Environmental Determinants Affecting the Occurrence of Defoliator Caterpillars on Eucalyptus (Myrtaceae) plantations in the Brazilian Amazonian Region

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Source: Florida Entomologist, 101(3) : 480-485

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.101.0306

Environmental determinants affecting the occurrence of defoliator caterpillars on *Eucalyptus* (Myrtaceae) plantations in the Brazilian Amazonian region

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Abstract

Lepidoptera defoliators can be very damaging to eucalyptus plantations in Brazil. The objective of this study was to evaluate how plant age, the number of rotations, the tree growth rate (m^3 of wood per ha per yr), the distance of native vegetation strips from the eucalyptus plantations, and the width of these strips affect the population dynamics of Lepidoptera defoliators in eucalyptus crops. The survey of the lepidopteran species was conducted fortnightly from Sep 1992 to Aug 1994 using light traps in *Eucalyptus urophylla* S. T. Blake (Myrtaceae) plantations in 4 areas of the Brazilian Amazon region. In total, 1,049, 1,096, 1,020, and 853 Lepidoptera species with 4,413, 3,457, 3,226, and 2,222 individuals and 11, 11, 11, and 10 species of primary pests were recorded. The primary pest species were represented by 272, 772, 963, and 411 individuals, corresponding to 1.1, 1.0, 1.1, and 1.2% of the species and of 6.2, 22.3, 29.8, and 18.5% of the individuals collected in the 4 areas, respectively. *Eupseudosoma aberrans* Schaus (Arctiidae), *Eupseudosoma involuta* Sepp (Arctiidae), *Nystalea nyseus* Cramer (Notodontidae), *Oxydia vesulia* Cramer (Geometridae), *Stenalcidia grosica* Schaus (Geometridae), and *Thyrinteina arnobia* Stoll (Geometridae) were the most abundant and represent 83.2% of primary pests species. The number of individuals of the primary pest species were not correlated with plant age, the number of rotations, the distance of native vegetation strips from the eucalyptus plantations, and the width these strips, but the total number of individuals of defoliating Lepidoptera had an inverse correlation with the growth rate (m^3 of wood per ha per yr) of eucalyptus plants.

Key Words: biological control; eucalypt; forest pest; light trap; monitoring; population dynamics

Resumo

Lepidópteros desfolhadores podem ser muito prejudiciais em cultivos de eucalipto no Brasil. O objetivo desse trabalho foi estudar o efeito da idade das plantas, número de rotações, crescimento das árvores (m^3/hectare/ano), distância das faixas de vegetação nativa das plantações de eucalipto e largura dessas faixas sobre a flutuação populacional de lepidópteros desfolhadores em cultivos de eucalipto. O levantamento das espécies de lepidópteros desfolhadores foi realizado, quinzenalmente, com armadilhas luminosas de setembro de 1992 a agosto de 1994 em cultivos de *Eucalyptus urophylla* S. T. Blake (Myrtaceae) em 4 áreas da região Amazônica do Brasil. Um total de 1049, 1096, 1020 e 853 espécies de lepidópteros com 4413, 3457, 3226 e 2222 indivíduos, sendo 11, 11, 11 e 10 espécies de pragas primárias foi registrado. As espécies de pragas primárias foram representadas por 272, 772, 963 e 411 indivíduos, correspondendo a 1,1; 1,0; 1,1 e 1,2% das espécies e a 6,2; 22,3; 29,8 e 18,5% dos indivíduos coletados, nas 4 áreas, respectivamente. *Eupseudosoma aberrans* Schaus (Arctiidae), *Eupseudosoma involuta* Sepp (Arctiidae), *Nystalea nyseus* Cramer (Notodontidae), *Oxydia vesulia* Cramer (Geometridae), *Stenalcidia grosica* Schaus (Geometridae) e *Thyrinteina arnobia* Stoll (Geometridae) foram as mais abundantes, com 83,2% das espécies de pragas primárias. O número de indivíduos de espécies de pragas primárias não se correlacionaram com a idade das plantas, número de rotações, distância das faixas de vegetação nativa das plantações e a largura dessas faixas, mas o número total de indivíduos de lepidópteros desfolhadores teve correlação inversa com o crescimento (m^3/hectare/ano) das plantas de eucalipto.

Palavras Chave: controle biológico, eucalipto, praga florestal, armadilha luminosa, monitoramento, dinâmica populacional

The study of factors affecting insect pest outbreaks is important in developing integrated management programs with reduced costs and adverse impacts. Environmental factors such as plant age and the diversity of the agro-ecosystem can affect populations of insect pests (Crocomo 1990).

Lepidoptera are among the most frequently used bio-indicators for monitoring ecosystems (Hilty & Merenlender 2000) and understanding environmental changes (Sparrow et al. 1994). They also are among the most destructive insects in affecting plant establishment, and can they be sampled easily (Axmacher & Fiedler 2004; Brehm & Axmacher 2006; Hawes et al. 2009).

Light traps are commonly used for monitoring, collecting, and defining methods of controlling insects. These traps have been used to

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evaluate Lepidoptera populations in eucalyptus crops (Pereira et al. 2001; Zanuncio et al. 1993, 2001a,b, 2003, 2014a), native forests (Ignatov et al. 2011; Santos et al. 2015; Vieira et al. 2015), and grazing areas (Delfina & Teston et al. 2013). They also are effective in the assessment of biodiversity. For example, in Altamira, Pará, Brazil, in a primary forest area, 78 species of Arctiinae were collected with 12 of them being new records (Teston et al. 2012). In Tijucas do Sul, Paraná, Brazil, 124 species of Bombycoidea were collected in a mixed rain forest (montane), with 10 new species records for this state (Santos et al. 2015).

The objective of this study was to observe the effects of plant age, number of rotations, tree growth (m^3 of wood per ha per yr), distance of native vegetation strips from the eucalyptus plantations, and width of these strips on the population dynamics of Lepidoptera defoliators in *Eucalyptus urophylla* S. T. Blake (Myrtaceae) plantations in 4 areas of the Amazonian region of Brazil.

Materials and Methods

STUDY SITE

The population fluctuation of Lepidoptera defoliators was studied from Sep 1992 to Aug 1994 in *E. urophylla* plantations established in 4 areas of the Amazonian region of Brazil (Ponte Maria in Mar 1991, Pacanari in Mar 1992, and Caracurú and Felipe in Mar 1990; Table 1). The first 3 were in the municipality of Almeirim, Pará State, and the last in the municipality of Laranjal do Jari, Amapá State, in a region of tropical humidity climate, with an average distance of 50 km between them at latitudes from 1.00° to 2.00°S and longitudes of 52.00° to 53.00°W.

EVALUATION AND INSTALLATION OF LIGHT TRAPS AND IDENTIFICATION OF INSECTS

Defoliating Lepidoptera were collected in traps with 55 amp blacklights powered by 12 V batteries. Four traps were fixed in wooden supports (1 per area) at the midpoint between 4 eucalyptus trees at 2 m height (Lara et al. 1977). The traps were installed fortnightly at 6:00 PM and withdrawn early in the next morning when they were turned off. A plastic bag (45 × 75 cm) was fixed at the base of each trap; it contained pieces of paper and a jar with ethyl acetate to kill the captured insects and reduce morphological damage (Ferreira & Martins 1982).

The insects collected were removed from the plastic bags, separated by size, packed in entomological envelopes (15 × 15 cm) lined with cotton, and identified with the date and place of collection. These insects were transported to the Universidade Federal de Viçosa (UFV) in Viçosa, Minas Gerais State, Brazil, where they were quantified, assembled, identified, and characterized as pests of eucalyptus based on the collection of the Regional Museum of Entomology (UFVB) (Zanuncio et al. 1993, 1994, 2003).

DATA ANALYSES

Pearson correlation and regression analyses were used to relate the numbers of individuals and Lepidoptera defoliator species with the plant age (yr), the number of rotations (2nd, 3rd, and 5th) (number of times the trees had been harvested since the plantation was initiated), the growth rate (m^3 of wood per ha per yr) of eucalyptus plants, the distance (km) of native vegetation strips from the eucalyptus plantations, and the width (m) of these strips. The significance of the linear correlation between variables (r) was determined at the 5% level of probability (SAS Institute Inc. 2002–2003).

Results

In total, 1,049, 1,096, 1,020, and 853 Lepidoptera species with 4,413, 3,457, 3,226, and 2,222 individuals were collected in the areas of Ponte Maria, Pacanari, Caracurú, and Felipe, respectively, including 11, 11, 11, and 10 primary pest species with 272, 772, 963, and 411 individuals. These values corresponded to 1.1, 1.0, 1.1, and 1.2% of the total number of species, and 6.2, 22.3, 29.8, and 18.5% of those individuals collected in the 4 areas (Table 2).

The percentage of primary pest species ranged from 1.0 to 1.2%, but the individuals of the group represented 6.2 to 29.8% of the total collected in the areas of Ponte Maria, Pacanari, Caracurú, and Felipe. *Eupseudosoma aberrans* Schaus (Arctiidae), *Eupseudosoma involuta* Sepp (Arctiidae), *Nystalea nyseus* Cramer (Notodontidae), *Oxydia vesulia* Cramer (Geometridae), *Stenalcidia grosica* Schaus (Geometridae),

Table 1. Locale and characteristics of Ponte Maria, Pacanari and Caracurú in Almerim Municipality, Pará State, and of Felipe, in Laranjal do Jari Municipality, Amapá State, Brazil, cultivated with *Eucalyptus urophylla* (Myrtaceae).

	Area			
Characteristic	Ponte Maria	Pacanari	Caracurú	Felipe
Latitude	0.79556°S	0.60361°S	0.53778°S	0.90528°S
Longitude	52.78861°W	52.61611°W	52.85944°W	52.36556°W
Altitude (m)	88	126	110	164
Source of eucalyptus seeds (SPA)[a]	Flores	Flores	Flores	Timor
Spacing between plants (m)	3.0 × 2.0	3.0 × 2.0	3.0 × 2.0	2.5 × 2.0
Date of planting	Mar 1991	Mar 1992	Mar 1990	Mar 1990
Topography type	Wavy	Plane	Wavy	Plane
Average annual rainfall (mm)	2,276.0	2,066.5	1,988.0	2,276.0
Average annual temperature (°C)	27.3	27.5	28.0	27.5
Average annual relative humidity (%)	84.0	—[c]	86.6	84.0
Distance (m) of native vegetation strips from eucalyptus plantation[b]	2,600	5,300	4,300	800
Width (m) of native vegetation strips[b]	700	50,000	2,100	600
Soil type	LA6	LU1	LA6	LA1
Vegetation type	Sparse	Dense	Dense	Sparse

[a]SPA: Seed production area.
[b]Relative to position of light trap.
[c]A dash (—) indicates data were not collected.

Table 2. Total numbers and percentages of individuals of the principal Lepidoptera defoliator species in 4 areas with *Eucalyptus urophylla* (Myrtaceae) plantations in Pará and Amapá states, Brazil.

	Ponte Maria		Pacanari		Caracurú		Felipe			
Lepidoptera	Total	%	Total	%	Total	%	Total	%	Total	%
Arctiidae										
Eupseudosoma aberrans Schaus	41	9.9	120	29.1	200	48.4	52	12.6	413	17.1
Eupseudosoma involuta Sepp	32	7.1	120	26.5	264	58.3	36	8.1	452	18.7
Saturniidae										
Dirphia rosacordis Walker	6	24.0	1	4.0	12	48.0	6	24.0	25	1.0
Notodontidae										
Misogada bleura Schaus	19	11.2	28	16.5	93	54.7	30	17.6	170	7.0
Nystalea nyseus Cramer	12	5.3	53	23.1	151	65.9	13	5.7	229	9.5
Psorocampa denticulata Schaus	2	18.2	1	9.1	8	72.7	0	0.0	11	0.5
Lymantriidae										
Sarsina violascens Herrich-Schäffer	20	16.7	11	9.2	26	21.6	63	52.5	120	5.0
Geometridae										
Oxydia vesulia Cramer	38	16.5	36	15.6	38	16.5	119	51.4	231	9.6
Stenalcidia grosica Schaus	54	15.8	96	27.8	127	36.6	69	19.8	346	14.3
Thyrinteina arnobia Stoll	40	11.9	267	79.2	26	7.7	4	1.2	337	14.0
Glena sp. Hulst	8	9.5	39	46.4	18	21.4	19	22.7	84	3.5
Total individuals	4,413	33.1	3,457	26.0	3,226	24.2	2,222	16.7	13,318	100
Individuals of primary pest species	272	6.2	772	22.3	963	29.8	411	18.5	2,418	100
Number of species	1,049	26.1	1,096	27.3	1,020	25.4	853	21.2	4,018	100
Primary pest species	11	1.1	11	1.0	11	1.1	10	1.2	2,418	100

and *Thyrinteina arnobia* Stoll (Geometridae) were the most abundant, comprising 83.2% of primary pest species (Table 2). *Eupseudosoma aberrans* and *E. involuta*, species with similar biological features, were most abundant in Caracurú, with 48.4 and 58.3% of the total number of primary pest individuals, as compared with 29.1 and 26.5%, 9.9 and 7.1%, and 12.6 and 8.1% of the individuals collected in Pacanari, Ponte Maria, and Felipe, respectively (Table 2). *Misogada bleura* Schaus (Notodontidae) and *N. nyseus* were most abundant in Caracurú with 54.7 and 65.9%, respectively, of the primary pest species individuals collected in the area. *Misogada bleura* comprised 11.2 and 17.6% of individuals of Ponte Maria and Felipe, respectively (Table 2). *Oxydia vesulia* and *Sarsina violascens* Herrich-Schäffer (Lymantriidae) comprised the highest percentages of individuals in Felipe (51.4 and 52.5%, respectively), whereas *Dirphia rosacordis* Walker (Saturniidae) was most abundant in Ponte Maria (24.0%), *S. grosica* in Caracurú (36.6%), and *T. arnobia* in Pacanari (79.2%) (Table 2).

Correlation and regression analyses of *O. vesulia* and *S. violascens* individuals versus the number of eucalyptus rotations revealed positive ($r = 0.63$; $P < 0.001$) and negative ($r = -0.64$; $P < 0.001$) relationships, respectively (Table 3; Fig. 1). The total number of individual Lepidop-

Table 3. Pearson correlation values between the total numbers of individuals and of the principal species of Lepidoptera defoliators in 4 areas cultivated with *Eucalyptus urophylla* (Myrtaceae) in Pará and Amapá states, Brazil, with plant age (A), the number of rotations (B), the tree growth (m^3 of wood per ha per yr) (C), the distance of native vegetation strips from the eucalyptus plantations (D), and the width these strips (E).

Lepidoptera	A	B	C	D	E
Total individuals	0.42	0.32	−0.72*	0.33	0.18
Individuals of primary pest species	0.00	0.41	0.20	0.69*	0.01
Arctiidae					
Eupseudosoma aberrans Schaus	−0.11	0.25	0.03	0.56	0.08
Eupseudosoma involuta Sepp	−0.19	0.20	−0.04	0.58	0.26
Saturniidae					
Dirphia rosacordis Walker	0.10	0.01	0.03	0.04	0.04
Notodontidae					
Misogada bleura Schaus	−0.40	−0.51	0.51	−0.63*	−0.05
Nystalea nyseus Cramer	−0.08	0.16	0.09	0.36	−0.37
Psorocampa denticulata Schaus	0.02	0.06	0.03	0.05	0.01
Lymantriidae					
Sarsina violascens Herrich-Schäffer	−0.57	−0.64*	0.44	−0.68*	−0.25
Geometridae					
Oxydia vesulia Cramer	0.60	0.63*	0.14	0.48	−0.07
Stenalcidia grosica Schaus	−0.36	−0.09	−0.03	0.23	−0.02
Thyrinteina arnobia Stoll	−0.17	0.09	−0.05	0.35	0.19
Glena sp. Hulst	0.29	0.37	0.29	0.29	−0.26

*Significance at 5% probability by the *t*-test.

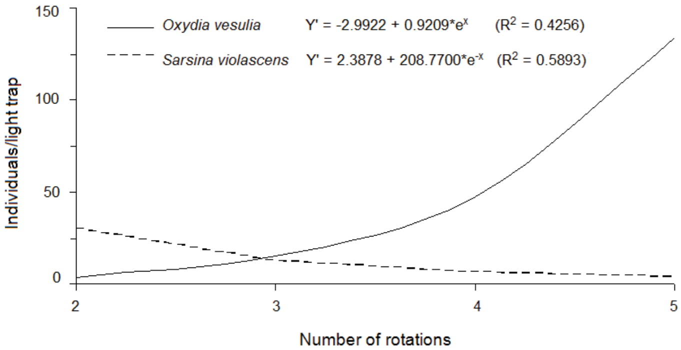

Fig. 1. Number of *Oxydia vesulia* (Lepidoptera: Geometridae) and *Sarsina violascens* (Lepidoptera: Lymantriidae) adults collected with light traps in *Eucalyptus urophylla* (Myrtaceae) plantations as a function of the number of rotations of this plant in the same area. (Almeirim Municipality, Pará State, and Laranjal do Jari Municipality, Amapá State, Brazil).

tera specimens collected was not correlated with plant age, number of rotations, distance of native vegetation strips from the eucalyptus plantations, and width these strips (Table 3). The most negative relationship was found between the average annual growth of eucalyptus trees with the total number of individuals of defoliating Lepidoptera ($r = -0.72$; $P < 0.001$) (Table 3; Fig. 2). Total numbers of individuals of primary pest species were not correlated with plant age, number of rotations, growth of eucalyptus trees, and width of native vegetation strips (Table 3), but they were positively correlated ($r = 0.69$; $P < 0.001$) with the distance of these strips from eucalyptus plantations. Correlation and regression analyses showed that the species *M. bleura* and *S. violascens* were negatively correlated ($r = -0.63$; $P < 0.001$ and $r = -0.68$; $P < 0.001$, respectively) with this parameter (Table 3; Fig. 3).

Discussion

The number of species of lepidopteran defoliators of eucalyptus in the Amazon region was similar to that reported for other areas of Brazil (Pereira et al. 2001; Zanuncio et al. 2003). This finding indicates that eucalyptus insect pests exist throughout the country, although their population densities depend on the presence of this crop. The 4 main species of lepidopteran pests of eucalyptus (*E. aberrans*, *E. involuta*, *S. grosica*, and *T. arnobia*) found in this region are generally those reported as the most harmful to eucalyptus in other regions of Brazil (Zanuncio et al. 1994).

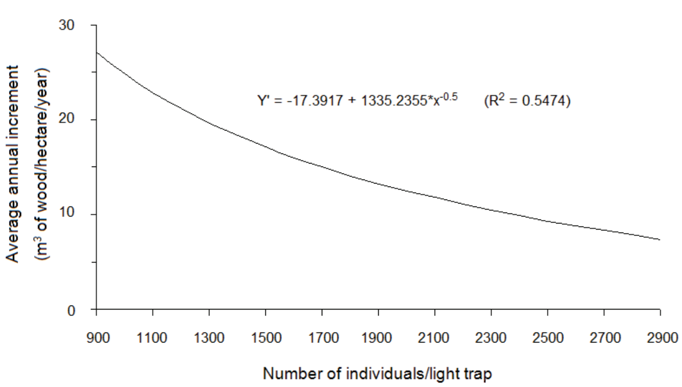

Fig. 2. Average annual growth of *Eucalyptus urophylla* (Myrtaceae) trees (m^3 of wood per ha per yr) as a function of the total number of Lepidoptera individuals collected per light trap (Almeirim Municipality, Pará State, and Laranjal do Jari Municipality, Amapá State, Brazil).

The low diversity of species and the large number of the individuals of primary pests may be related to increased supply of food in eucalyptus cultivation (Zanuncio et al. 1998), or reduced or insufficient natural biological control of their populations. Modified ecosystems are simpler than natural ones, with a stable food supply available and lower impact by natural enemies, factors that favor the development and multiplication of pest insects such as defoliating caterpillars (Price 1984; Bragança et al. 1998; Zanuncio et al. 1998). On the other hand, the implementation and maintenance of complex ecosystems with high numbers of species favor the biological control of these pests (Botham et al. 2015).

The lower percentages of primary pest individuals in Ponte Maria (6.2 %) and Felipe (18.5 %) than in Pacanari (22.3 %) and Caracurú (29.8 %) suggest that the benefits of native vegetation in these areas may enhance in the biological control of Lepidoptera defoliators of eucalyptus. Light traps 1 and 4, the nearest to these native areas, had the lowest percentages of individuals of the primary pests. Native vegetation areas can provide ecological corridors that facilitate the dispersal of natural enemies to eucalyptus plantations (Altieri 1999). This effect was demonstrated in the Cerrado and Amazonian regions, where fewer Lepidoptera pests were captured in eucalyptus plantations with adjacent strips of native vegetation (Bragança et al. 1998; Zanuncio et al. 2014b). The numbers of primary pest individuals were lower, and those of natural enemies higher, near native areas (remnants of Atlantic Forest) compared with the interior of eucalyptus plantations (Bragança et al. 1998; Zanuncio et al. 1998). These findings show the importance of native vegetation as an environmental manipulation mechanism to reduce populations of eucalyptus-defoliating species.

The positive correlation between the number of rotations on eucalyptus plantations and the number of *O. vesulia* individuals shows that populations of this species may increase with the time of cultivation of plants in the same area. In addition, the increase in the number of rotations of the culture may reduce the soil fertility, leaving the plants more susceptible to pests and diseases. This correlation indicates the importance of monitoring for pest insects and of silvicultural treatments such as the removal of lower branches to cultivate forests with high productivity and low pest susceptibility. On the other hand, the negative correlation between the number of *S. violascens* individuals with the number of rotations suggests differences in the behavior of eucalyptus-defoliating species that may become pests throughout the crop cycle.

The presence of dense undergrowth in eucalyptus stands at Pacanari and Caracurú, where traps 2 and 3 were placed, respectively, was not enough to foster adequate natural biological control of Lepidoptera pests, although this lack of natural control may also be due to the great distance from areas of native vegetation (Thomas et al. 2001; Teja & Roland 2004). The negative correlation ($r = -0.72$; $P < 0.001$) between the total number of individual Lepidoptera defoliators and the annual growth of eucalyptus plants indicates that low growth rate may favor the multiplication of these insects. However, the abundance of these defoliating insects could also be related to this reduction in growth. This correlation confirms reports that most of the outbreaks of Lepidoptera defoliators were observed in eucalyptus plantations with low productivity, such as those in sandy soils or with non-adapted clones and species (Zanuncio et al. 2003, 2014a). Furthermore, these reports reinforce the importance of selecting plants with good quality genotypes, especially those adapted to growth in various soil types and those resistant or tolerant to damage by pests and diseases (Silva et al. 2013).

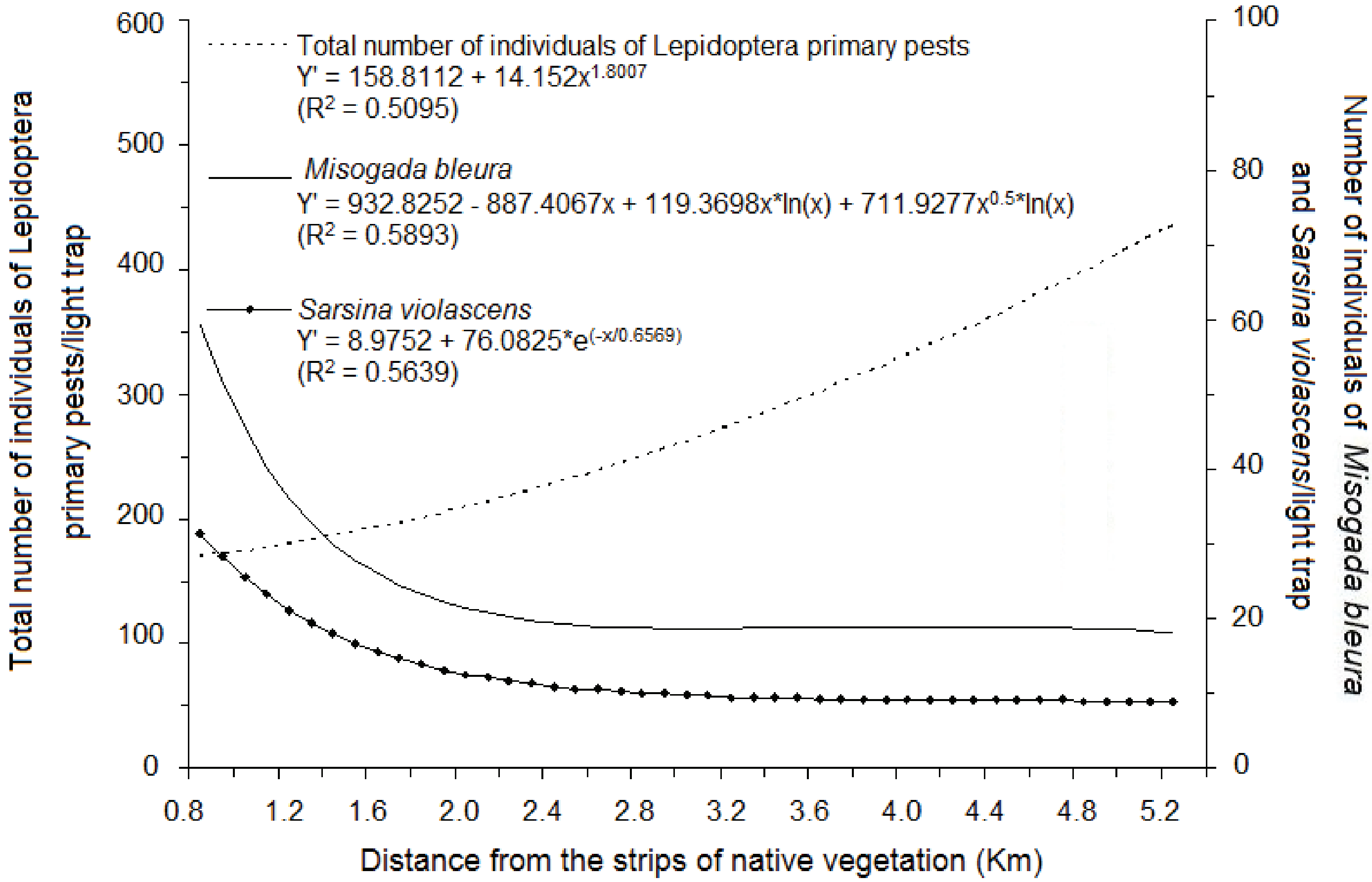

Fig. 3. Total number of individuals of the 2 Lepidoptera primary pests, *Misogada bleura* (Lepidoptera: Notodontidae) and *Sarsina violascens* (Lepidoptera: Lymantriidae), collected with light traps in *Eucalyptus urophylla* (Myrtaceae) plantations as a function of the distance from the area of native vegetation (Almeirim Municipality, Pará State, and Laranjal do Jari Municipality, Amapá State, Brazil).

The positive correlation ($r = 0.69$; $P < 0.001$) between the number of individuals of primary pests and the distance from the native vegetation to eucalyptus plantations may indicate that more diverse vegetation may result in more numerous natural enemies, which can suppress pest species in the eucalyptus plantations (Bragança et al. 1998; Zanuncio et al. 1998). Previous research has shown that Hymenoptera natural enemies were more abundant at the edge of eucalyptus plantations adjacent to native forests and inside native forests than inside eucalyptus plantations (Freitas et al. 2002). The abundance of Hymenoptera parasitoids was also higher at the edge of native vegetation adjacent to eucalyptus plantations compared with their abundance inside these plantations (Dall'oglio et al. 2003). Strips of native vegetation can increase the diversity and abundance of natural enemies and their effectiveness in biological control (Zanuncio et al. 1998; Freitas et al. 2002). The region of eucalyptus plantations sampled has more than 95% of its areas covered with native forests, but the distribution of these forests should be improved to facilitate the dispersion of natural enemies. The presence and dispersion of natural enemies might help to increase eucalyptus productivity, making it possible to reduce the number of hectares planted without reducing total wood production. In addition, planting on slopes is difficult, and therefore plantations in steep areas are being converted back to natural vegetation that can increase populations of natural enemies and reduce problems with insect pests. The negative correlation between the numbers of *M. bleura* and *S. violascens* individuals with the distance of native vegetation may indicate that these pests are dispersing to eucalyptus stands. However, their natural enemies can also migrate to these areas and contribute to keeping pest populations at low levels.

Numbers of adult Lepidoptera pests of eucalyptus showed positive and negative correlations with environmental and cultural factors such as average annual growth, rotation number, and distance to the native vegetation. This result shows the need for considering these factors in integrated pest management programs to increase the efficiency of biological control in cultivated forests.

Acknowledgments

We express our thanks to "Conselho Nacional de Desenvolvimento Cientifico e Tecnológico (CNPq)", "Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES)", "Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG)" and the "Programa Cooperativo sobre Proteção Florestal/PROTEF do Instituto de Pesquisas e Estudos Florestais/IPEF" for the financial support. Dr. Phillip John Villani (University of Melbourne, Australia) revised and corrected the English language used in this manuscript.

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