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Scientific Article

Dryinidae species (Hymenoptera, Aculeata) in the semiarid region of Bahia, Brazil

Dryinidae da região do semiárido bahiano, Brasil (Hymenoptera, Aculeata)

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ABSTRACT - Dryinidae is a family of parasitoids and predators; it is the third largest family in the superfamily Chrysidoidea, with 1,924 species worldwide. The diversity of this family may be even greater, but studies on its diversity and geographical distribution are scarce, especially in semiarid regions. The objective of this study was to describe the occurrence and diversity of Dryinidae genera in the Semiarid region of Bahia, Brazil. Five Malaise traps were distributed in two areas with native vegetation and in one with eucalyptus (*Eucalyptus urophylla*) plantation and monitored monthly for two years. Specimens were identified to genus and morphospecies levels. The collection consisted of 77 Dryinidae specimens from four subfamilies (Anteoninae, Aphelopinae, Dryininae, Gonatopodinae), seven genera (*Anteon* Jurine, 1807; *Aphelopus* Dalman, 1823; *Crovettia* Olmi, 1984; *Deinodryinus,* Perkins, 1907; *Dryinus* Latreille, 1804; *Gonatopus* Ljungh, 1810 and *Thaumatodryinus* Perkins, 1905), and 29 morphospecies. The genus *Dryinus* was the most frequent in the three study areas. Areas with native vegetation, mainly the forest area, showed greater diversity than the area with eucalyptus trees. This study contributes with data of identification and distribution of Dryinidae species in the Semiarid region of the state of Bahia, Brazil.

Keywords: *Chrysidoidea*. *Dryinus*. *Northeast*. *Pincer wasps*.

RESUMO - Composta por parasitoides e predadores, a família Dryinidae é a terceira maior família de Chrysidoidea, com 1.924 espécies descritas no mundo. A diversidade da família pode ser ainda maior, entretanto, estudos sobre a diversidade e distribuição geográfica são escassos, especialmente em regiões semiáridas. O objetivo deste trabalho foi determinar a ocorrência e a diversidade de gêneros de Dryinidae no Semiárido da Bahia. Foram utilizadas cinco armadilhas do tipo Malaise distribuídas em duas áreas de vegetação nativa e uma constituída por eucalipto (*Eucalyptus urophylla*), com monitoramento mensal por dois anos consecutivos. Os indivíduos foram identificados a nível de gênero e morfoespécies. Foram coletados 77 indivíduos de Dryinidae, distribuídos em quatro subfamílias (Anteoninae, Aphelopinae, Dryininae, Gonatopodinae), contidas em sete gêneros (*Anteon* Jurine, 1807; *Aphelopus* Dalman, 1823; *Crovettia* Olmi, 1984; *Deinodryinus,* Perkins, 1907; *Dryinus* Latreille, 1804; *Gonatopus* Ljungh, 1810 e *Thaumatodryinus* Perkins, 1905), e 29 morfoespécies. O gênero *Dryinus* foi o mais frequente nas três áreas de estudo. As áreas nativas (principalmente na área florestal) apresentaram maior diversidade do que a área de eucalipto. O presente estudo contribui com dados sobre o conhecimento e distribuição de espécies Dryinidae em zonas do semiárido brasileiro e no estado da Bahia.

Palavras-chave: Chrysidoidea. *Dryinus*. Nordeste. Vespas pinça.

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INTRODUCTION

Dryinidae (Hymenoptera, Aculeata) is a cosmopolitan family of parasitoid and predatory micro-wasps, considered the third most diverse family of Chrysidoidea, with 1,924 described species worldwide (OLMI et al., 2020; MARTINS, 2022; MARTINS; DOMAHOVSKI, 2022). Approximately 500 species are already known in the Neotropical region, but it may present a larger number; 171 of these species, which belong to 14 genera, are found for Brazil (OLMI; VIRLA, 2014; MARTINS; DOMAHOVSKI, 2022; MARTINS, 2023).

Faunal surveys of Dryinidae in Brazil are scarce and concentrated in areas within the Atlantic Forest and Cerrado biomes (MARTINS, 2023; MARTINS et al., 2020; VERSUTI et. al. 2014), although some studies have addressed the association of Dryinidae species with their leafhopper hosts (MARTINS; DOMAHOVSKI, 2017a, b; MARTINS, DOMAHOVSKI; RENDÓN-MERA, 2021).

Most studies on Dryinidae species are focused on taxonomic records of occurrence, records with their hosts, and description of new species, including the studies of Martins and Domahovski (2017a, b; 2022), Martins (2015, 2018, 2019, 2022, 2023), Martins and Perioto (2021), and Martins and Olmi (2021). Studies on Dryinidae species in the Semiarid region of Brazil are scarce, standing out the study of Olmi and Virla (2014), who investigated the fauna of Bahia and recorded 18 Dryinidae species: 17 in Atlantic Forest areas and one in a Caatinga biome area. However, studies providing a faunistic analysis of this family are not found

in the literature, besides some studies recording occurrences at the family level (PAULA et al., 2022).

The identification of species within the family Dryinidae is based on their antenna (with 10 antennomeres inserted near the clypeus) and the modified protarsus of females (except for Aphelopinae and Erwiniinae) shaped like a chela or pincer, composed of the fifth protarsomere projecting laterally and an elongated claw. This modification of the protarsus is an evolutionary novelty that assists in parasitism and predation, allowing the parasitoid to grasp its host or prey (OLMI, 2006; OLMI et al., 2020). Additionally, there is a marked sexual dimorphism in Dryinidae species, except in Aphelopinae, making it challenging to associate opposite sexes of the same species without breeding or DNA analysis (OLMI et al., 2020).

Dryinidae is a family of parasitoids that occasionally prey leafhoppers (Hemiptera, Auchenorrhyncha) of the superfamilies Membracoidea and Fulgoroidea (MARTINS; DOMAHOVSKI; RENDÓN-MERA, 2021; MARTINS; OLMI, 2021). Adult Dryinidae feed on nectar and sugary substances, but females with chela feed on tissues and hemolymph of their hosts and prey. Generally, these wasps are ectoparasitoids, except for those of the genus *Crovettia* Olmi, 1984, which are endoparasitoids. Considering *Aphelopus* Dalman, 1923 and other genera with known biology, endoparasitism occurs only in the first larval instar (OLMI et al., 2020).

Studies have reported Dryinidae species as efficient and generalist parasitoids, indicating that they can parasitize host species from different genera. Swezey (1928) found efficient activity of the species *Haplogonatopus vitiensis* Perkins and *Pseudogonatopus hospes* Perkins (Gonatopodinae) in programs of biological control of *Perkinsiella saccharicida* Kirk (Hemiptera, Delphacidae), which is a pest that severely attacked sugarcane plantations in Hawaii between 1906 and 1907 (OLMI, 2006; OLMI; VIRLA, 2014).

Identifying parasitoid species associated with different vegetation types, mainly commercial plantations, is essential for understanding the biological characteristics of species and their relationships with hosts. Therefore, the objective of this study was to determine the occurrence and diversity of Dryinidae genera in the Semiarid region of the state of Bahia, Brazil.

MATERIAL AND METHODS

Specimens of the family Dryinidae were collected in Barra do Choça, southwestern Bahia, Brazil (Figure 1), from January 2016 to December 2017. According to Barbosa et al. (2017), the region has a flat to slightly undulating relief and an average altitude of 840 meters. The climate was classified as Cwb, subtropical highland, according to the Köppen classification, with an average temperature of 25 °C and precipitation of 850 mm. The region is within the Brazilian Semiarid Region, according to the Deliberative Council (CONDEL) of the Superintendence for the Development of the Brazilian Northeast Region (SUDENE), by the resolution no. 150/2021 (SUDENE, 2021).

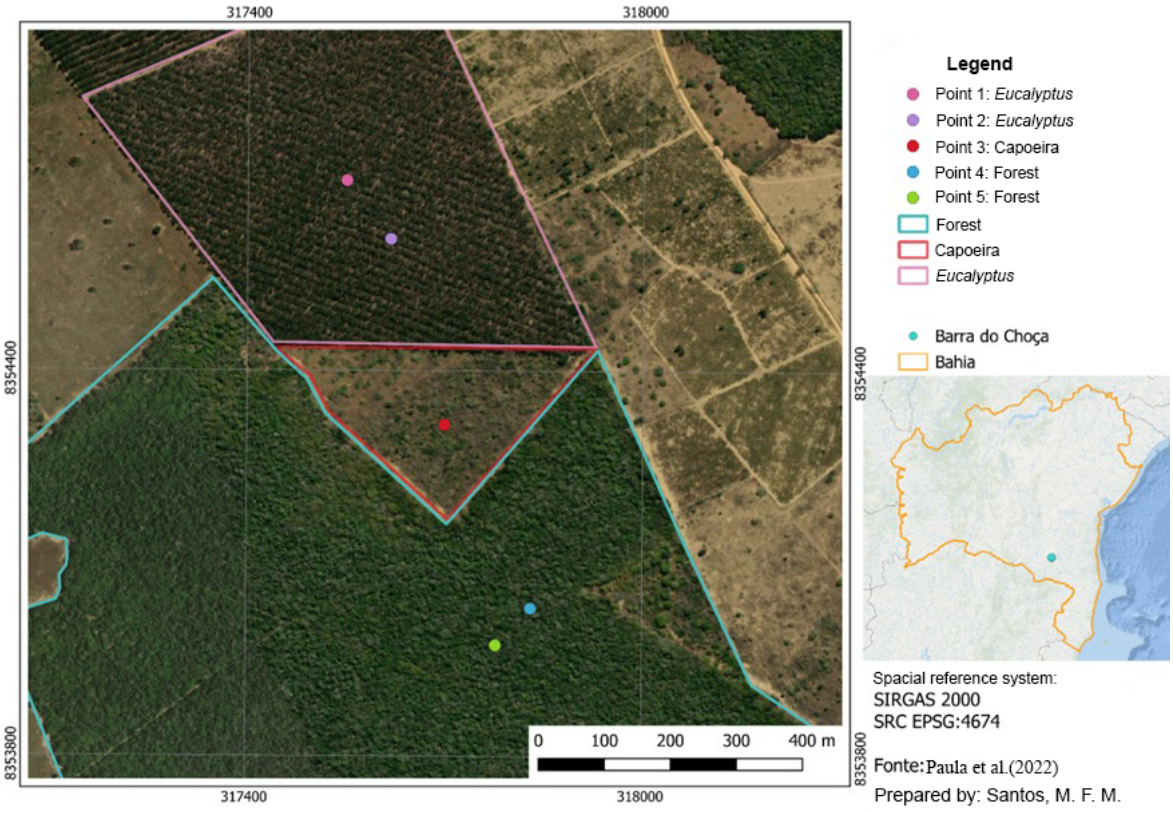

Figure 1. Aerial image with the location of the sampling points of Dryinidae specimens with Malaise traps in the areas: eucalyptus *(Eucalyptus urophylla*) plantation, secondary forest, and native forest. Barra do Choça, BA, Brazil.

Insects were captured using five Malaise traps (TOWNES, 1972) installed at ground level (Figures 2B, 2D, and 2E) in three different environments: 1) a 30-hectare area with eucalyptus (*Eucalyptus urophylla* Blake) plantation (Figures 2A and 2B), containing six-meter-tall trees (Figure 2A); 2) a secondary forest area (approximately 6 ha) with vegetation at initial stage of succession, containing five-meter -tall dominant plants (Figures 2C and 2D); 3) a native forest area (approximately 86 ha), classified as Montane Semideciduous Seasonal Forest (MARTINS; CAVARO, 2012), with plants reaching heights of up to 15 meters (Figures 2E and 2F).

The traps were distributed as follows: two traps installed in the eucalyptus plantation area (Sampling point 1: 14°52'33.59"S and 40°41'45.25"W; Sampling point 2: 14°52'35.99"S and 40°41'43.03"W); one trap in the secondary forest area (Sampling point 3: 14°52'45.99"S and 40°41'40.34"W), 250 m distant from the edge; and two traps in the native forest area (Sampling point 4: 14°52'55.3"S and 40°41'36.00"W; Sampling point 5: 14°52'57.16"S and 40°41'37.78"W), with 100 m between traps at 200 and 300 m from the edge, respectively (Figure 1).

The Dryinidae specimens were identified at the genus and morphospecies levels by the co-author taxonomist André Martins, following guidelines of Olmi and Virla (2014). The studied specimens are deposited in the Laboratory of Forest Ecology and Protection of the State University of Southwest Bahia (UESB). Images of the genera were obtained using the LAS X extended focus system coupled with a Leica SAP8 stereomicroscope.

Figure 2. Sampling areas and installed Malaise traps. A - eucalyptus (*Eucalyptus urophylla*) plantation area; B - trap installed at the eucalyptus plantation area; C - secundary forest area; D - trap at the secondary forest area; E - trap at the Native forest area; F - native forest area.

Determination of Faunal Indices

The morphospecies were analyzed using the faunal indices of abundance, relative frequency, and richness (SILVEIRA NETO et al., 1976). Additionally, the Shannon diversity index (H') evenness index (J') (PRICE et al., 2011), Chao-1 richness estimator, Morisita index of similarity (KREBS, 1989), and rarefaction curve were calculated using the statistical software Past 4.03 (HAMMER, HARPER; RYAN, 2001).

The abundance index corresponds to the absolute quantity of each collected individual. Relative frequency (RF; %) was obtained according to Equation 1:

$$RF = (n / T) * 100 \quad (1)$$

where,
n = number of individuals of each morphospecies;
T = total number of collected individuals.

Considering the richness index (S), which is the total number of morphospecies in the community, the Shannon diversity index (H') (PRICE et al., 2011) was determined using Equation 2:

$$H' = -\sum_{i=1}^{S} pi\ ln(pi) \quad (2)$$

where,
S = total number of morphospecies
pi = proportion of the community of the *i-th* morphospecies;
ln = natural logarithm.

The evenness index (J') was obtained using Equation 3:

$$J' = H' / Hmax \quad (3)$$

where,
$Hmax = log(S)$.

The Chao-1 richness was estimated using the statistical software Past 4.03 (2020) (HAMMER, HARPER; RYAN, 2001).

The sampling effort was represented by the rarefaction curve (KREBS, 1989), which was developed using the statistical software Past 4.03.

RESULTS AND DISCUSSION

A total of 77 Dryinidae specimens were collected from the three study areas; they were distributed into four subfamilies (Anteoninae, Aphelopinae, Dryininae, and Gonatopodinae), and seven genera: *Anteon* Jurine,1807; *Aphelopus* Dalman, 1823; *Crovettia* Olmi, 1984; *Deinodryinus* Perkins, 1907; *Dryinus* Latreille, 1804; *Gonatopus* Ljungh, 1905; and *Thaumatodryinus* Perkins, 1810, (Figure 3), and 29 morphospecies (Table 1).

Anteoninae was the most frequent of the four subfamilies found in the study areas, representing 55.84% of the collected Dryinidae individuals (Table 1). This high frequency may be related to the high diversity of this subfamily in the Neotropical region, as it is the Dryinidae subfamily with the highest number of described species, according to Olmi and Virla (2014).

Contrastingly, Martins (2013) surveyed Atlantic Forest areas and found Gonatopodinae as the most frequent subfamily, whereas Versuti (2014) found Aphelopinae as the most frequent in three areas within the Jatai Ecological Station, in Jatai, Sao Paulo, Brazil. These differences may be connected to the different vegetation types in the study areas. However, further studies are necessary to confirm the association between Dryinidae subfamilies and different vegetation types, as no information on factors associated with the geographic distribution of Dryinidae subfamilies is found. Additionally, Martins and Perioto (2021) emphasized the importance of conducting more exploratory research in areas where the Dryinidae entomofauna is poorly known.

Seven Dryinidae subfamilies have been recorded in the Neotropical region (OLMI; VIRLA, 2014), four of which were identified in the present study, which correspond to 57% of subfamilies occurring in this region. The same subfamilies were found by Martins (2013) and by Martins et al. (2020) in conventional-tillage coffee crops and agroforestry system areas in the state of São Paulo. Versuti (2014) studied typical Cerrado vegetation, Cerrado forest (cerradão), and riparian forest areas in the Jatai Ecological Station and found five subfamilies, Anteoninae, Aphelopinae, Dryininae, and Gonatopodinae, and Bocchinae, which correspond to those found in the present study, except the latter.

Considering the vegetation types, a higher frequency of Dryinidae individuals was found in the native forest area (79.22%), followed by the secondary forest (18.18%) and eucalyptus plantation (2.60%) areas. Paula, Pérez-Maluf, and Moreira (2022) conducted research in similar areas in the Semiarid region of Bahia and identified that the superfamily Chalcididae (Hymenoptera, Chalcidoidea) was more abundant in native vegetation areas. Versuti (2014) reported that Dryinidae specimens were more abundant in riparian forest areas. Native vegetation areas may favor the development of these parasitoids because they provide refuge, shelter, and food (DALL'OGLIO et al., 2003; PAULA et al., 2022).

Olmi and Virla (2014) reported that 23 genera of Dryinidae have been recorded in the Neotropical region; seven of which occurring in the Semiarid region of southwestern Bahia, corresponding to approximately 30% of the genera in the Neotropical region. *Dryinus* was the most frequent genus, totaling 32.47% of the wasps collected in the present study, followed by *Deinodryinus* (28.57%) and *Anteon* (27.27%) (Figure 3). Martins (2013), Martins et al. (2020), and Versuti (2014) reported the occurrence of these Dryinidae genera in different ecosystems in the Southeast region of Brazil. According to Versuti (2014), *Dryinus* species, including *D. ruficeps* Cameron, *D. striatus* (Fenton), *D. surinamensis* Olmi, *D. onorei* Olmi, *D. bocainanus* (Olmi), and *D. gibbosus* (Olmi), have a wide geographic distribution and are not very specific in terms of habitat preference, which explains the presence of this genus in the three study areas. Information about the association of the genera *Deinodryinus* and *Anteon* with the vegetation types where they were collected was not found in the literature.

Table 1. Richness, abundance, and relative frequency (RF) of Dryinidae morphospecies (Hymenoptera, Aculeata) collected from native forest, secondary forest, and eucalyptus plantation areas in the Semiarid region of Bahia, Brazil.

Subfamily, genera, and morphospecies	Native forest	Secondary forest	Eucalyptus	Total	RF (%)
Anteoninae	38	5	0	43	55.8
Anteon sp. 1	2			2	2.6
Anteon sp. 2	9			9	11.7
Anteon sp. 3	4			4	5.2
Anteon sp. 4	1			1	1.3
Anteon sp. 5	1			1	1.3
Anteon sp. 6	2			2	2.6
Anteon sp. 7	1			1	1.3
Anteon sp. 8	1			1	1.3
Deinodryinus sp. 1		1		1	1.3
Deinodryinus sp. 2	1			1	1.3
Deinodryinus sp. 3	9	4		13	16.9
Deinodryinus sp. 4	1			1	1.3
Deinodryinus sp. 5	1			1	1.3
Deinodryinus sp. 6	2			2	2.6
Deinodryinus sp. 7	1			1	1.3
Deinodryinus sp. 8	2			2	2.6
Aphelopinae	3	0	0	3	3.9
Aphelopus sp.	2			2	2.6
Crovettia sp.	1			1	1.3
Dryininae	19	6	1	26	33.8
Dryinus aff. *auratus*	1			1	1.3
Dryinus sp.	3	1		4	5.2
Dryinus sp. 1	5	2	1	8	10.4
Dryinus sp. 2	4	1		5	6.5
Dryinus sp. 3	5			5	6.5
Dryinus sp. 4		2		2	2.6
Thaumatodryinus sp.	1			1	1.3
Gonatopodinae	1	3	1	5	6.5
Gonatopus sp.			1	1	1.3
Gonatopus sp. 1		2		2	2.6
Gonatopus sp. 2	1			1	1.3
Gonatopus sp. 3		1		1	1.3
RF per area (%)	79.2	18.2	2.6	100.0	
Abundance	61	14	2	77	100
Number of individuals per trap	30.50	14	1		
Richness (S)	24	8	2	29	
Shannon diversity index (H')	2.85	1.95	0.69		
Evenness index (J')	0.90	0.94	1		
Chao-1 richness estimator	35	9	3	42	

Figure 3. Dryinidae genera collected with Malaise traps in the study areas: A - *Anteon*; B - *Dryinus*; C - *Deinodryinus*; D - *Gonatopus*; E - *Thaumatodryinus*. Scale bar: A, B, C, D, F: 2.0mm; E, 1.0mm.

The most frequent of the seven genera found in the native forest were *Anteon* (27.3%), *Dryinus* (23.4%), and *Deinodryinus* (22.1%) (Figure 3). *Dryinus* also was the most frequent genus (7.8%) of the three genera found in the secondary forest area. Two genera (*Dryinus* and *Gonatopus*) were identified in the eucalyptus plantation area, not differing significantly from each other, with a low frequency (1.3%) (Table 1).

The native forest had the highest morphospecies diversity (Shannon index (H') = 2.85), as it was the only area with the presence of individuals of all genera found in the tree areas, with the exclusive presence of individuals of the genera *Anteon, Aphelopus, Crovettia,* and *Thaumatodryinus* (Table 1). The secondary forest area had H' of 1.95, whereas the eucalyptus plantation area had the lowest diversity (H' = 0.69) of morphospecies of the three vegetation types.

Martins (2013) found indices (H') ranging from 0.62 to 1.20 for Dryinidae genera in five different sampling points of an Atlantic Forest area. Versuti (2014) reported H' of 1.30 (riparian forest), 1.84 (typical Cerrado vegetation), and 1.06 (Cerrado forest - cerradao) for Dryinidae genera.

The evenness index (J') was 0.90 and 0.94 for the native and secondary forest areas, respectively (Table 1), indicating uniformity in the distribution of genera in each vegetation type.

Regarding the sex ratio of this group of parasitoids, a total of 66 males and 11 females were collected (Table 2).

Martins (2013) hypothesized that this disproportion between the number of females and males may be due to the use of a single collection method, the Malaise trap; however, Versuti et al. (2014) used two additional capture methods (Moericke trap and Light trap) and found difference between numbers of males and females. Similarly, Martins (2013) reported a disparity between abundances of males and females of the genera *Aphelopus* (82.8% males and 17.2% females), *Dryinus* (79.1% males and 20.9% females), and *Gonatopus* (98.9% males and 1.1% females). According to Versuti (2014), the higher abundance of males in the genus *Gonatopus* is attributed to the apterous nature of females, which makes it challenging to collect these specimens in traps commonly used for parasitoid capture. Additionally, Versuti (2014) reported a higher number of females compared to males, but only for the subfamily Anteoninae.

Table 2. Abundance and relative frequency (%) of males and females of subfamilies and morphospecies of Dryinidae in native forest, secondary forest, and eucalyptus plantation areas in the Semiarid region of Bahia, Brazil.

Subfamily and morphospecies	Native forest		Secondary forest		Eucalyptus	
	Male	Female	Male	Female	Male	Female
Anteoninae						
Anteon	18	3				
Deinodryinus	14	3	4	1		
Aphelopinae						
Aphelopus		2				
Crovettia	1					
Dryininae						
Dryinus	17	1	6		1	
Thaumatodryinus	1					
Gonatopodinae						
Gonatopus		1	3		1	
Abundance	51	10	13	1	2	0
Relative frequency (%)	83.6	16.4	92.9	7.1	100.0	0.0

In the native forest area, 83.6% of the collected individuals were males and 16.4% were females. The secondary forest area also had a higher percentage of males compared to females (92.9% and 7.1%, respectively), whereas only males were collected in the eucalyptus area.

The Morisita indices found for the different vegetation areas indicated the formation of two groups (Figure 4); the native and secondary forest areas were more similar in morphospecies composition, presenting the highest similarity index (0.52), differing from the eucalyptus plantation area (Table 3).

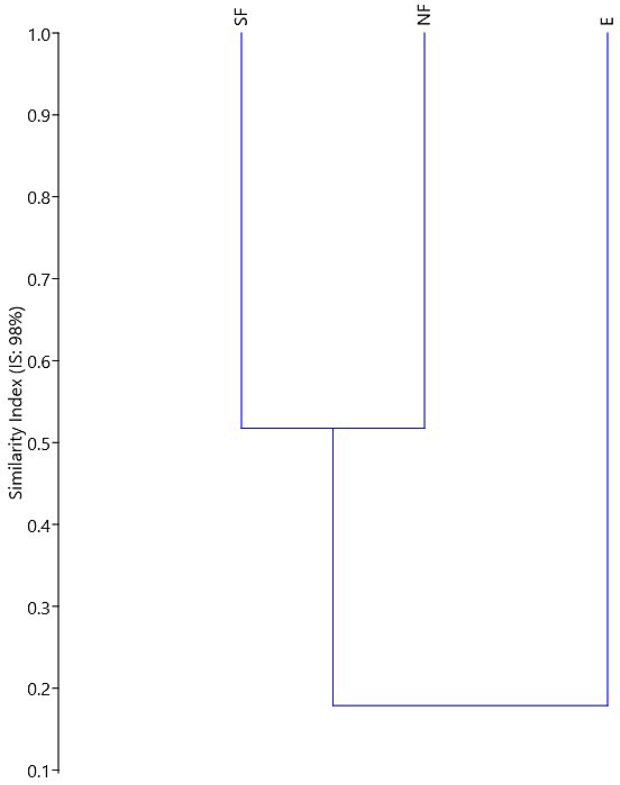

Figure 4. Dendrogram of Morisita index of similarity for Dryinidae morphospecies collected from native forest (NF), secondary forest (SF), and eucalyptus plantation (E) areas in the Semiarid region of Bahia, Brazil.

Table 3. Morisita index of similarity for the occurrence of Dryinidae morphospecies in native forest (NF), secondary forest (SF), and eucalyptus plantation (E) areas in the Semiarid region of Bahia, Brazil.

	NF	SF	E
NF	1	0.52	0.14
SF	0.52	1	0.22
E	0.14	0.22	1

The rarefaction curves for the different vegetation areas (Figure 5) showed that the total richness of Dryinidae morphospecies was 29 and the Chao-1 richness estimate was 42 (Table 1). The total richness (24) and Chao-1 richness (35) of the native forest area did not reach the asymptote of the curve during the study period (Figure 5); this indicated that 69% of the morphospecies in the area were captured and 31% of the morphospecies were not collected.

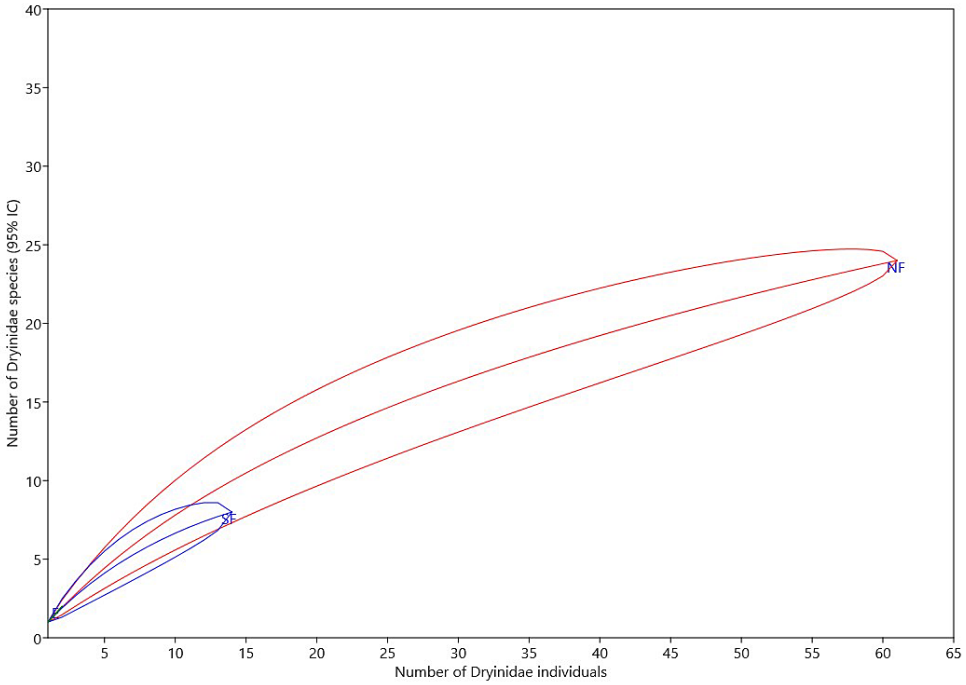

Figure 5. Rarefaction curve for Dryinidae morphospecies collected in Malaise traps installed in native forest (NF), secondary forest (SF), and eucalyptus plantation (E) areas in the Semiarid region of Bahia, Brazil. Cophenetic coefficient = 0.95%.

However, the estimated Chao-1 richness was significantly close to the observed morphospecies richness in the secondary forest and eucalyptus plantation areas (88.9% and 66.7% of morphospecies found, respectively), with only one additional morphospecies needed in each area to reach the asymptote of the curve.

CONCLUSION

The Dryinidae fauna in the Semiarid region of Bahia, Brazil, is composed of four subfamilies (Anteoninae, Aphelopinae, Dryininae, and Gonatopodinae), seven genera (*Anteon*, *Aphelopus*, *Crovettia*, *Deinodryinus*, *Dryinus*, *Gonatopus*, and *Thaumatodryinus*), and 29 morphospecies. The highest frequency of Dryinidae specimens was found in the native forest area; the genus *Dryinus* was the most frequent among the genera found. A higher number of males than females was found in the three different surveyed vegetation areas. The native and secondary forest areas showed similar composition of collected Dryinidae morphospecies, differing from the eucalyptus plantation area. This study provides information on the occurrence and distribution of Dryinidae specimens in the state of Bahia, especially in the Brazilian Semiarid region, where parasitoid fauna is poorly studied. Further studies can provide information on local biodiversity, contributing to taxonomic, ecological, and biogeographic research studies and the development of preservation policies and biological control programs.

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