a total area of 15,725 km2 with a particular phytogeographic formation called Altitude Natural Fields (IBGE, 2019) (Figure 1).

Figure 1 - Region of altitude fields in the State of Santa Catarina, South of Brazil. Highlight of Campos de Lages Microregion.



Source: Prepared by the authors

In each municipality 4 observation sites were established equally distributed, thus we tried to cover the variations in the environmental gradient existing in each municipality within the Altitude of Lages Microregion (Figure - 2).

Figure 2 - Scheme of sampling points in each municipality in the Campos de altitude region of Lages, Santa Catarina, Brazil.

Source: Prepared by the authors

Observations were made in two ways, direct and indirect. The direct form was carried out by observing the anthill's of leaf-cutters ants that were in the open field of easy visualization; The indirect form was carried out by locating the ant trails or tingling entry holes with the presence of individuals performing the foraging activity, followed by the individuals until they found the anthill. In order to assist in the observations, some characteristics were followed regarding the morphology of the individuals (Fort et al., 2006 and Delabie et al., 2011), and regarding the architecture of the anthill's (Loeck & Grutzmacher, 2005 and Delabie et al., 2011).

One made the location and identification of the anthill's as belonging to leaf-cutting ants, these were individually georeferenced with manual GPS (Garmin Etrex®). Subsequently, the surface measurement of the area of each anthill was performed by the method of evaluating the largest diameter by the smallest, with the aid of topographic tape measure 50 meters (Lukfin®). Subsequently, soil samples were collected at three equidistant points at 1.5 m from each anthill, at a depth of 10 to 20 cm. The soil samples were sent for physical and chemical analysis at the Soil Analysis Laboratory belonging to the Experimental Station of the Agricultural Research and Rural Extension Company of Santa Catarina/São Joaquim (EEpagri/São Joaquim, SC). The characterization of the anthill's of the *Atta* and *Acromyrmex* was carried out through the following requirements: 1- Form of the anthill's, in (a) circulars, (b) irregulars and (c) ovals; 2- visualization in the environment, in: (a) apparent, easy to visualize or (b) not apparent, difficult to visualize; 3- Categorization of relief using a clinometer (Abney® model) and from the results, the classification was made according to the slope in: Flat, Smooth wavy, Wavy, Strong wavy and Mountainous (EMBRAPA, 1999); 4- Characterization of Habitats predominant around the anthill's, in: (a) native pasture, (b) within forest fragment, (c) at the edge of the forest fragment, (d) within area with croups, (e) on the edge of the area with croups, f) with pasture area, g) on the edge of area with pasture and h) reforestation and orchard.

In this work, it was considered as a forest fragment, areas of natural vegetation, interrupted by anthropic or natural barriers, of variable size, with trails frequented by cattle or wild animals.

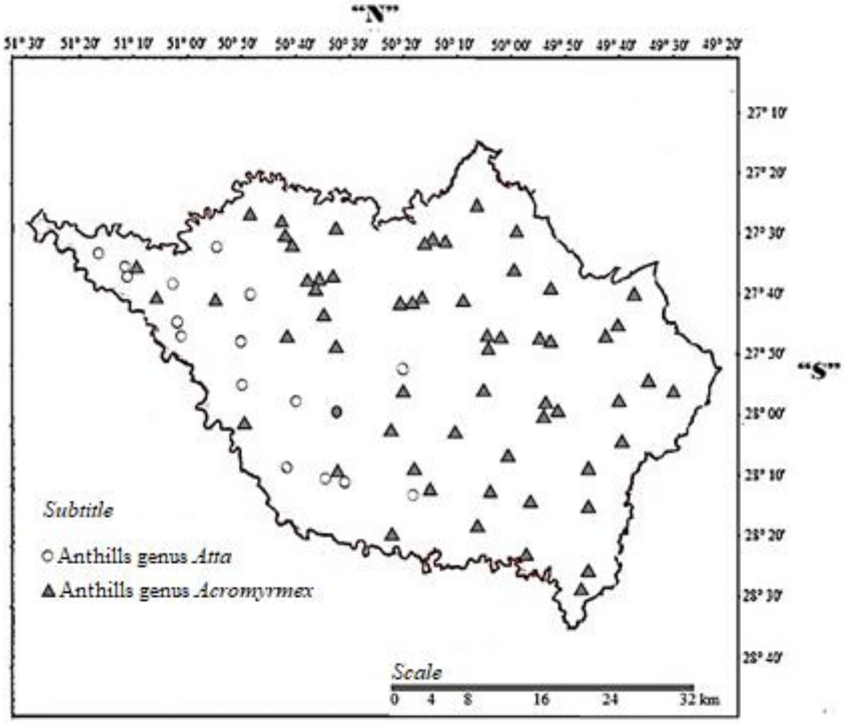
c) Evaluation

The observed results were subjected to an analysis of environmental heterogeneity around the anthill's selected by the Principal Component Analysis method (PCA) (R Development Core Team, 2014). For this, a different presence and absence matrix correlated the different species of leaf-cutting ants with the chemical and physical attributes of the soil samples collected from each anthill. The PCA was adopted because it allows organizing the sampling units along continuous environmental gradients defining the main soil components in relation to the species of leaf-cutting ants (Felfili, 2011). The environmental characterization of the anthill's surroundings was analyzed through the elaboration of a presence and absence matrix, determining the percentage of leaf-cutting anthills for each occasion. To carry out the statistical analyzes, the program R (R Development Core Team, 2012).

3. Results and Discussion

During the field research period, 75 anthills of leaf saws were sampled, 17 belonging to the genus Atta and 58 belonging to the genus *Acromyrmex*, distributed by the Microregion of Campos de Lages, as shown in Figure 3.

Figure 3 - Distribution of anthills of *Atta* and *Acromyrmex* sampled in the Microregion of Campos de Lages, SC, Brazil. Each point is represented by a single anthill.



Source: Prepared by the authors

The anthills of leaf-cutters of the *Acromyrmex* genus were widely distributed in the territory covered by the present study (Figure 3). The anthills of leaf-cutting ants of the *Atta* genus, on the other hand, did not present the same distribution in relation to the *Acromyrmex* genus, being located more southwest of the studied territory (Figure 3). In relation to the altitude and the size of the anthill of leaf-cutting ants, anthills of the genus *Atta* had a diameter of 132.75 ± 12.96 meters^2, located at an average altitude of 856.37 m. The anthills of the *Acromyrmex* genus had a diameter of 1.04 ± 0.93 meters^2, located at an average altitude of 992, 87 meters. There was no correlation between the anthills size and altitude for both *Atta* (r = 0.3; p> 0.05) and *Acromyrmex* genus (r = 0.4; p> 0.05).

The anthills of the *Atta* genus were located at a maximum altitude of 972.85 meters in the municipality of Campo Belo do Sul. Anthill's of the *Acromyrmex* genus were located at a maximum altitude of 1.467 meters in the municipality of Urupema. Thus, the altitude influenced the presence of leaf-cutting anthills of both *Atta* and *Acromyrmex* genera, mainly in relation to the presence of leaf-cutting anthills of the *Atta* genus, which were not observed at altitudes above 972 meters. In a study by Grandeza et al. (1999), anthill of the leaf-cutters of the species *A. sexdens rubropilosa* Forel and *A. laevigata* F. Smith were located at an average altitude of 830 meters in the Northwest Region of Minas Gerais. In a study Giesel et al. (2013), indicated an influence in relation to altitude on the nesting of leaf-cutting anthills, with those above 900 meters limiting for the genus *Atta*.

The altitude fields located in the south of Brazil have an altitude that can exceed 1800 meters (Klein, 1984), this environmental characteristic identified in the present study may have favored the better distribution of the *Acromyrmex* genus in relation to the *Atta* genus, which may present a greater sensitivity to the cold existing in the Campos de Lages Microregion.

In relation to the principal component analysis (PCA), this showed the existence of a correlation between the soil components and the distribution of leaf-cutting anthills, explaining, respectively, 70% and 65% of the relationship of these factors for the two genera *Atta* and *Acromyrmex*, of the values described by the first two axes of the diagram (Figure 4).

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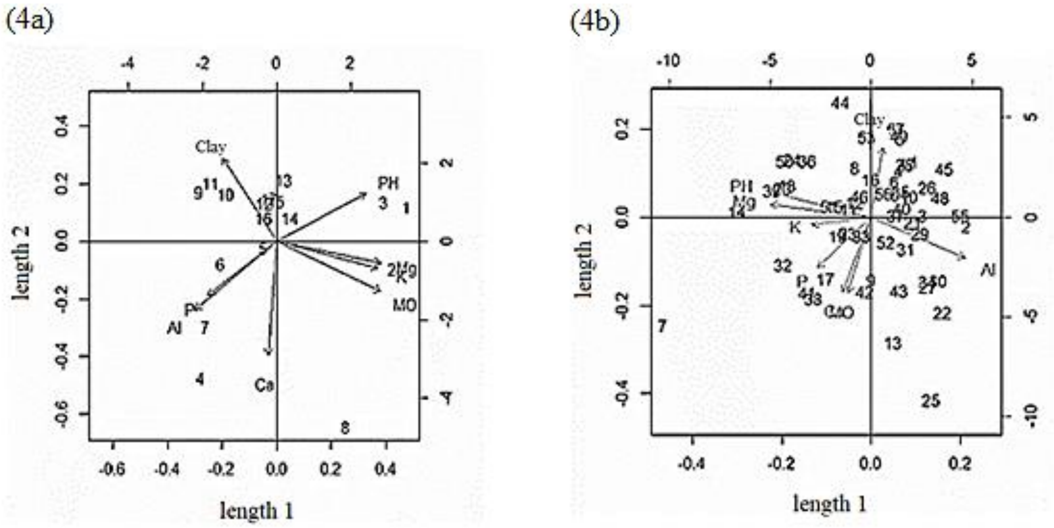
Figure 4 - Ordering diagram resulting from the Principal Component Analysis (PCA) of the edaphic variables of 17 soil samples from anthills of leaf-cutters of the genus *Atta* (4a), and from 58 soil samples of anthills of the genus *Acromyrmex* (4b), in the Microregion of Campos de Lages, SC, Brazil. The abbreviations indicate, respectively, pH = hydrogen potential, Arg = clay, P = phosphorus, K = potassium, MO = organic matter, Al = aluminum, Ca = calcium and Mg = magnesium. The numbers represent the anthills sampled.



Source: Prepared by the authors

Through the analysis of main components (PCA) it was possible to make a correlation analysis between the main components of the soil that influenced the distribution of the anthills of leaf-cutter ants saws of both genera *Atta* and *Acromyrmex* (Table 1).

Table 1 - Average physical-chemical attributes of the collected soils (± EP - mean standard error), in the vicinity of anthills of *Atta* and *Acromyrmex* present in the Microregion of Campos de Lages, SC, Brazil.

Soil attributes	Anthills	
	Atta sexdens piriventris	*Acromyrmex* spp.
Clay (%)	60.6 ± 11.1*	32,9 ± 11,1*
Hydrogen potential (pH)	4.9 ± 0.3	4.9 ± 0.8
Phosphor (mg/dm^3)	13.3 ± 9.8	16.0 ± 9.8
Potassium (mg/dm^3)	77.0 ± 54.2*	151.3 ± 54.2*
Organic matter (%)	3.2 ± 2.1	3.8 ± 2.1
Aluminum (Al^{3+})	2.7 ± 2.7	3.0 ± 2.7
Cálcio (cmolc/dm^3)	2.9 ± 3.6	3.4 ± 3.6
Magnesium (cmolc/dm^3)	0.9 ± 1.1*	1.7 ± 1.1*

Values followed by the asterisk (*), in the same line, they differ by the test T, a 5% probability. Source: Prepared by the authors.

The physical-chemical attributes of the soils collected in the vicinity of anthills showed significant differences ($p < 0.05$) between the genera *Atta* and *Acromyrmex* (Table 1).

The clay content and the availability of the element potassium and magnesium differed significantly ($p < 0.05$) between soil samples surrounding the anthills of both genera *Atta* and *Acromyrmex* (Table 1). The results demonstrate that the attributes of clay (%), potassium (mg / dm^3) and magnesium (cmolc / dm^3) influence the choice of ant nesting sites by young *Atta* and *Acromyrmex* queens, as they differed significantly ($p < 0.05$) in relation to the soils surrounding the anthills (Table 1). According to Vasconcelos et al. (2006), young queens of *Atta bisphaerica* Forel (1908) selected soils with higher clay contents for the installation of their anthills.

The anthills belonging to the *Atta* genus showed a positive correlation (70%, $p < 0.05$) differing significantly ($p < 0.05$) from the clay contents found around the anthills belonging to the *Acromyrmex* genus (Figure 4a, 4b and Table 1). This difference in relation to the clay contents around the anthills of belonging to the *Atta* genus may be related to their architecture, more specifically in relation to the depth they can reach, exceeding 8 meters in depth, in addition to presenting numerous chambers with different functions (Grutzmacher & Loeck, 2005).

Thus, in order for this architecture of the anthills of the *Atta* genus to be maintained, there is a need for a structured soil with higher clay contents to ensure that it does not collapse. The anthills belonging to the *Acromyrmex* genus are mostly more superficial, with the presence of one or two chambers, presenting a structure formed with a mixture of soil and vegetal remains to give structure (Delabie et al., 2011).

This difference in the architecture of the anthills belonging to the genus *Acromyrmex* in relation to the genus *Atta* may guarantee the maintenance of the architecture of the anthills of cutters of the genus *Acromyrmex* regardless of the clay contents of a given soil.

The potassium levels showed a significant difference ($p < 0.05$) in the soils surrounding the anthills of *Atta* genus in relation to the *Acromyrmex* genus (Table 1). Higher levels of phosphorus were found around the anthills of the genus *Acromyrmex* (151.3 ± 54.2 mg / dm^3), in relation to the soil around the anthills of the genus *Atta* (77.0 ± 54.2 mg / dm^3) (Table 1). The values of the potassium element in the soils surrounding the anthills of the genus *Atta* represented half of the phosphorus contents found in the soils around the anthills of the genus *Acromyrmex* (Table 1). According to Oliveira et al. (2020), soil chemical factors directly influence the floristic composition of a given phytogeographic formation. Thus, the floristic composition acts directly on the foraging behavior of leaf-cutting ants, due to the differentiated selectivity in the selection of materials for the covering of the different species of leaf-cutting ants (Giesel et al., 2020). The change in nutrient content represents a

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determining factor for numerous factors, such as the floristic conformation existing in a given location. This floristic conformation may or may not favor a certain species of leaf-cutting ant in its selectivity for foraging (Giesel et al., 2013). In the present study, magnesium contents also differed significantly ($p < 0.05$) in the soils surrounding the anthills of saws between the genera *Atta* and *Acromyrmex*, which may justify the theory mentioned above. Another factor related to foraging and floristic change is the adaptive morphological alteration in the mandible of leaf-cutting ants related to forage food change between the genera *Atta* and *Acromyrmex*. Such an aspect will define its selectivity in relation to foraged material, thus being directly related to the change in the floristic composition of a given area (da Silva et al., 2016).

The presence of the aluminum element (Al) in the soil was positively correlated with the presence of anthills of the genus *Acromyrmex* (76%) (Figure 4b). In relation to the genus *Atta*, this correlation was not observed in relation to the element Al with the presence of anthills (Figure 4a).

The element Al correlates negatively with the pH values determined in the soil (Ebeling et al., 2008). In a study by Loeck et al., (2004) it was noticed that anthills of *Atta sexdens piriventris* and *Acromyrmex* spp. were present in soils with lower pH levels (4.0 to 5.0). In this work, the average pH values found in the soils surrounding the anthills of both genera *Atta* and *Acromyrmex* were between 4.9 (Table 1). According to Loeck et al. (2004) the symbiotic fungus cultivated by leaf-cutting ants grows directly in the soil and at low pH, which suggests that fungiculture is benefited in these soils where the anthills were present. According to Rousk et al. (2009), the low pH is negatively correlated with the growth of fungi and bacteria in the soil, these microorganisms act as antagonists to the symbiotic fungus cultivated by leaf-cutting ants. Thus, soils with low pH values may be more suitable for the survival of leaf-cutters ants in general. The pH and aluminum values found in the soils surrounding the anthills of both genera *Atta* and *Acromyrmex* represent a typical characteristic of the soils found in the Region comprising the Altitude Fields, where there is a predominance of acidity combined with low fertility with high levels of exchangeable aluminum (de Carvalho et al., 2012).

Regarding the organic matter content of the soil around the anthills, this positively influenced the presence of anthills belonging to the genus *Acromyrmex* in relation to the genus *Atta* (Figures 4a and 4b). According to Ebeling et al. (2008), soil organic matter content is negatively correlated with the pH values of a given soil, which may directly influence the presence of anthills of both *Atta* and *Acromyrmex* genera in a given region. In this way, the microbiota, together with the edaphoclimatic conditions found in a given soil, have a direct role on anthill mowers, being able to limit their development and survival (Araújo et al. 2003). These same conditions described by Araújo et al. (2003), can justify the spatial distribution of the anthills of both *Atta* and *Acromyrmex* genera in the region of the present study (Figure 2). Which allows to deduce that the edaphoclimatic conditions found in regions of Altitude Fields are more favorable to the genus *Acromyrmex* in relation to the genus *Atta*, due to its better distribution in the territory (Figure 2).

About the environmental characteristics around the anthills of the leaf-cutter *Atta* and A*cromyrmex*, and their architecture are described in Table 2.

Table 2 - Environmental characterization and architecture of anthills of leaf-cutters ants *Atta* and *Acromyrmex*, present in the fields of Campos de Lages, SC, Brazil.

Observed aspects	**Anthills (%)**	
	Atta genus	***Acromyrmex* genus**
Anthill shape		
Circle	0	56.82
Irregular	100	34.51
Oval	0	8.67
Visualization of anthills in the environment		
Apparent	88.24	65.52
No apparent	11.76	34.48
Relief around the anthills*		
Flat	70.59	15.52
Smooth wavy	29.41	32.76
Wavy	0	31.03
Strong wavy	0	12.07
Mountainous	0	8.62
Anthills (total number)	17	58

* Ground slope: flat – 0 an 3%; Smooth wavy – 3 an 8%; Wavy – 8 an 20%, Strong wavy – 20 an 45% and Mountainous – 45 a 75%. Source: Prepared by the authors.

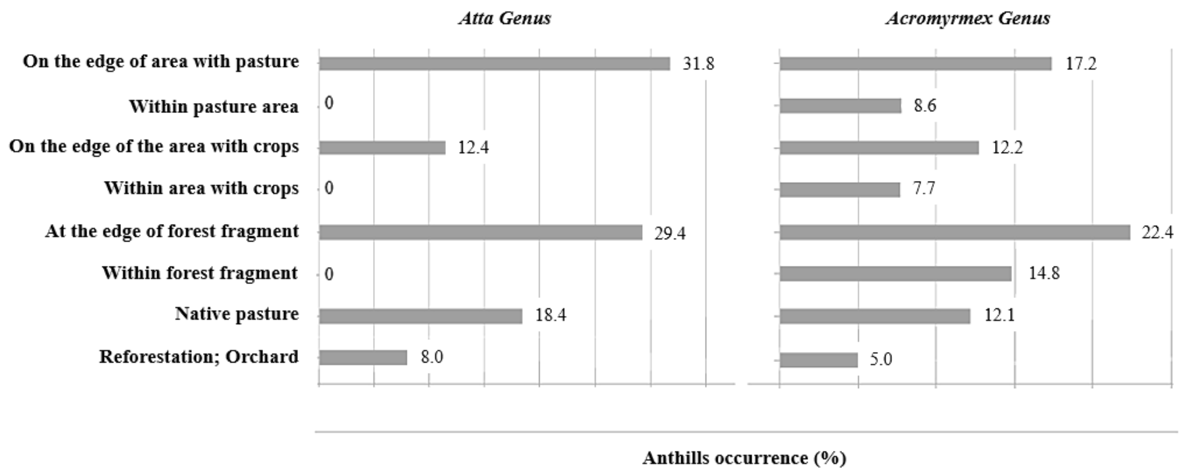
Regarding the environmental characteristics and architecture of the anthills, they differed between the genera *Atta* and *Acromyrmex* in the region of altitude fields (Table 2). All anthills belonging to the *Atta* genus presented irregular shapes (100%) (Table 2). The anthills belonging to the *Acromyrmex* genus presented varied shapes with predominance (56%) of circular shape, followed by the irregular shape (34%) and the oval shape, which represented only 8% of the total number of anthills of the sawmills evaluated (Table 3). In a study by Araújo et al. (2011) with anthills of the species *Atta* presented a semi-spherical shape, differing from the results found in our study (Table 2). Regarding the shape of the anthills of the *Acromyrmex* genus, Fort et al. (2011) reported that the majority of the anthills of *Acromyrmex laticeps, Ac. lobicornis* and *Ac. heyeri* had a spherical shape. These results are in line with the results observed in this study (Table 2). In a study by Caldato et al. (2016) in anthills of the species *Acromyrmex balzani*, they presented an irregular shape, thus differing from the results found in our study. These observations demonstrate the particularities between the genera of leaf-cutting ants and within the species themselves in relation to the architecture of their anthills. According to Caldato et al. (2016), these differences in the architecture of the anthills are closely related to the edaphoclimatic conditions of a given region. In this way, the observations made in this work on architecture of the anthills of both genera *Atta* and *Acromyrmex* can be particularized due to the unique conditions of climate, relief and vegetation existing in the region comprised by the altitude fields.

Regarding the visualization of the anthill's saws of both genera *Atta* and *Acromyrmex*, these presented themselves in a different way in the Campos de Altitude region (Table 3). The anthill's belonging to the *Atta* genus were mostly (88%) easy to see in the environment. Generally, anthills of the *Atta* genus have large adult sizes, in addition to their more common feature of having a plowed earth aspect on their surface, which thus facilitates their observation in the environment (Delabie et al., 2011). The anthills of the *Acromyrmex* genus were mostly (65%) apparent when viewed in the environment, 34% of the anthills did not present easy observation in relation to the environment (Table 3). According to Forti el al. (2011), anthills belonging to the genus *Acromyrmex* do not present, for the most part, easy visualization in the environment, due to the aspects of their architecture formed by the junction of land plus vegetal remains that make them almost inconspicuous. This difference in relation to our work may be related to the fact that the vegetal formation of altitude fields presents characteristics of lower vegetation, made the anthills more visible in the environment.

Regarding relief aspects, the majority of the anthill of the *Atta* genus (70.59%) were in flat relief environments, the rest of the anthills (29.41%), were located in soft undulated relief environments (Table 3). In relation to the anthills belonging to the *Acromyrmex* genus, there were varied reliefs with a higher percentage of environments with relief ranging from wavy to soft wavy (63%), these characteristics of relief common in regions of altitude fields (Alvares et al. 2013). The anthills belonging to the *Atta* genus can, as already mentioned, occupy large areas and also a considerable depth of their anthills (Perin et al., 2012). In this sense, the choice for ant nesting in flat environments by leaf-cutting ants of the genus *Atta*, aims to avoid deleterious climatic actions such as heavy rain and runoff, which can cause damage, such as the collapse or death of individuals in their anthills (Alves Sobrinho et al., 2011). This may also justify the difference in relation to the distribution of the anthills of *Atta* and A*cromyrmex* genera in the studied region (Figure 2). For where the anthills of the *Atta* genus were found, it comprises flatter environments of the altitude fields (Figure 2). Anthills of the *Acromyrmex* genus, however, had a wide distribution in the region of altitude fields, regardless of the relief, which can be favored by the unique architecture of their anthills, thus allowing greater environmental resistance to weather conditions such as rain and runoff. (Figure 2).

The Figure 5, shows the preferred ant nesting sites for anthills of the genus *Atta* and *Acromyrmex* in the region of altitude fields.

Figure 5 - Preferred ant nesting sites for leaf-cutting ants belonging to the genus *Atta* and *Acromyrmex* in the region of altitude fields, SC, Brazil.



Source: Prepared by the authors

The most of the anthills of the *Atta* genus were located in border environments of all the categories evaluated (73.59%) (Figure 5). No anthill of the *Atta* genus was found inside the observed environments (Figure 5). The rest of the anthills of the *Atta* genus (26.41%) were present in native field environments or other plant formations, such as orchards and planted forests, especially reforestation of pine and eucalyptus. According to Schoereder et al., (2008), ants of the genus *Atta* prefer open areas for ant nesting, preferably, edges of forest formations. In a study by Vasconcelos et al. (2006) with ants of the genus *Atta*, they preferred the edges of roads for ant nesting. These authors also suggest that environmental changes, especially those promoted by man, such as the opening of roads in protected forest areas, result in an increased abundance of anthills of the genus *Atta*, due to the greater exposure of the soil that would facilitate colonization by young queens. Araújo et al. (2003) observed that leaf-cutting ants of the *Atta bisphaerica* species chose to dig their ant nests in areas that suffered burnings in sugar cane plantation, possibly because the surface of these soils is exposed. Vasconcelos et al. (2006) observed that females of *Atta laevigata* preferred clean areas by the road than areas of vegetation in the surroundings.

In relation to the *Acromyrmex* genus, (51.89%) of its anthills were observed in border environments in all evaluated categories (Figure 5). The other anthills of the *Acromyrmex* genus, were found inside the environments of the evaluated categories (31.04%), and 7% were located in native field environments or other plant formations, such as orchards and planted forests, especially reforestation of pine. In a work carried out by Loeck and Gusmão (2003), with ants of the genus *Acromyrmex* in the Southern Region of Rio Grande do Sul, young queens of this gender preferred to ant nest in areas of crops with formation of pastures. In the present study, the formation with pastures represented 45.79% of the preferred environments for ant nesting by ants of the genus *Acromyrmex* (Figure 5). According to Ricalde et al. (2012), ants of the genus *Acromyrmex* prefer more vegetated areas for ant nesting. These authors also mention that young queens of this genus use soil components, such as plant roots to support the cultivation of the fungus, thus requiring environments that provide these materials.

For Versa et al. (2007), the ants *Acromyrmex* spp. prefers the more vegetated areas to obtain protection for their fragile anthills, thus avoiding predation. In general, we can consider that edge areas function as areas of refuge, to possible anthropic or natural changes due to the action of predators, in addition to allowing the formation of strategic sites for foraging in cultivation or reforestation areas. In this study, anthills belonging to the genus *Atta* and *Acromyrmex* presented a wide distribution in relation to their ant nesting process in the region composed of altitude fields, being greater for the genus *Acromyrmex* in relation to the genus *Atta*. This distribution in relation to the ant nesting process may be related to the set of environmental factors such as altitude, relief, soil, and floristic composition, being more limiting for the genus atta in relation to the genus *Acromyrmex* for regions composed by the altitude fields in the Southern Brazil. These characteristics of the chosen ant nesting site add to the physical and biological factors of a given environment, such as what was seen in our work. In this way, the knowledge of the factors that affect the ecological ant nesting process of leaf-cutting ants can contribute to a better understanding of their ecology, thus allowing practical applications in programs for integrated management of leaf-cutting ants in the most diverse environments.

4. Final considerations

In our work, the clay contents in the soil sampled around the anthills influenced the process of selecting the sites for nesting leaf-cutting ants belonging to the *Atta* genus. This same element did not influence the nesting process of ants belonging to the *Acromyrmex* genus, they were influenced in relation to the levels of Al and pH existing in the soils surrounding the anthills. The existing altitude in the evaluated territory demonstrated to have a relationship in the occurrence of anthills of leaf-cutting ants, thus the higher altitudes above 900 m limited the occurrence of anthills belonging to the genus *Atta*.

Regarding the shape of the anthills, they differed in relation to the genera of ants studied, anthills of the genus *Atta* were characterized with irregular shape and easily visible (Apparent), while anthills of the genus *Acromyrmex* presented a circular shape in most of them were not easily visible (Not apparent). The characterization of the environment around the anthills showed a difference between the genera *Atta* and *Acromyrmex* in the altitude fields of Lages. Anthills of the genus *Atta* were mostly located in a pasture border system, followed by areas with forest fragments and native field. Most anthills of the *Acromyrmex* genus were found in the forest fragments edge system, followed by pasture edge systems.

For future work it would be necessary to study the different species existing in the territory, checking their behavior in relation to the unique system existing in Brazil composed by the Campos de Altitude.

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Porcentagem de contribuição de cada autor no manuscrito

Alexandre Giesel – 40%

Pedro Boff – 20%

Mari Inês Carissimi Boff – 20%

Patricia Fernandes – 10%