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CROP PROTECTION

Edaphic mesostigmatid mites (Parasitiformes, Mesostigmata) in a region of the Pampa biome of the state of Rio Grande do Sul, Brazil

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ABSTRACT: *The diversity of edaphic mites in Brazilian natural environments is little known, especially in the Pampa biome, in southern region of Brazil. The objective of this study was to evaluate the diversity and abundance of edaphic fauna of mesostigmatid mites in a region of the Pampa biome of the state of Rio Grande do Sul. Soil samples were collected in the municipality of Aceguá, in 2012 and 2013. Mites were extracted using Berlese-Tullgren modified funnels. In total, 1900 mesostigmatid mites were collected, representing 44 species from 23 genera and 10 families. The most abundant families were Rhodacaridae, Ologamasidae and Laelapidae, with respectively 903, 578 and 214 specimens, corresponding respectively to 47.5, 30.4 and 11.3% of the Mesostigmata collected. Laelapidae was the most diverse family, being represented by 22 species. The remaining families were each represented by 1-5 species. Gaeolaelaps (Laelapidae) was the most diverse genus, with 14 species. Rhodacaridae was represented by a single species, Binodacarus aceguaensis Duarte, Castilho, Cunha & Moraes, representing 47.5% of the mesostigmatids. Ologamasidae was represented by four species, with Neogamasellevans sp. corresponding to the second most abundant species, representing 27.5% of the mesostigmatids. Further analysis of the data, in terms of mite identification to species level and the potential use of the mites collected for applied biological control are needed.*
Key words: *taxonomy, predators, biological control, biodiversity.*

Ácaros mesostigmatídeos edáficos (Parasitiformes, Mesostigmata) em uma região do bioma Pampa do estado do Rio Grande do Sul, Brasil

RESUMO: *A diversidade de ácaros edáficos em ambientes naturais brasileiros é pouco conhecida, especialmente no bioma Pampa na região sul do Brasil. O objetivo deste trabalho foi avaliar a diversidade e abundância da fauna edáfica de ácaros mesostigmatídeos no bioma Pampa, do sul do Brasil. Coletas de solo foram realizadas no município de Aceguá, em 2012 e 2013. Ácaros foram extraídos das amostras com o uso de funis de Berlese-Tullgren modificados. No total, 1900 ácaros mesostigmatídeos foram coletados, representando 44 espécies de 23 gêneros de 10 famílias. As famílias mais abundantes foram Rhodacaridae, Ologamasidae e Laelapidae, nesta ordem, com 903, 578 e 214 espécimes, correspondendo respectivamente a 47,5, 30,4 e 11,3% dos mesostigmatídeos coletados. Laelapidae foi a família mais diversa, sendo representada por 22 espécies. O restante das famílias foi representado por 1 - 5 espécies. Gaeolaelaps (Laelapidae) foi o gênero mais diverso, com 14 espécies. Rhodacaridae foi representada por uma única espécie, Binodacarus aceguaensis Duarte, Castilho, Cunha & Moraes, correspondendo a 47,5% dos mesostigmatídeos. Ologamasidae foi representado por quatro espécies, com Neogamasellevans sp. correspondendo a segunda espécie mais abundante, representando 27,5% dos mesostigmatídeos encontrados. Mais estudos são necessários para a identificação destes ácaros a nível de espécie, bem como para avaliar o potencial de uso destes no controle biológico aplicado.*
Palavras-chave: *taxonomia, predadores, controle biológico, biodiversidade.*

INTRODUCTION

Despite the ecological singularity of southern Brazil in relation to other parts of the country, biodiversity in this region is still poorly known (BENCKE, 2009), especially in relation to the edaphic fauna. Mites are very diverse in the soil, especially in less disturbed habitats (KRANTZ & WALTER 2009). Knowledge about their identify and behavior is important, for the evaluation of soil quality and for knowledge of the dynamics of production systems (PAOLETTI & BRESSAN,

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1996). Mesostigmatids mites are important as biological control agents, because of their effect as predators of different organisms, including other mites, nematodes, springtails, small insects and others (WALTER & PROCTOR, 2001; LINDQUIST et al., 2009; CARRILLO et al., 2015).

In Brazil, studies about the diversity of mesostigmatid mites have been conducted, mostly in the southeast (MINEIRO et al., 2009; MINEIRO & MORAES, 2001; SILVA et al., 2004) and northeast (SANTOS, 2013). In these studies, the authors reported high mite diversity and abundance. In the natural ecosystems in Alagoas State, in the Atlantic Forest and Caatinga biomes, the three most abundant families were Ologamasidae, Laelapidae and Rhodacaridae, being *Neogamasellevans*, the most common genus (SANTOS, 2013). In the Atlantic Forest and Cerrado biomes of São Paulo State, *Neogamasellevans* was also the most common genus (SILVA et al., 2004).

In the southern Brazil, the only information on the diversity of soil mites in the Pampa biome was published by Duarte et al. (2013), indicating high abundance of Mesostigmata, mainly Rhodacaridae. The aim of the present research was to evaluate the diversity and abundance of edaphic mesostigmatid mites in a region of the Pampa biome.

MATERIALS AND METHODS

Collection

Soil samples were collected at "Estância São José" (31º 51' 48"'S, 54º10'03.65"'W; 240 m above sea level) from an area used as natural pasture in Aceguá municipality, Rio Grande do Sul, Brazil, covered mostly by grasses (Poaceae) from genera *Panicum, Paspalum* and *Stipa*, and less frequently by leguminous from genera *Adesmia, Baccharis, Desmodium* and *Medicago* (Fabaceae) and by the Asteraceae *Baccharis*. The soil of the area was classified as Vertisolic Eutrophic Haplic Alfisol (STRECK et al., 2008) with high fertility and very hard layers in the dry season.

Samplings were conducted twice during the dry (March 5, 2012 and April 16, 2013) and wet (June 26, 2012 and August 20, 2013) seasons. Rainfall within the preceding month of each collection dates were respectively 224, 78, 59 and 79 mm (according to information provided by National Institute of Meteorology- INMET, Bagé Station, Rio Grande do Sul state, 2013).

At each sampling date, 15 random samples were taken at random from each of four sampling areas that were distant at least 2-3 km from each other. Each sample was collected with a metal cylinder 9 cm in diameter and 5 cm high, corresponding to a volume of 318 cm^3. At each sampling site, the vegetation and the dry leaves were removed, and the cylinder was introduced into the soil using a hammer, in a way that its upper rim was at the level of the soil surface.

Each cylinders was placed in a plastic bag, and the bags were placed in a cool box maintained at 12-21 ºC for transport to the Acarology Laboratory (LabAcaro) at Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas (FAEM/UFPEL), Pelotas, Rio Grande do Sul State, where mites were extracted through modified Berlese-Tullgren for seven days (OLIVEIRA et al., 2001). Falling mites were collected in 70% ethanol and all Mesostigmata were mounted in Hoyer's medium for identification.

Identification

Identification was done at the Acarology laboratory of Escola Superior de Agricultura "Luiz de Queiroz", Universidade de São Paulo (ESALQ-USP), Piracicaba, under phase and interference contrast microscopes. Mites were initially separated in families using the key provided by Lindquist *et al*. (2009). Subsequently, the genera were identified using the world literature about the groups collected (CASTILHO et al., 2016, 2012; MORAES et al., 2016; MOREIRA, 2014). Whenever possible, identification up to species level was done by comparisons with original descriptions and redescriptions, and with specimens available at the mite reference collection of ESALQ-USP. Voucher specimens were deposited at FAEM-UFPEL and ESALQ-USP.

Statistical analyses

The proportions of mites were calculated based only on the number of adults, of due to insufficient information concerning the identification of immatures. Abundance comparisons of mesostigmatid families (considering only adults) between the two seasons, were done using Fisher Exact test for $P<0.05$, considering the total of each family. Analyses of correlation between the precipitation and abundance of the each families were performed through the Core test, by Pearson method for $P<0.05$. All analyses were performed using R software version 3.4.1 (R Core Team 2015).

RESULTS

The number of mesostigmatid mites collected in the wet season was 2.1 times larger than the number collected in dry season (respectively 1288 and 612, table 1). However, no statistically significant

Table 1 - Total numbers (T) and proportions (%) of mesostigmatid families and species collected in the dry and wet seasons of 2012-2013 in soils of the Pampa biome at Aceguá, Rio Grande do Sul State.

	-------Dry-------		-------Wet-------		-------Total------	
Family	T	%	T	%	T	%
Ascidae	58	9.5	48	3.7	106	5.6
Asca lobata De Leon	30	4.9	31	2.4	61	3.2
Asca sp.	6	1.0	3	0.2	9	0.5
Gamasellodes rectiventris Lindquist	1	0.2	6	0.5	7	0.4
Gamasellodes n sp.	0	0.0	2	0.2	2	0.1
Protogamasellus aff. *similes* Genis, Loots & Ryke	21	3.4	6	0.5	27	1.4
Blattissociidae	1	0.2	5	0.4	6	0.3
Blattisocius keegani Fox	1	0.2	3	0.2	4	0.2
Cheiroseius sp.	0	0.0	2	0.2	2	0.1
Digamasellidae	1	0.2	3	0.2	4	0.2
Dendrolaelaps sp.	1	0.2	3	0.2	4	0.2
Laelapidae	61	10.0	153	11.9	214	11.3
Androlaelaps sp.	0	0.0	7	0.5	7	0.4
Cosmolaelaps brevistilis (Karg)	1	0.2	2	0.2	3	0.2
Cosmolaelaps guttulatus (Karg)	1	0.2	8	0.6	9	0.5
Cosmolaelaps pampaensis Duarte, Moreira, Cunha & Moraes	8	1.3	12	0.9	20	1.1
Gaeolaelaps sp1	0	0.0	5	0.4	5	0.3
Gaeolaelaps sp2	1	0.2	13	1.0	14	0.7
Gaeolaelaps sp3	0	0.0	2	0.2	2	0.1
Gaeolaelaps sp4	8	1.3	40	3.1	48	2.5
Gaeolaelaps sp5 n sp.	1	0.2	19	1.5	20	1.1
Gaeolaelaps sp6	6	1.0	1	0.1	7	0.4
Gaeolaelaps sp7	3	0.5	3	0.2	6	0.3
Gaeolaelaps sp8	5	0.8	11	0.9	16	0.8
Gaeolaelaps sp9	1	0.2	0	0.0	1	0.1
Gaeolaelaps sp10	2	0.3	1	0.1	3	0.2
Gaeolaelaps sp11	1	0.2	0	0.0	1	0.1
Gaeolaelaps sp12	5	0.8	8	0.6	13	0.7
Gaeolaelaps sp13	2	0.3	12	0.9	14	0.7
Gaeolaelaps sp14	11	1.8	2	0.2	13	0.7
Laelaspis sp1 n sp.	0	0.0	7	0.5	7	0.4
Laelaspis sp2	2	0.3	0	0.0	2	0.1
Laelaspis sp3	1	0.2	0	0.0	1	0.1
Pseudoparasitus sp.	2	0.3	0	0.0	2	0.1
Macrochelidae	0	0.0	4	0.3	4	0.2
Macrocheles sp.	0	0.0	4	0.3	4	0.2
Melicharidae	2	0.3	17	1.3	19	1.0
Proctolaelaps n sp.	1	0.2	8	0.6	9	0.5
Proctolaelaps diffissus Karg	0	0.0	1	0.1	1	0.1
Spadiseius n sp.	1	0.2	8	0.6	9	0.5
Ologamasidae	121	19.8	457	35.5	578	30.4
Acugamasus sp.	0	0.0	3	0.2	3	0.2
Neogamasellevans sp.	108	17.6	414	32.1	522	27.5
Ologamasus sp.	1	0.2	0	0.0	1	0.1
Rykellus	12	2.0	40	3.1	52	2.7
Phytoseiidae	6	1.0	2	0.2	8	0.4
Neoseiulus sp.	3	0.5	0	0.0	3	0.2
Proprioseiopsis sp.	3	0.5	2	0.2	5	0.3
Rhodacaridae	361	59.0	542	42.0	903	47.5
Binodacarus aceguaensis Duarte, Castilho, Cunha & Moraes	361	59.0	542	42.0	903	47.5
Uropodidae	1	0.2	57	4.4	58	3.1
Cyllibula sp1	0	0.0	32	2.5	32	1.7
Cyllibula sp2	1	0.2	24	1.9	25	1.3
Oplitis sp.	0	0.0	1	0.1	1	0.1
Total	612	-	1288	-	1900	-
Total of species/season	33		37			

differences were reported in the average of mites between wet and dry season (P=0.51), probably, due to low rainfall in 2013.

Family abundance

Considering the two seasons, most of the adult mites collected belong to Rhodacaridae (47.5% of all mesostigmatids), Ologamasidae (30.4%) and Laelapidae (11.3%) families. The remaining families (Ascidae, Blattisociidae, Digamasellidae, Melicharidae, Macrochelidae, Phytoseiidae and Uropodidae) represented 0.2 -5.6% of the mesostigmatids sampled (Figure 1). The families Rhodacaridae, Ologamasidae and Laelapidae showed higher abundance in wet than dry season (P<0.001). Yet, the other families did not differ in abundance between seasons evaluated (P≥0.05).

The abundance of each mite family was not correlated with precipitation (P<0.05). This is not surprising, given that the research was conducted in the field, where environmental factors vary continuously, often independently and in different directions, some favoring and other disfavoring the organisms in study.

Diversity at subfamilial levels

Adults collected corresponded to 44 species of 23 genera (Table 1); five of the species are new to science and will be described in separate papers. The most abundant genera were *Binodacarus* (Rhodacaridae, 47.5%) and *Neogamasellevans* (Ologamasidae, 27.5%). Twenty-two laelapid species were collected. This number corresponded to 4.4 times the number of species in relation to the second most diverse family (Ascidae, five species). *Gaeolaelaps* (Laelapidae) was the most diverse genus, represented by 14 species. Yet, all laelapid species were reported in low total numbers (1-20 specimens each), except *Gaeolaelaps* sp4., represented by 48 specimens.

The most numerous family, Rhodacaridae, was represented by a single species, *Binodacarus aceguaensis* Duarte, Castilho, Cunha & Moraes, being the dominant species in the samples. Ologamasidae, the second most numerous family, was represented by four species, among them, *Neogamasellevans* sp., which was the second most abundant species. *Binodacarus aceguaensis* species and *Neogamasellevans* sp. were respectively, 14.8 and 8.6 times more abundant than *Asca lobata* De Leon the third most abundant species.

Considering all families together, slightly more species were reported in the wet than in the dry season, respectively 37 and 33 species (Table 1). However, the number of species of the most diverse family (Laelapidae) was approximately the same in both seasons, respectively 17 and 18.

DISCUSSION

The prevailing climatic conditions and vegetation coverage of the Pampa biome initially suggested mite diversity to be relatively low in the research site, in comparison with other parts of the country, where temperature is higher, and where the natural vegetation is often more luxurious. Aceguá is just about 8 km from the border with Uruguay, and its climate is classified as Cfa type (KOPPEN-GEIGER classification system, 2019), humid temperate climate with hot summer (KOTTEK et al., 2006; MCMAHON et al., 2015). The vegetation type of this biome, constituted basically by low growing herbaceous plants, regularly explored as a pasture, leads to low accumulation of organic matter (BOLDRINI, 2009). However, mesostigmatid mite abundance reported in this study was higher than initially expected. The average number of Rhodacaroidea in this research (1.9 mites/100 cm^3) was similar to the highest density reported in soils of the Atlantic Forest biome (1.7 mites/100 cm^3) and, much higher than reported in soil of the Cerrado biome (0.1-0.2 mites/100 cm^3) in São Paulo state (SILVA et al., 2004).

The high proportion of Ologamasidae, Laelapidae and Ascidae reported in this study was also reported in studies of edaphic habitats in São Paulo (MINEIRO & MORAES 2001; SILVA et al., 2004) and Alagoas (SANTOS, 2013) states. The predominance of Rhodacaridae in this study is different from what has been observed in soils of those studies. Silva et al. (2004) reported few specimens of this family in the Atlantic Forest and in the Cerrado. It is intriguing that in the present research this family was represented by a single species (*B. aceguaensis*), described as new to science by Duarte et al. (2016). In fact, *Binodacarus* has only been reported from Brazil. Until then, it contained only the type species (*Binodacarus brasiliensis* Castilho & Moraes), collected from soils of the central part of São Paulo State (CASTILHO & MORAES, 2010) in areas of the Cerrado biome. Those areas are ecologically quite different from Aceguá.

The reason why only *B. aceguaensis* and no other Rhodacaridae was reported in this study could not be determined. Walter & Proctor (1999) classified the rhodacaroids as eu-edaphic, meaning that they are most abundant in the mineral fraction of the soil. The relatively small size, light sclerotization and divided dorsal shields of those mites could

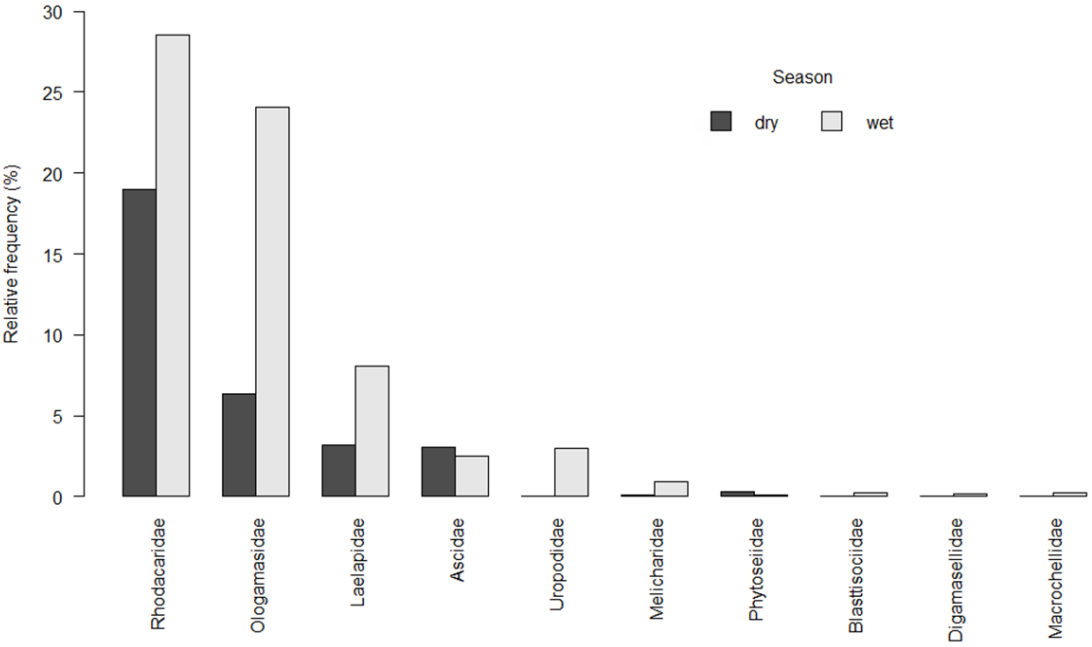

Figure 1 - Relative frequency (%) for each family of mesostigmatid mites reported in the dry and wet seasons of 2012-2013 in soils of the Pampa biome at Aceguá, Rio Grande do Sul state, Brazil.

probably allow them to move easily in the confined interstitial spaces between soil particles. Although, this is not one of the most numerous mesostigmatid families, about 150 rhodacarid species are known worldwide (CASTILHO et al., 2012). Eight species of this family have been reported from Brazil, mostly from São Paulo State (CASTILHO & MORAES, 2010; DUARTE et al., 2016; SANTOS et al., 2017).

The finding of Ologamasidae as another predominant family is not totally surprising, as this has also been determined in studies previously conducted in Brazil, in the Cerrado and Atlantic Forest biomes in São Paulo State (SILVA et al., 2004) and in the Atlantic Forest and Caatinga biomes in Alagoas state (SANTOS, 2013). As in the present study, the predominance of the ologamasid *Neogamasellevans* was also reported by Silva et al. (2004) and Santos (2013). Little is known about the ecology and biology of the 14 worldwide known *Neogamasellevans* species (CASTILHO et al., 2015, 2016). Descriptions of new species and complementary description of other species are presently being conducted, based on the specimens collected in this study.

The second most abundant genus of Ologamasidae, *Rykellus*, was represented by a single species, new to science and to be described in a later paper. Santos et al. (2015) also recently reported new *Rykellus* species from the Atlantic Forest of São Paulo, described as *Rykellus anibali* Santos, Castilho, Silva & Moraes and *Rykellus mineiroi* Santos, Castilho, Silva & Moraes.

The diversity of laelapids was outstanding, as the number of species of this family corresponded exactly to half the total number of mesostigmatid species collected. For Brazil, this is not surprising, given that in previous studies relatively high numbers of species of this family were found (FREIRE, 2007; MOREIRA, 2014). In the study conducted by Marticorena (2017) in natural vegetation (Cerrado and Atlantic Forest biomes), pasture and sugarcane field in Central-Southern region of Brazil, this was the most species rich family, with 29 species collected, most of which also *Gaeolaelaps*. The great diversity of mites of this family in the present study, especially of *Gaeolaelaps*, suggests the potential to find new candidates for practical use in the biological control of pest organisms reported in the soil. In the study conducted by Duarte et al. (2018), encouraging results were obtained in laboratory investigations of species reported in the present research.

Further analysis of the data, in terms of the potential use of the mites collected for applied biological control will be done at a later time, when their identification to the species level is concluded.

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DECLARATION OF CONFLICT OF INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

All authors contributed equally for the conception and writing of the manuscript. All authors critically revised the manuscript and approved of the final version.

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