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ARTICLE

Plant mites (Arachnida: Acariformes, Parasitiformes) in Caatinga remnants from Piauí State, Brazil

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Abstract. The Caatinga is a highly threatened Brazilian biome that may host numerous unknown plant mite species, as little is known about its mite fauna. Thus, our aim was to assess plant mite species from Caatinga vegetation remnants in Piauí State, Northwestern Brazil. The assessment was conducted through sampling mites in two natural vegetation remnants in the southern region of Piauí during December 2015. Species richness was estimated using the Jackknife 1 method (999 randomizations), while observed richness was calculated using the Mao-Tao method. Estimated and observed richness were compared using a species accumulation curve, set with a 95% confidence interval. In total, 177 mites belonging to nine species were sampled from the Caatinga vegetation remnants. The Iolinidae family accounted for the largest number of individuals, followed by Eriophyidae. The predator mite *Pronematus* sp. was the most abundant taxon in our samples followed by the phytophagous *Aculus* sp. (Eriophyidae) and *Oligonychus* sp. (Tetranychidae) The estimated richness (Jackknife 1) did not differ from the observed richness (Mao Tao). Furthermore, *Neoseiulus tunus* (De Leon) (Phytoseiidae) was recorded for the first time in the state of Piauí. This is the first scientific work to report mite species on plants from remnants of native vegetation exclusively in Piauí State, Brazil.

Keywords. Acari; Mesostigmata; Mite diversity; Natural vegetation; Phytoseiidae.

INTRODUCTION

Many predatory mites are used in biological control programs and have been shown to be effective in controlling phytophagous mite populations on several crops (Gerson *et al.,* 2003). In addition to feeding on plant resources such as pollen and nectar, these mites can also use leaf structures (*e.g.,* acarodomatia) as breeding and nesting sites (Romero & Benson, 2005; McMurtry *et al.,* 2013; De Moraes & Flechtmann, 2008). Consequently, the knowledge of predatory mites in natural vegetation remnants proves essential to support pest management programs in agroecosystems, as many native plants can provide shelter and food resources for predatory species with potential for use in biological control. Furthermore, the identification of native plant species that host a high diversity and abundance of predatory mites is crucial, but in Brazil most acarological studies focus on agroecosystems and livestock systems rather than natural ecosystems (Araújo & Daud, 2017; Pallini *et al.,* 2007).

Most studies conducted in Brazilian natural vegetation remnants have focused on plant mites sampled in the Atlantic Forest and Cerrado biomes of the Southwest and Midwest regions (review in Araújo & Daud, 2017), and they have highlighted the importance of plants in native vegetation remnants as reservoirs of several predatory mite species (*e.g.,* Buosi *et al.,* 2006; Demite *et al.,* 2009, 2011, 2017; Lofego *et al.,* 2009; Castro & De Moraes, 2010; Rezende & Lofego, 2011; De Moraes *et al.,* 2013; Rezende *et al.,* 2014; Abreu *et al.,* 2017; Teixeira *et al.,* 2017; Cavalcante *et al.,* 2021; Moraes *et al.,* 2022). For example, Demite *et al.* (2009) sampled high diversity of mites in native Cerrado plants in the state of Mato Grosso, identifying it as an important reservoir for predatory mites, especially Phytoseiidae. In Goiás State, Teixeira

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et al. (2017) and Abreu *et al.* (2017) studied plant mites in Cerrado native habitats near mining areas and found significant predatory mite biodiversity with potential for biological pest control, despite high anthropogenic impacts in the sampled areas. In the Atlantic Forest, Castro & De Moraes (2010) and De Moraes *et al.* (2013) surveyed the diversity of Phytoseiidae mites in plants from São Paulo, while Buosi *et al.* (2006) documented herbivorous and predatory species, providing a relevant species inventory for future studies. Conceição *et al.* (2021) sampled 30 species of Phytoseiidae on native plant species in the Amazon, Cerrado, and Pantanal biomes of the state of Mato Grosso. They found 15 species of Phytoseiidae on 10 native Cerrado plants, 14 species on 10 Amazonian plants, and 23 species on 10 Pantanal plants, for a total of 30 species of Phytoseiidae. Moreover, Mendonça *et al.* (2019) found 35 Phytoseiidae species on 40 native plants in Pantanal vegetation remnants from Mato do Grosso do Sul State, Brazil.

The Caatinga biome covers 800,000 km^2 in northeastern Brazil, accounting for 10% of Brazil's territorial area (Leal *et al.,* 2003, de Andrade Lima, 1954). The biome is characterized by a complex vegetation structure with low, crooked trees with thorns. In general, plants lose their leaves during the dry season and many cactus species have structures for water storage (de Andrade Lima, 1954). According to Giulietti *et al.* (2004), the Caatinga biome is a vegetation that occurs in contiguous areas under hot and semi-arid climates, but surrounded by areas of more humid climate, with plants that have morphological and physiological adaptations to hydric deficit. The Caatinga is one of the most threatened Brazilian biomes, suffering from constant human impact, mainly due to agricultural expansion, livestock and extractivism (Silva, 2002). Additionally, the Caatinga faces desertification as a result of deforestation caused by man-made fires. According to Moura *et al.* (2023), by 2,060, over 99% of plant communities in the Caatinga will experience species loss, with a decline in beta diversity leading to biotic homogenization in 40% of the region. In addition, at least 90% of the plant communities will undergo a shift as narrowly distributed woody species are replaced by broadly distributed non-woody species (Moura *et al.,* 2023).

The Caatinga hosts many species of mites on plants (Rodrigues *et al.,* 2020, 2025), however, few studies have been conducted on mite biodiversity in this biome, compared to the number of studies conducted in other Brazilian biomes (*e.g.,* Farias *et al.,* 1979; Lawson-Balagbo *et al.,* 2008; Gonçalves *et al.,* 2015; Rocha *et al.,* 2015; Mendonça *et al.,* 2019; Demite *et al.,* 2021; Conceição *et al.,* 2021; Mendes *et al.,* 2021; Bezerra & De Matos Andrade, 2022; Brito *et al.,* 2024; Castro *et al.,* 2024). Rodrigues *et al.* (2020) recorded some mite genera on Caatinga native habitats, predominantly from the families Iolinidae, Phytoseiidae, Tarsonemidae, Tenuipalpidae, Tetranychidae, Tydeidae and Winterschmidtiidae, while the most literature review of Phytoseiidae species in Caatinga was recently published by Araújo & Rodrigues (2023). Furthermore, Rodrigues *et al.* (2025) recently published a study reporting mite species occurrence in remnants of native vegetation in the Caatinga biome. The study recorded 32 species in 12 families and provided the formal description of a new species of Phytoseiidae (Araújo & Rodrigues *et al.*, 2025).

Given the economic importance of some mite species, such as Phytoseiidae for biocontrol programs, and the intense and continuous impact of human activities on natural areas, the need for mite biodiversity studies is urgent. Here, our aim was to assess plant mite species from Caatinga vegetation remnants in Piauí State, Brazil. Furthermore, the theoretical potential of these remnants in conserving mite species richness was also estimated according to the samples in our study.

MATERIAL AND METHODS

Mites were sampled in two natural remnants of Caatinga vegetation in the southern region of Piauí State, Brazil, during a single collection in December 2015 (Fig. 1): (i) Area 1 = Alvorada do Gurguéia Municipality (08°16′43.87″S and 43°39′39.23″W) and (ii) Area 2 = Bom Jesus Municipality (09°04′26.60″S and 44°22′42.96″W). The climate of the region is *Aw* according to the Köppen classification, characterized as hot and semi-humid with two well-defined seasons: the dry season, from May to October, and another rainy season, from November to April (Ribeiro & Walter, 1998). Both areas consist of arboreal Caatinga with dry forest and are in transition zones between the Caatinga and Cerrado biomes (Fernandes, 2000). The arboreal Caatinga is characterized by medium-sized trees, such as Juazeiro (*Ziziphus joazeiro* Mart.), (Rhamnaceae), Angico (*Anadenanthera colubrina* (Vell.) Brenan), (Fabaceae) and Aroeira (*Myracrodruon urundeuva* (Allemão) Engl.), (Anarcadiaceae), with twisted trunks and deciduous leaves adapted to the semi-arid climate (Oliveira *et al.,* 2020).

In each Caatinga remnant, we established 5 m × 5 m plots in parallel pairs at 10 m and 60 m from the edge of the remnant vegetation (Fig. 2). A total of four pairs of plots (eight plots) were distributed in Area 1, while three pairs (six plots) were distributed in Area 2. The plots were spaced at least 10 m apart. All plants in the plots with a canopy circumference equal to or greater than 15 cm were selected, identified and quantified. Then, 10 leaves from the median canopy extract of each selected plant in the plot were collected and stored in independent paper bags. Leaves from each plant were fully washed and agitated in 1L plastic containers with 200 mL of 70% alcohol for 40 seconds, to collect the mites harboring them. After this procedure, the leaves were carefully removed, and the plastic container was labeled. Each container represents the mite assemblage of each selected plant in the plot. Lastly, the samples were taken to the laboratory, observed under a stereomicroscope and all the mites found were fixed in microscopy slides with Hoyer's medium (De Moraes & Flechtmann, 2008). Mites were identified under phase contrast microscope.

To estimate the potential richness of mite species, Jackknife 1 was performed with 999 randomizations,

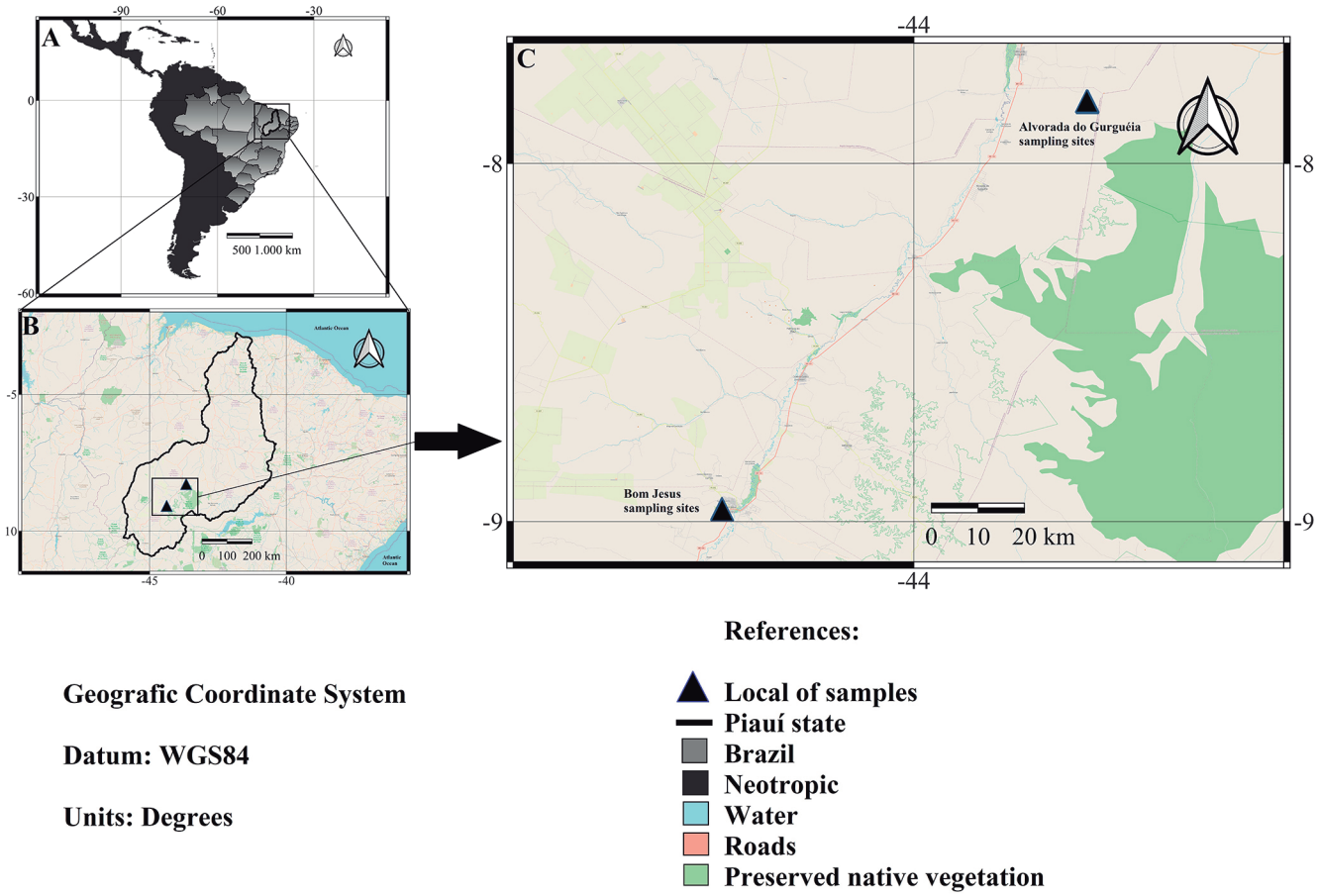

Figure 1. Sampling sites for plant mite collection in natural Caatinga vegetation remnants in the southern of Piauí State, Brazil. Reference: (A) Neotropic and Brazil; (B) Piauí state; (C) Sampling sites in Alvorada do Gurguéia and Bom Jesus.

while the observed richness was calculated using the Mao Tao procedure. From this, 95% confidence intervals were calculated for all richness values. Estimated and observed richness were compared using a species accumulation curve with a 95% confidence interval. All analyses were performed with R software version 4.3.1 (R Core Team, 2024) with the package *"vegan"* (Oksanen *et al.*, 2013).

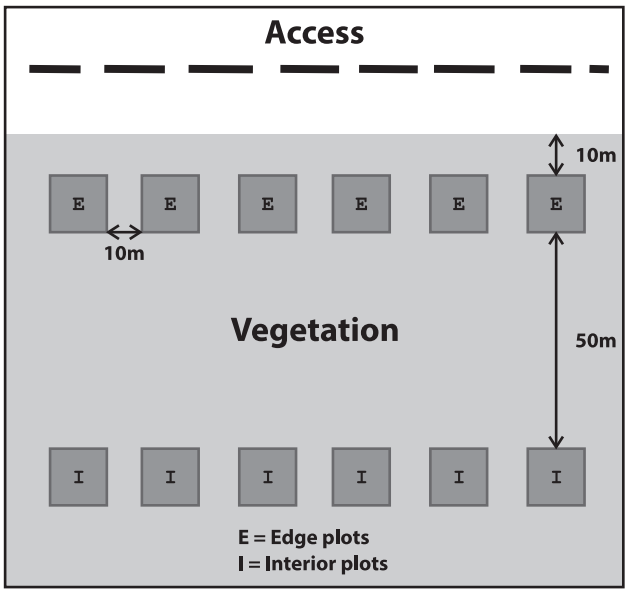

Figure 2. Sampling design used to collect plant mites from Caatinga vegetation remnants in the Southern portion of Piauí State, Brazil. (E) Plots of edge (at 10 m from the edge of remnant), (I) Plots of interior (at 60 m from the edge).

RESULTS

A total of 177 mites belonging to nine species, nine genera and eight families were sampled on plants in the two Caatinga vegetation remnants (Table 1). The mites were collected from seven plant species of five families (Table 2). The plant species with the highest mite species richness was *Piptadenia moniliformis* Benth. (Fabaceae) with eight mite species, while *Andira paniculata* Benth. (Fabaceae) harbored the greatest number of mites with a total of 117 individuals (Table 2). Area 1 showed the highest mite abundance with 171 mites sampled, and only six mites were collected in Area 2. Area 1 also had a higher mite species richness than Area 2 (Table 2).

Predatory mites were the most frequent in the samples, accounting for 68% of the mites collected, while phytophagous mites represented 31% of the total sample, followed by species with unknown feeding behavior, representing 1% of the samples. Plots established at the edge (10 m from the edge) had higher abundance of predatory species, albeit more phytophagous mites were sampled in the interior plots (Table 1).

Table 1. Mites sampled in the edge (10 m from the edge of remnant) and interior plots (60 m) established in two Caatinga vegetation remnants, Piauí State, Brazil.

Family	Genus/Species	Feed behavior*	Distance (m)		Total
			10 m	60 m	
Blattisociidae	*Platyseius* sp.	Predator	1	0	1
Eriophyidae	*Aculus* sp.	Phytophagous	7	23	30
	Unidentified immatures	Phytophagous	0	1	1
Iolinidae	*Metapronematus* sp.	Predator	0	3	3
	Pronematus sp.	Predator	73	20	93
	Unidentified immatures	Predator	13	4	17
Oribatida	Unidentified species	?	1	0	1
Phytoseiidae	*Euseius citrifolius* Denmark & Muma	Predator	1	0	1
	Neoseiulus tunus (De Leon)	Predator	1	3	4
	Unidentified immatures	Predator	2	0	2
Tarsonemidae	*Tarsonemus bilobatus* Suski	Phytophagous	1	1	2
Tenuipalpidae	*Brevipalpus yothersi* Baker	Phytophagous	4	1	5
	Unidentified immatures	Phytophagous	2	0	2
Tetranychidae	*Oligonychus* sp.	Phytophagous	4	9	13
	Unidentified immatures	Phytophagous	1	1	2
Total			**111**	**66**	**177**

* Feed behavior according to De Moraes & Flechtmann (2008) and McMurtry *et al.* (2013).

The most frequent predatory species recorded in our study were *Pronematus* sp. (Iolinidae) (93 specimens). The most abundant phytophagous species recorded were *Aculus* sp. (Eriophyidae) (30), *Oligonychus* sp. (Tetranychidae) (13) and *Brevipalpus yothersi* Baker (Tenuipalpidae) (5). Four taxa were identified to species level, namely *Euseius citrifolius* Denmark & Muma, *Neoseiulus tunus* DeLeon (Phytoseiidae), *Tarsonemus bilobatus* Suski (Tarsonemidae), and *B. yothersi* (Table 1).

Phytoseiidae and Iolinidae were represented by two species each. Nevertheless, Iolinidae showed the largest overall number of mites, encompassing 63% of the samples, followed by Eriophyidae with 30 individuals collected belonging to the genus *Aculus,* representing 17% of the mites sampled. Among taxa identified up to genus level, *Pronematus* sp. was the most abundant in our samples followed by the phytophagous *Aculus* sp. and *Oligonychus* sp. (Table 1).

The estimated richness (Jackknife 1) did not differ from the observed richness (Mao Tao), as indicated by the overlap of the error bars (confidence intervals at 95%) with the mean values for all samples. Furthermore, the estimated and observed richness curves tend to asymptote from the 16th sample onwards (Fig. 3).

Table 2. Mite species and abundance according to their host plant int the two Caatinga vegetation remnants, at Piauí State, Brazil. Area 1 = Alvorada do Gurguéia; Area 2 = Bom Jesus.

Plant species	Mite family	Mite species	Area 1	Area 2	Total
Andira paniculata Benth. (Fabaceae)	Eriophyidae	*Aculus* sp.	23	0	23
		Immature	0	1	1
	Iolinidae	*Metapronematus* sp.	1	0	1
		Pronematus sp.	66	1	67
		Immature	12	0	12
	Phytoseiidae	*Neoseiulus tunus*	1	0	1
	Tetranychidae	*Oligonychus* sp.	11	0	11
		Immature	1	0	1
Astronium fraxinifolium Schott (Anarcadiaceae)	Iolinidae	*Pronematus* sp.	1	0	1
Copaifera langsdorffii (Jacq.) (Fabaceae)	Eriophyidae	*Aculus* sp.	6	0	6
	Iolinidae	*Metapronematus* sp.	1	0	1
		Pronematus sp.	3	0	3
	Phytoseiidae	*Neoseiulus tunus*	1	0	1
Unidentified Myrtaceae	Iolinidae	*Pronematus* sp.	0	1	1
		Immature	0	1	1
Piptadenia moniliformis Benth. (Fabaceae)	Blattisociidae	*Platyseius* sp.	1	0	1
	Eriophyidae	*Aculus* sp.	1	0	1
	Iolinidae	*Pronematus* sp.	16	0	16
		Immature	2	0	2
	Oribatida	sp.	1	0	1
	Phytoseiidae	*Euseius citrifolius*	1	0	1
		Neoseiulus tunus	2	0	2
		Immature	2	0	2
	Tenuipalpidae	*Brevipalpus yothersi*	4	0	4
		Immature	2	0	2
	Tetranychidae	*Oligonychus* sp.	2	0	2
		Immature	1	0	1
Unidentified Rubiaceae	Iolinidae	*Pronematus* sp.	1	0	1
Terminalia sp. (Combretaceae)	Iolinidae	*Metapronematus* sp.	1	0	1
		Pronematus sp.	3	1	4
		Immature	2	0	2
	Tarsonemidae	*Tarsonemus bilobatus*	1	1	2
	Tenuipalpidae	*Brevipalpus yothersi*	1	0	1
Total			**171**	**6**	**177**

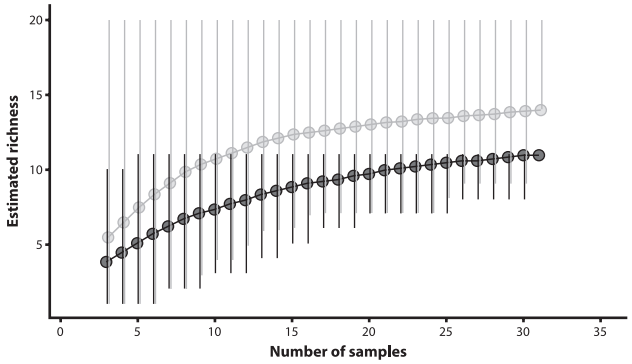

Figure 3. Estimated (Jackknife 1) and observed (Mao Tao) mite species richness for Caatinga vegetation remnants, Piauí State, Brazil. Reference: Estimated richness (Jackknife 1) = Gray circles; Observed richness (Mao Tao) = black circles. Lines extending from points indicate confidence intervals of 95%.

DISCUSSION

Most studies of mites in the Caatinga biome to date have consisted of quantitative analyses of individuals found in the biome, with limited taxonomic depth or records of new genera or species (*e.g.,* de Sousa *et al.,* 2015; Barbosa & De Moraes, 2020, 2021). For instance, Santos & Santos (2012) sampled 278 arthropods in an abandoned pasture area in the early successional stage of the Caatinga, from which 99 mites were collected, but the specimens were only identified to the order level (Santos & Santos, 2012). Nascimento (2019) sampled the arthropod diversity in soil litter, limiting the identification of some of the collected Mesostigmata mites to the genus level.

On the other hand, some studies exclusively focusing on mites from natural Caatinga vegetation have assessed the diversity of plant mites associated with the biome (Lofego *et al.,* 2013; Silva *et al.,* 2016; de Sousa *et al.,* 2015; Rodrigues *et al.,* 2020, 2025; Mendes *et al.,* 2021). For example, Rodrigues *et al.* (2020) recorded fourteen mite families on Myrtaceae plants, with most individuals belonging to the families Iolinidae, Phytoseiidae, Tetranychidae, Tarsonemidae, Tenuipalpidae, Tydeidae, and Winterschmidtiidae. Except for Tydeidae and Winterschmidtiidae, the other families were also recorded in the remnants of Alvorada do Gurguéia and Bom Jesus. Rodrigues *et al.* (2025) also documented the occurrence of mite families such as Ascidae, Cheyletidae, Cunaxidae, Eriophyidae, Erythraeidae, Iolinidae, Phytoseiidae, Tarsonemidae, Tenuipalpidae, Tetranychidae, Tydeidae, and Winterschmidtiidae on several plant families within the natural vegetation of the Caatinga biome. Among these, Eriophyidae, Winterschmidtiidae, and Iolinidae had the highest individual abundance (Rodrigues *et al.,* 2025). Moreover, the family Iolinidae was the most abundant among predatory mites in the study by Rodrigues *et al.* (2025), with *Pronematus* being the most abundant predatory mite. These findings are consistent with the results of the present study.

The predominant abundance of Iolinidae may be related to their feeding behavior, as these mites can feed on a variety of sources, including other mites, mite eggs, and pollen (Bellini *et al.,* 2005). Bellini *et al.* (2005) reported a *Pronematus* species feeding on the eggs of *Eutetranychus banksi* (McGregor) (Tetranychidae) in rubber trees (*Hevea brasiliensis* Muell. Arg., Euphorbiaceae). Because these mites consume different food sources, the number of predatory *mites* may exceed the number of phytophagous mites on plants, as observed in our study. Furthermore, our results revealed a significant abundance of predatory mites of the genus *Pronematus,* as well as phytophagous mites of the genus *Aculus.* Previous studies have suggested an association between the occurrence of Iolinidae and Eriophyidae, possibly due to predator-prey interactions (O'Dowd & Wilson, 1997). The co-occurrence of both mite families has recently been documented in remnants of native vegetation in the Caatinga biome (Rodrigues *et al.,* 2025), which reinforce the possible ecological interactions between these two families.

Two species of Phytoseiidae were sampled in the Caatinga remnants evaluated. Usually, this mite family is often reported in high diversity on plants from remnants of natural vegetation in Brazil (review in Araújo & Daud, 2017). Recently, Araújo & Rodrigues (2023) documented all Phytoseiidae species recorded in the Caatinga biome, registering 65 species of phytoseiids. *Euseius citrifolius* has been also previously recorded in the Amazon biome (*e.g.,* Gondim Jr. *et al.,* 2012; Vasconcelos & Silva, 2015; Conceição *et al.,* 2021; Demite *et al.,* 2021; Araújo *et al.,* 2022), Caatinga (*e.g.,* Lofego *et al.,* 2013; Rodrigues *et al.,* 2020, 2025), Cerrado (*e.g.,* Rezende & Lofego, 2011; Demite *et al.,* 2017; Moraes *et al.,* 2022), Atlantic Forest (Demite & Feres, 2005; Buosi *et al.,* 2006; Demite *et al.,* 2011; De Moraes *et al.,* 2013), and Pantanal (Mendonça *et al.,* 2019) while *N. tunus* has been recorded on native plants in the Cerrado biome (*e.g.,* Rezende & Lofego, 2011; Demite *et al.,* 2017; Teixeira *et al.,* 2017), Atlantic Forest (*e.g.,* Buosi *et al.,* 2006; Demite & Feres, 2005; Demite *et al.,* 2011), and Pampas (Toldi *et al.,* 2021). Similarly, *N. tunus* sampled here on *Copaifera langsdorffii* (Jacq.) (Fabaceae), has been previously reported on the same plant species in Cerrado remnants by Demite *et al.* (2009). Phytoseiid mites are known for their predatory habits, but some species may also consume pollen, fungi, and other food sources (McMurtry *et al.,* 2013; De Moraes & Flechtmann, 2008).

Some phytophagous mite species are considered pests of cultivated plants (De Moraes & Flechtmann, 2008). Among those reported in this study, species from the genus *Aculus* were the most representative in our samples, followed by *Oligonychus* and *Brevipalpus* species. Species of *Aculus* have been reported in Atlantic Forest remnants in São Paulo State (Demite & Feres, 2005). Some *Oligonychus* species have been recorded in the states of Alagoas, Bahia, Ceará, Goiás, Maranhão, Mato Grosso, Pará, Pernambuco, Rio Grande do Norte, and São Paulo in native vegetation from the Amazon, Caatinga, Cerrado, and Atlantic Forest (*e.g.,* Demite *et al.,* 2013, 2016; Rezende *et al.,* 2014; de Sousa *et al.,* 2015; Rodrigues *et al.,* 2020, 2025). Conversely, *Brevipalpus* species have been reported in Atlantic Forest and Cerrado remnants in São Paulo and Goiás states (Rezende *et al.,* 2014; Daud & Feres, 2005), and recently recorded in the

Caatinga areas of Alagoas, Ceará, and Paraíba states (Rodrigues *et al.,* 2025).

The species accumulation curve showed a tendency to reach an asymptote for the mite fauna sampled in the Caatinga vegetation remnants, which means that it is unlikely that new mite taxa will be recorded in the remnants as sampling effort increases. Thus, the acarofauna survey conducted in this study was representative for the Caatinga vegetation remnants evaluated. On the other hand, this observation differs from the pattern shown in other studies, since it is unusual for plant mite species accumulation curves to reach an asymptote for assemblages sampled in natural vegetation remnants (*e.g.,* Demite *et al.,* 2013; Teixeira *et al.,* 2017; Carvalho *et al.,* 2018).

Lastly, *N. tunus* is recorded for the first time in the state of Piauí. This is also the first study to document plant mite species in native vegetation remnants based exclusively on sampling conducted in Piauí State, Brazil. The present work contributed to increase the knowledge of plant mite occurrence in the Caatinga, a biome poorly studied. Moreover, the plant species of the Caatinga biome showed the potential to host a diversity of mites similar to that found in other phytogeographic domains. For instance, the host plants *P. moniliformis* and *A. paniculata* hosted different mite species belonging to various feeding guilds. Thus, the Caatinga vegetation remnants can be managed more appropriately to maintain and maximize the ecosystem services provided by the mites (*e.g.,* natural biological control) aiming for ecosystem sustainability.

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