Seasonal Abundance and Diversity of Arthropods on Acacia mangium (Fabales: Fabaceae) Trees as Windbreaks in the Cerrado

Authors: Silva, F. W. S., Leite, G. L. D., Guañabens, R. E. M., Sampaio, R. A., Gusmão, C. A. G., et al.

Source: Florida Entomologist, 98(1) : 170-174

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.098.0129

Seasonal abundance and diversity of arthropods on *Acacia mangium* (Fabales: Fabaceae) trees as windbreaks in the cerrado

F. W. S. Silva[1,2,], G. L. D. Leite[1], R. E. M. Guañabens[1], R. A. Sampaio[1], C. A. G. Gusmão[1], J. E. Serrão[3] and J. C. Zanuncio[4]*

Abstract

Our aim was to assess the seasonal abundance and diversity of arthropods on *Acacia mangium* Willd. (Fabales: Fabaceae) trees. Phytophagous arthropods, natural enemies and pollinators were quantified biweekly in 20 trees during 3 years. The Shannon biodiversity index (H') of arthropods was greater in the summer and smaller in the winter and spring on *A. magium*. The diversities of species and abundances of individuals of all arthropod taxa were greater in the autumn and smaller in the winter and in the spring. The H' index of arthropods was greater in 2005 and smaller in 2007. The diversity of species and abundance of individuals of phytophagous taxa were greater in 2005 and 2006, respectively, whereas those of natural enemies and pollinators was greater in 2006. *Aethalion reticulatum* L. (Hemiptera: Aetalionidae) was the most abundant phytophagous species found in the various seasons, while *Camponotus* sp.2 (Hymenoptera: Formicidae), *Trigona spinipes* Fabricius (Hymenoptera: Apidae, Meliponini), *Tetragonisca angustula* Latreille (Hymenoptera: Meliponinae, Meliponini) and *Polistes* sp. (Hymenoptera: Vespidae) were the most abundant natural enemies and pollinators. The great diversity of predators on this tree species can explain the little damage to its leaves. These results may be applied to support programs of pest control and maintenance of natural enemies and pollinators in future plantations of *A. mangium*.

Key Words: biodiversity; insects, phytophagous; natural enemies and pollinators

Resumen

Nuestro objetivo era evaluar la abundancia y diversidad estacional de artrópodos en *Acacia mangium* Willd. (Fabales: Fabaceae) árboles. Artrópodos fitófagos, enemigos naturales y polinizadores se cuantificaron bisemanal en 20 árboles durante tres años. El índice de biodiversidad de Shannon (H') de estos tres artrópodos fue mayor en el verano y más bajos en invierno y primavera en *A. magium*. La diversidad de especies y abundancia de individuos de todos los artrópodos fueron mayores en el otoño y la más baja en el invierno y en la primavera. El índice H' de artrópodos fue mayor en 2005 y menor en 2007. La diversidad de especies y abundancia de individuos de fitófagos fueron mayores en 2005 y 2006, respectivamente, mientras que de los enemigos naturales y polinizadores fue mayor en 2006. *Aethalion reticulatum* L. (Hemiptera: Aetalionidae) fue el fitófago más abundante en las diferentes estaciones del año, mientras *Camponotus* sp. 2 (Hymenoptera: Formicidae), *Trigona spinipes* Fabricius (Hymenoptera: Apidae, Meliponini), *Tetragonisca angustula* Latreille (Hymenoptera: Meliponinae, Meliponini) y *Polistes* sp. (Hymenoptera: Vespidae) fueron los más abundantes enemigos naturales y polinizadores. La gran diversidad de depredadores de esta especie arbórea puede explicar el bajo daño en sus hojas. Estos resultados pueden ser un apoyo para los programas de control de plagas y el mantenimiento de los enemigos naturales y polinizadores en las futuras plantaciones de *A. mangium*.

Palabras Clave: biodiversidad; insectos, fitófagos; enemigos naturales y polinizadores

Distributions of arthropod species may differ in different years in response to changes in climate and food availability, which may directly impact their abundances and diversity (Wolda 1988; Chilima & Leather 2001; Leite et al. 2005). In tropical areas with well-defined dry and wet seasons, the population dynamics of many insect species is influenced by climatic changes, which probably cause changes in the physiology of the host plants (Hamer et al. 2005; Leite et al. 2006a).

The abundance and diversity of arthropods may be greater in some developmental stage of the host plant. The nutritional quality and chemical defenses of plants, which are linked to the age of leaves, are important for phytophagous insects (Bowers & Stamp 1993; Coley & Barone 1996; Leite et al. 2006b). *Acacia mangium* Willd. (Fabales: Fabaceae) is a pioneer species that can grow on acid and infertile soils due to its capacity of N-fixing (Galiana et al. 1998), with this nutrient

[1]Institute of Agricultural Sciences, Universidade Federal de Minas Gerais, CEP: 39404-006, Montes Claros-MG, Brazil
[2]Department of Entomology, Universidade Federal de Viçosa, CEP: 36.570-900, Viçosa-MG, Brazil
[3]Department of General Biology, Universidade Federal de Viçosa, CEP: 36.570-900, Viçosa-MG, Brazil
[4]Department of Animal Biology, Universidade Federal de Viçosa, CEP: 36.570-900, Viçosa-MG, Brazil
[*]Corresponding author; E-mail: farleyw@gmail.com

being one of the most important for the tree growth (Lea & Azevedo 2006).

Interactions between plants of *Acacia* spp. and insects have been studied (Fleming et al. 2007; McLeish et al. 2007; Palmer et al. 2007; Silva et al. 2014), and insects are the main organisms responsible for the decline of Arabic gum production from these trees in Sudan (Jamal 1994). The main herbivores found damaging *A. mangium* were leaf-cutter ants (*Atta* spp. and *Acromyrmex* spp.), termites and *Costalimaita ferruginea* Fabr. (Coleoptera: Chrysomelidae) (Arco-Verde 2002) in the northern Brazil, and *Trigona spinipes* Fabr. (Hymenoptera: Apidae), *Aethalion reticulatum* (Hemiptera: Aetalionidae) and Pentatomidae sp. 1 (Hemiptera) in southeastern Brazil (Silva et al. 2014).

Acacia spp. are broadly used in the initial restoration process of degraded lands (Tsai 1988; Yu & Li 2007), in places where initially a number of barriers prevent plant development (Chada et al. 2004). Moreover, they are also used as windbreaks to prevent wind and water erosion (Michels et al. 1998; Bird et al. 2002) and as barriers to movements of arthropods (Rao et al. 2000).

The aim of this study was to assess the seasonal abundance and diversity of arthropods during 3 years of sampling on *A. mangium* trees.

Materials and Methods

STUDY SITES

This study was carried out in a pasture area of the Institute of Agricultural Sciences at the Universidade Federal de Minas Gerais (ICA/UFMG), Brazil. Samplings occurred from Jan 2005 to Mar 2007 in an area with an Aw climate, i.e., tropical savanna according to the classification of Köppen with a dry winter and a rainy summer and a dystrophic red-yellow latosol.

STUDY DESIGN

Windbreaks, 100 m long with 2 rows of *A. mangium* spaced 3 × 3 m were used. Saplings were prepared in a nursery and planted in Sep 2003 in 30 × 30 × 30 cm holes with 360 grams of natural reactive phosphate mixed into the subsoil of a *Brachiaria decumbens* Stapf. (Poales: Poaceae) pasture. The phytophagous, natural enemies and pollinators arthropods in twenty 16-month old *A. mangium* trees were visually counted biweekly every yr. The arthropods were counted on the adaxial and abaxial leaf surfaces in the upper, median and smaller apical canopy on branches facing north, south, east and west; and with a total of 12 leaves per canopy and 9 per tree branch position in each sampling. Arthropod collection also occurred on the trunks of 20 trees per sampling. All material collected was stored in flasks with 70% ethanol, separated by morphospecies and sent for identification. The climatic data (rainfall, temperature, relative humidity, solar irradiation and wind speed) were obtained from the Main Climatic Station of Montes Claros of the 5th DISME-INMET.

STATISTICAL ANALYSIS

The natural enemies and pollinators were grouped as evaluating them separately would not meet the requirements of the tests. The ecological indices (number of individuals, richness, diversity and abundance of species) were calculated for the arthropod species identified. All ecological indices were measured by calculating the dataset of taxa by samples in BioDiversity Pro Version 2 software. Diversity was calculated by the Shannon-Weaver formula: H' = pi ln (pi). Abundance and species richness (S) were calculated by the Simpson formula: D = (ni /N) * 100, where: pi = ni /N; ni = number of individuals per species; N = total number of individuals; S = richness (number of species). *k*-Dominance were calculated by plotting the percentage cumulative abundance against log species rank (Lambshead et al. 1983). The *k*-dominance values indicate the dominance and evenness distribution of individuals among species (Gee et al. 1985). The Spearman correlation was applied for the data ($P < 0.05$).

Results and Discussion

A total of 418 individuals of phytophagous arthropods were sampled, with Hemiptera having the greatest diversity (4 species, 4 genera, 7 families and 4 unidentified species), followed by Coleoptera (1 species, 2 genera, 2 families and 1 unidentified species), Orthoptera (1 species, 1 genus, 2 families and 1 unidentified species), Lepidoptera (1 genus, 1 family and 1 unidentified species) and Diptera (1 genus and 1 family). *Aethalion reticulatum* L. (Hemiptera: Aetalionidae) was the most abundant phytophagous species on *A. mangium* trees during the various seasons of the year (Figs. 1 and 2). *Aethalion reticulatum* feed on plant sap, which can affect the development of fruits and sprouting, and at high infestations, kill the plant (Silva et al. 2007; Vanin et al. 2008).

A total of 1,148 specimens of natural enemies and pollinators arthropods were sampled. The greatest diversity was found in the Hymenoptera (4 species, 8 genera, 3 families and 3 morphospecies), followed by Araneae (2 species, 2 genera, 3 families and 1 unidentified species), Coleoptera (1 species, 1 genus, 2 families and 1 unidentified species), Neuroptera (1 species, 1 genus, 1 family and 1 unidentified species), Mantodea (1 species, 1 genus and 1 family) and Hemiptera (1 unidentified species). The most abundant natural enemies and pollinators were *Camponotus* sp. 2 (Hymenoptera: Formicidae), *Trigona spinipes* Fabricius (Hymenoptera: Apidae, Meliponini), *Tetragonisca angustula* Latreille (Hymenoptera: Meliponinae, Meliponini) and *Polistes* sp. (Hymenoptera: Vespidae) (Figs. 1 and 2). Despite species of the genus *Camponotus* being known as predators (or natural enemies) (Cortez et al. 2012), they are also found tending sucking insects, such as *A. reticulatum* (Brown 1976); protecting them against predators and parasitoids (Renault et al. 2005). *Camponotus* sp. 1 was correlated positively with *A. reticulatum* ($r = 0.37$), so this could explain the greatest abundance of this phytophage on *A. mangium*. Therefore, *Camponotus* sp. 1 can indirectly affect host plants by hindering the impact of other natural enemies. However, *T. angustula* and *T. spinipes* are important for pollination and for increasing the genetic variability of plants (Proni & Macieira 2004; Costa et al. 2008). *Polistes* spp. are important predators of different species, mainly lepidopterans (Prezoto et al. 2006).

Arthropods had the greatest H' index in 2005, and the smallest H' in 2007 (Table 1). The greatest number of species and individuals of phytophages was observed in 2005 and 2006, respectively; while natural enemies and pollinators had the greatest number of species and individuals in 2006 (Table 1). The phytophages had the greatest H' index in 2005 owing the presence of rare species, leading thus to greater equitability between number of species and abundance of individuals. This might have occurred owing to the initial colonization stage of different phytophagous arthropod species in the first year of the study. Linzmeier & Ribeiro-Costa (2008) found a similar colonization pattern for species of Galerucinae (Coleoptera: Chrysomelidae) in the first year of study in an Araucaria (Pinales: Araucariaceae) forest.

The smallest H' index may be explained by the reduced number of rare species in the second year when other likely more adapted species to *A. mangium* were predominant. The natural enemies had the greatest H' index in 2005 and the greatest number of species and individuals in 2006, likely owing to a greater abundance of phytophages in the second year, as observed in the positive correlation between

Table 1. Shannon (H') biodiversity indices of phytophagous and natural enemies + pollinators arthropods, number of leaves per branch and number of branches per tree of *Acacia mangium.* Climatic data during 3 years of sampling.

	Climate seasons			
	Spring	Summer	Autumn	Winter
	Phytophagous			
H'	0.053 ± 0.012*	0.770 ± 0.091	0.510 ± 0.062	0.044 ± 0.008
No. of species	3**	7	12	1
No. of individuals	6	148	263	1
	Natural enemies + Pollinators			
H'	0.652 ± 0.0251	0.726 ± 0.065	0.683 ± 0.045	0.653 ± 0.038
No. of species	7	15	17	12
No. of individuals	173	299	499	177
	Trees			
No. of leaves/branch	49.03 ± 3.40	57.36 ± 2.38	44.51 ± 2.33	32.09 ± 1.43
No. of branches/tree	29.33 ± 2.69	23.38 ± 1.05	18.91 ± 0.87	28.25 ± 2.20
	Climatic data			
Mean temperature	24.1	24.5	21.2	21.9
Total rainfall	605.0	531.0	128.0	45.0
Relative humidity	71.0	76.0	72.0	56.0
Solar irradiation	5.1	6.7	8.1	8.6
Wind speed	1.93	1.71	1.65	2.03

	Year		
	2005	2006	2007
	Phytophagous		
H'	0.674 ± 0.143	0.142 ± 0.017	0.082 ± 0.011
No. of species	12	8	3
No. of individuals	108	258	52
	Natural Enemies + Pollinators		
H'	0.763 ± 0.061	0.687 ± 0.032	0.642 ± 0.028
No. of species	13	17	9
No. of individuals	460	551	137
	Trees		
No. of leaves/branch	33.66 ± 0.91	51.10 ± 1.66	110.92 ± 7.91
No. of branches/tree	17.41 ± 0.60	28.42 ± 1.33	38.60 ± 3.74
	Climatic data		
Mean temperature	23.1	22.7	23.4
Total rainfall	1328.0	1281.2	634.7
Relative humidity	67.9	69.5	60.5
solar irradiation	7.2	7.1	8.3
Wind speed	1.88	1.78	1.95

*Standard error of average.
**Total number.

phytophages and their natural enemies (r = 0.45), in agreement with other studies (Donaldson et al. 2007; Öberg et al. 2008; Philpott et al. 2008; Venturino et al. 2008). In general, natural enemies (such as spiders in this study) have greater population densities in more complex habitats (Bragança et al. 1998; Landis et al. 2000) in response to more favorable microclimates and reductions of cannibalism and competition (Ramalho et al. 2007).

The increase in number of phytophagous arthropods in the second year is likely due to the greatest number of branches and leaves present on *A. mangium* trees, which implies an enhanced food resource (Table 1). Other studies have also found this same positive correlation between phytophagous arthropods and complexity of plant architecture (Lara et al. 2008; Obermaier et al. 2008; Sinclair & Hughes 2008). Another possibility is that temperature, rainfall and wind speed had smaller values in 2006 than in 2005 (Table 1), which could have favored some phytophagous, natural enemies and pollinators. This is shown by the negative correlation between temperature (r = -0.44) and rainfall (r = -0.32) with *A. reticulatum*; temperature with phytophagous arthropods (Hemiptera) (r = -0.42); *T. spinipes* with temperature (r = - 0.56) and wind speed (r = -0.44); and *Camponotus* sp. 1 with temperature (r = -0.44). The wind speed found here (over 2.0 m/s) might negatively affect visits of bees (such as of *T. spinipes*) to flowers (Dutra & Machado 2001).

In the first year, the greatest number of some natural enemies, such as *Camponotus* sp. 2, *Camponotus* sp. 5, *Polistes* spp. and spiders on *A. mangium* trees (Table 1 and Fig. 1) might have negatively affected the number of phytophages, as indicated by the negative correlation between *Camponotus* sp. 2 and *A. reticulatum* (r = -0.41). Some studies have reported *Camponotus* sp. as important natural enemy in the system (Prezoto et al. 2006; Philpott et al. 2008). This negative correlation between *Camponotus* sp. 2 and *A. reticulatum* may also be

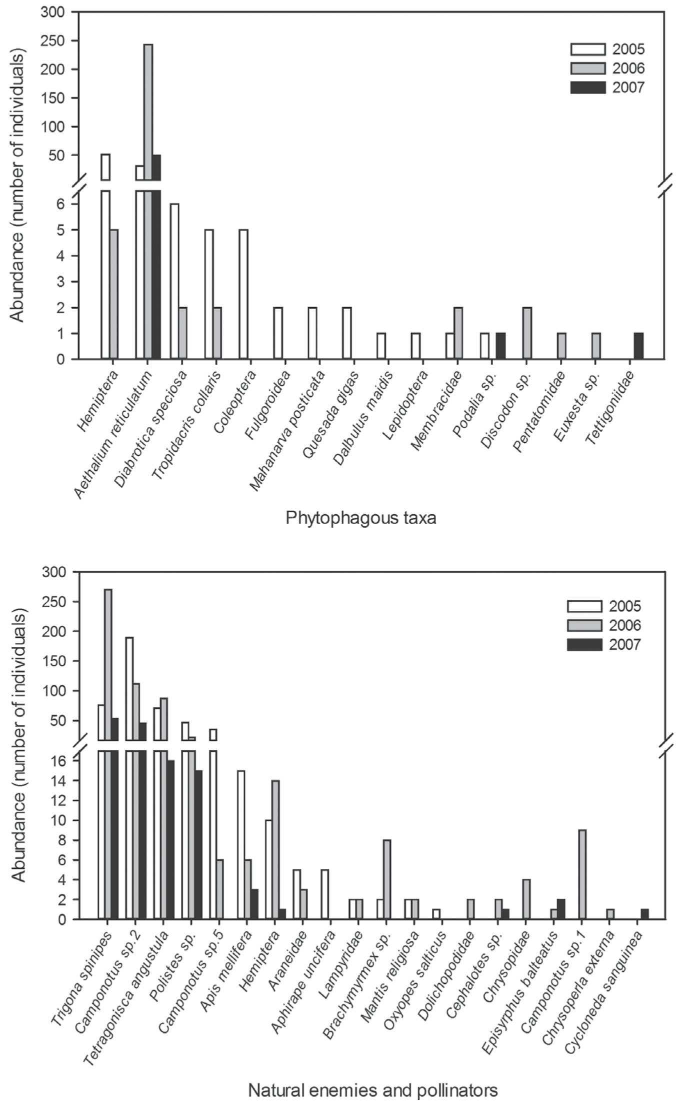

Fig. 1. Abundance of phytophagous, natural enemies and pollinators arthropods on *Acacia mangium* trees during 3 years of sampling. Samplings occurred from 2005 to 2007.

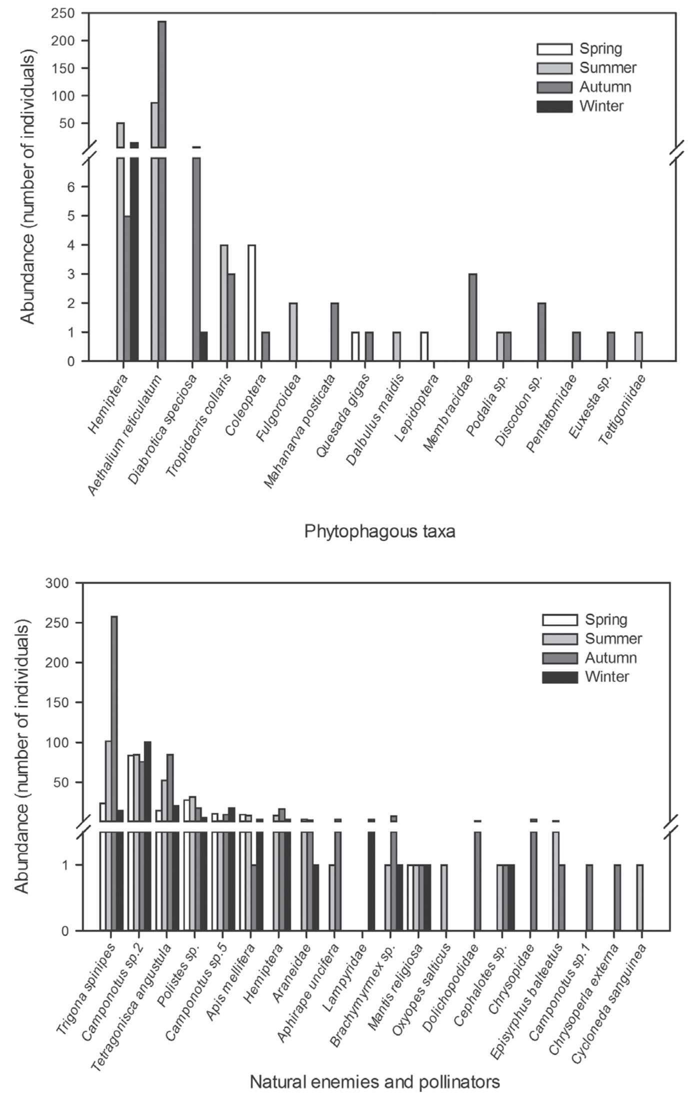

Fig. 2. Abundance of phytophagous, natural enemies and pollinators arthropods on *Acacia mangium* trees according to the climate seasons. Samplings occurred from 2005 to 2007.

a result of competition with *Camponotus* sp. 1, which is reported as frequently tending this hemipteran trophobiont (see the positive correlation above). Thus, *Camponotus* sp. 2 and 5 could be expelled from plants hosting *Camponotus* sp. 1 and *A. reticulatum*.

All arthropod species had greater Shannon (H') biodiversity indices in the summer than in the winter and spring (Table 1). We found a greater number of species and greater abundance of individual arthropod species in the autumn than in the winter and spring, respectively (Table 1). The greatest diversity of phytophagous arthropods may be associated with the availability of resources in the wetter seasons (Wolda 1978). In biomes with well-defined seasons (such as dry and wet in the Cerrado), because population densities and herbivory rates decrease in the dry season (winter) and increase gradually during the wet season (summer) (Tanaka & Tanaka 1982; Coley & Barone 1996). This implies that phytophagous arthropods thrive when present during seasons when trees have new leaves (Wolda 1978), and as observed in this work, when *A. mangium* had more grown leaves in the summer and fewer in the winter (Table 1).

The greatest abundance of phytophagous arthropods in the autumn is likely due to the effect of herbivore concentration during seasons in which *A. mangium* has few leaves (Table 1). This was also found for other tree species such as *Copaifera langsdorffii* Desf. (Fabales: Fabaceae) in the same biome (Almeida et al. 2006). Whereas abundance of natural enemies and pollinators seems to vary according to the phytophagous population density, because their abundance is maximal in the autumn during the peak of population density of phytophages ($r = 0.45$) (Table 1), and minimal in the spring after the decrease of prey availability (Donaldson et al. 2007; Öberg et al. 2008; Philpott et al. 2008; Venturino et al. 2008).

In conclusion, the diversity of natural enemies and pollinators on *A. mangium* trees varies according to the population density of phytophagous arthropods. The diversity of natural enemies may explain the small damage on leaves and flowers of this tree species. Finally, control strategies of phytophagous arthropods should be implemented whenever needed at the beginning of tree development and/or in the wet season.

Acknowledgments

We wish to thank Dr Antônio Domingos Brescovit (Instituto Butantã) (Aracnidae), Dr Ayr de Moura Bello (Coleoptera), Dr Ivan Cardoso Nascimento (CEPLAC) (Formicidae), Dr Paulo Sérgio Fiuza Ferreira (UFV) (Hemiptera) and Dr Luci Boa Nova Coelho (UFRJ) (Cicadellidae) for species identification. We also wish to thank "Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)" and "Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG)".

References Cited

Almeida CIM, Leite GLD, Rocha SL, Machado MML, Maldonado WCH. 2006. Fenologia e artrópodes de *Copaifera langsdorffii* Desf. no cerrado. Revista Brasileira de Plantas Medicinais 8: 64-70.

Arco-Verde MF. 2002. Potencialidades e usos da *Acacia mangium* Willd. no estado de Roraima, pp. 18. *In* Embrapa-Roraima [ed.], Boa Vista.

Bird PR, Jackson TT, Kearney GA, Williams KW. 2002. Effect of two tree windbreaks on adjacent pastures in south-western Victoria, Australia. Journal of Experimental Agriculture 42: 809-830.

Bowers MD, Stamp NE. 1993. Effects of plant-age, genotype, and herbivory on plantago performance and chemistry. Ecology 74: 1778-1791.

Bragança M, DeSouza O, Zanuncio JC. 1998. Environmental heterogeneity as a strategy for pest management in *Eucalyptus* plantations. Forest Ecology and Management 102: 9-12.

Brown RL. 1976. Behavioral observations on *Aethalion reticulatum* (Hem, Aethalionidae) and associated ants. Insectes Sociaux 23: 99-107.

Chada SdS, Campello EFC, Faria SMd. 2004. Sucessão vegetal em uma encosta reflorestada com leguminosas arbóreas em Angra dos Reis, RJ. Revista Árvore 28: 801-809.

Chilima CZ, Leather SR. 2001. Within-tree and seasonal distribution of the pine woolly aphid *Pineus boerneri* on *Pinus kesiya* trees. Agricultural and Forest Entomology 3: 139-145.

Coley PD, Barone JA. 1996. Herbivory and plant defenses in tropical forests. Annual Review of Ecology, Evolution, and Systematics 27: 305-335.

Cortez V, Favila ME, Verdu JR, Ortiz AJ. 2012. Behavioral and antennal electrophysiological responses of a predator ant to the pygidial gland secretions of two species of Neotropical dung roller beetles. Chemoecology 22: 29-38.

Costa AJC, Guimarães-Dias F, Pérez-Maluf R. 2008. Abelhas (Hymenoptera: Apoidea) visitantes das flores de urucum em Vitória da Conquista, BA. Ciência Rural 38: 534-537.

Donaldson JR, Myers SW, Gratton C. 2007. Density-dependent responses of soybean aphid (*Aphis glycines* Matsumura) populations to generalist predators in mid to late season soybean fields. Biological Control 43: 111-118.

Dutra JCS, Machado VLL. 2001. Entomofauna visitante de *Stenolobium stans* (Juss.) Seem (Bignoniaceae), durante seu período de floração. Neotropical Entomology 30: 43-53.

Fleming PA, Hofmeyr SD, Nicolson SD. 2007. Role of insects in the pollination of *Acacia nigrescens* (Fabaceae). South African Journal of Botany 73: 49-55.

Gee JM, Warwick RM, Schaanning M, Berge JA, Ambrose WG. 1985. Effects of organic enrichment on meiofaunal abundance and community structure in sublittoral soft sediments. Journal of Experimental Marine Biology and Ecology 91: 247-262.

Hamer KC, Hill JK, Mustaffa N, Benedick S, Sherratt TN, Chey VK, Maryati M. 2005. Temporal variation in abundance and diversity of butterflies in Bornean rain forests: opposite impacts of logging recorded in different seasons. Journal of Tropical Ecology 21: 417-425.

Jamal A. 1994. Major insect pests of gum arabic trees *Acacia senegal* Willd and *Acacia seyal* L in Western Sudan. Journal of Applied Entomology 117: 10-20.

Lambshead PJD, Platt HM, Shaw KM. 1983. The detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. Journal of Natural History 17: 859-874.

Landis DA, Wratten SD, Gurr GM. 2000. Habitat management to conserve natural enemies of arthropod pests in agriculture. Annual Review of Entomology 45: 175-201.

Lara DP, Oliveira LA, Azevedo IFP, Xavier MF, Silveira FAO, Carneiro MAA, Fernandes GW. 2008. Relationships between host plant architecture and gall abundance and survival. Revista Brasileira de Entomologia 52: 78-81.

Lea PJ, Azevedo RA. 2006. Nitrogen use efficiency. 1. Uptake of nitrogen from the soil. Annals of Applied Biology 149: 243-247.

Leite GLD, Picanço M, Jham GN, Moreira MD. 2005. Whitefly population dynamics in okra plantations. Pesquisa Agropecuária Brasileira 40: 19-25.

Leite GLD, Picanço M, Zanuncio JC, Ecole CC. 2006a. Factors affecting herbivory of *Thrips palmi* (Thysanoptera : Thripidae) and *Aphis gossypii* (Homoptera: Aphididae) on the eggplant (*Solanum melongena*). Brazilian Archives of Biology and Technology 49: 361-369.

Leite GLD, Veloso RVdS, Zanuncio JC, Fernandes LA, Almeida CIM. 2006b. Phenology of *Caryocar brasiliense* in the Brazilian cerrado region. Forest Ecology and Management 236: 286-294.

Linzmeier AM, Ribeiro-Costa CS. 2008. Seasonality and temporal structuration of Alticini community (Coleoptera, Chrysomelidae, Galerucinae) in the Araucaria Forest of Parana, Brazil. Revista Brasileira de Entomologia 52: 289-295.

McLeish MJ, Chapman TW, Schwarz MP. 2007. Host-driven diversification of gall-inducing *Acacia* thrips and the aridification of Australia. BMC Biology 5: 3.

Michels K, Lamers JPA, Buerkert A. 1998. Effects of windbreak species and mulching on wind erosion and millet yield in the sahel. Experimental Agriculture 34: 449-464.

Öberg S, Mayr S, Dauber J. 2008. Landscape effects on recolonisation patterns of spiders in arable fields. Agriculture, Ecosystems & Environment 123: 211-218.

Obermaier E, Heisswolf A, Poethke J, Randlkofer B, Meiners T. 2008. Plant architecture and vegetation structure: Two ways for insect herbivores to escape parasitism. European Journal of Entomology 105: 233-240.

Palmer WA, Lockett CJ, Senaratne KADW, McLennan A. 2007. The introduction and release of *Chiasmia inconspicua* and *C. assimilis* (Lepidoptera: Geometridae) for the biological control of *Acacia nilotica* in Australia. Biological Control 41: 368-378.

Philpott SM, Perfecto I, Vandermeer J. 2008. Behavioral diversity of predatory arboreal ants in coffee agroecosystems. Environmental Entomology 37: 181-191.

Prezoto F, Santos-Prezoto HH, Machado VLL, Zanuncio JC. 2006. Prey captured and used in *Polistes versicolor* (Olivier) (Hymenoptera: Vespidae) nourishment. Neotropical Entomology 35: 707-709.

Proni EA, Macieira OJD. 2004. Ritmo circadiano da taxa respiratória de *Tetragonisca angustula fiebrigi* (Schwarz), *T. a. angustula* (Latreille) e *Trigona spinipes* (Fabricius) (Hymenoptera, Apidae, Meliponinae). Revista Brasileira de Zoologia 21: 987-993.

Ramalho FDS, A. M. Silva AMCd, Zanuncio JC, Serrão JE. 2007. Competition between *Catolaccus grandis* (Hymenoptera: Pteromalidae) and *Bracon vulgaris* (Hymenoptera: Braconidae), parasitoids of the boll weevil. Brazilian Archives of Biology and Technology 50: 371-378.

Rao MR, Singh MP, Day R. 2000. Insect pest problems in tropical agroforestry systems: Contributory factors and strategies for management. Agroforestry Systems 50: 243-277.

Renault CK, Buffa LM, Delfino MA. 2005. An aphid-ant interaction: effects on different trophic levels. Ecological Research 20: 71-74.

Silva FWS, Leite GLD, Guanabens REM, Sampaio RA, Gusmão CAG, Zanuncio JC. 2014. Spatial distribution of arthropods on *Acacia mangium* (Fabales: Fabaceae) trees as windbreaks in the Cerrado. Florida Entomologist 9: 631-638.

Silva WC, Ribeiro JDA, Souza HEMd, Corrêa RdS. 2007. Atividade inseticida de *Piper aduncum* L. (Piperaceae) sobre *Aetalion* sp. (Hemiptera: Aetalionidae), praga de importância econômica no Amazonas. Acta Amazonica 37: 293-298.

Sinclair RJ, Hughes L. 2008. Incidence of leaf mining in different vegetation types across rainfall, canopy cover and latitudinal gradients. Austral Ecology 33: 353-360.

Tanaka LK, Tanaka SK. 1982. Rainfall and seasonal changes in arthropod abundance on a tropical oceanic island. Biotropica 14: 114-123.

Tsai LM. 1988. Studies on *Acacia mangium* in Kemasul Forest, Malaysia. I. Biomass and productivity. Journal of Tropical Ecology 4: 293-302.

Vanin SA, Ramos CS, Guimarães EF, Kato MJ. 2008. Insect feeding preferences on Piperaceae species observed in São Paulo city, Brazil. Revista Brasileira de Entomologia 52: 72-77.

Venturino E, Isaia M, Bona F, Chatterjee S, Badino G. 2008. Biological controls of intensive agroecosystems: Wanderer spiders in the Langa Astigiana. Ecological Complexity 5: 157-164.

Wolda H. 1978. Seasonal fluctuations in rainfall, food and abundance of tropical insects. Journal of Animal Ecology 47: 369-381.

Wolda H. 1988. Insect seasonality - Why? Annual Review of Ecological Systems 19: 1-18.

Yu H, Li JT. 2007. Physiological comparisons of true leaves and phyllodes in *Acacia mangium* seedlings. Photosynthetica 45: 312-316.