



Faunistic composition of hymenopteran parasitoids in cultivation of *Eucalyptus urophylla* S.T. Blake and adjacent areas of Seasonal Semi-deciduous Montana forest situated in the Semi-arid State of Bahia, Brazil

Rita de Cássia Antunes Lima de Paula^{1✉}, Jennifer Guimarães Silva¹,
Daniell Rodrigo Rodrigues Fernandes², Aldenise Alves Moreira¹, Onice Teresinha Dall'Oglio³,
Juvenal Cordeiro Silva Junior¹ & Raquel Pérez-Maluf¹

1. Universidade Estadual do Sudoeste da Bahia, Vitória da Conquista, BA, Brazil. 2. Instituto Nacional de Pesquisas da Amazônia, Manaus, AM, Brazil. 3. Universidade Federal de Mato Grosso (UFMT), Cuiabá, MT, Brazil.

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Abstract. Hymenopteran parasitoids are insects that play a fundamental role in ecosystems as they reduce the population density of insects that are considered pests in monocultures. However, little is known about the fauna in association to the eucalyptus trees in comparison to adjacent native vegetations. Therefore, this study was aimed to determine the fauna of parasitoid wasps that occur in a commercial plantation of *Eucalyptus urophylla* S.T. Blake, as well as in native forest and capoeira environments in the plateau of Conquista, Bahia, a semi-arid region of Bahia. The study was conducted for two consecutive years with monthly monitoring using five Malaise traps. The collected insects were sorted and identified at the family level. The faunal indices referring to the families of each area were studied by evaluating the frequency, species richness, Shannon diversity and equitability. In total, 5,899 individuals were collected, which were distributed in 24 families and eight superfamilies. The most abundant families were Braconidae, Ichneumonidae and Bethyridae. Capoeira and eucalyptus trees showed greater similarity and equitability when compared to the rest of the forest. Given the diversity of Hymenopteran parasitoid families found in the area, it was concluded that the maintenance of native vegetation environments is important, even at the initial stage of succession.

Keywords: Braconidae; capoeira; diversity; Malaise; native forest.

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✉ Corresponding author:

Rita de Cássia Antunes Lima de Paula

✉ rcassia@uesb.edu.br

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Among the eucalyptus species present in Brazil, *Eucalyptus urophylla* S. T. Blake (Myrtaceae) is one of the most cultivated species, which has a good productivity due to its high growth rate. In addition, it has a huge potential to be used as a forest frontier in the reforestation areas, mainly in the Northern and Northeastern regions, where this is a growing practice (SCANAVACA-JUNIOR & GARCIA 2004).

The state of Bahia is a large eucalyptus producer with extensive areas of monoculture, which is always vulnerable to phytosanitary problems, such as pest-insects, which restrict production, causing damage to national eucalyptus plantations. Severe attacks on this crop can be caused by leaf-cutting ant species (DELLA LUCIA *et al.* 1993), defoliating lepidopterans (ZANUNCIO *et al.* 1993), galler wasps (WILCKEN & BERTI FILHO 2008), weevils (SOUZA *et al.* 2016) and wasps (MASSON *et al.* 2017).

Native vegetation close to the eucalyptus plantation areas can reduce pest-insect populations of the crop in question, as the environment with greater plant diversity tends to provide greater richness and abundance of beneficial insects (SILVA & BRITO 2015). It is even recommended as a pest management strategy for this crop (DALL'OGGIO *et al.* 2003).

Among natural enemies, those with parasitoid behavior, play a fundamental role in ecosystems as they are able to reduce the population density of other arthropods (mainly insects that are considered pests), and consequently, their decline (HEINRICH & BARRION 2004; PERIOTO *et al.* 2004; FERNANDES *et al.* 2018; BARBOSA *et al.* 2019).

There are several studies comparing the diversity of parasitoid hymenopterans associated with monocultures, with adjacent areas of native vegetation (FREITAS *et al.* 2002; DALL'OGGIO *et al.* 2003; OLIVEIRA *et al.* 2014; SCHOENINGER *et al.* 2019), the main families sampled being, Ichneumonidae, Braconidae (DALL'OGGIO *et al.* 2003), Ichneumonidae (LARA *et al.* 2015) and Encyrtidae (LARA *et al.* 2015; SCHOENINGER *et al.* 2019).

Faunistic studies involving study of the diversity of parasitoid wasps in monoculture environments and surrounding vegetation are extremely important as they help to understand the community of these existing insects, as well as to understand the potential of each group, providing basic and important information for future bioecological studies of the species. This would aid in the monitoring and development of pest management

programs, and study of natural enemies (GARLET *et al.* 2016).

The state of Bahia is constituted by the forest formations of Caatinga, Cerrado and Atlantic Forest types (IBGE 2012). The semi-arid region of this state has a territorial area of 446,221 km² and 278 municipalities (CONDEL SUDENE 2017). Among the physiognomies that constitute the region, we can mention the Seasonal Semideciduous Montana Forest, regionally called "Vine Forest" (SANTOS NETO *et al.* 2015). This type of vegetation is predominantly composed of medium-sized trees with a loss of up to 50% of the leaves during the dry period, surrounded by woody vines that remain green throughout the year.

The knowledge about the hymenopteran parasitoid fauna of the semi-arid region of the state of Bahia presents studies related practically to relevant agricultural crops in this region, such as coffee plantations (MELO *et al.* 2007; PALMA-SANTOS & PÉREZ-MALUF 2010). In the different types of natural vegetation that have been introduced in this region, similar studies are still less. In the fragments of Caatinga, the studies of FERNANDES *et al.* (2019a) in the municipality of Jequié and SILVA *et al.* (2019) in Senhor do Bonfim can be mentioned, and the study by SANTOS & PÉREZ-MALUF (2012) can be mentioned in the areas of Seasonal Semideciduous Montana Forest and coffee plantations in Vitória da Conquista.

Given the lack of information about this group of insects, this study aims to conduct a survey of the diversity of hymenopteran parasitoids that occur in a plantation of *Eucalyptus urophylla* S.T. Blake, as well as in the surrounding environments constituted by Seasonal Semi-deciduous Montana Forest (Capoeira and native Forest) in a semi-arid region of Bahia.

The sampling was carried out in three different phytophysiological types – *E. urophylla*, Capoeira and native forest culture in the municipality of Barra do Choça, Bahia, Brazil, at an altitude of 847 m above sea level and characterized by Aw type tropical climate according to the Köppen classification (SEI 2021).

Monthly collections were carried out from January 2016 to December 2017, using five Malaise traps, which were installed at the following coordinates: Point 1 - 14°52'33.59"S and 40°41'45.25"W and Point 2 - 14° 52'35.99"S and 40° 41'43.03"W (located at 200 m and 300 m from the edges of the eucalyptus plantation, respectively); Point 3 - 14° 52'45.99"S and 40° 41'40.3403 W (located at 250 m from the edge of the capoeira); Point 4 - 14°52'57.16"S and 40°4'37.78"W and Point 5 - 14° 52'55.3" S and 40° 41'36.00" W (located at 200 m and 300 m from the edges of the native forest respectively). The phytophysiological types are not separate rather contiguous.

The plantation of *E. urophylla* has an area of 30 ha and is more than 10 years old, with the trees arranged with a spacing of 3 x 3 m. The capoeira has an area of about 6 ha, in the initial stage of succession, consisting of pioneer species reaching heights of up to 5 m, such as *Pyrostegia venusta* (Ker Gawl.) Miers, *Vernonia chamaedrys* Less., *Zanthoxylum rhoifolium* Lam and *Solanum lycocarpum* St. Vall. The native forest has an area of approximately 86 ha, being classified as Seasonal Semideciduous Montana Forest with the presence of some species, which are around 15 meters tall, such as *Anadenanthera colubrina* (Vell.) Brenan, *Trichilia hirta* Le and *Aspidosperma pyriforme* Mart.

The screening of hymenopteran parasitoids including Chrysoidea was carried out at the Laboratory of Semi-Arid Biodiversity (LABISA) at the Universidade Estadual do Sudoeste da Bahia (UESB), and subsequently quantified and identified at the family taxonomic level. For each

superfamily, the following literature were used: HANSON & GAULD (2006) (Ceraphronoidea, Evanioidea, Ichneumonoidea, Platygastroidea, Proctotrupeoidea, Stephanoidea and Trigonalioidea), RONQUIST (1995) (Cynipoidea) and GRISSEL & SCHAUFF (1997) (Chalcidoidea). In this study, it was decided not to consider Scelionidae synonymous with Platygastriidae, according to ORTEGA-BLANCO *et al.* (2014) and TALAMAS *et al.* (2015). Afterwards, the classification of Proctotrupeoidea/Diaprioidea by AGUIAR *et al.* (2013) was updated.

Part of the identified species were incorporated into the Brazilian Entomological Collections under the care of the following curators: Valmir A. Costa (Collection of Entomophagous Insects "Oscar Monte", at Instituto Biológico, Campinas), Angélica M. Penteado-Dias (Entomological Collection of the Department of Ecology and Evolutionary Biology, Universidade Federal de São Carlos - DCBU) and Marcelo T. Tavares (Entomological Collection of the Universidade Federal do Espírito Santo- UFES). Some voucher specimens remained at the collection of LABISA (Laboratory of Semi-Arid Biodiversity), at UESB, campus of Vitória de Conquista, BA, under the care of Raquel Pérez-Maluf.

The faunal indices adopted in this study were frequency, species richness, shannon diversity and equitability. The data were analyzed using the statistical program Past, version 2.16 (HAMMER *et al.* 2001) with a confidence interval (CI) of 95%.

The comparison of the diversity of the families captured in each physiognomy was performed using rarefaction curves by the bootstrap process with resampling in order to obtain a confidence interval for the family richness. Bootstrap analyses were calculated using EstimateS Win9.1 software (COLWELL 2013), using 2000 randomizations and 95% confidence interval.

A total of 5,988 Hymenopteran parasitoid specimens were collected in the three phytophysiological types, belonging to eight superfamilies and distributed in 24 families (Table 1). In Brazil, there are 15 superfamilies and 42 families (OLIVEIRA *et al.* 2021) and, according to the data in this study, it is possible to verify the presence of 53% and 57% of these values, respectively, which indicates that the sampled area has a high representation of parasitoid hymenopterans.

The phytophysiological type that presented the highest abundance of individuals collected by trap was the capoeira with 1,814 insects/trap, followed by the native forest, with 1,373.5 insects/trap, and eucalyptus, with 713.5 insects/trap, which means that both capoeira and forest had an important participation in the collection of hymenopteran parasitoids when compared to monoculture. This bias may be related to the fact that these phytophysiological types (capoeira and native forest) have a higher degree of complexity, which creates more nesting sites, shelter and greater availability of food resources (pollen, nectar and honeydews) for adults (GODFRAY 1994), contributing to ecosystem services (SALAS *et al.* 2019; SILVA *et al.* 2019; O'DONNELL & WRIGH 2021) when compared to monoculture.

Similar results were found by DALL'OGGIO *et al.* (2003) who also found a higher amount of Hymenopteran parasitoid/trap in the border environment rather than in the eucalyptus monoculture. In Goiás, MARCHIORI & PENTEADO-DIAS (2002) also observed more Hymenopteran parasitoids in Capoeira than in the forest. More open areas such as borders and even Capoeira can act as transition areas for these insects, contributing to the movement and distribution of parasitoids to the interior of the cultivation.

The most abundant superfamily was Ichneumonoidea (48.03%) followed by Chalcidoidea (19.82%), which together

Table 1. Richness and abundance of Hymenopteran parasitoid families collected in *Eucalyptus urophylla* (E), Capoeira (C) and Native Forest (M) in the plateau of Conquista, Bahia, Brazil, from January 2016 to December 2017.

SUPERFAMILY	Abundance			Grand Total	RF (%)	
	Family	E	C			M
CERAPHONOIDEA		147	6	11	164	2.74
Ceraphronidae		147	6	11	164	2.74
CHALCIDOIDEA		272	543	372	1187	1.82
Aphelinidae		5	2	3	10	0.17
Chalcididae		22	113	47	182	3.04
Encyrtidae		13	7	22	42	0.70
Eucharitidae		1	56	1	58	0.97
Eulophidae		70	74	86	230	3.84
Eupelmidae		2	18	22	42	0.70
Eurytomidae		9	65	8	82	1.37
Mymaridae		88	32	82	202	3.37
Perilampidae		1	26	2	29	0.48
Pteromalidae		48	144	91	283	4.73
Signiphoridae		13	2	0	15	0.25
Torymidae		0	4	8	12	0.20
CHRYSIDOIDEA		196	302	288	786	13.13
Bethylidae		186	271	193	650	10.86
Chrysididae		5	16	12	33	0.55
Dryinidae		5	15	83	103	1.72
CYNIPOIDEA		88	73	54	215	3.59
Figitidae		88	73	54	215	3.59
EVANIOIDEA		44	69	44	157	2.62
Evaniidae		44	69	44	157	2.62
ICHNEUMONOIDEA		469	691	1716	2876	48.03
Braconidae		306	430	817	1553	25.94
Ichneumonidae		163	261	899	1323	22.09
PLATYGASTROIDEA		92	55	84	231	3.86
Platygastridae		86	31	71	188	3.14
Scelionidae		6	24	13	43	0.72
DIAPRIOIDEA		119	75	178	372	6.21
Diapriidae		108	31	101	240	4.01
Monomachidae		11	44	77	132	2.20
Grand Total		1427	1814	2747	5988	100.00
No. of ins./trap		713.5	1814	1373.5	1197.6	
S		23	24	23	24	

Note: Number of Malaise traps in eucalyptus and in the forest: two traps; Number of Malaise traps in capoeira: one trap. Source: elaborated by the author. Where: no. of ins./trap: number of insects per trap; RF: Relative Frequency; S: Family Richness.

comprise of almost 70% of the collected parasitoids (Table 1). Possibly, the predominance of Ichneumonoidea is due to the fact that it consists of the two most dominant families among all existing groups of Hymenopteran parasitoids (Ichneumonidae and Braconidae) and, therefore, it presents a high number of individuals and high species richness (QUICKE 2015).

Chalcidoidea was also observed to be the richest with 12 families (Table 1) and according to GRISSEL & SCHAUFF (1997), this superfamily comprises of 17 families, which shows that the present study represented 70% of the group. The species of these two superfamilies were the principal participants in biological control programs of agrosystems, such as the use of *Cotesia flavipes* (Cameron, 1891) (Hymenoptera: Braconidae) in the control of the sugarcane borer *Diatraea saccharalis* (Fabricius, 1794) (Lepidoptera: Crambidae), among others (PARRA & COELHO JÚNIOR 2019).

Regarding the family richness, among the total of 24

registered families, all were present in capoeira, and, only one of them were absent in the eucalyptus and in the native forest. Signiphoridae was not collected in the forest, and Torymidae was absent from the eucalyptus.

The predominant families in this study were Braconidae (25.94%), Ichneumonidae (22.09%) and Bethylidae (10.86%), which together represented more than half of the collected parasitoids. DALL'OGGIO *et al.* (2003) also observed Braconidae and Ichneumonidae as predominant, with an inverted position with 22% and 27%, respectively. These families have various parasitism strategies, and hence they are considered as dominant groups in the regulation of herbivorous species (FERNÁNDEZ & SHARKEY 2006), being surpassed only by the Chalcidoidea (NOYES 2021).

In capoeira and eucalyptus, the most abundant family was Braconidae, and in the forest, it was Ichneumonidae (Table 1). Both families feed especially on Lepidoptera and Coleoptera larvae and pupae (QUICKE 2015), being of the orders of pests that

include species of great economic importance in eucalyptus culture. The parasitoids of *Apanteles* sp. (Braconidae); *Apechthis sarsinae* and *Pimpla videonis* (Ichneumonidae) were found in eggs, caterpillars and pupae of *Sarsina violascens* (Herrich-Schaeffer, 1856) (Lepidoptera: Lymantriidae), a primary pest of eucalyptus plantations, mainly in Bahia (SILVA 1964). In the plantations of *E. urophylla* ZANUNCIO et al. (2009) found a high rate of parasitism caused by *Itopectis* sp. (Ichneumonidae) in pupae of *Euselasia eucerus* (Hewitson, 1872) (Riodinidae), another eucalyptus defoliating pest species. Considering the biological potential that these families have and as they act as agents for the biological control of relevant pest-species in that culture, they deserve attention in terms of identification at a species level.

Regarding the Shannon diversity index of the Hymenopteran parasitoid families for each phytophysiognomy, the capoeira had the highest index ($H' = 2.50$), followed by the eucalyptus plantation ($H' = 2.47$) and the native forest ($H' = 2.07$). The highest indices (capoeira and eucalyptus) did not differ from each other by the *t* test with 5% probability level ($t: -0.825$ $p > 0.05$). The forest showed a significant difference as compared to the capoeira ($t: 12.761$ $p: 1.2043 \times 10^{-36}$) and the eucalyptus ($t: 12.143$ $p: 2.516 \times 10^{-33}$).

According to the rarefaction curves, it was verified that in capoeira there was a tendency to reach the asymptote curve faster than the other environments (even with only one Malaise trap installed in this environment). In addition, it presented greater family diversity and a higher number of sampled insects than eucalyptus. On the other hand, the native forest, despite having captured a lower number of families, had a greater overall number of captured insects (Figure 1).

Although the environments have captured similar diversity of families, the number of insects in Eucalyptus was lower than the other environments, which may indicate a possible disadvantage for the maintenance of this fauna in this environment. Similar results were found by FERNANDES et al. 2019b, who found a lower number of specimens of Ichneumonidae captured with Malaise traps in agricultural areas as compared to the native forests and adjacent pastures, in Rocha province, Uruguay.

Therefore, further detailed studies in similar areas are essential for a better understanding of the parasitoid fauna dynamics in the studied environments (Eucalyptus plantation/ Capoeira/Forest).

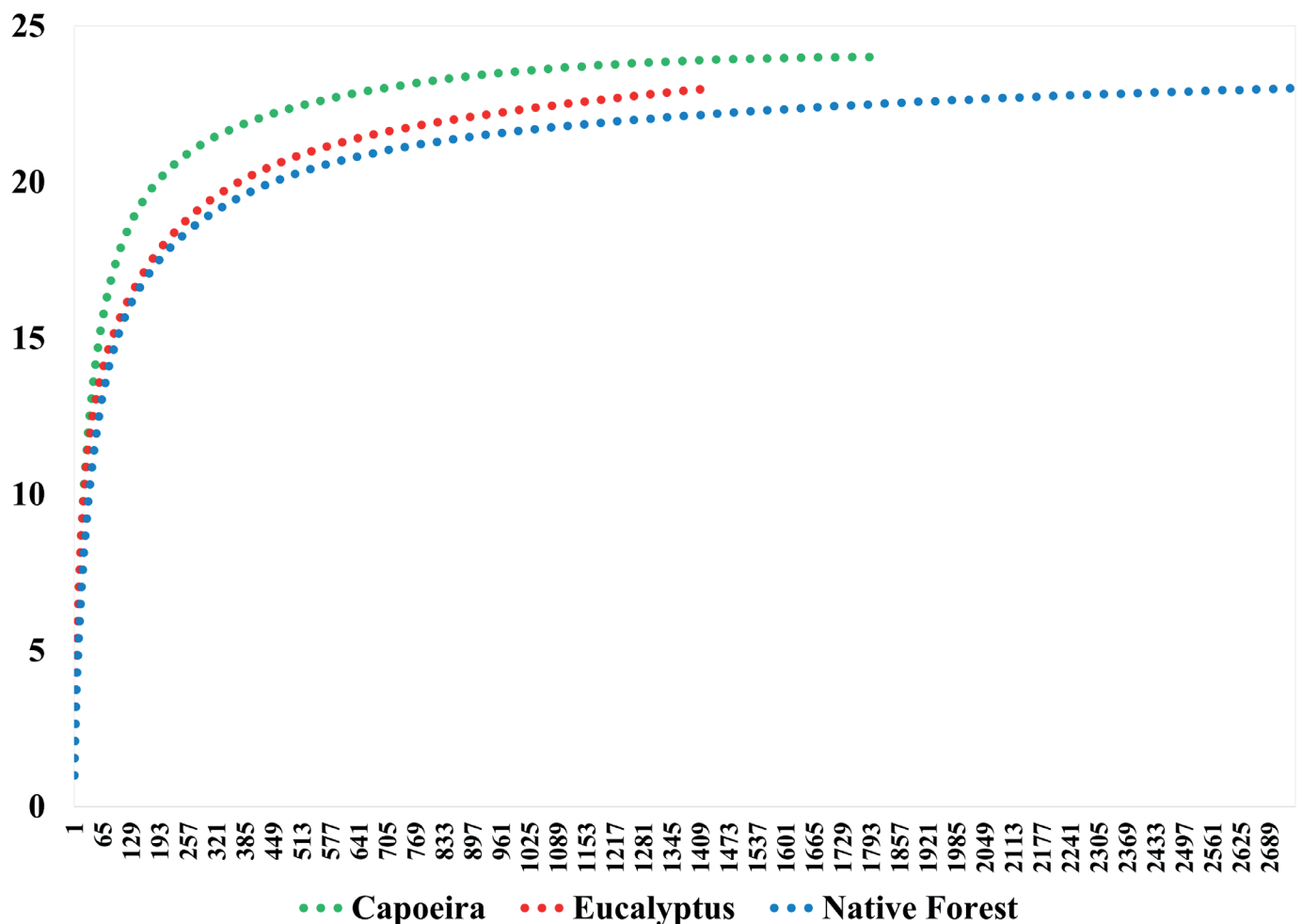


Figure 1. Parasitoid family diversity by Individuals

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