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

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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 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 semiarid 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 Bethylidae. Capoeira and eucalyptus plantation of 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’Oglio 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 (Heinrichs & 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’Oglio et al. 2003; Oliveira et al. 2014; Schoeninger et al. 2019), the main families sampled being, Ichneumonidae, Braconidae (Dall’Oglio et al. 2003), Ichneumonidae (Lara et al. 2015) and Encyrtidae (Lara et al. 2015; Schoeninger et al. 2019).

Faunistic studies involving 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 biocological 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 semiarid region of this state has a territorial area of 446,221 km² and 278 municipalities (Condel Súdene 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 semiarid 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 Jequiti 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 semiarid region of Bahia.

The sampling was carried out in three different phytophysiognomies – 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 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′34.03″W (located at 250 m from the edge of the capoeira); Point 4 - 14°52′57.16″S and 40°43′37.78″W and Point 5 - 14°52′55.3″S and 40°41′36.0″W (located at 200 m and 300 m from the edges of the native forest respectively). The phytophysiognomies 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, Vernonnia chamaedrys Less., Zanthoxylum rhoifolium Lam and Solanum lycopersicum 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 pyrifolium 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, Evanioida, Ichneumonoidea, Platygasteroidea, Proctotrupoidea, Stephanoidea and Trigonalyoidea), Ronquist (1995) (Cynipoidea) and Grissel & Schaff (1997) (Chalcidoidea). In this study, it was not decided to consider Scelionidae synonymous with Platygastridae, according to Ortega-Blanco et al. (2014) and Talamas et al. (2015). Afterwards, the classification of Proctotrupoidea/Diaprioidae 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 - DCEB) 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 phytophysiognomies, 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 phytophysiognomy 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 phytophysiognomies (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 (Sales et al. 2019; Silva et al. 2019; O’Donnell & Wigh 2021) when compared to monoculture.

Similar results were found by Dall’Oglio 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
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 & Schaufl (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’Oglio 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 (Noves 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

### 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 |
| Ceraphronida | 147       | 6           | 11     | 164    | 2.74 |
| CHALCIDIOIDEA | 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 |
| Eurytomiidae | 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 |
| CHALCIDIOIDEA | 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 |
| EVANIIOIDEA  | 44        | 69          | 44     | 157    | 2.62 |
| Evanidae     | 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.
include species of great economic importance in eucalyptus culture. The parasitoids of *Apanteles* sp. (Braconidae); *Apechtis 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 *Itoplectis* 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). From the other forest showed a significant difference as compared to the capoeira (t: 12.761 p: 1.2043\(^{-36}\)) and the eucalyptus (t: 12.143 p: 2.516\(^{-33}\)).

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).

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