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Impact of Eucalyptus Plantations in Different Regions of Brazil on the Distribution and Abundance of Defoliating Caterpillars

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ABSTRACT: *Eucalyptus* species are cultivated in homogeneous plantations in Brazil, mainly to supply wood for the cellulose and steel industries, which favors the establishment of insect pests. The objective was to determine the geographical distribution and structure abundance of Lepidoptera defoliators of eucalypt. Primary pest species of eucalypt of the order Lepidoptera were found in all areas sampled and their populations were correlated with the age of the eucalypt plants, rainfall, and monthly average temperature. They presented population peaks between February and July (Três Marias and Niquelândia) and July to November (Monte Dourado) during periods of lower rainfall. The highest population peaks of these species were recorded when the eucalypt plants were three to six years old. The area of Guanhães presented better stability and fewer possibilities for the occurrence of eucalyptus Lepidoptera primary pests.

Key words: Eucalypt, Distribution, Defoliators, Lepidoptera, Light traps, Monitoring

INTRODUCTION

Eucalyptus species which are native to Australia, Indonesia, Papua New Guinea and Philippines (Ohmart & Edwards 1991a) are the main ones used in plantations for wood supply. This is because of their rapid growth, precocity and adaptation to many habitats (Zanuncio *et al.*, 2001; Iwakiri *et al.*, 1999) in monocultures (Zanuncio *et al.*, 2000). The eucalypt is cultivated as homogeneous plantations in Brazil, mainly, to supply wood for the cellulose and steel industries, which favors the establishment of insect pests. Monocultures can favor several pests, especially Lepidoptera, that cause damage to eucalyptus plantations particularly in areas of low vegetation diversity (Zanuncio *et al.*, 1998a). For this reason insects usually found at endemic levels on native plants of the Myrtaceae family are now damaging eucalyptus plantations in Brazil (Zanuncio *et al.*, 2000). Worldwide, Brazil is ranked fourth in terms of area (> 4 million ha's) under homogeneous forest plantations (Ohmart & Edwards, 1991a; Ohmart & Edwards,1991b).

The damage by Lepidoptera defoliators of eucalypt necessitated a study on the fluctuation of these species in many areas of Brazil (Guedes *et al.*, 2000). The spatial and temporal distribution and the factors that affect these parameters are important for pest management programs in eucalypt plantations (Freitas *et al.*, 2005). This is important because pest outbreaks in temperate and tropical areas are, mainly, preceded by stress conditions to the plant, especially dry periods (Thomson *et al.*, 1984). Light traps were used biweekly or monthly to identify the occurrence of Lepidoptera in areas reforested such as those with eucalypt species (Guedes *et al.*, 2000). This enabled the preparation of a list of insect pests and to determine their population peaks, especially those considered important for the eucalypt industry. Besides, the occurrence of these species have been correlated with the age of the plants and climatic factors including rainfall and average monthly temperature (Zanuncio *et al.*, 1998a; Zanuncio *et al.*,1998b).

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The objective was to determine the geographical distribution and population structure of Lepidoptera primary pests of eucalypt in the main eucalypt regions of Brazil as the municipalities of Três Marias and Guanhães (Minas Gerais State), Monte Dourado (Pará State) and Niquelândia (Goiás State) and to correlate the number of individuals with the average temperature, monthly rainfall and age of the eucalypts plants.

MATERIALS & METHODS

Lepidoptera species were collected in *Eucalyptus* spp. plantations in the municipalities of Três Marias and Guanhães (Minas Gerais State), Monte Dourado (Pará State) and Niquelândia (Goiás State), Brazil (Table 1) during five years in traps with black lights powered by 12V batteries and 55 amperes. Four or five traps were used per area in the lateral part of eucalypt stands. These traps were installed at two meters height which is ideal to collect positive phototropic insects at a minimum distance of 1,000 meter intersections. They were turned on every two weeks from 06:00 P.M. to 06:00 A.M. of the following day. A 50-litre plastic bag was put in the inferior part of each trap with a 20 ml vial with ethyl acetate and paper ribbons to kill the insects collected and to minimize the damage to them (Hegazi *et al.*, 2009; Zanuncio *et al.*, 1998a). The Lepidoptera collected were put in entomological blankets made with newspaper (15 x 15 cm), lined with cotton and identified with the day, month and year of the collection and place of each trap. These blankets were sent to the Department of Animal Biology of the Federal University of Viçosa (UFV), Municipality of Viçosa, Minas Gerais State, Brazil. The insects collected were sorted, quantified, mounted and identified to prepare a reference collection for each area. The Lepidoptera collected were identified based on the entomology collection of the UFV and when necessary by taxonomists.

The Lepidoptera pests were identified at the genus and/or species and divided in primary pests (species reported in outbreaks with economic damage) and other pest species (reported but without economic damage) (Zanuncio *et al.*, 1998a; Zanuncio *et al.*, 1998b). The number of individuals of the species of the first group was analyzed in relation to the total collected during the five years for each area. Data of the rainfall and average temperature during the period studied were obtained from meteorological stations in the areas where the traps were located. The linear coefficient (r) and the Student t-test were used to correlate the monthly number of individuals of the primary pests with the monthly rainfall, monthly average temperature and age of eucalypt plants in each area.

RESULTS & DISCUSSION

Individuals of the Lepidoptera primary pests were the most common in all areas (Table 2). Três Marias had 12 species of these pests (PP) and a total of 731 species of Lepidoptera (TE) with the first group presenting 1.64% of the number of species (% PP) and 66.32% of the individuals collected (% PPI) (Table 2). Monte Dourado had 12 species of Lepidoptera primary pests and 578 species of this order with 2.08% of the species and 39.78% of the individuals collected. A total of 459 species were collected in Niquelândia including eleven Lepidoptera primary pests, with the second group representing 2.40% of the species and 54.45% of the individuals (Table 2). The area of Guanhães had a higher number of species (804) where the 12 Lepidoptera primary pests represented 1.49% of the total species and 19.96% of the individuals collected (Table 2).

The number of Lepidoptera species collected was higher than that reported by similar studies (Pereira *et al.*, 2001; Guedes *et al.*, 2000; Zanuncio *et al.*, 1998a; Zanuncio *et al.*, 1998b). The total number of individuals collected shows the high adaptability and coexistence of Lepidoptera pests with eucalyptus plantations mainly of primary pests. In this study was register at least 12 species of Lepidoptera defoliators of eucalypt primary pests (Geometridae: *Thyrinteina arnobia*, *Thyrinteina leucocerae*, *Glena* sp., *Oxydia vesulia*, *Stenalcidia grossica* and *Sabulodes caberata*; Notodontidae: *Nystaleanyseus* e *Blera varana*, Arctiidae: *Eupseudosoma involuta* and *Eupseudosoma aberrans*, Lymantriidae: *Sarsina violascens* and Eupterotidae: *Apatelodes sericea*). These species were register in different areas of Brazil (Guedes *et al.*, 2000; Zanuncio *et al.*, 1998a; Bragança *et al.*, 1998b).

The large number of primary pests indicate more specialized herbivores are favored by higher quantity of food in these crops which could be associated with reduced pressure of natural enemies thus can increasing their damage to these plants. On the other hand these herbivores have more difficulties to find and to colonize their host plants in more heterogeneous environments where food is scarcer and survival and persistence of natural enemies are higher (Bragança *et al.*, 1998a; 1998b; Zanuncio *et al.*, 1998a).

The high number of individuals of the primary pests underscores the importance of a relatively small group of lepidopteran species in eucalypt cultivation in Brazil. These species are native of Brazil where they may originally feed on native Myrtaceae but they can increase their populations in eucalyptus plantations. That high number of individuals of the primary pests

Table 1. State, original vegetation, latitude, longitude, altitude, planted species, spacing, age of the plants at the beginning of the collection period, sampling period and number of traps used in the areas of Três Marias and Guanhães (Minas Gerais State), Monte Dourado (Pará State) and Niquelândia (Goiás State), Brazil

General characteristics	Três Marias	Guanhães	Monte Dourado	Niquelândia
State	Minas Gerais	Minas Gerais	Pará	Goiás
Original vegetation	Savannah	Atlantic Forest	Amazonian Forest	Savannah
Latitude	$18^0$10'S	$18^0$39'S	$00^0$42'S	$14^0$20'S
Longitude	$45^0$00'W	$42^0$57'W	$52^0$38'W	$48^0$43'W
Altitude (m)	590m	875m	122m	610m
Species planted	*E. urophylla*	*E. grandis*	*E. urophylla*	*Eucalyptus* spp.
Spacing (m)	3 x 2 m	3 x 2 m	3 x 2 m	3 x 2 m
Initial age	24 months	54 months	16 months	36 months
Period of collection	06/89 a 05/94	06/89 a 05/94	06/92 a 05/97	06/91 a 05/96
Number of traps	5	5	4	5

Table 2. Variation coefficient (VC), number of species of Lepidoptera primary pests (PP), all species of Lepidoptera (TE), percentage of species of the Lepidoptera primary pests (% PP) and of individuals of the primary pests in relation to the total number of individuals (% PPI) per year and during five years in the areas of Três Marias and Guanhães, Minas Gerais State, Monte Dourado, Pará State and Niquelândia, Goiás State, Brazil

Regions	Individuals	Year of collection					
		1º	2º	3º	4º	5º	Total
	TE	262	215	396	419	485	731
Três Marias	PP	7	8	9	11	12	12
VC= 383.79	%PP	2.67	3.72	2.27	2.633	2.48	1.64
	%PPI	29.39	83.61	79.14	51.88	51.85	66.32
	TE	492	538	399	538	588	804
Guanhães	PP	10	11	11	11	12	12
VC= 94.61	%PP	2.03	2.04	2.76	2.04	2.04	1.49
	%PPI	25.27	18.91	15.58	25.36	14.37	19.96
	TE	243	404	297	337	236	578
Monte Dourado	PP	9	11	11	11	12	12
VC= 419.09	%PP	3.70	2.72	3.70	2.26	3.81	2.08
	%PPI	16.38	16.72	12.95	23.39	76.82	39.78
	TE	205	285	322	280	298	459
Niquelândia	PP	10	10	10	11	11	11
VC= 437.60	%PP	4.85	3.51	3.10	3.93	3.69	2.40
	%PPI	53.22	21.15	73.56	27.72	35.46	54.45

is related to low plant diversity. Areas with larger plant diversity usually sustain a lower number of pest species (Andow, 1991) because herbivores have more difficulties to find and to colonize their host plants in such conditions (Zanuncio *et al.*, 1998a) In addition, their natural enemies can have higher survival rates due to better pollen, nectar and alternative prey supply in these areas (Zanuncio *et al.*, 1998a; Andow, 1991).

The Lepidoptera primary pests comprised 83.61% and 79.14% (% PPI) of the individuals collected in the second and third years, respectively, in Três Marias and 76.82% and 73.56% in the fifth and third years in Monte Dourado and Niquelândia, respectively. The percentage of individuals of the primary pests had lower variations in Guanhães where it represented 14.37 to 25.36% of the insects collected in the fifth and fourth years, respectively (Table 2).

The area of Niquelândia presented higher variations (VC= 437.60) with irregular distribution of the number of individuals per year of the primary pest species, followed by Monte Dourado and Três Marias (Table 2). On the other hand, the area of Guanhães had a more homogeneous distribution of the number of individuals per period. Analysis of historical records outbreaks in Quebec over the 1938-2002 period indicates six outbreak cycles, with a 9-year cycle Insect pests, usually, present periods of low and high populations (Pereira *et al.*, 2008). On the other hand, endemic populations or rare species present more stable numbers (Wallner, 1987). Analysis of historical records outbreaks in Quebec over the 1938-2002 periods indicates six outbreak cycles, with a 9-year cycle. Six major defoliations could be identified and individual outbreaks tended to span only 36.6% (±13.1% S.E.) of the total area, suggesting they terminated before attaining their maximum potential extent (Cooke & Lorenzetti, 2006). A total of 534 species of Lepidoptera was reported feeding on 69 tree species in Papua, New Guinea with one species presenting 48% of the individuals collected (Novotny *et al.*, 2002). Different areas in Brazil such as Montes Claros, Minas Gerais State, Brazil presented similar results where eight species of primary pests comprised 54% of the annual number of individuals collected in eucalypt plantations (Pereira *et al.*, 2001). The values reinforce the importance of the Lepidoptera primary pests to eucalypt especially in the region of Três Marias and Niquelândia.

The low number of individuals of the primary pests and highest abundance of species collected indicate a better ecological stability in Guanhães. Areas of native vegetation where the diversity of food and refuge for different insect species is higher surrounded the plantation in this region. This also helps the biological control agents which can lead to a great number of species but with a low number of individuals per species, including those considered pests of eucalypt. A similar situation was observed in the areas of São Mateus and Aracruz, Espírito Santo State, Brazil where the primary pests comprised 30.52% of the individuals collected (Bragança *et al.*, 1998a). The presence of areas with native plants, which are sources of natural enemies of Lepidopotera defoliators (Freitas *et al.*, 2005) can explain the fact that the primary pest species did not reach an unbalanced level in Guanhães such as reported for Aracruz, Espírito Santo State (Bragança *et al.*, 1998a, Zanuncio *et al.*, 1998b). However, the presence of the primary pest species at endemic levels can indicate possibilities of outbreaks because the eucalypt plantations are under constant modifications. Population peaks or outbreaks of pests in temperate and tropical areas are, in general, preceded by stress conditions to plants such as dry periods (Thomson *et al.*, 1984).

These situations can hinder defense mechanisms in eucalyptus plants against herbivorous insects, which include the presence of essential oils and secondary compounds (tannins and phenols) and liberation of volatile (semiochemicals) to attract natural enemies (Ohmart & Edwards, 1991). Eucalyptus species are native to Australia, Indonesia, Papua New Guinea and Philippines (Ohmart & Edwards, 1991) and they belong to the Myrtaceae family. This can explain the adaptation of insects which feed at endemic levels on native plants in reforestations areas of eucalyptus in Brazil (Zanuncio *et al.*, 2001). For this reason it is important to maintain plantations of eucalyptus in good physiological conditions which may increase their defense systems.

The age of the eucalypt plants, between 16 and 54 months from the beginning of this study (Table 1) and the rainfall and temperature did not present significant correlations with the number of primary pests ($P > 0.05$) (Table 3) except a positive correlation between the age of the eucalypt plants and the number of individuals collected in Três Marias. On the other hand, the Lepidoptera primary pests presented higher numbers of individuals from February to July and in December in Três Marias, which coincides with the end of the rainy period and the beginning of the dry season in these areas (Fig. 1). Highest population peaks of these species were registered in April and June 1991 and May 1994 (2,373; 4,111 and 1,185 individuals per trap, respectively) when the eucalyptus plants were 48 and 84 months old (Fig. 1). The number of individuals of the Lepidoptera primary pests was higher from April to October in Monte Dourado. The highest population

peaks of the primary pests in this area were recorded when the eucalypt plants were five years old with the collection of 1,522 individuals/trap in September 1996 at the end of the rainy period (Fig. 1). The primary pests showed a higher number of individuals from January to June in Niquelândia with 1,579 individuals/ trap in May 1994 when the plants were 72 months old (Fig. 1). Again, the highest number of individuals of the Lepidoptera pests was found at the end of the rainy season and at the beginning of the dry periods (Fig. 1). The primary pests showed the largest number of individuals from June to October, during the dry months, but without accentuated population peaks in Guanhães (Fig. 1).

Table 3. Correlation coefficient (r) between the population fluctuation of the Lepidoptera primary pests and the month rainfall, the monthly average temperature and the age of eucalypt plants in the areas of Três Marias and Guanhães (Minas Gerais State), Monte Dourado (Pará State) and Niquelândia (Goiás State), Brazil during five years

Regions	Rainfall	Monthly Average Temperature	Plant Age
Três Marias	- 0.0911 $^{ns.}$	0.0575 ^{ns}	0.2722 *
Guanhães	- 0.0942 ^{ns}	- 0.0702 ^{ns}	- 0.1447 ^{ns}
Monte Dourado	0.1574 ^{ns}	0.1271 ^{ns}	0.0345 ^{ns}
Niquelândia	- 0.0832 ^{ns}	- 0.1162 ^{ns}	- 0.1027 ^{ns}

Ns = non-significant with t-test at 5% probability level
* = significant with t-test at 5% probability level

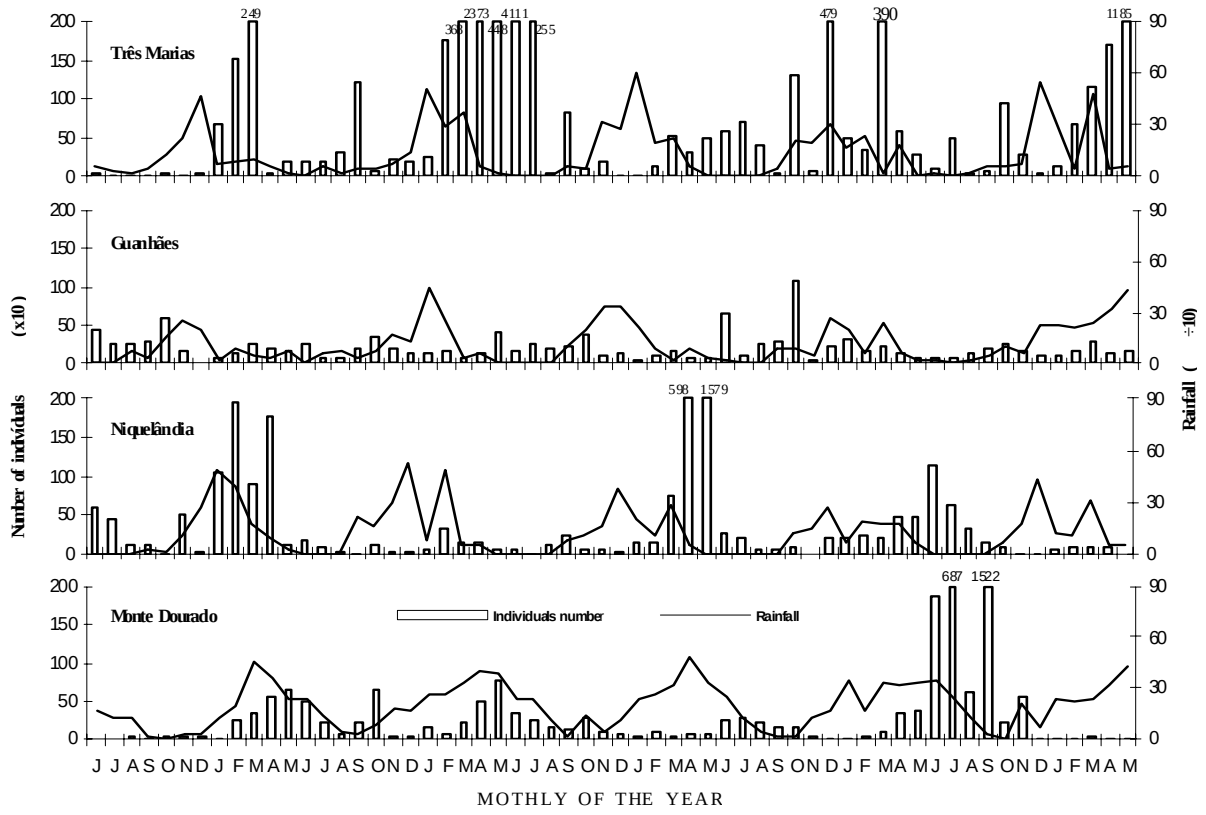

Fig. 1. Number of individuals of the primary pests and rainfall in the areas of Três Marias and Guanhães (Minas Gerais State), Niquelândia (Goiás State) and Monte Dourado (Pará State), Brazil during the 60 months of the collecting period

Timing of population cycle forest tent caterpillar over the period 1938-2002 in Canada showed a variance between regions. Although they appeared predictable, at least within the core regions, the levels of defoliation were unpredictable and may be modulated by factors yet to be identified (Cooke & Lorenzetti, 2006). The temperature seems to be the most important factor affecting defoliator species in temperate areas where the intense cold can kill these insects (Cooke & Roland, 2003; Cooke & Roland, 2000) but periods of higher temperatures can favor their populations (Levesque *et al.*, 2002). In Brazil, most of the areas present high daily mean temperatures during the whole year (above 20ºC). For this reason, this factor may have a low impact on the occurrence of Lepidoptera pests such as evidenced by the lack of correlation between these parameters. No significant correlation ($P > 0.05$) between population peaks of the primary pest species and the rainfall were observed, but the largest numbers of individuals collected for these species coincides with periods of water deficit in the areas studied. This tendency has been observed for other regions, such as the Alto São Francisco, Belo Oriente and Santa Barbara, Minas Gerais State and Niquelândia, Goiás State (Freitas *et al.*, 2005; Zanuncio *et al.*, 1998b).

The area of Monte Dourado is characterized by equatorial climate (Amazonian) with abundant and regular raining defined by a dry period (low hydric deficit). Native forests surround the plantations in this area, with high diversity and better conditions for the biological control of pests (Zanuncio *et al.*, 1992). The other areas are characterized by tropical climate. The Atlantic forest was the original vegetation in Guanhães before pasture was planted and later the eucalypt. The altered relief in this area favored the planting of homogeneous stands of eucalyptus in the valleys separated by areas with natural vegetation in the steepest hillsides and streams in the bottom of the valleys. Such conditions can limit the occurrence of outbreaks of Lepidoptera pests due to the action of natural enemies. On the other hand, the areas of Três Marias and Niquelândia present a defined raining period and water deficit (low variations between the start and end of these seasons). Besides, they are located in plane areas of the Brazilian savannah, favoring the plantations of extensive homogeneous stands and occurrence of outbreaks of Lepidoptera pests. The rainfall seems to be the key climatic factor affecting the occurrence of most defoliator primary pests of the eucalypt because their outbreaks are associated with the dry season, although no positive correlation with rain and primary pest numbers were observed. Patterns of occurrence of eucalyptus pest species can be affected by climatic factors along time and space and it can help to define periods of higher populations of these species and to reduce monitoring and control costs. Besides, it can facilitate introduction of natural enemies to maintain pest populations below levels of economic damage (Zanuncio *et al.*, 2001; Bragança *et al.*, 1998a; Bragança *et al.*, 1998b).

Periods of lepidopteran pest occurrence have been associated with host plant age (Freitas *et al.*, 2004). This was showed for *Stenalcidia grossica* Schaus (Lepidoptera: Geometridae) which preferred younger eucalyptus plants of about 54 months old while *Glena unipennaria* Guenée (Lepidoptera: Geometridae) presented higher populations on 60 months old plants (Freitas *et al.*, 2005). The age of the trees (72 to 84 months old) and the average temperature (18ºC) were the main environmental factors favoring the abundance of individuals of *S. grosica* in Santa Bárbara, Minas Gerais State (Guedes *et al.*, 2000). However, other factors such as the area, eucalyptus species and the intensity of herbivore previous to population peaks can influence the occurrence of outbreaks of Lepidoptera defoliators in eucalypt plantations (Freitas *et al.*, 2005; Guedes *et al.*, 2000).

CONCLUSION

It is important to train the technicians of the forestry companies on aspects relating to the climate and region, besides the type of vegetation when collecting insects and defining the time and period of occurrence. Caterpillars of primary pest species of eucalypt had the majority of their individuals collected during months of low raining intensity in Monte Dourado, Niquelândia and Três Marias regions. This indicates that monitoring of these insects should start at the beginning of the dry season.

Três Marias and Niquelândia presented the most favorable conditions for the development of populations of Lepidoptera defoliators, where problems with these insects may occur. Monte Dourado can, eventually, present outbreaks of these pests, but the climatic conditions and the diversified native vegetation surrounding the plantations can favor the natural biological control. Guanhães seems to have a better biological condition with few possibilities of occurrence of outbreaks of Lepidoptera defoliators of eucalypts. The Guanhães region, therefore, did not favor outbreaks of Lepidoptera defoliators of eucalypt, what may be explained by native vegetation areas surrounding its eucalypt plantation. The distribution of these areas may represent a good strategy to prevent the occurrence of outbreaks of Lepidoptera defoliators of eucalypt. The Guanhaes region, therefore, did not support outbreaks of Lepidoptera defoliators of eucalypt.

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