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Original Article

Ecological importance of lepidopteran defoliators on eucalyptus plantations based in faunistic and natural enemy analyses

Importância ecológica de lepidópteros desfolhadores em cultivo de eucalipto baseado em análises faunísticas e inimigos naturais

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Abstract

Areas planted with *Eucalyptus urophylla* S.T. Blake variety *platyphylla* F. Muell. (Myrtaceae) expand annually in most regions of Brazil. Many lepidopteran species defoliate this plant, but with damage varying per species. The objective of this study was to identify the pest status of lepidopteran defoliators based in the faunistic analysis of these insects and of their natural enemies on *E. urophylla* variety *platyphylla* plantations in a representative producing region of Brazil. Adult moths of lepidopterans and of their natural enemies were captured using a light trap, installed every two weeks, from September 2016 to August 2018. A total of 183, 10, three and 139 lepidopteran species was captured and classified as primary, secondary, without defined importance to eucalypt plants and non-identified with 1,419, seven, 465 and 876 individuals, respectively. Two primary pest species were constants, two accessories and six accidentals and all secondary ones were accidentals. Six primary pest species were common and dominant and four non-dominants. Faunistic indices indicated the main lepidopteran species that should be monitored in pest management programs. Seven hymenopteran species (65 individuals), three dipterans (49 individuals) and two hemipterans (four individuals) were the natural enemies collected using light traps. The monitoring of lepidopteran pests with light traps can contribute to the management and to reduce damage and control costs for these species, besides identifying natural enemies for biological control programs in *Eucalyptus* plantations.

Keywords: defoliating caterpillar, forest pest, light trap, monitoring, population dynamic.

Resumo

Áreas plantadas com *Eucalyptus urophylla* S.T. Blake variedade *platyphylla* F. Muell. (Myrtaceae) se expandem anualmente na maioria das regiões do Brasil. Muitas espécies de lepidópteros desfolham esta planta, mas com danos que variam de acordo com a espécie. O objetivo deste estudo foi identificar o status de praga de lepidópteros desfolhadores com base na análise faunística desses insetos e de seus inimigos naturais em plantios de *E. urophylla* variedade *platyphylla* em uma região produtora representativa do Brasil. As mariposas e seus inimigos naturais foram capturadas com armadilha luminosa, instalada quinzenalmente, de setembro de 2016 a agosto de 2018. Um total de 183, 10, três e 139 espécies de lepidópteros foram capturadas e classificadas como primária, secundária, sem importância definida para eucaliptocultura e não identificadas com 1419, sete, 465 e 876 indivíduos, respectivamente. Duas espécies de pragas primárias foram constantes, duas acessórias e seis acidentais e todas as secundárias foram acidentais. Seis espécies de pragas primárias foram comuns e dominantes e quatro não dominantes. Os índices faunísticos indicaram as principais espécies de lepidópteras que devem ser monitoradas em programas de manejo de pragas. Sete espécies de himenópteros (65 indivíduos), três dípteros (49 indivíduos) e dois hemípteros (quatro indivíduos) foram os inimigos naturais coletados com armadilha luminosa. O monitoramento de lepidópteros-praga com armadilha luminosa pode contribuir para o manejo e redução de danos e custos de controle para essas espécies, além de identificar inimigos naturais para programas de controle biológico em cultivos de eucalipto.

Palavras-chave: lagarta desfolhadora, praga florestal, armadilha luminosa, monitoramento, dinâmica populacional.

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1. Introduction

Biotic, such as natural enemies, and abiotic, such as the environmental conditions and food availability, factors affect insect diversity (Kemp and Ellis, 2017; Agathokleous et al., 2020) because individuals of the same or different species may require similar environment and food sources (Sharma et al., 2018; Gutiérrez et al., 2020). Insect species diversity is typically high in more diverse environments where competition between individuals for resources is lower (Muiruri et al., 2019; Lyu et al., 2020).

Faunistic analysis can estimate insect diversity indices to generate information upon conservation and dominance besides interactions between species (Schneider and Azevedo Filho, 2017; Paiva et al., 2020). Entomofauna surveys in forest plantations include the collection of all possible insect stages with the necessity of rearing immatures until adults, used for their identification via external morphology (Pereira et al., 2001; Pratissoli et al., 2003; Zanuncio et al., 2006). Faunistic analysis and species identification studies provide information on damage potential and the need of control measures (Jactel et al., 2002; Ribeiro et al., 2016; Masson et al., 2017a).

Collection using light trap can provide data on the effect of biotic and abiotic factors on the local entomofauna numbers and species per area (Guedes et al., 2000; Zanuncio et al., 2001; Freitas et al., 2005). Conventional traps are modified to meet local requirements such the use of vials filled with alcohol to reduce damage on insect bodies allowing species identification via external morphology (Zanuncio et al., 2014a). In Brazil, lepidopteran species collected with traps allow to study their dynamics, diversity and distribution in commercial forest plantations (Dall'Oglio et al., 2013; Zanuncio et al., 2014b).

The propagation including root strike *Eucalyptus urophylla* S.T. Blake variety *platyphylla* F. Muell. (Myrtaceae) and its height growth, survival and productivity vary in commercial plantations according to environmental and management factors. Sustainable practices contribute to maintaing patterns of richness, abundance and interaction of entomofauna to keep the biodiversity in the Brazilian forest sector (Souza et al., 2012; Fernandes et al., 2014).

Lepidopteran pest species, managed with different methods, can reduce the productivity of eucalypt plantations in Brazil and worldwide (Tachi et al., 2020; Tavares et al., 2020). Integrating insecticides with biological control to target insect stages make the control more successful with lower social and ecological impacts (Zanuncio et al., 2009, 2014c; Dias et al., 2014). Insecticides effective against lepidopteran pests in forest plantations may reduce populations of natural enemies, intoxicate applicators, contaminate the environment, and cause the emergence of resistant insects (Zanuncio et al., 1998; Kkadan et al., 2020). Biological control, with release of predators and parasitoids and application of entomopathogens, can regulate the populations of insect pests at different stages (Dall'Oglio et al., 2000; Masson et al., 2017b).

The present work was developed on demand of Brazilian forest companies from the Midwest, Northeast, Southeast and South regions, where *E. urophylla* variety *platyphylla* is largely planted. The objective of this study was to identify lepidopteran pests and of their natural enemies, and classify them through faunistic and natural enemy analyses, in a region with large *E. urophylla* variety *platyphylla* plantations.

2. Materials and Methods

2.1. Study site

The insects were collected in an approximately six-year-old *E. urophylla* variety *platyphylla* stand with tree height from 28 to 30 m in an area of 582 ha in Salto de Pirapora, São Paulo State, Brazil (23°39' S × 47°36' O, 580 m altitude) with spacing between trees and rows of 2.5 and 3 m, respectively. The insects collected were analyzed at the Entomology Laboratory of the Federal University of São Carlos (UFSCar) in Sorocaba, São Paulo State. The study area was partially bordered by *Zea mays* L. (Poaceae) and soybean, *Glycine max* (L.) Merr. (Fabaceae) crops and perennial *Citrus* spp. (Rutaceae) during a part of the insect survey period.

The values of maximum and minimum temperatures (°C), rainfall (mm) and relative humidity (%) were obtained from the meteorological station of the Meteorological Database for Education and Research (BDMEP) – N°. 83851 in Sorocaba (23º30' S × 47º27' W, 645 m altitude). The National Institute of Meteorology (INMET) of the Ministry of Agriculture, Livestock and Food Supply (MAPA) of Brazil controls this station. The climate in the region is of Cfa type (humid temperate climate with hot summer), according to the Köppen-Geiger climate classification (Alvares et al., 2013) with average annual temperature of 21.4 ºC, maximum of 30.1 ºC and minimum of 12.2 ºC and predominant red latosol soil (Silva 2008). The average annual rainfall is 1,311 mm. Silvicultural operations such as fertilization, leaf-cutting ant (*Acromyrmex* Mayr, 1865 and *Atta* F., 1805, Hymenoptera: Formicidae) and weed control were carried out following regular protocols used by the Brazilian forest companies (Stape et al., 2001, 2010).

2.2. Lepidopterans and their natural enemy' collection

Adult moths of lepidopteran defoliators and of their natural enemies were collected using an Al Intral® light trap (BioControle, Indaiatuba, São Paulo state, Brazil) with a light sensor and a 20 W white FT15T12 fluorescent Philips® lamp powered by a 12 V Moura® battery (Bernardi et al., 2011). An L-shaped wooden support, approximately, 50 m inwards from the edge of the stand and at the midpoint between of four *E. urophylla* variety *platyphylla* trees supported the hook of the trap top two meters above the ground (Zanuncio et al., 2018). Chemicals control of lepidopteran defoliators were not used in the plantation since six months before the first trap installation. A 3 L plastic container with a diameter of 12 cm was fixed to the trap bottom and filled with a solution of 200 mL of hydrated ethanol (70%) mixed with 3 mL of household detergent to quickly sacrifice, preserve and reduce the surface tension of the solution and the damage to insects besides reducing their escape (Mafia et al., 2018; Carvalho et al., 2021).

The light trap was installed every fortnight, in the late afternoon, and retrieved early morning of the following day, from September 2016 to August 2018. The insects collected were removed from the plastic container of the trap and placed in 150 mL glass containers with cotton pieces moistened with hydrated ethanol (70%) covering its inner base, labeled with the collection place and date. This material was transported to the UFSCar Entomology Laboratory, where they were sorted, fixed, identified, and quantified by external morphology analysis (Pratissoli et al., 2003; Zanuncio et al., 2018).

2.3. Lepidopterans and their natural enemy' classification

Faunistic analysis characterized the structure and abundance of the lepidopteran community and their natural enemies (Garlet et al., 2016; Andrade and Teixeira, 2017). The lepidopteran collected were separated into four groups according to their importance to eucalypt plantations in Brazil (Ribeiro et al., 2016; Zanuncio et al., 2018) as: group I- primary pest species (with outbreaks recorded in *Eucalyptus* L'Hér. plantations in Brazil), group II- species considered as secondary pests (seen on *Eucalyptus* plantations in Brazil, associated or not associated with primary pests, but without outbreaks), group III- other species identified, without record of damage to *Eucalyptus* plants in Brazil, group IV- unidentified species.

2.4. Data collection and statistics

The number of lepidopterans and of their natural enemy individuals captured in the light trap per family (mean ± standard deviation of the mean) was used to calculate the confidence intervals (CIs) at 1 and 5% significance, where $\bar{x} \pm z \times (\sigma \div \sqrt{n})$, being $\bar{x}$= mean of the sample, σ= standard deviation of the population, *n*= size of the sample, z= appropriate value of the standard normal distribution for the desired CI.

Lepidopteran families were grouped in abundance classes according to CIs (Thomazini and Thomazini, 2002; Silva et al., 2011; Marsaro Júnior et al., 2012): ma= very abundant (number of individuals greater than the upper limit of the CI at 1%), abundant (a), common (c), dispersed (d) and rare (r), respectively, with number of individuals between the upper limits of the CI at 5 and 1%, within the CI at 5%, between the lower limits of the CI at 5 and 1%, and under the lower limit of the CI at 1%.

Percentage per family, genus and/or species in relation to the total number of individuals characterized the frequency index (F), where PI – $ni \div N$, being PI= frequency of each species, *ni*= number of individuals of species *i*, *N*= total number of individuals in the sample.

Families, genera and/or species were grouped according to ther CI of the mean of their frequencies at 5% significance (Thomazini and Thomazini, 2002), in the classes: very frequent (vf), frequent (f) and infrequent (i), with a percentage of individuals greater than the upper limit of the CI at 5%, within the CI at 5% and under the lower limit of the CI at 5%.

The Simpson dominance index (D) of the species was determined with frequency values higher than those corresponding to D. The value calculated is dominant with frequency higher than 1 ÷ D, expresses the lower the diversity, the greater the value of D, where S_d= 1 ÷ D, being S_d= total number of individuals in the community (Uramoto et al., 2005).

The percentage of samples with certain species, genus or family expresses the constancy index (C) (Zanuncio et al., 1998), where: C= (P × 100) ÷ N, being P= number of collections with certain species, genera or families captured, N= number of collections. The species were distributed into constancy classes as constant (w), accessory (y) and accidental (z) when present in more than 50%, from 25 to 50% and in less than 25% of the collections (Ramalho et al., 2000).

Species richness and equability or uniformity, when the entire community cannot be inventoried, were derived in samples and the data analyzed with the Shannon-Weaver diversity index (H') (Shannon and Weaver, 1949). This diversity index considers species as rare or abundant with the same weight (Melo, 2008), where: H'= Σ^{∞}*pi* × ln *pi*, where *pi*= *ni* ÷ N, being *pi*= proportion of individuals in the *i*-th species, ln= logarithm of neperian base (e), *ni*= number of individuals sampled of species *i*, and *N*= total number of individuals.

The abundance of species was calculated using the Equability Index (J) (Magurran, 1988) or Pielou uniformity (Pielou, 1975). This index assumes a maximum value of one according to the species richness with direct relation to the diversity, where: J= H' ÷ lnS, being lnS= H' maximum (neperian logarithm of the total species).

3. Results

3.1. Faunistic analysis of lepidopteran defoliators

A total of 183 lepidopteran species with 1,419 individuals captured was separated into four groups per family, genus and species, when their identification was possible. Forty-four species of 13 families were identified, being 10, three and 31 from groups I, II and III, respectively, in addition to 139 species of group IV. The 13 species of groups I and II represented 7.61% of the total species collected (Table 1).

The number of species of the primary pests (57.14%) was higher for Geometridae (4.00%), followed by Arctiidae and Bombycidae (12.86% each), Lymantriidae (11.43%), Notodontidae (4.29%), Saturniidae (1.43%) and Riodinidae (1.43%) families. Secondary pest species were from Notodontidae and Saturniidae. The percentages of species in groups III and IV were 17.39 and 75.54%, respectively (Table 1).

Apatelodes sericea Schaus, 1895 (Bombycidae), *Blera varana* Schaus, 1856 (Notodontidae), *Eupeudosoma involuta* Sepp, 1855 (Arctiidae), *Euselasia eucerus* Hewitson, 1872 (Riodinidae), *Fulgurodes* sp., *Glena unipennaria unipennaria* Guenée, 1857, *Melanolophia* sp., *Oxydia vesulia* Cramer, 1779, *Sabulodes caberata caberata* Guenée, 1857 (Geometridae) and *Sarsina violascens* Herrich-Schäeffer, 1856 (Lymantriidae) were the primary pest species collected (Table 1).

The numbers of individuals collected, of groups I, II and III, were higher for *O. vesulia*, *Automeris* sp. (Saturniidae)

Table 1. Family, species, group (G), number of individuals (N), dominance classes (D), abundance (A), frequency (F) and constancy (C) of Lepidoptera captured in a *Eucalyptus urophylla* variety *platyphylla* (Myrtaceae) plantation in Salto de Pirapora, São Paulo State, Brazil from September 2016 to August 2018.

Family	Species	G	N	D	A	F	C
Arctiidae	*Eupseudosoma involuta*	I	9	d	c	f	y
	Idalus sp.	III	10	d	c	f	y
Bombycidae	*Apatelodes sericea*	I	9	d	c	f	y
	Olceclostera sp.	III	1	nd	r	i	z
	Drepatelodes sp.	III	25	d	a	vf	w
	Tarchon trilunula	III	16	d	c	f	z
Crambidae	*Pleuroptya silicalis*	III	25	d	a	vf	w
	Diatraea albicrinella	III	6	d	c	f	z
	Argyria croceivittella	III	7	d	c	f	z
	Nomophila noctuella	III	2	nd	d	i	z
	Polygrammodes ostrealis	III	3	nd	d	i	y
Erebidae	*Dinia eagrus* Cramer 1779	III	3	nd	d	i	y
	Dinia mena Hübner 1827	III	3	nd	d	i	z
	Syntomeida melanthus	III	2	nd	d	i	z
	Hypercompe scribonia	III	3	nd	d	i	z
	Agaraea semivitrea	III	18	d	c	f	w
	Gymnelia sp.	III	19	d	c	f	w
	Cosmosoma auge	III	7	d	c	f	y
	Cosmosoma festivum	III	13	d	c	f	w
	Correbia obtuse	III	41	d	a	vf	w
	Aclytia punctata	III	1	nd	r	i	z
	Dysschema sacrifica Hübner, 1831	III	4	nd	d	i	y
Geometridae	*Melanolophia* sp.	I	6	d	c	f	z
	Glena unipennaria unipennaria	I	2	nd	d	i	z
	Sabulodes caberata caberata	I	14	d	c	f	w
	Fulgurodes sp.	I	2	nd	d	i	z
	Oxydia vesulia	I	16	d	c	f	w
	Eois sp.	III	1	nd	r	i	z
Hesperiidae	*Astrapes* sp.	III	1	nd	r	i	z
Lymantriidae	*Sarsina violascens*	I	8	d	c	f	z
Noctuidae	*Anicla infecta*	III	3	nd	d	i	z
	Cabralia trifasciata	III	60	d	a	vf	y
	Cirphis sp.	III	172	d	a	vf	w
	Mocis latipes Guennée, 1852	III	8	d	c	f	z
	Spodoptera dolichos	III	3	nd	d	i	z
Notodontidae	*Blera varana*	I	3	nd	d	i	z
	Nystalea ebalea Cramer, 1781	II	2	nd	d	i	z
	Rosema languida	III	2	nd	d	i	z
	Lepasta bractea	III	1	nd	r	i	z
	Dasylophia sp.	III	3	nd	d	i	z
Riodinidae	*Euselasia eucerus*	I	1	nd	r	i	z
Saturniidae	*Automeris* sp.	II	3	nd	d	i	z
	Dirphia sp.	II	2	nd	d	i	z
	Hyperchiria incisa	III	2	nd	d	i	z

D: d= dominant, nd= non-dominant; A: a= abundant, c= common, d= disperse, r= rare; F: vf= very frequent, f= frequent, I= infrequent; C: w= constant, y= accessory, z= accidental.

and *Nystalea ebalea* Cramer, 1781 (Notodontidae) and *Dirphia* sp. (Saturniidae) with 16, three and two individuals and 22.86, 42.86 and 28.57% of the total, respectively. The number of individuals captured (246 and 45.81%) of group III was higher for Noctuidae (Table 1).

Anicla infecta Ochsenheimer, 1816 (Noctuidae), *Automeris* sp., *B. varana*, *Dasylophia* sp. (Notodontidae), *Dinia eagrus* Cramer, 1779, *Dinia mena* Hübner, 1827 (Erebidae), *Dirphia* sp., *Dysschema sacrifice* Hübner, 1825 (Erebidae), *Fulgurodes* sp., *G. unipennaria unipennaria*, *Hyperchiria incisa* Walker, 1855 (Saturniidae), *Hypercompe scribonia* Stoll, 1790 (Erebidae), *Nomophila noctuella* Denis & Schiffermüller, 1775 (Crambidae), *N. ebalea*, *Polygrammodes ostrealis* Guenné, 1854 (Crambidae), *Rosema languida* Schaus, 1892 (Notodontidae), *Spodoptera dolichos* F., 1794 (Noctuidae) and *Syntomeida melanthus* Cramer, 1779 (Erebidae) were dispersed species (Table 1).

Agaraea semivitrea Rothschild, 1909 (Erebidae), *A. sericea*, *Argyria croceivittella* Walker, 1863 (Crambidae), *Cosmosoma auge* L., 1767, *Cosmosoma festivum* Walker, 1854 (Erebidae), *Diatraea albicrinella* Box, 1931 (Crambidae), *E.involuta*, *Gymnelia* sp., *Idalus* sp. (Erebidae), *Melanolophia* sp., *Mocislatipes* Guenée, 1852 (Noctuidae), *O. vesulia*, *S. caberata caberata*, *S. violascens* and *Tarchon trilunula* Herrich-Schäffer, 1856 (Bombycidae) were common with a reduced number of individuals. The very abundant species represented 11.1% of the individuals captured (Table 1).

Aclytia punctata Butler, 1876 (Erebidae), *Astrapes* sp. (Hesperiidae), *Eois* sp. (Geometridae), *Lepasta bractea* Felder, 1874 (Notodontidae) and *Olceclostera* sp. (Bombycidae) were rare, with 13.3%, with *E. eucerus* (group I) represented by a single individual captured. *Apatelodes sericea*, *E. involuta*, *Melanolophia* sp., *O. vesulia*, *S. caberata caberata* and *S. violascens* were frequent (group I) and no species of group II was represented in this class. *Cabralia trifasciata* Moore, 1882, *Cirphis* sp. (Noctuidae), *Correbia obtusa* H. Druce, 1884 (Erebidae), *Drepatelodes* sp. (Bombycidae) and *Pleuroptya silicalis* Guenée, 1854 (Crambidae) from group III were very frequent (Table 1).

Dominant species were also abundant, while the non-dominant ones (57.8%) were infrequent, dispersed or rare. In group I, *B. varana*, *E. eucerus*, *Fulgurodes* sp. and *G. unipennaria unipennaria* were non-dominant. No species of the group II was dominant (Table 1).

A total of 22.2% of the constant species was dominant, including *O. vesulia* and *S. caberata caberata* (group I). Eight of the accessory species were identified, representing 15.6% of them, being *E. involuta* and *A. sericea* (group I) accessories and important for eucalypt plants. These species were not constant and, therefore, they were classified as accidental. The remaining accessory species were from group III (Table 1).

Accidental species (62.2%) were more than half of the records including *B. varana*, *E. eucerus*, *Fulgurodes* sp., *G. unipennaria unipennaria*, *Melanolophia* sp. and *S. violascens*, from group I and *Automeris* sp., *Dirphia* sp. and *N. abalea* from group II (Table 1).

The H' value= 2.7942 and the H'CI, calculated for the general composition of identified species (P= 0.05)=> [2.788969, 2.799341], was from 1.5 to 3.5. This demonstrates sufficiency of the number of samples to determine the species diversity. The value of E= 0.7340 indicates that 73.40% of the maximum theoretical diversity was obtained with the sampling performed (Table 1).

3.2. Faunistic analysis of natural enemies

A total of 118 lepidopteran natural enemy individuals of three orders, five families and 12 species was captured. The number of species (seven) and of individuals (65) captured of Hymenoptera represented 55.08% of the total number of individuals, followed by Diptera and Hemiptera, with three and two species and 49 (41.53%) and four (3.39%) individuals, respectively (Table 2).

Table 2. Order: family, genus/species, number of individuals (N) and dominance (D), abundance (A), frequency (F) and constancy (C) of natural enemies of Lepidoptera defoliators captured in a *Eucalyptus urophylla* variety *platyphylla* (Myrtaceae) plantation in Salto de Pirapora, São Paulo State, Brazil from September 2016 to August 2018.

Order: Family	Genus/Species	N	D	A	F	C
Hymenoptera: Ichneumonidae	*Neotheronia* sp.	5	nd	d	i	y
	Coccygominus sp.	2	nd	d	i	z
	Glypta sp.	3	nd	d	i	y
	Areoscelis sp.	4	nd	d	i	y
	Enicospilus sp.	1	nd	r	i	z
	Labena sp.	4	nd	d	i	y
Hymenoptera: Braconidae	*Apanteles* sp.	46	d	a	vf	w
Diptera: Tachinidae	*Winthemya* sp.	2	nd	d	i	z
	Lespesia sp.	20	d	a	vf	w
	Chetogena sp.	27	d	a	vf	w
Hemiptera: Pentatomidae	*Arocera acroleuca*	3	nd	d	i	y
Hemiptera: Reduviidae	*Rasahus* sp.	1	nd	r	i	z

D: d= dominant, nd= non-dominant; A: a= abundant, d= disperse, r= rare; F: vf= very frequent, i = infrequent; C: w= constant, y= accessory, z= accidental.

The numbers of individuals of Tachinidae (Diptera), Braconidae (Hymenoptera), Ichneumonidae (Hymenoptera), Pentatomidae and Reduviidae (Hemiptera: Heteroptera) were 49, 46, 19, three and one representing 41.53, 38.98, 16.10, 2.54 and 0.85% of the total, respectively (Table 2). The number of Ichneumonidae species was higher, followed by Braconidae with *Apanteles* sp., being the most numerous species collected, with 38.98% of the individuals for the natural enemy group (Table 2).

Chetogena sp. and *Lespesia* sp. (Tachinidae), *Coccygominus* sp., *Glypta* sp., *Areoscelis* sp., *Enicospilus* sp., *Labena* sp., *Neotheronia* sp., and (Ichneumonidae), *Arocera acroleuca* Perty, 1833 (Pentatomidae), *Winthemya* sp. (Tachinidae) and *Rasahus* sp. (Reduviidae) represented 22.88, 16.95, 4.24, 3.3, 3.39, 2.54, 1.69, 0.85, 2.54, 1.69 and 0.85% of the individuals of the natural enemies captured, respectively (Table 2).

Apanteles sp., *Lespesia* sp. and *Chetogena* sp. were dominant (d), abundant (a), very frequent (vf) and constant (c). The number of *Apanteles* sp. individuals captured (46) was higher, followed by *Chetogena* sp. (27) and *Lespesia* sp. (20) (Table 2).

The value of H'= 1.741 (P= 0.05)=> [1.572, 1.90] indicated sufficiency of the number of samples to determine the species diversity of natural enemies and the value of E= 0.7249 that 72.49% of the maximum theoretical diversity was obtained with the sampling.

4. Discussion

The low frequency of species in groups I and II and the high frequency of Amatidae, Arctiidae, Bombycidae, Crambidae and Noctuidae, abundant and with high frequency, especially Noctuidae (246 individuals), may be related to the proximity of the *E. urophylla* variety *platyphylla* plantation to cultivated areas, with annual crops where resources for insects are generally abundant. This is similar to that reported for *Eucalyptus dunnii* Maiden, *Eucalyptus grandis* W. Hill. and *Eucalyptus saligna* Sm. plantations with highest number of Noctuidae individuals captured with light traps near sugarcane crops, *Saccharum officinarum* L., wheat, *Triticum aestivum* L., *Z. mays*, *G. max* and common beans, *Phaseolus vulgaris* L. (Fabaceae) (Duarte Júnior and Schlindwein, 2005; Lafontaine and Fibiger, 2006; Bernardi et al., 2011; Luz et al., 2013; Santos et al., 2017). The high number of species and individuals of Noctuidae may also be related to possible resistance of *E. urophylla* variety *platyphylla* to species of other lepidopteran families as reported for *Mnesampela private* Guenée, 1858 (Geometridae) feeding preferably on *Eucalyptus aggregata* H. Deane & Maiden and *Eucalyptus camphora* R.T. Baker rather than on other *Eucalyptus* and *Corymbia* K.D. Hill & L.A.S. Johnson (Steinbauer and Matsuki, 2004; Bernardi et al., 2008; Samira et al., 2020) species.

The six species of group I as rare may be due to limited resources from *E. urophylla* variety *platyphylla* or competition favouring more frequent species for population increases. However, greater sampling efforts tend to increase the number of rare species collected (Bernardi et al., 2011; Ribeiro et al., 2016).

The total of 44 lepidopteran species, with 20 dominant and 24 non-dominants, is high and may be due to abundant ones, such as those from Noctuidae (Bernardi et al., 2011; Ribeiro et al., 2016). Some dominant insects can adapt to new environments by consuming the foliage of *Eucalyptus* and of alternative plants from the surrounding vegetation reducing the food available for other insect species (Bernardi et al., 2011; Dall'Oglio et al., 2016; Ribeiro et al., 2016). High populations of dominant insects in *E. saligna* and *E. urophylla* plantations with abundant food availability and the upgrade of new lepidopteran species to pest status indicate that competition for food resources between insects can occur in plantations with several eucalypt species (Zanuncio et al., 1998; Bernardi et al., 2008).

The constancy index, with 27 accidental species, may be related to the large number of lepidopteran species with low abundance, 18 of them disperse and six rare, indicating environmental resistances against their population increase (Dorval et al., 1995; Zanuncio et al., 2006). Furthermore, the high number of very abundant, constant and dominant species confirms their adaptation to the *Eucalyptus* environment (Bernardi et al., 2011; Ribeiro et al., 2016).

The sufficiency of the evaluation period to determine the species diversity and the large number of accidental ones (27) as found for the H' index value, indicate a balanced environment characterised by inter and intraspecific competition determining the species behaviour (Freitas et al., 2005; Zanuncio et al., 2014b). The increase in the vegetation uniformity tends to decrease H' values, favouring population increase of reduced group of insect species. The forest cultivation near areas with native forests and green belts can reduce the number of insect pests (Zanuncio et al., 1998; Bernardi et al., 2011). The value of E= 0.73 reveals a heterogeneous lepidopteran community with uniform distribution of individuals between species. This is simikat to that of nymphalid butterflies from the canopy and understorey of a rainforest (DeVries and Walla, 2001) and male euglossine bees from a fragmented landscape of Atlantic Forest (Tonhasca Junior et al., 2002).

The highest numbers of individuals per species, 65 and 49, of Hymenoptera and Diptera, respectively, indicates that species of these families are the most common groups of natural enemies in the *E. urophylla* variety *platyphylla* plantation with high rates of parasitism on insect preys (Dall'Oglio et al., 2003; Ribeiro et al., 2016, Favoreto et al., 2021). The higher number of Braconidae, Ichneumonidae, Eulophidae, Pteromalidae, Encyrtidae and Aphelinidae species and individuals confirm the fact that species from these families are the most used in biological control programs by being numerous, besides easy rearing and effectives (Dall'Oglio et al., 2000; Azevedo et al., 2002; Ribeiro et al., 2016). Ichneumonidae, with the highest number of species, is generally the most abundant hymenopteran parasitoids in natural environments or agricultural areas (Pacheco et al., 2020). Furthermore, it is the largest Hymenoptera family and present in regions with a mild and humid climate, parasitizing insects and arachnids, but with Lepidoptera as its most common host group (Tavares et al., 2013a; Garlet et al., 2016).

The higher number of *Apanteles* sp. individuals, the only Braconidae species captured, may be due to the solitary habit of species of this family, although with some gregarious and widely used in biological control programs in tropical and subtropical agroecosystems (Othim et al., 2019; Awad et al., 2019). Species of this genus parasitized defoliating caterpillars, such as *Automeris* sp., *G. bipennaria*, *E. imperialis magnifica*, *T. arnobia* and *S. violascens* in areas with cultivated forests and agrosilvopastoral systems (Pereira et al., 2015). In North America, Braconidae are most active foragers in places with partially open vegetation and high temperature, low relative humidity and low wind speed (Pérez-de la O et al., 2020).

The low frequency of *Areoscelis* sp., *Coccygominus* sp., *Enicospilus* sp., *Glypta* sp., *Labena* sp. and *Neotheronia* sp. and their lack of dominance, even though *Coccygominus* sp., *Glypta* sp. and *Neotheronia* sp. are natural enemies of Lepidoptera defoliators, prevented the analysis of their behavior. The lower availability of resources such as nectar, pollen and shelter in eucalypt clonal plantations reduce the survival and reproduction of these species (Dall'Oglio et al., 2000, 2016). On the other hand, the increase in the structural complexity of the vegetation favors the reproduction of hymenopteran parasitoids and the reduction of insect pest populations in forest plantations, reinforcing the importance of environmental diversity in the integrated pest management in eucalypt plantations. The number of defoliating Lepidoptera was lower in *Eucalyptus cloeziana* F. Muell., *E. grandis* and *E. urophylla* plantations, interspersed with strips of native vegetation, due to greater plant species diversity, favoring the reproduction of natural enemies and increasing biological control (Dall'Oglio et al., 2016; Zanuncio et al., 1998, 2018).

The Diptera as the second largest group of natural enemies agrees with reports of species of this order with *Lespesia aletiae* Riley, 1879, *L. archippivora* Riley, 1871, *Winthemia deilephilae* Osten Sacken, 1887 and *Archytas marmoratus* Townsend, 1915 (Tachinidae) recovered from outbreaks of *Spodoptera frugiperda* J.E. Smith, 1797 (Lepidoptera: Noctuidae) in *Z. mays* crops (Maldonado et al., 2018). Many species of this order, with approximately 150,000 described (Sanei-Dehkordi et al., 2020), are important in the regulation of herbivorous insect populations (Nakamura, 2018).

The highest numbers and the greater dominance, abundance, frequency and constancy of *Chetogena* sp. and *Lespesia* sp. with 27 and 20 individuals, respectively, are important due to the diversity and ecological importance of Tachinidae to regulate defoliating Lepidoptera communities (Stireman et al., 2006). The genus *Lespesia* is one of the largest and most important of this family (Sabrosky, 1980) with species and those of *Chetogena* frequently recovered from agricultural caterpillar pests, such as *Helicoverpa armigera* Hübner, 1805 (Lepidoptera: Noctuidae) on cotton, *Gossypium* L. sp. (Malvaceae), *G. max*, *P. vulgaris*, *Z. mays*, sorghum, *Sorghum bicolour* Moench (Poaceae) and tomato, *Solanum lycopersicum* L. (Solanaceae) crops (Tavares et al., 2013b). The report of *Lespesia* sp. and *Chetogena* sp. on the *E. urophylla* variety *platyphylla* plantation agrees with reports on their adaptation to survive in monocultures near diversified agriculture crops (Weber et al., 2021).

The highest number of *Lespesia* sp. (20 individuals) than *Winthemya* sp. (two individuals) reinforces the importance of species of that genus as parasitoids of defoliating caterpillars of the Noctuidae, Notodontidae, Saturniidae and Sphingidae families (Gil-Santana et al., 2014) and also *E. aberrans*, *S. violascens* and *T. arnobia* on *E. urophylla* and *E. grandis* × *E. urophylla* plantations (Masson et al., 2017a) and with potential for biological control programs (Tavares et al., 2015).

The low frequency and non-dominance of Pentatomidae and Reduviidae species may be due to the wide variety of their feeding habits on a large number of preys and supplementary feeding on plants (Ambrose, 2006; Weirauch, 2008). Climatic factors, food availability and intra and interspecific competitions can also affect the activity, abundance, diversity and survival of these predators (Tavares, 2017). The forest fragmentation reduces the diversity and numbers of natural enemies, favoring outbreaks of pests and increasing the importance of community ecology studies (Bernardi et al., 2011; Dall'Oglio et al., 2016; Ribeiro et al., 2016).

5. Conclusions

In summary, the results of the present study showed that ten primary pest species, i.e., *A. sericea*, *B. varana*, *E. involuta*, *E. eucerus*, *Fulgurodes* sp., *G. unipennaria unipennaria*, *Melanolophia* sp., *O. vesulia*, *S. caberata caberata* and *S. violascens* and three secondary, i.e., *Automeris* sp., *Dirphia* sp. and *N. ebalea* should be monitored in programs of pest management. The number of Noctuidae individuals was higher, but none of its species have been registered as pest in eucalypt plantations. The frequency and abundance of primary and secondary pest species were low without outbreaks in the period. The higher number of Braconidae and Tachinidae individuals reinforces the importance of these families in the biological control of Lepidoptera defoliators in eucalypt plantations. The low numbers of predators may be due to low efficiency of light traps to sample these natural enemies.

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