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► **To cite this version:**

Maicon Toldi, Elisete Maria de Freitas, Vinícius Leão da Silva, Monique Caumo, Júlia Jantsch Ferla, et al.. Communities of predatory mites (Phytoseiidae and Stigmaeidae) in different environments of the Brazilian Pampa. *Acarologia*, 2021, 61 (1), pp.20-30. <10.24349/acarologia/20214413>. <hal-03110422>

HAL Id: hal-03110422

<https://hal.science/hal-03110422v1>

Submitted on 14 Jan 2021

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HAL Authorization

Acarologia

A quarterly journal of acarology, since 1959
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Subscriptions: Year 2021 (Volume 61): 450 €

<http://www1.montpellier.inra.fr/CBGP/acarologia/subscribe.php>

Previous volumes (2010-2020): 250 € / year (4 issues)

Acarologia, CBGP, CS 30016, 34988 MONTFERRIER-sur-LEZ Cedex, France

ISSN 0044-586X (print), ISSN 2107-7207 (electronic)

The digitalization of Acarologia papers prior to 2000 was supported by Agropolis Fondation under the reference ID 1500-024 through the « Investissements d'avenir » programme (Labex Agro: ANR-10-LABX-0001-01)



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Communities of predatory mites (Phytoseiidae and Stigmaeidae) in different environments of the Brazilian Pampa

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Original research

ABSTRACT

The Brazilian Pampa presents a high diversity of fauna and flora within a mosaic of environments. The aim of this study was to evaluate the assemblages of predatory mites (Phytoseiidae and Stigmaeidae) in three different Pampa environments: Grassland shrub vegetation, Grazing Exclusions fenced for six years and Riparian Forest with tree vegetation. Phytoseiidae and Stigmaeidae were evaluated with a total of 324 plant sampled from nine sites in three environments. Twenty-two Phytoseiidae species and six Stigmaeidae species were found. Riparian Forest presented the highest abundance of predatory mites (243) and the greatest species diversity. Mites were more abundant in Grazing Exclusions (64) than in Grassland (25) environments, but species diversity was similar. In Riparian Forest, the most abundant species were *Amblyseius tamatavensis* Blommers, *Amblyseius herbicolus* (Chant) and *Agistemus floridanus* González-Rodríguez. *Arrenoseius gaucho* Ferla, Silva and Moraes and *Zetzellia malviniae* Matioli, Ueckermann and Oliveira were the most abundant in Grassland environment. Our results demonstrate that the Brazilian Pampa has a high diversity of predatory mites and mite communities seem to be affected by the type of environment, showing the importance of this ecosystem as a reservoir of natural enemies.

Keywords forest; grassland; natural environment; Phytoseiidae; Stigmaeidae

Introduction

The Pampa environment is present in several countries (Argentina, Brazil, Paraguay and Uruguay) and is characterized by vegetation composed mainly of grasses and herbaceous species (Carvalho *et al.* 2009). South Brazilian native pastures occupy about 13.7 million hectares and support very high levels of biodiversity, it provides several environmental services and forage potential for livestock (Pillar *et al.* 2009). In Brazil, the Pampa vegetation comprises a mosaic riparian forests within a dominant grassland habitat (Behling *et al.* 2005). This habitat is under considerable human pressure, with less than 40% of its original native vegetation remaining (MMA 2010).

The high diversity of fauna and flora in the Pampa provides environmental services, conserves water resources, pollinators, genetic resources, and foraging for livestock (Pillar *et al.* 2009). Some human activities favor the maintenance of the grassland environment, e.g. grazing

Received 09 August 2020
Accepted 05 January 2021
Published 14 January 2021

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Academic editor
Tixier, Marie Stephane

DOI
10.24349/acarologia/20214413

ISSN 0044-586X (print)
ISSN 2107-7207 (electronic)

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activities and fire that prevent the expansion of forest formations over grasslands (Behling *et al.* 2007). However, grasslands have been recently replaced by grain crops and *Eucalyptus saligna* Smith (Myrtaceae) plantations (Pillar *et al.* 2009). These modifications in land use can have deleterious effects on the diversity and distribution of organisms in this environment, such as abundance and diversity of collembolans and edaphic mites (Rieff *et al.* 2016).

Several factors might affect environmental recovery and analyses are required to compare different mature forest areas and assess changes in species composition and regeneration of degraded areas (Coote *et al.* 2013; Derroire *et al.* 2016). Since it is not possible to totally analyze the environment with high biological diversity such as the Pampa, the use of ecological indicators is an alternative way for the diagnosis of environmental quality (Coote *et al.* 2013). Studies indicate that soil mites might be environmental indicators of both native areas and areas of exotic monocultures (Rieff *et al.* 2016). These ecological indicators are used in decision-making processes regarding management and public policies for environmental recovery and conservation (Niemi and McDonald 2004).

Plant mites represent one of the most diverse and abundant groups in terrestrial ecosystems (Walter and Proctor 2013). In spite of that, studies that analyze their potential as indicators of both anthropised environments and preserved environments are scarce (Rocha *et al.* 2015). One of the most abundant groups are the predatory mites of the families Phytoseiidae and Stigmaeidae, which are abundant on plants worldwide (Gerson *et al.* 2003) and are often employed for biological control issues (i.e. Tixier 2018). The number of Phytoseiidae species is high in the Neotropical region (McMurtry *et al.* 2013; Araújo and Daud 2018; Araújo and Kollár 2019), with 2,798 species reported in the world (Demite *et al.* 2020). Stigmaeidae live on plants and soil, and this family comprises 577 species described worldwide (Fan *et al.* 2016). In the state of Rio Grande do Sul, stigmaeids live in several agroecosystems and are considered the second most abundant predatory family after Phytoseiidae (Ferla and Moraes 2002). Several studies provide information on the occurrence of predatory mites on plants, but little is known about the parameters that explain this occurrence (i.e. Tixier 2018).

The aim of this study was to evaluate the communities of predatory mites (Phytoseiidae and Stigmaeidae) in grasslands, modified grasslands, and riparian forests in the Pampa of the South of Brazil. The main hypothesis, herein tested, is that forests have different communities of predatory mites compared to grassland environments, in a way that the forest area presents an assembly of specific predatory mites and the diversity within grassland areas is lower.

Material and methods

Study area

In the municipality of Pântano Grande, Brazil (30°19'36.59" S, 52°29'24.83" W, 100 meters above sea level), the sampling units (sites) are located in permanent preservation areas composed of native species. Around these sites, there are plantations of *Eucalyptus* sp. These areas belong to the "Shrub Field vegetation type", located in the Central Depression of the Pampa. This area is classified as Cfa, i.e., with a well-delimited summer and winter seasons, and annual rainfall varying from 1,600 to 1,900 mm (Peel *et al.* 2007). The soil is Red dystrophic Argisol (Streck *et al.* 2018). The areas herein investigated were used for agriculture and cattle breeding until 2006, when *Eucalytus* sp. plantations started and environmental recovery areas were defined.

The samplings were carried out in nine sites included in three environments, with areas larger than 0.5 ha and for each type of environment. The three types of environments were (i) Riparian Forest, with tree vegetation occurring in the margins of water resources. Riparian forests composed of a vegetation of Seasonal Semi-deciduous Forest (high litter-fall in autumn); (ii) Grazing Exclusions, with environmental recovery measures, fenced for six years, with patches of shrub vegetation; and (iii) Grassland, with compacted soil and herbaceous vegetation, with no fencing or recovery measures, and access for cattle to grazing.

Three surveys were carried out (September 2017, November 2017 and February 2018), starting 20 meters away from the edge of the area to avoid border effects (Rodrigues *et al.* 2010). Twelve native plant species were selected at each site based on studies of plant communities in the same areas (Caumo 2018). In total, 55 species of native plants were sampled, some plant species being sampled in different sites. The plant species selected for the present study were those that had the highest Importance Value Indices at each sampling unit, calculated using the mean of the sum of Relative Cover and Relative Frequency values. These data were provided by the Department of Horticulture and Forestry of the Agronomy School of Federal University of Rio Grande do Sul, Porto Alegre, RS and by the Laboratory of Botany of Univates, Lajeado, RS.

At each of the nine sites, 12 plant species were sampled with three replications over time, totaling 324 plant samples. Plant leaves were collected and kept in plastic bags within Styrofoam boxes (approximate temperature of 5 °C) until they were brought back to the laboratory. For each sample, mites were searched on leaves and stems for one hour, using a stereomicroscope Leica EZ4 HD, for standardizing the observation effort per plant. All mites retrieved were mounted on microscope slides in Hoyer's medium and kept at 40 °C for a period of seven days for clearing (Moraes and Flechtmann, 2008). Female specimens were identified at species level using a phase-contrast optical microscopy (Zeiss Axio Scope A1), based on identification keys (Moraes *et al.* 2004; Lindquist *et al.* 2009; Walter *et al.* 2009; Fan *et al.* 2016).

The plants were identified by the Department of Horticulture and Forests of the School of Agronomy of the Federal University of Rio Grande do Sul (UFRGS) and by the Botany Laboratory of the University of Vale do Taquari (Univates), with consultation specialists and herbariums.

Data analyses

Interactions between mites and plants were analyzed using the ecological network analysis using the “network-level” function of the Bipartite package of the R software (R Core Team, 2019). We evaluated connectivity and robustness, which expresses the proportion of all possible interactions between species of mites and plants and assess the resistance of the network to disturbances, respectively (Dunne *et al.* 2002; Blüthgen *et al.* 2006).

Predatory mite communities from the three environments were analyzed using a non-metric multidimensional scaling (NMDS), to assess dissimilarity in the assemblages of predatory mites in the different environments analyzed (Riparian Forest, Grazing Exclusions and Grassland). We also applied the Bray-Curtis dissimilarity index, through an abundance matrix. To detect significant differences in predatory mite communities between environments, we performed a similarity analysis (ANOSIM) using the software PRIMER-E, version 5.2.9 (Clarke and Gorley 2002).

Potential ecological indicator species were identified with the Indicator Value method (IndVal) (Dufrene and Legendre 1997). The IndVal method is based on exclusivity for a habitat and frequency of occurrence within the same habitat. Calculations of IndVal were performed for each species and site with the package ‘labdsv’ v1.8-0 in R (R Core Team, 2019). The statistical significance of indicator values was measured using random iterative methods by relocating 10,000 samples within sample groups. Species were considered as indicators if their maximum value of IndVal was 25% (Dufrene and Legendre 1997).

Results

On the 55 plant species analyzed, predatory mites were observed on only 33 species in the three environments (Table 1). A total of 332 mite specimens were found, most of them belonging to the family Phytoseiidae (22 species, 293 specimens) followed by stigmatids (6 species, 39 specimens). Riparian Forest was the environment with the highest number of specimens (243),

followed by Grazing Exclusions (64) and Grassland (25). The most abundant species were represented by only five species: *Neoseiulus tunus* (De Leon) (64 specimens), *Amblyseius tamatavensis* Blommers (56 specimens), *Amblyseius herbicolus* (Chant) (48 specimens), *Amblydromalus limonicus* (Garman and McGregor) (30 specimens) and *Agistemus floridanus* Gonzalez-Rodriguez (25 specimens) (Table 1).

Networks of mites and plants showed 98 interactions (Robustness = 0.583; connectivity = 0.090) (Figure 1). *Amblyseius tamatavensis* and *A. floridanus* were the species with the highest number of interactions within the families Phytoseiidae and Stigmaeidae, respectively. *Baccharis dracunculifolia* De Candolle was the plant species showing the highest number of interactions (with six species in the Grassland environment: *Euseius inouei* Ehara and Moraes, *Euseius mesembrinus* (Dean), *Neoseiulus californicus* (McGregor), *Phytoseiulus macropilis* (Banks), *Typhlodromalus aripo* (De Leon) and *Zetzellia malvinae* Matioli, Ueckermann and Oliveira). *Elephantopus mollis* Kunth was the plant species with the highest number of interactions in Grazing Exclusion environment (with six species). Four plant species had high number of interactions in the Riparian Forest environment, *Vitex megapotamica* (Sprengel) (with six species), *Symplocos uniflora* (Pohl) (with six species), *Ruellia angustiflora* (Ness) (with six species), and *Myrcianthes pungens* (Berg) Legrand (with six species).

NMDS analysis ordinated the nine sites of the three environments, grouping together the Grassland and Grazing Exclusions, the forest remaining separated (Figure 2). The disturbance value provided by the scaling (stress value = 0.06) indicates that the ordination well fits the graphical representation. This result was confirmed by the ANOSIM analysis (global R = 0.462, $P < 0.001$), indicating that the three areas are characterized by different mite communities. Comparisons between Grassland and Grazing Exclusions did not show any differences ($R = 0.092$, $P > 0.05$), where difference was observed between Grassland and Riparian Forest environments ($R = 0.45$, $P < 0.001$), and between Grazing Exclusions and Riparian Forest environments ($R = 0.46$, $P < 0.001$). The Riparian Forest was the environment with the greatest predatory mite richness and abundance, and the Grassland and Grazing Exclusions areas presented more similar diversity and lower diversity and abundance of predatory mites.

Approximately 50% of mite species were detected as environmental indicators. Riparian Forest was the environment with the highest number of environmental indicator species, with *A. tamatavensis*, *A. herbicolus*, *A. floridanus* and *A. limonicus*, with IndVal higher than 0.50. *Zetzellia malvinae* and *Arrenoseius gaucho* Ferla, Silva and Moraes were detected as indicator species in Grassland environment and only one species, *T. aripo*, was detected as an indicator species in the Grazing Exclusions environment (Table 2).

Discussion

The results herein obtained support our initial hypothesis: mite communities are different between Riparian Forest and Grassland areas. Mite communities in Grasslands and modified grasslands areas were similar to each other's and diversity was lower than in the Riparian Forest area. Those results show that the Brazilian Pampa, because of diverse vegetation biome, shelter a high diversity of predatory mites associated with native plants, demonstrating the importance of this ecosystem as a reservoir of natural enemies.

Studies on mite diversity in the Brazilian Pampa are scarce, here we found 28 species of predatory mites (22 species of Phytoseiidae and 6 species of Stigmaeidae) on 33 plant species. In Brazilian Cerrado, Demite *et al.* (2017) found 34 phytoseiid species on 37 plant species. In Pantanal, Mendonça *et al.* (2019) found 35 phytoseiid species on 40 native plants and Rodrigues *et al.* (2020) found 11 phytoseiid species associated with Myrtaceae plants in the Caatinga. In the Brazilian Atlantic Forest, Ferla and Moraes (2002) found 23 phytoseiid species on 45 plant species; Castro and Moraes (2010) found 54 phytoseiid species on 187 species of plants; Demite *et al.* (2013) found 31 Phytoseiid species on two native plants in fragments of semi-deciduous seasonal forest; Rocha *et al.* (2015) reported 29 Phytoseiid species on 62

Table 1 Number and species of predatory mites retrieved in the three environments assessed in the municipality of Pântano Grande, State of Rio Grande do Sul, Brazil.

Plant species	Environments	Predatory mite species	N
<i>Adiantopsis chlorophyll</i> (Swartz) Fée	GE	<i>Typhlodromalus aripo</i> De Leon	2
<i>Baccharis dracunculifolia</i> De Candolle	G and GE	<i>Amblyseius</i> sp.3	1
		<i>Neoseiulus californicus</i> (McGregor)	1
		<i>Euseius inouei</i> Ehara & Moraes	2
		<i>Euseius mesembrinus</i> (Dean)	1
		<i>Phytoseiulus macropilis</i> (Banks)	4
		<i>Typhlodromalus aripo</i>	7
		<i>Zetzellia malvinae</i> Matioli, Ueckermann & Oliveira	4
<i>Baccharis trimera</i> (Less)	G	<i>Phytoseiulus macropilis</i>	5
<i>Bromelia antiacantha</i> Bertoloni	RF	<i>Amblyseius</i> sp.4	1
<i>Casearia sylvestris</i> Swartz	RF	<i>Amblyseius herbicolus</i> (Chant)	5
		<i>Amblydromalus limonicus</i> (Garman & McGregor)	6
		<i>Amblyseius tamatavensis</i> Blommers	1
<i>Chrysophyllum marginatum</i> (Hooker & Arnott) Radlkofer	RF	<i>Amblyseius tamatavensis</i>	1
<i>Cyathea atrovirens</i> (Langsdorff & Fischer)	RF	<i>Amblyseius herbicolus</i>	25
		<i>Amblyseius tamatavensis</i>	1
		<i>Iphiseiodes moraesii</i> Ferla & Silva	3
		<i>Typhlodromips mangleae</i> De Leon	1
<i>Daphnopsis racemosa</i> Grisebach	RF	<i>Iphiseiodes moraesii</i>	1
		<i>Amblyseius tamatavensis</i>	2
		<i>Amblydromalus limonicus</i>	1
		<i>Agistemus brasiliensis</i> Matioli, Ueckermann	1
<i>Desmodium incanum</i> De Candolle	GE	<i>Agistemus brasiliensis</i> Matioli, Ueckermann	1
<i>Dichondra sericea</i> Swartz	G	<i>Chelaseius</i> sp.	1
<i>Elephantopus mollis</i> Kunth	G and GE	<i>Neoseiulus tunus</i> (De Leon)	27
		<i>Agistemus</i> sp.1	1
		<i>Arrenoseius gaucho</i> Ferla, Silva & Moraes	13
		<i>Graminaseius</i> sp.1	1
		<i>Agistemus floridanus</i> Gonzalez-Rodriguez	5
		<i>Agistemus brasiliensis</i>	1
		<i>Arrenoseius</i> sp.	1
<i>Typhlodromalus aripo</i>	1		
<i>Eugenia hiemalis</i> Cambess	RF	<i>Amblyseius herbicolus</i>	2
<i>Gymnanthes klotzschiana</i> Müller Argoviensis	RF	<i>Typhlodromips mangleae</i>	2
		<i>Amblydromalus limonicus</i>	4
		<i>Amblyseius</i> sp.4	1
<i>Ilex brevicuspis</i> Reissek	RF	<i>Amblydromalus limonicus</i>	1
		<i>Typhlodromips mangleae</i>	2
		<i>Amblyseius tamatavensis</i>	1
<i>Lithraea brasiliensis</i> Marchand	RF	<i>Eustigmaeus</i> sp.	1
<i>Miconia hyemalis</i> A.St.-Hilaire & Naudin	RF	<i>Neoseiulus tunus</i>	1
		<i>Agistemus floridanus</i>	2
		<i>Agistemus</i> sp.1	3
		<i>Phytoseius guianensis</i> De Leon	2
<i>Myrcia palustris</i> De Candolle	RF	<i>Agistemus floridanus</i>	5

Table 1 Continued.

Plant species	Environments	Predatory mite species	N
<i>Myrcianthes pungens</i> (O.Berg) D.Legrand	RF	<i>Amblyseius herbicolus</i>	3
		<i>Agistemus brasiliensis</i>	1
		<i>Agistemus floridanus</i>	2
		<i>Neoseiulus tunus</i>	1
		<i>Amblyseius tamatavensis</i>	14
		<i>Amblyseius</i> sp.2	1
<i>Myrciaria tenella</i> (De Candolle) O.Berg	RF	<i>Amblyseius tamatavensis</i>	1
<i>Myrsine gardneriana</i> (De Candolle)	RF	<i>Iphiseiodes moraesii</i>	5
		<i>Agistemus floridanus</i>	3
<i>Ocotea pulchella</i> (Nees)	RF	<i>Neoseiulus tunus</i>	6
		<i>Agistemus floridanus</i>	1
		<i>Amblyseius tamatavensis</i>	2
<i>Paspalum umbrosum</i> von Trinius	G and GE	<i>Neoseiulus tunus</i>	1
		<i>Neoseiulus anonymus</i> (Chant & Baker)	1
<i>Piptochaetium montevidense</i> (Sprengel)	GE	<i>Neoseiulus tunus</i>	5
<i>Psidium cattleianum</i> Sabine	G and GE	<i>Iphiseiodes moraesii</i>	6
<i>Psychotria carthagenensis</i> Jacquin	RF	<i>Neoseiulus tunus</i>	2
		<i>Agistemus floridanus</i>	1
		<i>Typhlodromips mangleae</i>	1
		<i>Amblydromalus limonicus</i>	1
		<i>Amblyseius tamatavensis</i>	15
		<i>Amblyseius</i> sp.4	6
<i>Ruellia angustiflora</i> (Ness) Lindau ex Rambo	RF	<i>Amblyseius tamatavensis</i>	13
		<i>Amblydromalus limonicus</i>	3
		<i>Amblyseius herbicolus</i>	4
		<i>Neoseiulus tunus</i>	14
		<i>Typhlodromips japi</i> Lofego, Demite & Feres	5
		<i>Iphiseiodes moraesii</i>	3
<i>Sebastiania brasiliensis</i> Sprengel	RF	<i>Amblyseius tamatavensis</i>	1
<i>Sida rhombifolia</i> Linnaeus	G and GE	<i>Typhlodromalus aripo</i>	1
		<i>Amblyseius herbicolus</i>	4
<i>Symplocos uniflora</i> (Pohl) Benth	RF	<i>Agistemus floridanus</i>	2
		<i>Neoseiulus tunus</i>	5
		<i>Amblydromalus limonicus</i>	8
		<i>Phytoseius guianensis</i>	4
		<i>Amblyseius</i> sp.1	1
		<i>Typhlodromips japi</i>	4
<i>Trichilia elegans</i> A. Jussieu	RF	<i>Agistemus</i> sp.2	1
		<i>Agistemus floridanus</i>	1
		<i>Amblydromalus limonicus</i>	1
		<i>Amblyseius tamatavensis</i>	1
		<i>Typhlodromalus aripo</i>	3
		<i>Zetzellia malvinae</i>	1
<i>Vernonanthura nudiflora</i> (Less) H. Rob	G and GE	<i>Neoseiulus tunus</i>	2
<i>Vitex megapotamica</i> (Sprengel) Moldenke	RF	<i>Agistemus floridanus</i>	3
		<i>Typhlodromalus aripo</i>	1
		<i>Amblyseius herbicolus</i>	5
		<i>Amblydromalus limonicus</i>	5
		<i>Amblyseius tamatavensis</i>	3

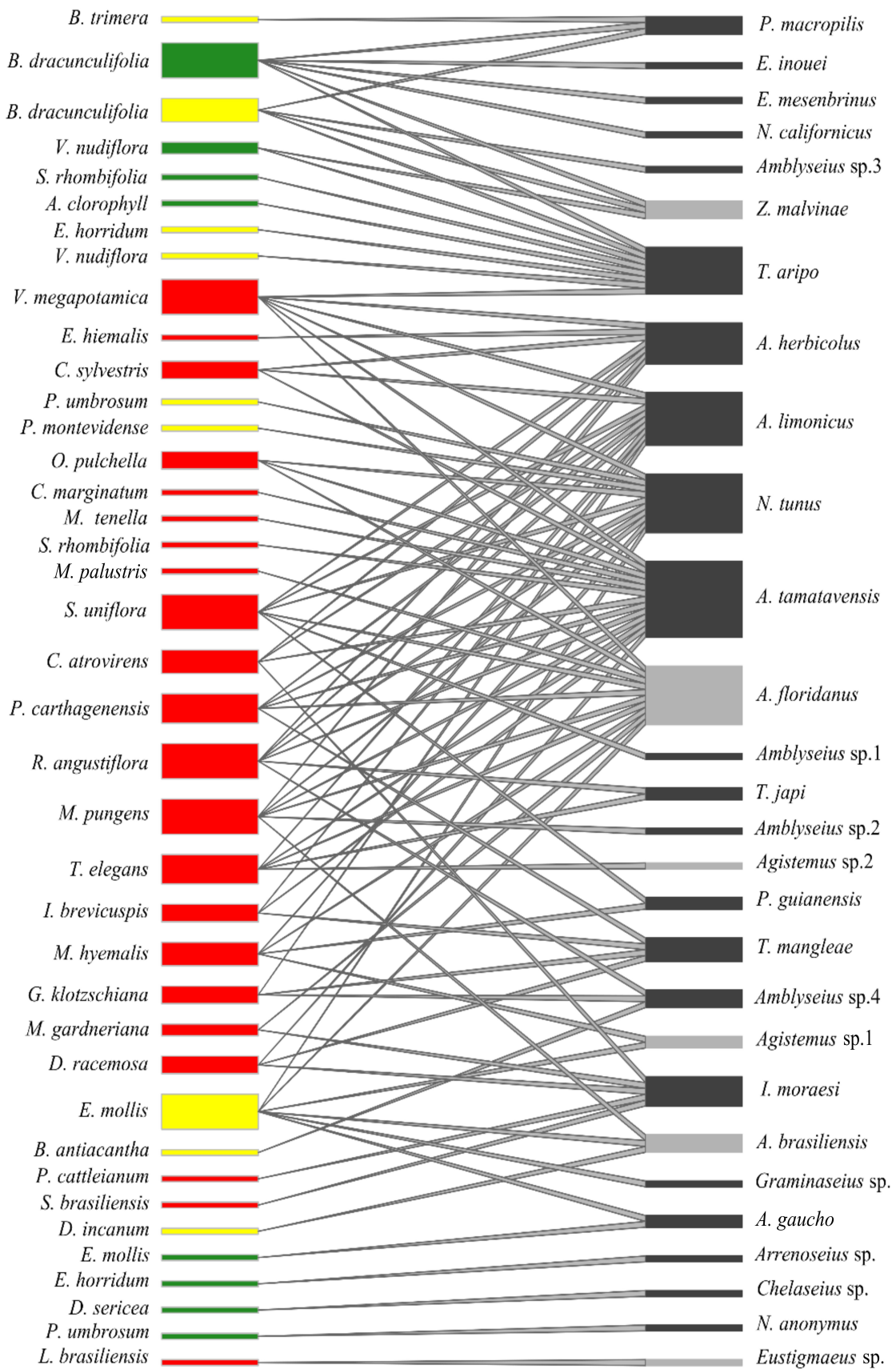


Figure 1 Bipartite network of mite and host plant species. Bars on the left side represent host plant species and bars on the right side represent mite species; green bars represent Grassland; yellow bars represent Grazing Exclusions; red bars represent Riparian Forest; grey bars represent Stigmaeidae and black bars represent Phytoseiidae.

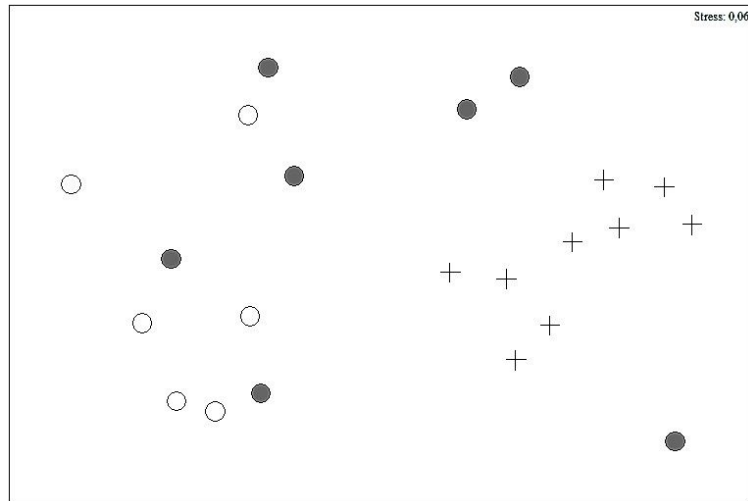


Figure 2 Ordination (NMDS) of mites. ○: Grassland, ●: Grazing Exclusions; + Riparian Forest. The low stress value (=0.06) indicates good fit of the two-dimensional representation of the distances between samplings.

plants; Lofego *et al.* (2017) found 29 species on *Cecropia pachystachya* Trec. and Nuvoloni *et al.* (2015) found 29 Phytoseiid species on *Hevea* spp. from the Amazon Forest.

The richness of Phytoseiidae found in this study is very similar to that found in the Brazilian Caatinga and Cerrado and is lower than that observed in the Atlantic Forest and Amazon Forest. The richness of Stigmaeidae found in this study was higher than that observed in other studies (Ferla and Moraes 2002; Demite *et al.* 2013; Demite *et al.* 2015; Lofego *et al.* 2017; Noronha *et al.* 2020; Rodrigues *et al.* 2020), but similar to that found by Johann *et al.* (2014) in vineyard agro-ecosystems. Many plants sheltered more than one mite species and the interaction value was high with 98 interactions of 28 mite species. The robustness of the networks was similar to that found by Araujo and Kollár (2019). This can be explained by the fact that these mites are predators, as networks with phytophagous mites have lower connectivity (Araújo and Daud 2018). The assemblages of predatory mites of Riparian Forest contrasts with grassland and

Table 2 Predatory mite species in Pampa and associated indicators (IndVal) of environment Pampa Grassland (G), Grazing exclusion (GE) and Riparian Forest (RF), in decreasing order of IndVal.

IndVal	Predatory Mite Species	Environment
0.78	<i>Amblyseius tamatavensis</i>	RF
0.67	<i>Amblyseius herbicolus</i>	RF
0.62	<i>Agistemus floridanus</i>	RF
0.56	<i>Amblydromalus limonicus</i>	RF
0.44	<i>Typhlodromalus aripo</i>	GE
0.44	<i>Iphiseiodes moraesii</i>	RF
0.44	<i>Typhlodromips mangleae</i>	RF
0.38	<i>Neoseiulus tunus</i>	RF
0.33	<i>Amblyseius</i> aff. <i>euterpes</i>	RF
0.33	<i>Phytoseius guianensis</i>	RF
0.33	<i>Typhlodromips japi</i>	RF
0.31	<i>Arrenoseius gaucho</i>	G
0.27	<i>Zetzellia malvinae</i>	G

grazing exclusions. Thus, predatory mites can also be considered a meaningful indicator of environmental characteristics in the Brazilian Pampa. *Amblyseius tamatavensis*, *A. herbicolus* and *A. floridanus* are associated to Riparian Forest. *Amblyseius tamatavensis* and *A. herbicolus* are worldwide distributed (Demite *et al.* 2019) and *A. floridanus* only occurs in the American continent (Johann *et al.* 2013). *Arrenoseius gaucho*, collected to Grassland, has been described in this environment (Ferla *et al.* 2010), but there is no ecological information in literature regarding this species. Similar to *Z. malvinae*, which is related to Grassland, it is distributed throughout Brazil and occurs in rubber trees, vineyards, citrus, and coffee crops (Matioli *et al.* 2002; De Vis *et al.* 2006; Mineiro *et al.* 2006; Diehl *et al.* 2012). *Typhlodromalus aripo* was more associated with Grazing and Grazing Exclusions, this species was also associated to unstable environments with extreme windy conditions (Rocha *et al.* 2015).

Plant species that showed the highest number of predatory species could be selected in future studies on environmental indicators, especially to determine what are the factors affecting mite species occurrence. These plants occur throughout several countries and biomes (Ezcurra 1989; Patrício and Cervi 2005; Borges and Forzza 2008; Carvalho 2008; Cruz *et al.* 2016) and may be favorable to mites due to particular plant traits, such as trichomes and domatia, providing shelter and food (i.e. Tixier 2018). The main questions would be: the mite species occurrence is led by factors associated to environmental and /or plant features?

Predatory mites are important biological control agents of other mite groups and several species are used in many biological control programs (Gerson *et al.* 2003; McMurtry *et al.* 2013). Here, we found economically important biocontrol agents (MAPA 2018) particularly *P. macropilis* (9 specimens) and *N. californicus* (1 specimen). Other predators found in this study have also economic importance in biological control as shown in several studies: *Agistemus floridanus* (Ferla and Moraes 2003), *A. limonicus* (Vangansbeke *et al.* 2014), *A. tamatavensis* (Cavalcante *et al.* 2017), *E. mesembrinus* (Landeros *et al.* 2004) and *T. aripo* (Onzo *et al.* 2012).

Finally, we conclude that the Brazilian Pampa has many species of predatory mites, whose diversity is affected by the vegetation. The different environments of the Brazilian Pampa show a rich diversity of predators and can contribute to biological control programs. Thus, the monitoring of these areas is important to assess how these populations are maintained and evolve through time, especially in the ecological succession processes.

Acknowledgments

The authors are grateful to Celulose Riograndense and UNIVATES for their financial support. This study was partly financed by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001. The authors are grateful to the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) [productivity scholarship n°. 310035-2017-1. awarded to NJF].

References

- Araújo W.S., Kollár J. 2019. First characterization of a highly specialized ecological network composed by gall-inducing mites and their host plants. *Int. J. Acarol.*, 45: 223-226. doi:10.1080/01647954.2019.1591505
- Araújo W.S., Daud R.D. 2018. Investigating effects of host-plant diversity on Brazilian mite richness in natural ecosystems. *Syst. Appl. Acarol.*, 23: 1598-1613. doi:10.11158/saa.23.8.10
- Behling H., Pillar V.D., Müller S.C., Overbeck G.E. 2007. Late Holocene fire history in a forest grassland mosaic in southern Brazil: Implications for conservation. *Appl. Veg. Sci.*, 10: 81-90. doi:10.1111/j.1654-109X.2007.tb00506.x
- Behling H., Pillar V.D., Bauermann S.G. 2005. Late Quaternary grassland (Campos), gallery forest, fire and climate dynamics, studied by pollen, charcoal and multivariate analysis of the São Francisco de Assis core in western Rio Grande do Sul (southern Brazil). *Rev. Palaeobot. Palynol.*, 133: 235-248. doi:10.1016/j.revpalbo.2004.10.004
- Blüthgen N., Menzel F., Blüthgen N. 2006. Measuring specialization in species interaction networks. *BMC Ecol.*, 6: 1-12. doi:10.1186/1472-6785-6-9

- Borges R.A.X., Forzza R.C. 2008. A tribo Astereae (Asteraceae) no Parque Estadual do Ibitipoca, Minas Gerais, Brasil. *Boll. Bot. Univ. São Paulo*, 26: 131-154. doi:10.11606/issn.2316-9052.v26i2p131-154
- Carvalho P.E.R. 2008. Maria-Mole-do-Banhado (*Symplocos uniflora*). Embrapa Florestas Circular Técnica, p. 148.
- Carvalho P.C.F., Batello C. 2009. Acesso à terra, produção pecuária e conservação de ecossistemas no bioma Campos: o dilema dos pastagens naturais. *Pecuária Ciência*, 1: 158-162.
- Castro T.M.M.G., Moraes G.J. 2010. Diversity of phytoseiid mites (Acari: Mesostigmata: Phytoseiidae) in the Atlantic Forest of São Paulo. *Syst. Biodiv.*, 8: 301-307. doi:10.1080/14772001003801375
- Caumo M. 2018. Estudo de comunidades vegetais em áreas de preservação permanente associadas à silvicultura e à pecuária no bioma Pampa, Rio Grande do Sul [Master's Thesis]. Universidade Federal do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brasil.
- Cavalcante A.C.C., Mandro M.E., Paes E.R., Moraes G. J. 2017. *Amblyseius tamatavensis* Blommers (Acari: Phytoseiidae) a candidate for biological control of *Bemisia tabaci* (Gennadius) biotype B (Hemiptera: Aleyrodidae) in Brazil. *Int. J. Acarol.*, 43: 10-15. doi:10.1080/01647954.2016.1225816
- Clarke K.R., Gorley R.N. 2002. Primer 5.2.9. [Internet]. Available in: <https://www.primer-e.com/>
- Coote L., Dietzsch A.C., Wilson M.W., Graham C.T., Fuller L., Walsh A. T., Irwin S., Kelly D.L., Mitchell F.J.G., Kelly T.C., O'Halloran J. 2013. Testing indicators of biodiversity for plantation forests. *Ecol. Indicators*, 32: 107-115. doi:10.1016/j.ecolind.2013.03.020
- Cruz A.P.O., Viana P.L., Santos J.U. 2016. Flora das cangas da Serra dos Carajás, Pará, Brasil: Asteraceae. *Rodriguésia*, 67: 1211-1242. doi:10.1590/2175-7860201667520
- Demite P.R., Lofego A.C., Feres R.J. 2013. Mite (Acari; Arachnida) diversity of two native plants in fragments of a semideciduous seasonal forest in Brazil. *Syst. Biodiv.*, 11: 141-148. doi:10.1080/14772000.2013.806368
- Demite P.R., Feres R.J.F., Lofego A.C. 2015. Influence of agricultural environment on the plant mite community in forest fragments. *Braz. J. Biol.*, 75: 396-404. doi:10.1590/1519-6984.14913
- Demite P.R., Dias M.A., Cavalcante A.C.C., Ramos M.V.V., Lofego, A.C. 2017. Phytoseiid mites (Acari: Mesostigmata: Phytoseiidae) associated with Cerrado biome plants in Brazil, with description of a new species. *Syst. Appl. Acarol.*, 22: 2141-2177. doi:10.11158/saa.22.12.9
- Demite P.R., Moraes G.J., McMurtry J.A., Denmark H.A., Castilho, R.C. 2020. Phytoseiidae Database. [Internet]. Available online: www.lea.esalq.usp.br/phytoseiidae
- Derroire G., Balvanera P., Castellanos-Castro C., Decocq G., Kennard D.K., Lebrija Trejos E., Leiva J.A., Odén P.C., Powers J.S., Rico-Gray V., Tigabu M., Healey J.R. 2016. Resilience of tropical dry forests-a meta-analysis of changes in species diversity and composition during secondary succession. *Oikos*, 125: 1386-1397. doi:10.1111/oik.03229
- De Vis R.M.J., Moraes G.J., Bellini, M.R. 2006. Effect of air humidity on the egg viability of predatory mites (Acari: Phytoseiidae, Stigmaeidae) common on rubber trees in Brazil. *Exp. Appl. Acarol.*, 38: 25-32. doi:10.1007/s10493-005-5444-8
- Diehl M., Ferla N.J., Johann, L. 2012. Plantas associadas a videiras: uma estratégia para o controle biológico no Rio Grande do Sul. *Arq. Inst. Biol.*, 79: 579-586. doi:10.1590/S1808-16572012000400015
- Dufrêne M., Legendre P. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecol. Monogr.*, 67: 345-366. doi:10.1890/0012-9615(1997)067[0345:SAAI]2.0.CO;2
- Dunne J.A., Williams R.J., Martinez N.D. 2002. Food-web structure and network theory: the role of connectance and size. *Proc. Natl. Am. Soc.*, 99: 12917-12922. doi:10.1073/pnas.192407699
- Ezcurra C. 1989. *Ruellia sanguinea* (Acanthaceae) y especies relacionadas en Argentina, Uruguay y sur de Brasil. *Darwiniana*, 29: 269-287.
- Fan Q.H., Flechtman C.H., Moraes G.J. 2016. Annotated catalogue of Stigmaeidae (Acari: Prostigmata), with a pictorial key to genera. *Zootaxa*, 4176: 1-199. doi:10.11646/zootaxa.4176.1.1
- Ferla N.J., Moraes G.J.D. 2002. Ácaros predadores (Acari) em plantas nativas e cultivadas do Estado do Rio Grande do Sul, Brasil. *Rev. Bras. Zool.*, 19: 1011-1031. doi:10.1590/S0101-81752002000400006
- Ferla N.J., Moraes G.J.D. 2003. Biologia de *Agistemus floridanus* Gonzalez (Acari, Stigmaeidae). *Rev. Bras. Zool.*, 20: 261-264. doi:10.1590/S0101-81752003000200015
- Ferla N.J., Silva G. L., Moraes G.J. 2010. Description of a new species of *Arrenoseius* Wainstein (Acari: Phytoseiidae) from Brazil and a redescription of a similar species from Argentina. *Int. J. Acarol.*, 36: 15-19. doi:10.1080/01647950903490095
- Gerson U., Smiley R.L., Ochoa R. 2003. Mites (Acari) for pest control. Blackwell Science Ltd. pp. 540. doi:10.1002/9780470750995
- Johann L., Carvalho G.S., Majolo F., Ferla N.J. 2013. Stigmaeid mites (Acari: Stigmaeidae) from vineyards in the state of Rio Grande do Sul, Brazil. *Zootaxa*, 3701: 238-256. doi:10.11646/zootaxa.3701.2.6
- Johann L., Horn T.B., Carvalho G.S., Ferla N.J. 2014. Diversity of mites (Acari) in vineyard agroecosystems (*Vitis vinifera*) in two viticultural regions of Rio Grande do Sul state, Brazil. *Acarologia*, 54: 137-154. doi:10.1051/acarologia/20142122
- Landeros J., Cerna E., Badii M.H., Varela S., Flores A.E. 2004. Patrón de distribución espacial y fluctuación poblacional de *Eutetranychus banksi* (McGregor) (Acari: Tetranychidae) y su depredador *Euseius mesembrinus* (Dean) (Acari: Phytoseiidae) en una huerta de naranjos. *Acta Zool. Mex.*, 20: 147-155.
- Lindquist E.E., Krantz G.W., Walter D.E. 2009. Order Mesostigmata. In Krantz G.W., Walter D.E. (Eds). *A Manual of Acarology*; Texas Tech University Press. p. 124-232.
- Lofego A.C., Rezende J.M., Feres R.J.F. 2017. Mite fauna associated with *Cecropia pachystachya* Trec.(Urticaceae) the importance of the plant as reservoir and dissemination means for predatory mites. *Syst. Appl. Acarol.*, 22: 1780-1794. doi:10.11158/saa.22.10.16

- MAPA, Ministério da Agricultura, Pecuária e Abastecimento. 2018. Produtos registrados. [Internet]. [August 3, 2020]. Available online: <http://www.agricultura.gov.br>
- Matioli A.L., Ueckermann E. A., Oliveira C.A.L. 2002. Some stigmatid and eupalopsellid mites from citrus orchards in Brazil (Acari: Stigmatidae and Eupalopsellidae). *Int. J. Acarol.*, 28: 99-120. doi:10.1080/01647950208684287
- McMurtry J.A., Moraes G. J., Sourassou N.F. 2013. Revision of the lifestyles of phytoseiid mites (Acari: Phytoseiidae) and implications for biological control strategies. *Syst. Appl. Acarol.*, 18: 297-320. doi:10.11158/saa.18.4.1
- Mendonça A.L., Lofego A.C., Pott A., Daud R.D., Demite P.R. 2019. Phytoseiidae (Parasitiformes: Mesostigmata) from the Pantanal, Mato Grosso do Sul State, Brazil. *Syst. Appl. Acarol.*, 24:587-612. doi:10.11158/saa.24.4.6
- Mineiro J.L.D.C., Sato M.E., Raga A., Arthur V., Moraes G.J., Sarreta F.D.O., Carrijo A. 2006. Diversidade de ácaros (Arachnida: Acari) em *Coffea arabica* L. cv. Mundo Novo, nos municípios de Jeriquara e Garça, Estado de São Paulo. *Biota Neotrop.*, 6: 1-15. doi:10.1590/S1676-06032006000200012
- MMA, Ministério do Meio Ambiente. O bioma Pampa. [Internet]. [August 3, 2020]. Available online: <http://www.mma.gov.br/>
- Moraes G.J., McMurtry J.A., Denmark H.A., Campos C.B. 2004. A revised catalog of the mite family Phytoseiidae. *Zootaxa*, 434: 1-494. doi:10.11646/zootaxa.434.1.1
- Moraes G.J., Flechtmann C.H.W. 2008. Manual de acarologia: acarologia básica e ácaros de plantas cultivadas no Brasil. Ribeirão Preto: Holos Editora. pp. 288.
- Niemi G.J., McDonald M.E. 2004. Application of ecological indicators. *Ann. Rev. Ecol. Evol. Sci.*, 35: 89-111. doi:10.1146/annurev.ecolsys.35.112202.130132
- Noronha A., Mineiro J.L., Ferla N.J., Castro T.M., Silva G.L., Lofego A.C., Azevedo A.O. 2020. Mites associated with *Byrsonima crassifolia* (L.) Kunth (Malpighiaceae) in the state of Pará, Brazil. *Entomol. Commun.*, 2: 1-3. doi:10.37486/2675-1305.ec02026
- Nuvoloni F.M., Lofego A.C., Rezende J.M., Feres R.J.F. 2015. Phytoseiidae mites associated with *Hevea* spp. from the Amazon region: a hidden diversity under the canopy of native trees. *Syst. Biodiv.*, 13: 182-206. doi:10.1080/14772000.2014.985344
- Onzo A., Hanna R., Sabelis M.W. 2012. The predatory mite *Typhlodromalus aripo* prefers green-mite induced plant odours from pubescent cassava varieties. *Exp. Appl. Acarol.*, 58: 359-370. doi:10.1007/s10493-012-9595-0
- Patrício P.C., Cervi A.C.O. 2005. O gênero *Trichilia* P. Browne (Meliaceae) no estado do Paraná, Brasil. *Acta Biológica Paranaense*, 34: 27-71. doi:10.5380/abpr.v34i0.953
- Peel M.C., Finlayson B.L., McMahon T. A. 2007. Updated world map of the Köppen-Geiger climate classification. *Hydrol. Earth Syst. Sc.*, 11: 1633-1644. doi:10.5194/hess-11-1633-2007
- Pillar V.D., Müller S.C., Castilhos Z.M.S. Jacque A.V.A. 2009. Campos Sulinos: conservação e uso sustentável da biodiversidade. Brasília: Ministério do Meio Ambiente. pp. 403.
- R Core Team. 2019. R: A language and environment for statistical computing [Internet]. Vienna, Austria: The R Foundation for Statistical Computing. [August 3, 2020]. Available online: <http://https://www.r-project.org/>
- Rieff G.G., Natal-da-Luz T., Sousa J.P., Wallau M.O., Hahn L., Sá E.L.S. 2016. Collembolans and mites communities as a tool for assessing soil quality: effect of *Eucalyptus* plantations on soil mesofauna biodiversity. *Curr. Sci.*, 110: 713-719. doi:10.18520/cs/v110/14/713-719
- Rocha M.S., Silva G.L., Oliveira J.S., Freitas E.M., Ferla N.J. 2015. Phytoseiid mites (Acari: Phytoseiidae) in the northern coastal region of the Rio Grande do Sul State, Brazil. *Neotrop. Biodiv.*, 1: 22-35. doi:10.1080/23766808.2015.1052230
- Rodrigues E.N.L., Mendonça M.S., Rosado J.L.O., Loeck A.E. 2010. Soil spiders in differing environments: *Eucalyptus* plantations and grasslands in the Pampa biome, southern Brazil. *Rev. Colomb. Entomol.*, 36: 277-284.
- Rodrigues J.K., Furtado I.P., Lofego A.C. 2020. Mites (Arachnida: Acari) associated with plants of family Myrtaceae from the Caatinga Domain, Brazil. *Syst. Appl. Acarol.*, 25: 942-956. doi:10.11158/saa.25.5.14
- Streck E.V., Kämpf N., Dalmolin R.S.D., Klamt E., Nascimento P.C., Giasson E., Pinto L.F.S. 2018. Solos do Rio Grande do Sul. Porto Alegre: Emater/RS-Ascar.
- Tixier M.S. 2018. Predatory mites (Acari: Phytoseiidae) in agro-ecosystems and conservation biological control: a review and explorative approach for forecasting plant-predatory mite interactions and mite dispersal. *Front. Ecol. Evol.*, 6: 1-21. doi:10.3389/fevo.2018.00192
- Vangansbeke D., Nguyen D.T., Audenaert J., Verhoeven R., Deforce K., Gobin B., Tirry L., De Clercq P. 2014. Diet-dependent cannibalism in the omnivorous phytoseiid mite *Amblydromalus limonicus*. *Biol. Contr.*, 74: 30-35. doi:10.1016/j.biocontrol.2014.03.015
- Walter D.E., Lindquist E.E., Smith I.M., Cook D.R., Krantz G.W. 2009. Order Trombidiformes. In Krantz G.W., Walter D.E. (Eds). *A Manual of Acarology*; Texas Tech University Press. p. 233-420.
- Walter D.E., Proctor H.C. 2013. *Mites: ecology, evolution & behaviour - life at a microscale*. New York: Springer. pp 494. doi:10.1007/978-94-007-7164-2