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Articles

Glena bipennaria bipennaria and *Apatelodes pandara* (Lepidoptera): new defoliating insects associated with *Khaya* in Brazil

Luana de Souza Covre[1], Robert A. Haack[2], Carlos Alberto Hector Flechtmann[3]*

[1]Department of Zoology, Federal University of Paraná, Curitiba, 81531-980, Paraná, Brazil
[2]USDA Forest Service, Northern Research Station, East Lansing, Michigan, USA (Emeritus)
[3]Department of Plant Protection, São Paulo State University, Ilha Solteira, 15385-007, São Paulo, Brazil

***Corresponding author:**
carlos.flechtmann@unesp.br

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Abstract - The expansion of African mahogany (*Khaya* spp.) plantations in Brazil has led to an increase in the number of associated insect pests. Here we report the first instances of defoliating caterpillars [*Glena bipennaria bipennaria* (Guenée) (Geometridae) and *Apatelodes pandara* Druce (Apatelodidae)] on commercial stands of African mahogany in Brazil, specifically *Khaya grandifoliola* C. DC. and *Khaya senegalensis* (Desr.) A. Juss. *Glena b. bipennaria* was the dominant defoliator in all stands, with *A. pandara* only found in *K. senegalensis* stands. We provide data on seasonal development, defoliation severity, and natural enemies. It is currently unclear whether the *Glena b. bipennaria* outbreak reported is an isolated incident or will become more common in the future. Serious insect outbreaks, particularly those caused by defoliating caterpillars, only became frequent several decades after the introduction of *Eucalyptus* species to Brazil. African mahogany species were introduced much more recently, suggesting that additional native insects may adapt to these new exotic *Khaya* species in the coming years.

Glena bipennaria bipennaria e *Apatelodes pandara* (Lepidoptera): novos insetos desfolhadores associados a *Khaya* no Brasil

Resumo - A expansão de plantios de mogno africano (*Khaya* spp.) no Brasil resultou em um aumento das espécies de insetos-praga associados à cultura. Relatamos aqui os primeiros casos de lagartas desfolhadoras [*Glena bipennaria bipennaria* (Guenée) (Geometridae) e *Apatelodes pandara* Druce (Apatelodidae)] em plantios comerciais de mogno africano no Brasil, especificamente *Khaya grandifoliola* C. DC. e *Khaya senegalensis* (Desr.) A. Juss. *Glena b. bipennaria* foi a espécie dominante em todos os plantios, enquanto que *A. pandara* foi encontrada apenas em plantios de *K. senegalensis*. Dados sobre a sazonalidade, severidade da desfolha e inimigos naturais foram fornecidos. Atualmente, não está claro se o surto de *Glena b. bipennaria* relatado é um incidente isolado ou se tornará mais comum no futuro. Surtos graves de insetos em *Eucalyptus*, especialmente aqueles causados por lagartas desfolhadoras, só se tornaram frequentes várias décadas após a sua introdução no Brasil. As espécies de mogno africano foram introduzidas muito mais recentemente, sugerindo que outros insetos nativos podem se adaptar a essas novas espécies exóticas de *Khaya* nos próximos anos.

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Introduction

The genus *Khaya* (Meliaceae), commonly known as African mahogany, includes several tree species. It was introduced to Brazil in the 1970s (Falesi & Baena, 1999; Ferraz Filho et al., 2021) and has since become highly valued for its adaptability to different soil and climate conditions, as well as the economic value of its high quality wood. As a result, African mahogany plantations have rapidly expanded in Brazil (Reis et al., 2019; Oliveira & Franca, 2020), now covering approximately 50,000 ha, with *Khaya grandifoliola* C. DC. and *Khaya senegalensis* (Desr.) A. Juss. being the dominant species planted in the country (Ferraz Filho et al., 2021).

During the first 20 years after African mahogany was introduced to Brazil, few insect pests were reported on these trees (Falesi & Baena, 1999). More recently, however, many native insects have become associated with African mahogany in Brazil, especially certain leaf-cutting ants (Souza et al., 2021), wood-boring beetles (Covre et al., 2018a, 2018b, 2018c, 2021; Cristovam et al., 2018) and the mahogany shoot borer, *Hypsipyla grandella* Zeller, which can affect shoots, trunks, fruits and seeds (Zanetti et al., 2017; Covre et al., 2018d; Lemes et al., 2019; Lunz & Reis, 2019 for a general review). Although defoliating caterpillars (Lepidoptera) of mahogany have been reported in the literature, particularly in Africa (Gardner, 1957; Browne, 1968; Roberts, 1969; CIRAD, 1988), none had been reported in Brazil.

Eucalyptus trees (*Eucalyptus* spp.) are also exotic to Brazil, and represent the largest portion of forest plantations in Brazil with ca of 7.6 million hectares (Indústria Brasileira de Árvores, 2023). In contrast to African mahogany, eucalyptus plantations are often attacked by defoliating caterpillars, with many species considered important pests in Brazil (Berti Filho, 1981; Kowalczuck et al., 2012). Most of these economically important lepidopteran species belong to the genera *Apatelodes*, *Eupseudosoma*, *Euselasia*, *Glena*, *Oxydia*, *Sarcina* and *Thyrinteina*, and are all native to Brazil (Menezes et al., 1986; Kowalczuck et al., 2012). Although these lepidopteran species typically occur in low numbers in their native habitats, they can reach outbreak levels in eucalyptus plantations (Majer & Recher, 1999; Wingfield et al., 2008). Under outbreak situations, a “spillover effect” can occur, where a pest of one tree species may attack other tree species growing nearby that are not normally their hosts (Kriticos et al., 2005; Blitzer et al., 2012).

Glena bipennaria bipennaria (Guenée) (GBB for short) (Lepidoptera: Geometridae) is a defoliator that is frequently found in eucalyptus plantations. This species is mainly distributed in the Humid Subtropical Zone of South America, covering Bolivia, Brazil, Ecuador, Paraguay and Peru (Rindge, 1967), and is occasionally found in Argentina (Mc Kay, 2019). In Brazil, it occurs in the states of Bahia, Espírito Santo, Mato Grosso, Minas Gerais, Paraná, Rio de Janeiro, Rio Grande do Sul, Santa Catarina, and São Paulo (Rindge, 1967; Nagaraja, 1983; Molina, 2014; Motta & Bezerra Junior, 2016).

GBB is a common pest of eucalyptus plantations in Brazil, and often requires control measures (Wilcken et al., 2022; Barbosa et al., 2023). However, despite its economic importance, most literature only reports collections of GBB adults in light traps that did not target GBB specifically (Menezes et al., 1986; Dall’Oglio et al., 2013, to name a few). Nonetheless, GBB caterpillars have been successfully reared to adults on 14 species of native trees and shrubs from 11 different plant families in Brazil, including *Myrcia tomentosa* DC., a species of Myrtaceae, which also includes eucalyptus trees (Barros, 2007; Marconato et al., 2008; Geraldo, 2011; Abreu, 2014; Mc Kay, 2019). Some aspects of GBB’s life history have been described based on an outbreak that occurred in a *Pinus patula* Schiede ex Schltdl. and Cham. plantation in Brazil (Pedrosa-Macedo, 1993).

Apatelodes pandara Druce (Lepidoptera: Apatelodidae) has a wide distribution in South America (Argentina, Bolivia, Brazil, Colombia, Ecuador, French Guiana and Peru), and also parts of Central America (Costa Rica and Panama) and the Caribbean (Trinidad and Tobago) (Barcode of Life Data System, 2022; The Global Biodiversity Information Facility, 2023). In Brazil, *A. pandara* occurs in the states of Distrito Federal, Espírito Santo, Maranhão, Mato Grosso and Rio Grande do Sul (Berti Filho, 1981; Biezanko, 1986; Diniz et al., 2001; Januário et al., 2013). Although little

information is available on *A. pandara*, it does occasionally reach pest status on eucalyptus in Brazil (Berti Filho, 1981). Another known host plant of *A. pandara* in Brazil is *Xylopia aromatica* (Lam.) (Annonaceae) (Diniz et al., 2001).

Our objectives were to (1) document for the first time defoliation by lepidopteran caterpillars on commercial African mahogany stands in Brazil, and (2) provide some life-history data on each species.

Material and methods

Study sites

An infestation of *Glena bipennaria bipennaria* was observed in commercial stands of *Khaya grandifoliola* and *Khaya senegalensis* in Natalândia, state of Minas Gerais, Brazil (16°35'20.09"S, 46°30'19.50"W) in 2022. Both GBB adults and caterpillars were first observed in March 2022 in *K. grandifoliola* stands, which ranged in age from 40 to 124 months old and covered a total area of 199 ha. In nearby *K. senegalensis* stands that covered 134 ha, the infestation was found in trees that were 16 to 40 months old (Figure 1).

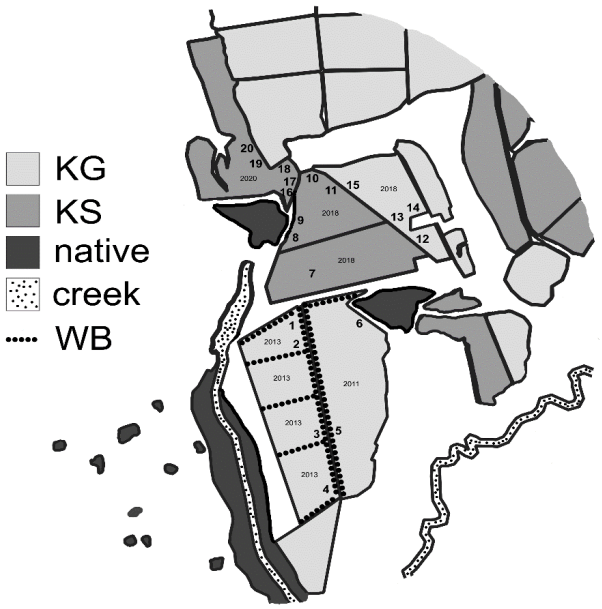


Figure 1. Map of study area showing sites of attack primarily by *Glena bipennaria bipennaria* (GBB) in Natalândia, state of Minas Gerais, Brazil. Key to acronyms and terms used: KG: *Khaya grandifoliola*, KS: *Khaya senegalensis*, native: *cerradão* fragment or riparian forest (when next to the creek), WB – windbreak with *Eucalyptus urograndis*, 2013 ... 2020: year of African mahogany planting (always in December), 1 ... 20: GBB sampling points.

Sampling

At the end of March 2022, we surveyed stands where we had received reports that adults of an unknown moth (at that time) and African mahogany defoliation had been observed. We also surveyed nearby stands where we suspected the moth to be present in both *K. grandifoliola* and *K. senegalensis* stands.

The stands that we evaluated had all been planted in the month of December in various years. Hereafter, we will refer to these *K. grandifoliola* and *K. selegalensis* stands as KG and KS, respectively, with subscripts denoting their respective planting years: KG_{2011}, KG_{2013}, KG_{2018}, KS_{2018} and KS_{2020}.

We conducted surveys at 10 points in three KG stands (points 1-6 and 12-15), and another 10 points in two KS stands (points 7-11 and 16-20; Figure 1). The survey points were selected based on three criteria: (1) proximity to eucalyptus trees, *Eucalyptus urograndis* (hybrid of *Eucalyptus grandis* x *Eucalyptus urophylla*) clone I144, used as windbreaks, as it is known that GBB attacks trees of this genus, (2) proximity to native fragments of cerradão (a tall woodland, a physiognomy of cerrado), which could be a possible source of the infestation, and (3) distance from the border of the stand (Figure 1). All trees in each survey plot were visually examined and the number of damaged trees and defoliation levels were recorded. We estimated the percentage of defoliation visually, using the following levels (Choi et al., 2021): 0% (no defoliation), < 10% (low defoliation), 11-50% (medium defoliation) and > 50% (high defoliation).

In addition, we conducted a survey at one location in the native cerradão that bordered KS_{2018} to determine if GBB or *A. pandara* were present. Due to the high density of the remnant, we limited our survey to its outer perimeter.

We also collected soil samples around one tree per survey plot (radius of 60 cm, depth of 5 cm) at seven of the survey plots (plots 1, 3, 7, 9, and 11-13) in search of Lepidoptera pupae. All insect life stages observed were taken to the Laboratory of Entomology at the UNESP campus in Ilha Solteira São Paulo state. In the lab, caterpillars were fed on *K. senegalensis* leaves until they pupated. We placed all collected or reared pupae into cages and observed them until emergence of adults.

Species determination

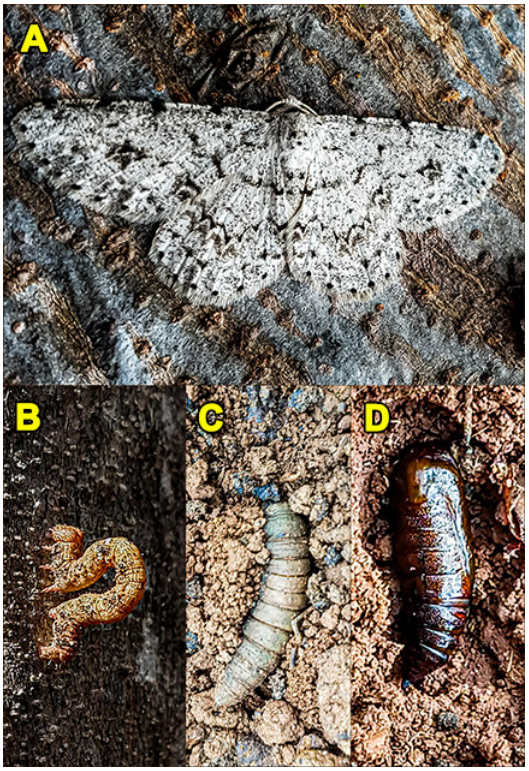
The Geometridae specimens were determined by Manoel Martins Dias Filho, Universidade Federal de São Carlos (UFSCar), São Carlos, state of São Paulo. The Apatelodidae specimens were determined by Sinval Silveira Neto, Escola Superior de Agricultura "Luiz de Queiroz" (ESALQ), Piracicaba, state of São Paulo and Elton Orlandin, Universidade Federal do Paraná, Curitiba, state of Paraná. The Tachinidae specimens reared from pupal GBB were determined by Ronaldo Toma, Fiocruz, Campo Grande, state of Mato Grosso do Sul, while specimens of the Hymenoptera hyperparasitoids were determined by Valmir Antonio Costa, Instituto Biológico, Campinas, state of São Paulo. Voucher specimens were deposited at MEFEIS, Museu de Entomologia da FEIS/UNESP (Museum of Entomology of FEIS/UNESP) in Ilha Solteira, São Paulo state, Brazil.

Results

The Lepidoptera species causing the defoliation were determined as *Glena bipennaria bipennaria* (Geometridae) (Figures 2A-D) and *Apatelodes pandara* (Apatelodidae) (Figures 3A-D). By far, GBB was the dominant species found in all life-stages collected (caterpillars, pupae and adults). Due to the lower number of *A. pandara* observed, we consider that most defoliation was caused by GBB larvae (Figure 4).

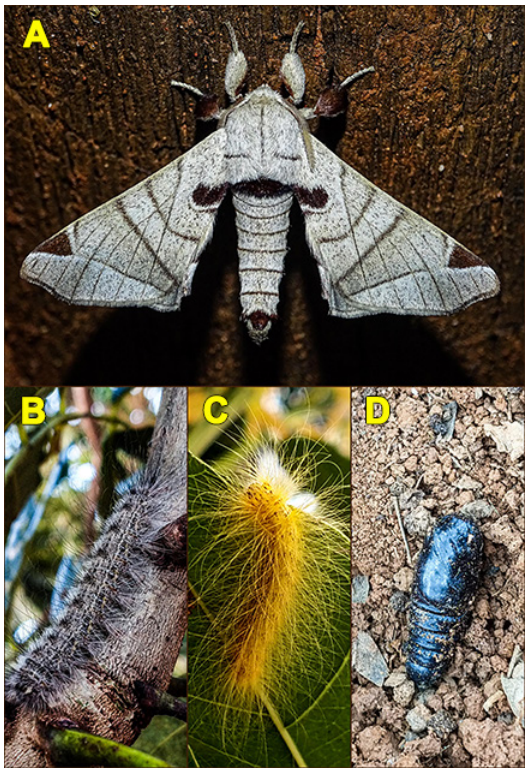
Two Tachinidae (Diptera) species emerged from GBB pupae, including *Hemisturmia flavipalpis* Guimarães and *Houghia* sp. Coquillett, with the latter being the most abundant. Two hyperparasitoid species emerged from the Tachinidae pupae, including *Trichopria* sp. (Hymenoptera: Diapriidae) and *Perilampus* sp. (Hymenoptera: Perilampidae).

We sampled a total of 910 *K. grandifoliola* trees and 1056 *K. senegalensis* trees across the 20 sampling plots. Considering only those trees with some level of defoliation at the time of our surveys, most trees were classified as having low defoliation. For example, the overall percentage of trees with low, medium and high levels of defoliation were 90.8%, 6.2% and 3.0% for *K. grandifoliola* trees and, 48.1%, 20.6% and 31.3% for *K. senegalensis* trees, respectively (Table 1).



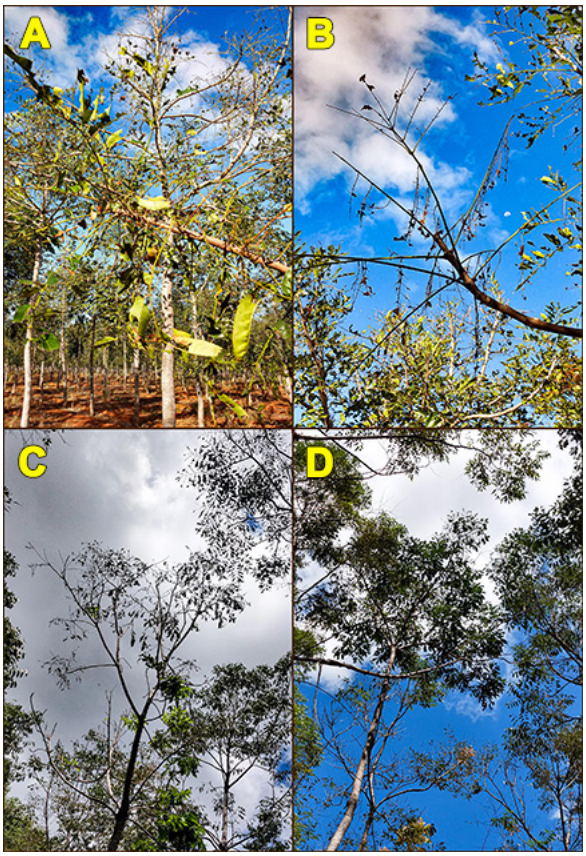
Photos: Luana de Souza Covre.

Figure 2. *Glena bipennaria bipennaria* adult (a), caterpillar (b), prepupa (c) and pupa (d) in Natalândia, state of Minas Gerais, Brazil.



Photos: Marcos Cesar Campis (A); Luana de Souza Covre (B, C e D).

Figure 3. *Apatelodes pandara* adult (A) Vargem Bonita, state of Minas Gerais, Brazil), gray and golden caterpillar color types (B and C, respectively) and pupa (D).



Photos: Luana de Souza Covre.

Figure 4. *Glena bipennaria bipennaria* defoliation in *Khaya senegalensis* (A, B) and *Khaya grandifoliola* (C, D) trees in Natalândia, state of Minas Gerais, Brazil.

Based on the degree of defoliation observed, the 2022 GBB outbreak originated at the southern periphery of stand KS_{2018}, which borders the northernmost eucalyptus windbreak found in stand KG_{2013} (Figure 1). From there, the infestation seemed to have spread northward as evidenced by decreasing defoliation from point 7 to points 8 and 9, and from there to points 10 and 11 (Figure 1). In the northern neighboring KS_{2020} stand, the infestation was in its early stages (low defoliation levels) at the border with KS_{2018} (points 16, 17), and absent further to the north (points 18, 19, 20). Apparently, the infestation was also spreading eastward from KS_{2018} to the KG_{2018} stand. In this stand (KG_{2018}), low levels of defoliation were observed at the border with KS_{2018} (points 12, 13, 15), while no defoliation was found farther away (point 14) (Figure 1, Table 1).

We observed GBB caterpillars feeding on *K. senegalensis* and *K. grandifoliola* leaves in all stands. Defoliation on both *Khaya* species occurred mostly in a top-down direction within the tree crowns. Defoliation also occurred on the eucalyptus trees that were used as windbreaks; however, their height made an accurate defoliation measurement difficult and therefore we did not estimate defoliation on those trees. Nevertheless, it appeared that defoliation on the eucalypts occurred in a bottom-up direction.

In addition to feeding on *Khaya*, we also found GBB caterpillars on various understory plants. Three caterpillars were found on defoliated *Senna obtusifolia* (L.) (Fabaceae) plants in KG_{2013}, two on defoliated *Calea* sp. (Asteraceae) plants in KG_{2011}, and three other caterpillars were found on non-defoliated *Digitaria insularis* (L.) (Poaceae) plants in KS_{2018}.

During surveys in both *K. grandifoliola* and *K. senegalensis* stands that bordered fragments of native cerradão (points 6, 8, 9), we found low

Table 1. Summary data for percent defoliation (0, < 10, 11-50, > 50%) caused primarily by *Glena bipennaria bipennaria* (Geometridae) caterpillars on species (sp.) of African mahogany, *Khaya grandifoliola* (KG) and *Khaya senegalensis* (KS), including the number of sampled trees (# trees) for each sampling point (P). Natalândia, state of Minas Gerais, Brazil, March 2022.

P	sp.	# trees	% defoliation
1	KG	100	<10 (n = 91), >50 (n = 9)
2		50	11-50 (n = 40), >50 (n= 10)
3		60	0 (n = 2), <10 (n = 58)
4		150	< 10 (n = 150)
5	KG	100	< 10 (n=100)
6		100	< 10 (n=100)
7	KS	306	11-50 (n = 122), > 50 (n = 184)
8		50	0 (n = 37), < 10 (n = 13)
9		100	0 (n = 40), < 10 (n = 59), > 50 (n = 1)
10		100	< 10 (n = 100)
11	KS	100	< 10 (n = 100)
12	KG	100	0 (n = 53), < 10 (n = 47)
13		50	0 (n = 21), < 10 (n = 29)
14		100	0 (n = 100)
15		100	0 (n = 95), < 10 (n = 5)
16	KS	50	0 (n = 42), < 10 (n = 8)
17		50	0 (n = 45), < 10 (n = 5)
18		100	0 (n = 100)
19		100	0 (n = 100)
20		100	0 (n = 100)

levels of defoliation (Figure 1, Table 1). Moreover, during our survey of the remnant native cerradão that bordered KS_{2018}, we found only a few GBB caterpillars that were hanging from silk-threads on native vegetation (but not necessarily hosts), and no *A. pandara* individuals.

We observed GBB caterpillars of different instars hanging from silk threads in KS_{2018}, which was the most defoliated stand. In addition, as a result of the heavy defoliation by GBB in stands KG_{2011}, KG_{2013}, and KS_{2018}, frass accumulated on the ground in several stands, and could be heard dropping to the soil during some of our surveys.

We found GBB pupae in stands KS_{2018}, KS_{2020}, KG_{2013} and KG_{2018}, with most pupae buried in the soil to depths up to 3 cm (Figure 3D). Only rarely were pupae found just under the litter layer. The majority of the pupae were concentrated within a radius of 15 cm from the tree trunk, but some were found as far as 60 cm from the tree trunks.

Adult GBB moths were found resting on tree trunks of both African mahogany species (Figure 2A), as well as on eucalyptus tree trunks. Most adults were seen on the lower 2 m of the trunks.

Various life stages (caterpillar, pupa, adult) of *A. pandara* were only found in the sampled *K. senegalensis* stands (Figure 3A-D). This is the first report of *A. pandara* in the state of Minas Gerais. The *A. pandara* caterpillars exhibited two distinct color forms with one having a golden hue while the other was predominantly gray (Figure 3B-C). The golden type was the most abundant, and both types were observed feeding on *K. senegalensis* leaves. During our surveys, specimens of *A. pandara* were mostly in the pupal stage. At one site where both defoliators occurred and where pupae were counted (point 7, KS_{2018}), 81% of the pupae found were GBB while 19% were *A. pandara.* Similar to GBB, most *A. pandara* pupae were concentrated within 15 cm of the tree trunks and located to depths of about 5 cm.

Given that the GBB population appeared to be growing and spreading, insecticides were applied to selected stands or portions of stands, which consisted of an 80-m wide strip of the southern border of KS_{2020}, and in the entire stands of KS_{2018}, KG_{2018}, KG_{2011} and KG_{2013}, including the eucalyptus windbreaks. An aerial application of the stands was conducted in late March 2022 using the chitin synthesis inhibitor lufenuron 100 EC at a rate of 20 l/ha (20 g a.i./ha). In mid-April, additional ground-based spraying was conducted only in stand KS_{2018}, which had the highest numbers of GBB, to target the caterpillars emerging from eggs that had been laid on the tree trunks. For this latter treatment, an atomizer was used to apply the contact insecticide deltamethrin 25 EC on the lower 2-m of all tree trunks at a rate of 200 l/ha (5 g a.i./ha). The combination of both the aerial and ground-based insecticide sprays provided complete control of the defoliating caterpillars based on visual observations that were made by company employees for several weeks after the spraying.

Discussion

Based on the existing literature (Motta & Bezerra Junior, 2016), which clearly classifies *Glena bipennaria bipennaria* as a eucalyptus defoliator, we presumed that the observed defoliation on these windbreak trees was inflicted by GBB. It is possible that GBB developed initially on the windbreak eucalyptus trees along the northern border of KG_{2013} and then spread to KS_{2018}. These eucalyptus trees could therefore have been the original source of GBB caterpillars. Such a pattern of spread is suggested by our sampling points 3 and 4, where the degree of GBB defoliation decreased from the eucalyptus border trees to the interior of *Khaya grandifoliola* stands (data not shown).

The presence of a eucalyptus windbreak by itself proved not to be the only factor contributing to defoliation in the African mahogany stands, and this was particularly true for KG_{2013} and KG_{2011}. While roughly 53% of trees in KS_{2018} showed medium to high levels of defoliation, only around 11% of trees in stands KG_{2011} and KG_{2013} were similarly affected (Table 1, Figure 4). It is unclear whether *K. senegalensis* is a more suitable host for GBB development than *K. grandifoliola*, possibly due to variations in secondary compounds found in the leaves of these African mahogany species (Olatunji et al., 2021, and references therein), or if the much younger KS_{2018} stand provided a better environment for caterpillar development than the significantly older KG_{2011}/KG_{2013} stands. Further

research is necessary to elucidate this relationship.

Our survey of *K. grandifoliola* and *K. senegalensis* stands bordering fragments of native cerradão remnants revealed surprisingly low levels of defoliation (Figure 1, Table 1). This finding contradicts our initial expectations where we thought it probable that native tree species present in these remnants would harbor endemic populations of GBB. As a result, we had anticipated higher levels of defoliation in African mahogany trees that grew close to these cerradão fragments. This observation suggests that GBB populations are more likely to thrive in eucalyptus trees, where GBB is known to be a significant pest (Wilcken et al., 2022; Barbosa et al., 2023), and seldom build to such high levels in native cerradão to threaten nearby African mahogany stands. The low number of GBB caterpillars found in our native cerradão survey area supports this hypothesis.

GBB attacks on eucalyptus trees started in the lower canopy and progressed upward in a bottom-up pattern, as previously described in the literature for both *Eucalyptus* (Motta & Bezerra Junior, 2016) and *P. patula* (Pedrosa-Macedo, 1993). However, the opposite trend was observed in the current study on African mahogany trees, where defoliation progressed from the upper crown foliage to the lower crown.

The "rainfall-sound phenomenon" of frass falling on the forest floor, was especially detectable in areas where GBB caterpillars were at high densities and later instars. Hearing frass hit the forest floor is common during outbreaks of many defoliating insects, especially frass from larvae of many Lepidoptera and sawflies (Hymenoptera: Symphyta) (Drooz, 1960; Coyle et al., 2013; Banko et al., 2022). As previously mentioned, we observed GBB caterpillars of varying instars hanging from self-made silk threads. This behavior, often called ballooning is a common dispersal mechanism by larvae in many families of moths (Bell et al., 2005; Darr & Coyle 2021). Ballooning allows caterpillars to disperse and possibly locate new host plants, as well as to reach the soil for pupation and predator avoidance (Pedrosa-Macedo, 1993; Fedic et al., 2002; Castellanos & Barbosa, 2006; Sugiura & Yamazaki 2006; Ciesla & Asaro, 2013). It is possible that the GBB caterpillars we observed on understory plants had simply dropped from nearby trees and landed by chance on those understory plants, finding some suitable as a food plant and others not. Late instar GBB caterpillars are known to reach the forest floor by both ballooning and by crawling down the tree trunks (Pedrosa-Macedo, 1993).

The GBB pupae we recovered were usually buried in the soil at depths of less than 3 cm, which aligns with the findings of Pikart et al. (2010), but that were in contrast with those of Pedrosa-Macedo (1993), who reported finding pupae at soil depths of 5-10 cm. The pupae of *A. pandara* that we found were buried somewhat deeper in the soil, about 5 cm, which is a depth similar to that of *Apatelodes kotzschi* Draudt pupae (Orlandin et al., 2023).

The preponderance of GBB pupae over *A. pandara* pupae in our soil samples may suggest that *A. pandara* caterpillars were active earlier in the year than GBB. This finding is consistent with the literature, which reports that *A. pandara* adults typically fly between January and March (Biezanko, 1986).

We found GBB adults resting primarily on the lower 2 m of tree trunk, after inspecting most trees to a trunk height of 5 m. This pattern is similar to observations made of GBB on both *P. patula* (Pedrosa-Macedo, 1993) and *Eucalyptus* (Motta & Bezerra Junior, 2016) trees.

It is likely that GBB adults can be found year-round (Rindge, 1967). However, apparently in warmer regions they are active for more months throughout the year (Motta & Bezerra Junior, 2016) than places where temperatures are milder (Martins et al., 1984). Outbreaks are often favored by periods of high temperatures and low rainfall (N.S. Bezerra Junior, Equilíbrio Proteção Florestal, personal communication, December 2022). Interestingly, the weather conditions in the five months before the outbreak reported here were mild (i.e., average monthly temperatures were below 25°C) with normal to above-average rainfall (i.e., over 200 mm per month) (data not shown).

The GBB outbreak reported here is similar in ways to some earlier reports. Firstly, we noted overlapping GBB generations, as evidenced by the presence of all GBB life stages (excluding

eggs, which were not searched for) during our surveys, which was also reported by Martins (1988). Secondly, our finding that GBB larvae and another defoliator (*A. pandara*) were both present and feeding on the same host tree in many of the surveyed stands, is similar to other reports where GBB outbreaks occurred in conjunction with other defoliating caterpillar species (Berti Filho, 1981; Martins et al., 1984; Texeira & Villa, 1987).

As noted above, company personnel informed us that the insecticidal treatments used against GBB in selected stands were very effective in controlling GBB. Insecticides have been shown to be particularly effective against geometrid pests (Barbosa et al., 2023) and *Glena* spp. in eucalypts (Zanuncio et al., 1994; AGROFIT, 2023).

We identified two Tachinidae species parasitizing GBB pupae. It is well-documented that tachinid parasitoids frequently attack tree-defoliating caterpillars (Berti Filho, 1981; Marconato et al., 2008). Besides the species we reared, many other tachinids have been reared from GBB, including species in the genera *Chrysoexorista, Euphorocera, Leschenaultia* and *Lespesia* (Teixeira & Vila, 1987; Pedrosa-Macedo, 1993).

Conclusions

At this time, it is uncertain whether the *Glena bipennaria bipennaria* (GBB) outbreak reported here was an isolated event or if it will become more common in the future. It took several decades after the introduction of *Eucalyptus* species to Brazil for serious insect outbreaks to become frequent, particularly those caused by defoliating caterpillars. African mahogany species were introduced to Brazil much more recently and therefore it is likely that additional native insects will adapt to these new exotic species of *Khaya* in future years. GBB has already shown great potential to cause damage to African mahogany, mainly for *K. senegalensis*, while *Apatelodes pandara* less so. Nevertheless, it is possible that populations of *A. pandara* could reach outbreak levels in the future and thereby become a cause for concern.

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Conflict of interest

All authors declare that they have no conflict of interest.

Authors' Contributions

Luana de Souza Covre: Conceptualization, formal analysis, investigation, methodology, writing – original draft. **Carlos Alberto Hector Flechtmann**: Conceptualization, formal analysis, methodology, supervision and writing – review & editing. **Robert A. Haack**: Writing – review & editing.

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