Diversity and Abundance of Edaphic Arthropods Associated with Conventional and Organic Sugarcane Crops in Brazil

Authors: Santos, Luan Alberto Odorizzi dos, Naranjo-Guevara, Natalia, and Fernandes, Odair Aparecido

Source: Florida Entomologist, 100(1) : 134-144

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.100.0119
Diversity and abundance of edaphic arthropods associated with conventional and organic sugarcane crops in Brazil

Luan Alberto Odorizzi dos Santos, Natalia Naranjo-Guevara, and Odair Aparecido Fernandes*

Abstract

Although studies have shown enhancement of insects, birds, and plants in organically managed agroecosystems, information on arthropod diversity and abundance in conventional and organic sugarcane farms is scarce. This research was conducted to analyze and compare the diversity and abundance of edaphic arthropods in organic and conventional sugarcane by using pitfall traps. The study was conducted during 2 growing seasons in Jaboticabal, São Paulo, Brazil. In total, 13,244 individuals belonging to 190 morphospecies were collected. In the conventional system, 4,964 specimens were collected, representing 122 morphospecies distributed in 15 orders and 50 families. In the organic system, 8,280 individuals were captured, representing 142 morphospecies in 13 orders and 45 families. Ants of the genera Pheidole Westwood, Dorymyrmex Mayr, Camponotus Mayr, and Crematogaster Lund (Hymenoptera: Formicidae) were predominant. Higher abundance and richness of arthropods (especially predators and omnivores) were found in the organic than the conventional system, which could be important in regulating key pests of sugarcane. Our results show that the organic management in sugarcane increased the abundance and diversity of arthropods.

Key Words: community; conservation biological control; environmental disturbance; functional group

Resumo

Embora estudos já tenham mostrado que há incremento de insetos, pássaros e plantas em agroecossistemas manejados orgânica, informação sobre diversidade e abundância de artrópodes em plantios orgânicos e convencionais de cana-de-açúcar é rara. Este trabalho foi realizado para analisar e comparar a diversidade e abundância de artrópodes edáficos em cana-de-açúcar convencional e orgânica utilizando armadilhas pitfall. O estudo foi conduzido durante duas safras de cana-de-açúcar em Jaboticabal, São Paulo, Brasil. Foram coletados 13244 indivíduos e representavam 122 morfoespécies, distribuídos em 15 ordens e 50 famílias. No sistema orgânico, 8280 indivíduos foram capturados, correspondendo a 142 morfoespécies, distribuídos em 13 ordens e 45 famílias. Formigas dos gêneros Pheidole Westwood, Dorymyrmex Mayr, Camponotus Mayr e Crematogaster Lund (Hymenoptera: Formicidae) foram predominantes. Maior abundância e riqueza de artrópodes (especialmente predadores e onívoros) foram encontradas no sistema orgânico em comparação ao sistema convencional e poderiam ser importantes para a regulação de pragas chaves da cana-de-açúcar. Os resultados mostram que o manejo orgânico em cana-de-açúcar aumentou a abundância e diversidade de artrópodes.

Palavras Chave: comunidade; controle biológico conservativo; distúrbio ambiental; grupo funcional

Conventional agriculture has often caused the simplification of agricultural landscapes, mainly due to the establishment of monocultures (Pogue & Schnell 2001). These simplified agricultural practices and overuse of insecticides can lead to a reduction in biodiversity (Butler et al. 2007), and thus the reduction of ecological services. On the other hand, with the increase of organic farming, conservative biological control is also expected to increase due to the reduction in pesticide use and land management, which in turn enhance survival, fecundity, efficiency, longevity, and maintenance of natural enemies of arthropod pests (Eilenberg et al. 2001; Landis et al. 2005).

Current agricultural system management can be characterized by frequent and intense disturbances, which are unfavorable for conservation of natural enemies (Letourneau 1998). Thus, development and maintenance of an ecological infrastructure to provide food resources, shelter, and alternative prey and hosts are the basis of environmental management. Consequently, it is possible to expand natural biological control by preserving and increasing existing populations of beneficial arthropods in crops (Gurr et al. 2000; Landis et al. 2000; Wilkinson & Landis 2005).

Environmental problems associated with conventional sugarcane agriculture due to the use of fire prior to harvest (forbidden in certain Brazilian regions since 2014), and use of pesticides, are well documented (Nunes et al. 2006). However, few studies have characterized the soil-dwelling arthropods that could be affected by these disturbances in sugarcane agroecosystems (Castelo Branco et al. 2010; Pasqualin et al. 2012; Abreu et al. 2014). Consequently, the objective of this work was to analyze and compare the diversity and abundance of edaphic arthropods in conventional and organic sugarcane fields.
CHARACTERIZATION OF THE AREA

The experiment was conducted in 2 sugarcane areas in Jaboticabal municipality, São Paulo, Brazil. The sugarcane variety RB5536 was used in each of 2 seasons. Each area was about 10 ha. In the conventional field (21.1978°S, 48.2897°W, altitude 589 m), agricultural practices included pre-harvest burning and herbicide use for weed control but no insecticide application. In the organic field (21.1858°S, 48.2450°W; altitude 623m), sugarcane has been harvested without burning for about 10 yr (green cane) and grown without use of any pesticide. In the 1st growing season (2011/2012, 7th ratoon), the experiment started when plants were in the 4th month of development, whereas in the 2nd growing season (2012/2013, 8th ratoon), the experiment started just after harvest.

COLLECTION METHOD

In each plot, 3 parallel transects distanced 10 m apart from each other were established. Five pitfall traps (700 mL plastic cups buried and adjusted to ground level) were installed every 10 m on each transect, with the 1st trap installed 20 m from the edge of the plot. The traps received 100 mL of solution (98 mL water + 2 mL detergent) to prevent captured arthropods from escaping. Sample collections began 24 h after installation of traps to reduce the effect of disturbance caused by soil excavation and trap installation (Araújo et al. 2005). The traps remained for 48 h in the experimental areas. Collected arthropods were taken to the laboratory for sorting and identification. Fifteen monthly collections were conducted during the 2011/2012 (Dec 2011 to May 2012) and 2012/2013 (Oct 2012 to Mar 2013) growing seasons.

IDENTIFICATION OF COLLECTED ARTHROPODS

The arachnids were sent to Instituto Butantan (São Paulo, Brazil) for identification. The other arthropods collected were identified to lowest possible taxonomic level by using specialized literature (Loureiro & Queiroz 1990; Borror et al. 1992; Baccaro 2006; Suguituru et al. 2015). Unidentified species were differentiated into morphospecies (Oliver & Beattie 1996).

DATA ANALYSES

Data were analyzed using the software ANAFAU (Moraes & Haddad 2003), and the faunistic indices dominance, abundance, frequency, and constancy were obtained for each system. Moreover, the program performs residual analysis of discrepant data that can be classified into 2 principal components. Each component presents the effect of disturbance caused by soil excavation and trap installation (Silva-Mattos & Pivello 2009). Other ant genera

To estimate the total species richness for each system, the software Estimates' 9.1 was used to generate species accumulation curves and to compare the conventional and organic system (Colwell 2006). Samples were randomized 100 times, without replacement, using the non-parametric estimator first order Jackknife (Jack 1), which uses the number of unique species or species occurring only once in a sample to produce richness estimates (Heltshe & Forrester 1983). Also, principal component analysis (STATISTICA, StatSoft, Inc., Tulsa, Oklahoma) was performed separately on the collection from each month. Thus, 15 samples (= months of evaluation) were used in the analysis for each area.

RESULTS

ARTHROPOD RICHNESS AND ECOLOGICAL ANALYSIS

In total, 13,244 individuals belonging to 190 morphospecies were collected in sugarcane. The number of individuals collected during the 2 growing seasons in the conventional system was 4,964 (37.48%), and was represented by 122 morphospecies distributed in 15 orders and 50 families. In the organic system, 8,280 individuals (62.52%) were captured, corresponding to 142 morphospecies in 13 orders and 45 families (Table 1). The number of individuals collected in the organic crop was 66.8% higher, although the numbers of taxonomic orders and families observed were slightly lower than in the conventional crop.

The Shannon–Wiener index (H'), used to estimate the diversity of arthropods considering the uniformity of abundance of species, was 2.3 for the conventional system and 2.5 for the organic system (Table 1). The Margalef index (α), calculated by the number of species and the logarithm of the total number of individuals, was 14.1 for the conventional system and 17.1 for the organic system. The equitability or uniformity parameter, which varies from 0 to 1 (the closer to 1 the greater the equality of species abundance), was approximately 0.49 for both production systems, suggesting that the arthropod community sampled tends to coexist in both systems with some dominance of certain species. The similarity between the areas was 0.687.

FAUNISTIC ANALYSIS

Dominance

In total, 2 and 17 morphospecies in the conventional system and 4 and 30 morphospecies in the organic system were observed to be super-dominant and dominant, respectively (Table 2). The number of non-dominant species was about 7% lower for the conventional system (103 morphospecies) in comparison with the organic system (108 morphospecies) (Table 2).

Among the 43 super-dominant and dominant morphospecies, which represented 23.5% of the total number of morphospecies, 10 (23.3% of the super-dominant and dominant) were collected in both systems. The numbers of individuals of the dominant and non-dominant morphospecies were 1,577 and 367 (conventional system) and 1,825 and 345 (organic system), respectively. However, the number of individuals of the super-dominant morphospecies in the organic system (6,110) was twice that observed in the conventional system (3,020) (Table 2).

Ants (Hymenoptera: Formicidae) of the genera Pheidole Westwood and Dorymyrmex Mayr collected in the conventional system were super-dominant morphospecies whereas Camponotus Mayr and Camptomastigaster Lund were considered dominant. On the other hand, these 4 genera were super-dominant in the organic system. Super-dominant species are native species that behave as invaders in a disturbed environment (Silva-Mattos & Pivello 2009). Other ant genera
Table 1. Number of individuals captured, faunistic indices (dominance, abundance, frequency, constancy) and functional groups of arthropods captured using pitfall traps in conventional and organic sugarcane systems in Jaboticabal, São Paulo, Brazil, during the 2011/2012 and 2012/2013 growing seasons.

| Taxon          | Morphospecies | Conventional | Organic |
|----------------|---------------|--------------|---------|
|                | No. Individuals Captured | No. collections | Dominance | Abundance | Frequency | Constancy | No. Individuals Captured | No. collections | Dominance | Abundance | Frequency | Constancy | Functional Group |
| Blattodea      |               |              |          |          |          |          |                |                |          |          |          |          | Omnivore               |
| Blattella      | Blatellidae sp.1 | 11 | 6 | ND | C | F | Y | 3 | 3 | ND | R | LF | Z | Omnivore               |
|                | Blatellidae sp.2 | . | . | . | . | . | . | 44 | 11 | D | VA | VF | W | Omnivore               |
| Coleoptera     |               |              |          |          |          |          |                |                |          |          |          |          |                      |
| Carabidae      | Loxandrus sp.1 | . | . | . | . | . | . | 5 | 2 | ND | R | LF | Z | Predator               |
|                | Loxandrus sp.2 | . | . | . | . | . | . | 4 | 2 | ND | R | LF | Z | Predator               |
|                | Loxandrus sp.3 | 2 | 2 | ND | R | LF | Z | 2 | 2 | ND | R | LF | Z | Predator               |
|                | Pseudabarys sp.1 | . | . | . | . | . | . | 1 | 1 | ND | R | LF | Z | Predator               |
|                | Pseudabarys sp.2 | . | . | . | . | . | . | 1 | 1 | ND | R | LF | Z | Predator               |
|                | Pseudabarys sp.3 | 1 | 1 | ND | R | LF | Z | 1 | 1 | ND | R | LF | Z | Predator               |
|                | Carabidae sp.1 | . | . | . | . | . | . | 1 | 1 | ND | R | LF | Z | Predator               |
|                | Carabidae sp.2 | . | . | . | . | . | . | 1 | 1 | ND | R | LF | Z | Predator               |
|                | Carabidae sp.3 | . | . | . | . | . | . | 1 | 1 | ND | R | LF | Z | Predator               |
|                | Carabidae sp.4 | . | . | . | . | . | . | 1 | 1 | ND | R | LF | Z | Predator               |
|                | Carabidae sp.5 | 2 | 2 | ND | R | LF | Z | . | . | . | . | . | . | Predator               |
| Cincidinae     | Microcepha l. sp.1 | 2 | 2 | ND | R | LF | Z | 20 | 7 | D | C | F | Y | Predator               |
|                | Cincidinae sp.1 | 4 | 1 | ND | R | LF | Z | 4 | 2 | ND | R | LF | Z | Herbivore               |
|                | Cincidinae sp.2 | 4 | 3 | ND | R | LF | Z | . | . | . | . | . | . | Predanor               |
| Chrysomelidae  | Bruchinae sp.1 | 111 | 2 | D | VA | VF | Z | . | . | . | . | . | . | Detritivore             |
| Curculionidae  | Metamasius hemipterus | 1 | 1 | ND | R | LF | Z | 4 | 2 | ND | R | LF | Z | Herbivore               |
|                | Curculionidae sp.1 | 1 | 1 | ND | R | LF | Z | . | . | . | . | . | . | Herbivore               |
|                | Curculionidae sp.2 | 4 | 3 | ND | R | LF | Z | 2 | 2 | ND | R | LF | Z | Herbivore               |
|                | Conoderus scalaris | 4 | 3 | ND | R | LF | Z | 1 | 1 | ND | R | LF | Z | Herbivore               |
| Elateridae     | Conoderus sp.1 | . | . | . | . | . | . | 1 | 1 | ND | R | LF | Z | Herbivore               |
|                | Conoderus sp.2 | . | . | . | . | . | . | 1 | 1 | ND | R | LF | Z | Herbivore               |
| Passalidae     | Passalidae sp.1 | 1 | 1 | ND | R | LF | Z | . | . | . | . | . | . | Herbivore               |
| Rhizophagidae  | Rhizophagidae sp.1 | 261 | 3 | D | VA | VF | Z | . | . | . | . | . | . | Herbivore               |
| Scarabaeidae   | Attaenius sp.1 | 1 | 1 | ND | R | LF | Z | . | . | . | . | . | . | Detritivore             |
|                | Attaenius sp.2 | 1 | 1 | ND | R | LF | Z | . | . | . | . | . | . | Detritivore             |
|                | Canthon sp.1 | 11 | 6 | ND | C | F | Y | 3 | 1 | ND | R | LF | Z | Detritivore             |
|                | Canthon sp.2 | . | . | . | . | . | . | 1 | 1 | ND | R | LF | Z | Detritivore             |
|                | Canthon sp.3 | . | . | . | . | . | . | 1 | 1 | ND | R | LF | Z | Detritivore             |
|                | Canthon sp.4 | . | . | . | . | . | . | 1 | 1 | ND | R | LF | Z | Detritivore             |
|                | Canthon sp.5 | 1 | 1 | ND | R | LF | Z | . | . | . | . | . | . | Detritivore             |
|                | Cyclocephala sp.1 | . | . | . | . | . | . | 22 | 7 | D | A | VF | Y | Herbivore               |
|                | Cyclocephala sp.2 | . | . | . | . | . | . | 2 | 2 | ND | R | LF | Z | Herbivore               |
|                | Cyclocephala sp.3 | 10 | 5 | ND | C | F | Y | . | . | . | . | . | . | Herbivore               |

SD = super-dominant; D = dominant; ND = non-dominant; SA = super-abundant; VA = very abundant; A = abundant; C = common; D = dispersed; R = rare; SF = super-frequent; VF = very frequent; F = frequent; LS = less frequent; W = constant; Y = accessory; Z = accidental.
Table 1. (Continued) Number of individuals captured, faunistic indices (dominance, abundance, frequency, constancy) and functional groups of arthropods captured using pitfall traps in conventional and organic sugarcane systems in Jaboticabal, São Paulo, Brazil, during the 2011/2012 and 2012/2013 growing seasons.

| Taxon          | Morphospecies | No. Individuals Captured | No. collections | Domination | Abundance | Frequency | Constancy | Functional Group |
|----------------|---------------|--------------------------|-----------------|------------|-----------|-----------|-----------|-----------------|
|               |               | Conventional             |                 |            |           |           |           | Organic         |                  |
|               |               |                          |                 |            |           |           |           |                 |                  |
| Staphylinidae | Staphylinidae sp.1 | 3                        | 2               | ND         | R         | LF        | Z         | Predator         |                  |
|               | Staphylinidae sp.2 | 165                      | 2               | D          | VA        | VF        | Z         | Predator         |                  |
|               | Staphylinidae sp.3 | .                        | .               | .          | .         | .         | .         | Predator         |                  |
|               | Staphylinidae sp.4 | 16                       | 6               | ND         | C         | F         | Y         | Predator         |                  |
|               | Staphylinidae sp.5 | 1                        | 1               | ND         | R         | LF        | Z         | Predator         |                  |
|               | Staphylinidae sp.6 | .                        | .               | .          | .         | .         | .         | Predator         |                  |
|               | Staphylinidae sp.7 | 5                        | 3               | ND         | R         | LF        | Z         | Predator         |                  |
| Dermaptera    | Forficulidae   | Doru sp.                 | 1               | 1          | ND         | R         | LF        | Z         | Predator         |                  |
|               | Forficulidae sp.1 | 15                       | 5               | ND         | C         | F         | Y         | Predator         |                  |
|               | Forficulidae sp.2 | .                        | .               | .          | .         | .         | .         | Predator         |                  |
| Labiduridae   | Labidura sp.   | 15                       | 5               | ND         | C         | F         | Y         | Predator         |                  |
| Diptera       | Agromyzidae    | Agromyzidae sp.1         | 5               | 2          | ND         | R         | LF        | Z         | Predator         |                  |
|               | Asilidae       | Asilidae sp.             | .               | .          | .         | .         | .         | Predator         |                  |
|               | Culicidae      | Culicidae sp.1           | .               | .          | .         | .         | .         | Predator         |                  |
|               | Culicidae sp.2 | 7                        | 1               | ND         | D         | LF        | Z         | Predator         |                  |
| Dolichopodida | Condylomyia sp. | 2                        | 1               | ND         | R         | LF        | Z         | Predator         |                  |
| Dolichopodida | Dolichopodida sp.1 | 2                       | 1               | ND         | R         | LF        | Z         | Predator         |                  |
| Drosophilida  | Drosophilidae sp.1 | 1                       | 1               | ND         | R         | LF        | Z         | Predator         |                  |
|               | Drosophilidae sp.2 | .                        | .               | .          | .         | .         | .         | Predator         |                  |
|               | Drosophilidae sp.3 | 8                       | 2               | ND         | D         | LF        | Z         | Predator         |                  |
|               | Drosophilidae sp.4 | .                        | .               | .          | .         | .         | .         | Predator         |                  |
|               | Drosophilidae sp.5 | .                        | .               | .          | .         | .         | .         | Predator         |                  |
| Muscidae      | Muscidae sp.1  | 5                        | 1               | ND         | R         | LF        | Z         | Predator         |                  |
|               | Muscidae sp.2  | .                        | .               | .          | .         | .         | .         | Predator         |                  |
| Mycetophilida | Mycetophillus sp.1 | 2                       | 2               | ND         | R         | LF        | Z         | Predator         |                  |
|               | Mycetophillus sp.2 | .                        | .               | .          | .         | .         | .         | Predator         |                  |
| Phoridae      | Phoridae sp.1  | 11                       | 6               | ND         | C         | F         | Y         | Predator         |                  |
|               | Phoridae sp.2  | 12                       | 5               | ND         | C         | F         | Y         | Predator         |                  |
|               | Phoridae sp.3  | 7                        | 4               | D          | D         | LF        | Y         | Predator         |                  |
|               | Phoridae sp.4  | 8                        | 3               | ND         | D         | LF        | Z         | Predator         |                  |
|               | Phoridae sp.5  | .                        | .               | .          | .         | .         | .         | Predator         |                  |
|               | Phoridae sp.6  | .                        | .               | .          | .         | .         | .         | Predator         |                  |
|               | Phoridae sp.7  | .                        | .               | .          | .         | .         | .         | Predator         |                  |
|               | Phoridae sp.8  | 3                        | 3               | ND         | R         | LF        | Z         | Predator         |                  |

SD = super-dominant; D = dominant; ND = non-dominant; SA = super-abundant; VA = very abundant; A = abundant; C = common; D = dispersed; R = rare; SF = super-frequent; VF = very frequent; F = frequent; LS = less frequent; W = constant; Y = accessory; Z = accidental.
Table 1. (Continued) Number of individuals captured, faunistic indices (dominance, abundance, frequency, constancy) and functional groups of arthropods captured using pitfall traps in conventional and organic sugarcane systems in Jaboticabal, São Paulo, Brazil, during the 2011/2012 and 2012/2013 growing seasons.

| Taxon | Morphospecies | Functional Group | No. Collections | No. Individuals Captured | Dominance | Abundance | Frequency | Constancy |
|-------|---------------|------------------|-----------------|--------------------------|-----------|-----------|-----------|-----------|
| Piophilidae | Piophilidae sp.1 | Omnivore | 6 | 4 | ND | D | LF | Y | 6 |
| Psychodidae | Psychodidae sp.1 | Omnivore | 1 | 1 | | ND | R | LF | Z | 1 |
| Sciaridae | Sciaridae sp.1 | Omnivore | 3 | 2 | ND | R | LF | Z | 6 |
| | Sciaridae sp.2 | Omnivore | 2 | 1 | | ND | R | LF | Z | 43 |
| | Sciaridae sp.3 | Omnivore | 3 | 3 | | ND | R | LF | Z | 20 |
| | Sciaridae sp.4 | Omnivore | 1 | 1 | | ND | R | LF | Z | 1 |
| | Sciaridae sp.5 | Omnivore | 2 | 8 | | ND | D | LF | Z | 43 |
| | Sciaridae sp.6 | Omnivore | 3 | 2 | ND | R | LF | Z | 32 |
| | Sciaridae sp.7 | Omnivore | 1 | 1 | | ND | R | LF | Z | 1 |
| | Sciaridae sp.8 | Omnivore | 1 | 1 | | ND | R | LF | Z | 2 |
| | Sciaridae sp.9 | Omnivore | 1 | 2 | | ND | R | LF | Z | 1 |
| | Sciaridae sp.10 | Omnivore | 1 | 1 | | ND | R | LF | Z | 1 |
| | Sciaridae sp.11 | Omnivore | 1 | 1 | | ND | R | LF | Z | 1 |
| | Sciaridae sp.12 | Omnivore | 1 | 1 | | ND | R | LF | Z | 1 |
| Sphaeroceridae | Sphaeroceridae sp.1 | Omnivore | 23 | 3 | | ND | D | LF | Z | 1 |
| | Sphaeroceridae sp.2 | Omnivore | 7 | 2 | | ND | D | LF | Z | 1 |
| | Sphaeroceridae sp.3 | Omnivore | 3 | 1 | | ND | R | LF | Z | 1 |
| | Sphaeroceridae sp.4 | Omnivore | 1 | 1 | | ND | R | LF | Z | 1 |
| | Sphaeroceridae sp.5 | Omnivore | 1 | 1 | | ND | R | LF | Z | 1 |
| Tachinidae | Tachinidae sp.1 | Omnivore | 4 | 1 | ND | C | F | Y | 6 |
| Ulidiidae | Ulidiidae sp.1 | Omnivore | 1 | 1 | | ND | R | LF | Z | 1 |
| Diptera sp.1 | | Omnivore | 2 | 1 | | ND | R | LF | Z | 1 |
| Diptera sp.2 | | Omnivore | 1 | 1 | | ND | R | LF | Z | 1 |
| Diptera sp.3 | | Omnivore | 2 | 2 | | ND | R | LF | Z | 1 |
| Diptera sp.4 | | Omnivore | 9 | 1 | | ND | C | F | Z | 1 |
| Diptera sp.5 | | Omnivore | 1 | 1 | | ND | R | LF | Z | 1 |
| Diptera sp.6 | | Omnivore | 1 | 1 | | ND | R | LF | Z | 1 |
| Diptera sp.7 | | Omnivore | 1 | 1 | | ND | R | LF | Z | 1 |
| Hemiptera | | | | | | | | | |
| Aphididae | Aphididae sp.1 | Omnivore | 24 | 2 | ND | D | LF | Z | 11 |
| Aetalionidae | Aetalionidae sp.1 | Herbivore | 4 | 1 | ND | C | F | Z | 3 |
| Cercopidae | Cercopidae sp.1 | Herbivore | 2 | 2 | ND | R | LF | Z | 5 |
| Coreidae | Coreidae sp.1 | Herbivore | 1 | 1 | ND | R | LF | Z | 11 |
| Cydnidae | Cydnidae sp.1 | Herbivore | 90 | 1 | | ND | C | F | Z | 11 |

Legend: SD = super-dominant; D = dominant; ND = non-dominant; SA = super-abundant; VA = very abundant; A = abundant; C = common; D = dispersed; R = rare; SF = super-frequent; VF = very frequent; F = frequent; LS = less frequent; W = constant; Y = accessory; Z = accidental.
**Table 1.** (Continued) Number of individuals captured, faunistic indices (dominance, abundance, frequency, constancy) and functional groups of arthropods captured using pitfall traps in conventional and organic sugarcane systems in Jaboticabal, São Paulo, Brazil, during the 2011/2012 and 2012/2013 growing seasons.

| Taxon                  | Morphospecies | Conventional | Organic | Conventional | Organic |
|------------------------|---------------|--------------|---------|--------------|---------|
|                        |               | No. Individuals Captured | No. collections | Dominance | Abundance | Frequency | Constancy | No. Individuals Captured | No. collections | Dominance | Abundance | Frequency | Constancy |
| Reduviidae             | Rosahus sp.   | 1             | 1       | ND         | R         | LF       | Z        | .         | .         | .         | .         | Predator |
| Reduviidae sp.         |               | 1             | 1       | ND         | R         | LF       | Z        | .         | .         | .         | .         | Predator |
| Hemiptera species (nymph) |             | .             | .       | .         | .         | .         | .        | 25        | 3         | D         | VA       | VF       | Z        | Herbivore |
| Hymenoptera            |               |              |         |           |           |           |          |           |           |           |           |          |          |          |
| Apidae                 | Apis mellifera| 1             | 1       | ND         | R         | LF       | Z        | .         | .         | .         | .         | Pollinator |
| Formicidae             | Acanthognathus sp. | 1           | 1       | ND         | R         | LF       | Z        | 1         | 1         | ND         | R         | LF       | Z        | Predator |
| Formicidae             | Acromyrmex sp. | 21            | 8       | D          | C         | F        | W        | 10        | 5         | ND         | C         | F        | Y        | Herbivore |
| Formicidae             | Anochetus sp.  | 2             | 2       | ND         | R         | LF       | Z        | .         | .         | .         | .         | .         | .         | Predator |
| Formicidae             | Atta sp.1      | 33            | 9       | D          | VA        | VF       | W        | 22        | 8         | D          | A         | VF       | W        | Herbivore |
| Formicidae             | Atta spp.      | 151           | 41      | D          | VA        | VF       | W        | 622       | 15        | ND         | C         | F        | Z        | Predator |
| Formicidae             | Camponotus sp. | 184           | 14      | D          | VA        | VF       | W        | 1,749     | 15        | ND         | C         | F        | Z        | Predator |
| Formicidae             | Dolichoderus sp. | 63            | 2       | D          | VA        | VF       | Z        | 8         | 2         | ND         | C         | F        | Z        | Predator |
| Formicidae             | Dorymyrmex sp. | 988           | 15      | SD         | SA        | SF       | W        | 1,026     | 15        | ND         | C         | F        | Z        | Predator |
| Formicidae             | Ectatomma sp.  | 66            | 12      | D          | VA        | VF       | W        | 62        | 10        | D          | VA        | VF       | W        | Predator |
| Formicidae             | Geniantogenys sp. | 25          | 7       | D          | A         | VF       | Y        | 17        | 5         | ND         | C         | F        | Y        | Predator |
| Formicidae             | Hypoepoxyris sp. | 8            | 1       | ND         | D          | LF       | Z        | 9         | 2         | ND         | C         | F        | Z        | Predator |
| Formicidae             | Odontomachus sp. | 26           | 6       | D          | A         | VF       | Y        | 8         | 5         | ND         | C         | F        | Y        | Predator |
| Formicidae             | Paratrechina sp. | 1            | 1       | ND         | R          | LF       | Z        | 4         | 2         | ND         | R         | LF       | Z        | Predator |
| Formicidae             | Pheidole sp.   | 2,032         | 15      | SD         | SA        | SF       | W        | 2,716     | 15        | ND         | C         | F        | Z        | Predator |
| Formicidae             | Pseudomyrmex sp. | 1            | 1       | ND         | R          | LF       | Z        | 3         | 3         | ND         | R         | LF       | Z        | Predator |
| Formicidae             | Solenops sp.   |               | .       | .         | .         | .         | .        | 1         | 1         | ND         | R         | LF       | Z        | Omnivore |
| Formicidae             | Tapinoma sp.   | 98            | 2       | D          | VA        | VF       | Z        | 7         | 1         | ND         | D         | LF       | Z        | Predator |
| Formicidae             | Trachymyrmex sp. | 1            | 1       | ND         | R          | LF       | Z        | .         | .         | .         | .         | .         | .         | Herbivore |
| Formicidae             | Wasmania sp.   |               | .       | .         | .         | .         | .        | 10        | 1         | ND         | C         | F        | Z        | Predator |
| Formicidae             | Formicinae sp.1 | 3             | 1       | ND         | R          | LF       | Z        | 2         | 2         | ND         | R         | LF       | Z        | Predator |
| Formicidae             | Vespidae sp.1  | 2             | 2       | ND         | R          | LF       | Z        | 1         | 1         | ND         | R         | LF       | Z        | Predator |
| Isoptera               |               |              |         |           |           |           |          |           |           |           |           |           |          |          |          |
| Isoptera               | Termesidae sp. | 3             | 3       | ND         | R          | LF       | Z        | 26        | 5         | D          | VA        | VF       | Y        | Detritivore |
| Lepidoptera            |               |              |         |           |           |           |          |           |           |           |           |           |          |          |          |
| Hesperidida            | Hesperidida sp.1 | 5            | 2       | ND         | R          | LF       | Z        | 4         | 2         | ND         | R         | LF       | Z        | Herbivore |
| Hesperidida            | Hesperidida sp.2 | 1            | 1       | ND         | R          | LF       | Z        | 1         | 1         | ND         | R         | LF       | Z        | Herbivore |
| Noctuidae              | Noctuidae sp.1 | 1             | 1       | ND         | R          | LF       | Z        | 2         | 1         | ND         | R         | LF       | Z        | Herbivore |

SD = super-dominant; D = dominant; ND = non-dominant; SA = super-abundant; VA = very abundant; A = abundant; C = common; D = dispersed; R = rare; SF = super-frequent; VF = very frequent; F = frequent; LS = less frequent; W = constant; Y = accessory; Z = accidental.
Table 1. (Continued) Number of individuals captured, faunistic indices (dominance, abundance, frequency, constancy) and functional groups of arthropods captured using pitfall traps in conventional and organic sugarcane systems in Jaboticabal, São Paulo, Brazil, during the 2011/2012 and 2012/2013 growing seasons.

| Taxon                  | Morphospecies         | Conventional | Organic |
|------------------------|-----------------------|--------------|---------|
|                        |                       | No. Individuals Captured | No. collections | Dominance | Abundance | Frequency | Constancy | No. Individuals Captured | No. collections | Dominance | Abundance | Frequency | Constancy | Functional Group |
| Pieridae               | Pieridae sp.1         | 2            | 1       | ND | R | LF | Z | . | . | . | . | . | Herbivore |
| Lepidoptera sp.1.      | . . . . . . .         | . . . . . . . | 7 | 4 | ND | D | LF | Y | Herbivore |
| Lepidoptera sp.2.      | 4 | 3 | ND | R | LF | Z | . | . | . | . | . | . | Herbivore |
| Lepidoptera sp.3 (immature) | 2 | 2 | ND | R | LF | Z | . | . | . | . | . | . | Herbivore |
| Neuroptera             | Chrysoperla extrema   | 1            | 1       | ND | R | LF | Z | . | . | . | . | . | Herbivore |
| Hemerobiidae           | Hemerobiidae sp.1     | 2            | 2       | ND | R | LF | Z | . | . | . | . | . | Omnivore |
| Orthoptera             | Acrididae sp.1        | 11           | 6       | ND | C | F | Y | 107 | 11 | D | VA | VF | W | Herbivore |
| Lycosidae              | Lycosa sp.            | 2            | 1       | ND | R | LF | Z | . | . | . | . | . | Predator |
|                        | Lycosidae sp.1        | 6            | 5       | ND | R | LF | Y | 11 | 7 | ND | C | F | Y | Predator |
| Miturgidae             | Temenius insularis    | 2            | 2       | ND | R | LF | Z | 23 | 8 | D | A | VF | W | Predator |
| Oonopidae              | Onopinae sp.1         | 1            | 1       | ND | R | LF | Z | . | . | . | . | . | Predator |

SD = super-dominant; D = dominant; ND = non-dominant; SA = super-abundant; VA = very abundant; A = abundant; C = common; D = dispersed; R = rare; SF = super-frequent; VF = very frequent; F = frequent; LS = less frequent; W = constant; Y = accessory; Z = accidental.
Table 1. Number of individuals captured, faunistic indices (dominance, abundance, frequency, constancy) and functional groups of arthropods captured using pitfall traps in conventional and organic sugarcane systems in Jaboticabal, São Paulo, Brazil, during the 2011/2012 and 2012/2013 growing seasons.

| Taxon         | Morphospecies | Conventional | Organic | Ecological Indices | Functional Group |
|---------------|---------------|--------------|---------|--------------------|------------------|
|               |               | No. Individuals Captured | No. collections | Dominance | Abundance | Frequency | Constancy | No. Individuals Captured | No. collections | Dominance | Abundance | Frequency | Constancy |
| Philodromidae | *Berlandiella* sp.1 | 1 | 1 | ND | R | LF | Z | 1 | 1 | ND | R | LF | Z | Predator |
|               | *Berlandiella* sp.2 | 1 | 1 | ND | R | LF | Z | 1 | 1 | ND | R | LF | Z | Predator |
|               | Philodromidae sp.1 | . | . | . | . | . | . | 1 | 1 | ND | R | LF | Z | Predator |
| Salticidae    | Salticidae sp.1 | 1 | 1 | ND | R | LF | Z | 1 | 1 | ND | R | LF | Z | Predator |
|               | Salticidae sp.2 | 1 | 1 | ND | R | LF | Z | . | . | . | . | . | . | Predator |
|               | Salticidae sp.3 | 1 | 1 | ND | R | LF | Z | 1 | 1 | ND | R | LF | Z | Predator |
|               | Salticidae sp.4 | 1 | 1 | ND | R | LF | Z | 1 | 1 | ND | R | LF | Z | Predator |
|               | Salticidae sp.5 | . | . | . | . | . | . | 1 | 1 | ND | R | LF | Z | Predator |
|               | Salticidae sp.6 | 4 | 1 | ND | R | LF | Z | 8 | 4 | ND | C | F | Y | Predator |
| Scytodidae    | Scytodes sp. | 3 | 2 | ND | R | LF | Z | 3 | 3 | ND | R | LF | Z | Predator |
|               | Scytodes *yu* | 1 | 1 | ND | R | LF | Z | . | . | . | . | . | . | Predator |
|               | Scytodidae sp.1 | 2 | 2 | ND | R | LF | Z | . | . | . | . | . | . | Predator |
|               | Tetragnathidae | . | 3 | 2 | ND | R | LF | Z | 5 | 4 | ND | R | LF | Y | Predator |
| Theridiidae   | Coleosoma sp.1 | 3 | 2 | ND | R | LF | Z | 29 | 8 | D | VA | VF | W | Predator |
|               | Coleosoma sp.2 | 3 | 3 | ND | R | LF | Z | . | . | . | . | . | . | Predator |
|               | Dipoena sp.1 | 7 | 2 | ND | D | LF | Y | 20 | 2 | D | C | F | Z | Predator |
|               | Dipoena sp.2 | 5 | 4 | ND | R | LF | Z | 49 | 8 | D | VA | VF | W | Predator |
|               | Dipoena sp.3 | 1 | 1 | ND | R | LF | Z | 1 | 1 | ND | R | LF | Z | Predator |
| Theridiidae   | Theridiidae sp.1 | . | . | . | . | . | . | 2 | 2 | ND | R | LF | Z | Predator |
| Opiliones     | Goeldia sp.1 | 4 | 2 | ND | R | LF | Z | 7 | 2 | ND | D | LF | Z | Predator |
|               | Goeldia sp.2 | . | . | . | . | . | . | 13 | 3 | ND | C | F | Z | Predator |
| Diplopoda     | Diplopoda sp.1 | 24 | 11 | D | C | F | W | 74 | 10 | D | VA | VF | W | Detritivore |
| Chilopode     | Chilopode sp.1 | 15 | 8 | ND | C | F | W | . | . | . | . | . | . | Detritivore |
|               | Chilopode sp.2 | . | . | . | . | . | . | 13 | 3 | ND | C | F | Z | Detritivore |

Ecological Indices

|             | Conventional | Organic |
|--------------|--------------|---------|
| Shannon–Wiener (H') | 2.343       | 2.455   |
| Margalef (α)   | 14.101       | 17.063  |
| Equitability   | 0.488        | 0.487   |
| Similarity     | 0.687        |         |

SD = super-dominant; D = dominant; ND = non-dominant; SA = super-abundant; VA = very abundant; A = abundant; C = common; D = dispersed; R = rare; SF = super-frequent; VF = very frequent; F = frequent; LS = less frequent; W = constant; Y = accessory; Z = accidental.
were important and classified as dominant. For example, leaf-cutting ants of the genus *Atta* F. are important pests in sugarcane crops and were found in both sugarcane fields. Moreover, other beneficial ant genera (*Brachymyrmex* Mayr, *Ectatomma* Smith, and *Gnamptogenys* Roger) were found in both organic and conventional systems. Also, we found dominant morphospecies of spiders (4 morphospecies in total) only in the organic system.

**Abundance**

Similarly to the observed dominance, morphospecies of the genera *Pheidole* and *Dorymyrmex* were super-abundant in both the conventional and organic systems, but morphospecies of the genera *Camponotus* and *Crematogaster* were super-abundant only in the organic system. These 2 latter genera, on the other hand, were classified as very abundant in the conventional system. The super-abundant and very abundant species are native species that behave as invaders in a disturbed environment (Silva-Mattos & Pivello 2009). The conventional system presented a greater number of rare morphospecies (84) compared with common (16), very abundant (11), occasional (7), and abundant (2) morphospecies. A similar trend was observed for the organic system, in which a greater number of rare morphospecies (86) were observed compared with common (19), very abundant (19), and occasional morphospecies (9), as well as abundant (5) morphospecies. Therefore, 69.4% and 61.1% of the morphospecies were rare in the conventional and organic systems, respectively. Twenty-eight morphospecies (14.7% of the total morphospecies) considered to be rare occurred on both systems.

**Frequency**

The super-frequent morphospecies (i.e., species that occurred on all sampling dates) were the same as the super-abundant and the super-dominant morphospecies. Ants of the genera *Camponotus*, *Crematogaster*, *Dorymyrmex*, and *Pheidole* were the super-frequent morphospecies in the organic system, whereas only the last 2 genera were super-frequent in the conventional system (Tables 1 and 2).

Most morphospecies were considered uncommon, i.e., their occurrence was below 34% of the samplings, in both systems. In this category, 91 (47.9%) and 95 (51%) morphospecies occurred at low frequencies in the conventional and organic systems, respectively.

**Constancy**

In this category, most morphospecies occurred accidentally. In the conventional system, 95 morphospecies were considered accidental, 16 accessories, and 11 constant, whereas in the organic system, there were 103 accidental, 23 accessories, and 16 constant morphospecies (Table 1). The most constant morphospecies were the ants with 30% and 40% of total morphospecies in the organic and the conventional system, respectively. We also analyzed the specimens classified among the high faunistic values (super-dominant, dominant, super-abundant, very abundant, abundant, super-frequent, very frequent, frequent, and constant), and we found 22 (8 predators, 5 omnivores, 5 detritivores, and 4 herbivores) and 10 (5 predators, 3 omnivores, and 2 herbivores) species for organic and conventional systems, respectively. Among the morphospecies collected, 7 were common in both systems (3 omnivores [Brachymyrmex spp., Camponotus spp., Pheidole spp.], 3 predators [Crematogaster spp., Dorymyrmex spp., Ectatomma spp.], and 1 herbivore [Atta spp.]), 3 were found exclusively in the conventional system (2 predators and 1 herbivore), and 15 were found exclusively in the organic system (5 predators, 5 detritivores, 2 omnivores, and 3 herbivores).

Estimates of species richness were similar and close to the expected number of species as shown in Fig. 1. The species curves for both organic and conventional sugarcane systems tended to stabilize (plateau) when 15 samples were taken on a monthly basis. Thus, the number of monthly collections and traps adopted in the study was adequate for assessing species diversity in sugarcane agroecosystems.

A comparison of the edaphic arthropods by using principal component analysis indicated that there was a difference between the sugarcane systems. Eleven samples (73.3%) out of 15 taken from the organic sugarcane field presented negative values, whereas 13 samples...
Menopteran is shown by the high dominance and frequency of coleopteran and hy-
smaller numbers of herbivores were captured in the organic field. This
Also, greater numbers of arthropod predators and omnivores and
organic cropping system, relative to conventional sugarcane production.

Discussion

Twice as many soil-dwelling arthropods were captured in the or-
getic cropping system, relative to conventional sugarcane production.
Also, greater numbers of arthropod predators and omnivores and
smaller numbers of herbivores were captured in the organic field. This
is shown by the high dominance and frequency of coleopteran and hy-
menopteran predators in the organic system. These predators are re-
ported as important natural control agents of several pests that occur in
different stages of sugarcane development (Mendonça & Marques
2005; Costa et al. 2007; Silva et al. 2009).

Our results also suggest that compared with the conventional sys-
em, the organic system could provide greater availability and abun-
dance of resources such as pollen, nectar, and alternative sources of
food and shelter, which favor the abundance and diversity of species
(Landis et al. 2000). Root (1973) noted that systems providing appro-
riate conditions (food and shelter) tend to have greater abundance of
arthropod predators and omnivores, and therefore greater potential
for biological control of herbivores.

Among the predators, ant and spider species occurred frequently
in both systems. Several studies have shown ants in the genera Cremat-
tagaster, Dorymyrmex, Ectatomma, and Pheidole are effective control
agents of pests in sugarcane (Rossi & Fowler 2002, 2004; Araújo et al.
2004, 2005; Pereira et al. 2004; Philpott et al. 2008; Schatz et al. 2008),
but their population dynamics remain to be better understood. For spi-
ders in the sugarcane agroecosystem, there is practically no published
information about their diversity, although this work suggests that they
are especially abundant elements in organic sugarcane production,
and their contribution should be assessed.

Pheidole spp. and Dorymyrmex spp. ants were the only super-dom-
inant species in the conventional system. Thus, even with the disruption
cased by the use of fire in conventional harvesting, populations
of these species were not affected, as also observed by Araújo et al.
(2004). Ant species generally present rapid colony restructuring, wide
foraging area, and social organization. These features may have con-
tributed to the high abundance, frequency, and constancy in the con-
ventional area (Rossi & Fowler 2002; Araújo et al. 2004, 2005). The fact
that most super-dominant species were detected in the organic system
(Pheidole spp., Dorymyrmex spp., Crematogaster spp., and Campono-
tus spp.) may be related to the nesting strategy of these species. Ac-
ccording to Longino (2003), Crematogaster and Dorymyrmex ants have
shallow nests and therefore may be more affected by the fire, so the
reestablishment of colonies requires longer period of time.

However, it is not only the direct effects of fire that can lead to re-
duced biodiversity in the conventional system. Herbicides are used to
control weeds whose elimination can indirectly affect the population of
arthropods. Many herbivorous insects feed on the weeds that occur in
in crops (Chiverton & Sotherton 1991). Arthropod predators and parasit-
oids also can utilize these weeds to supplement their diet by feeding on
pollen and nectar. Thus, herbicides can affect biodiversity, either by ac-
ting directly (on herbivores) or indirectly (on predators and omnivores).

In spite of the higher species richness in the organic than the con-
ventional system, both the faunistic and diversity indices were gener-
ally similar. We hypothesize that this finding may be related to sur-
rounding sugarcane areas, which may have been used as a shelter or
refuge for some arthropods, especially beneficial arthropods, during
harvest in the 2 systems. Although this needs to be further studied in
this agroecosystem, harvesting the sugarcane at different times may
facilitate the movement of arthropods between different areas, allow-
ing the reoccupation of the disturbed environment more quickly.

The study of arthropod biodiversity may allow us to identify im-
portant naturally occurring beneficials in the agroecosystem. Despite
having used only pitfall trapping, this study provided comparative
information on biodiversity in the sugarcane agroecosystem under 2
management systems. This new information may assist future studies
on biological control, or even risk assessment of genetically modified
sugarcane, where it is essential to know the diversity of arthropods.
Overall, our results indicated that the organic management of sugar-
cane improves the abundance and diversity of arthropods (especially
predators and omnivores) relative to conventional management.

---

Fig. 1. Curve estimating species richness of edaphic arthropods in conven-
tional and organic sugarcane fields in Jaboticabal, São Paulo, Brazil. Error bars
represent the standard deviation.

Fig. 2. Principal component analysis of the arthropod communities in organic
(ORG) and conventional (CON) sugarcane fields.
Acknowledgments

The authors are grateful to Antonio Brescovit and João Lucas Cha-
vari, Instituto Butantan, São Paulo, Brazil, who kindly identified the spi-
ders. Scholarship to the first author was provided by CAPES, Brazil.

References Cited

Abreu RRL, Lima SS, Oliveira NCR, Leite LFC. 2014. Fauna edáfica sob diferen-
tes níveis de palhada em cultivo de cana-de-açúcar. Pesquisa Agropecuária
Tropical 44: 409–416.

Araújo MS, Della Lucia TMC, Picanço MC. 2004. Impacto da queima da palhada
dana-de-açúcar no ritmo diário de forrageamento de Atta bispheara
Forél (Hymenoptera: Formicidae). Revista Brasileira de Zootologia 2: 33–38.

Araújo RA, Araújo MS, Gonring AHR, Guedes RNC. 2005. Impacto da queimada
controlada da palhada da cana-de-açúcar sobre a comunidade de insetos
locais. Neotropical Entomology 34: 649–658.

Baccaro FB. 2006. Chave para as principais subfamílias e gêneros de formigas
(Hymenoptera: Formicidae). Instituto Nacional de Pesquisas da Amazônia,
Programa de Pesquisa em Biodiversidade, Faculdades Cathedral, Barra do
Garças, Mato Grosso, Brazil.

Borrow DJ, Triplehorn CA, Johnson NF. 1992. An Introduction to the Study of
Insects, 6th Edition. Saunders College Publishing, Philadelphia, Pennsyl-
vania.

Butler SJ, Vickery JA, Norris K. 2007. Farmland biodiversity and the footprint
of agriculture. Science 315: 381–384.

Castelo Branco RT, Portela GLF, Barbosa OAA, Silva PRR, Pádua LEM. 2010.
Análise faunaística de insetos associados à cultura da cana-de-açúcar, em
área de transição floresta amazônica- cerrado (mata de cocal), no munici-
pício de União-Piauí, Brasil. Semina 31: 113–1120.

Chiverton PA, Sotherton NW. 1991. The effects of beneficial arthropods of the
exclusion of herbicides from cereal crop edges. Journal of Applied Ecology
28: 1027–1039.

Colwell RK. 2006. EstimateS: Statistical Estimation of Species Richness and
Shared Species from samples. Version 8.0 User’s Guide and Application,
http://viceroy.eeb.uconn.edu/estimates (last accessed 9 Dec 2016).

Costa NP, Oliveira HD, Brito CH, Silva AB. 2007. Influência do nim na biologia
do predador Euborellia annulipes e estudo de parâmetros para a sua cria-
cão massal. Revista de Biologia e Ciências da Terra 7: 1–10.

Eilenberg H, Hajek A, Lomer C. 2001. Suggestions for unifying the terminology
in biological control. Annual Review of Entomology 45: 175–201.

Landis DA, Menalled FD, Costamagna AC, Wilkinson TK. 2005. Manipulating
plant resources to enhance beneficial arthropods in agricultural land-
scapes. Weed Science 53: 902–908.

Letourneau DK. 1998. Conserving biology, lessons for conserving natural enemies,
pp. 9–38 in Barbosa P [ed.], Conservation Biological Control. Academic Press;
San Diego, California.

Longino JT. 2003. The Crematogaster (Hymenoptera, Formicidae, Myrmicinidae) of
Costa Rica. Zootaxa 151: 1–150.

Loureiro MC, Queiroz RMVB. 1990. Insetos de Viçosa—Formicidae. Universidade
Federal de Viçosa, Viçosa, Minas Gerais, Brazil.

Mendonça AF, Marques EJ. 2005. Cigarra da folha Mahanarva posticata (Stål)
(Hemiptera: Cercopidae), pp. 295–301 in Mendonça AF [ed.], Cigarraças da
Cana-de-açúcar. Insecta. Maceió, Alagoas, Brazil.

Moraes RCB, Haddad ML. 2003. Software para análise faunaística-ANAFAU, p.195
In Simpósio de Controle Biológico, 8. São Pedro. Resumos. Sociedade Entomológi-
do do Brasil, Piracicaba, Brazil.

Nunes L, Silva I, Pitê M, Rego F, Leather S, Serrano A. 2006. Carabid (Coleoptera)
community change following prescribed burning and the potential use of cara-
bids as indicator species to evaluate the effects of fire management in Medi-
terranean regions. Silva Lusitana 14: 85–100.

Oliver I, Beattie AJ. 1996. Invertebrate morphospecies as surrogates for species: a
case study. Conservation Biology 10: 99–109.

Paspalum L, Dionísio SA, Zawadneak MAC, Marçal CT. Macrofauna edáfica em
lavouras de cana-de-açúcar e mata no noroeste do Paraná, Brasil. Semina 33:
7–18.

Pereira JA, Bento A, Cabanas JE, Torres LM, Herz A, Hassan SA. 2004. Ants as preda-
tors of the egg parasitoid Trichogramma cacoeciae (Hymenoptera: Trichogram-
mattidae) applied for biological control of the olive moth, Prays oleae (Lepidop-
tera: Plutellidae) in Portugal. Biocontrol Science and Technology 14: 653–664.

Phippott SM, Perfecto I, Vandermeer J. 2008. Behavioral diversity of predatory ar-
boval ants in coffee agroecosystems. Environmental Entomology 37: 181–191.

Pogue DW, Schnell GD. 2001. Effects of agriculture on habitat complexity in a prairie-
forest ecotone in the southern Great Plains of North America. Agriculture, Eco-
systems & Environment 87: 287–298.

Root RB. 1973. Organization of plant–arthropod association in simple and diverse
habitats: the fauna of collards (Brassica oleraceae). Ecological Monographs 43:
95–124.

Rossi MN, Fowler HG. 2002. Manipulation of fire ant density, Solenopsis spp., for
short-term reduction of Diatraea saccharalis larval densities in Brazil. Scientia
Agricola 59: 389–392.

Rossi MN, Fowler HG. 2004. Predaceous ant fauna in new sugarcane fields in the
state of São Paulo, Brazil. Brazilian Archives of Biology and Technology 47:
805–811.

Schatz B, Kjellberg F, Nyawa S, Hossaert-McKey M. 2008. Fig wasps: a staple food for
ants on Ficus (Lauraceae) in Portugal. Biocontrol Science and Technology 14: 653–664.

Silva AB, Batista JL, Brito CH. 2009. Capacidade predatorária de Euborellia annulipes
(Hymenoptera: Euborellidae) applied for biological control of the olive moth,
Prays oleae (Lepidoptera: Plutellidae) in Portugal. Biocontrol Science and Technology 14:
653–664.

Silva LA, Dionísio SA, Zawadneak MAC, Marçal CT. Macrofauna edáfica em
lavouras de cana-de-açúcar e mata no noroeste do Paraná, Brasil. Semina 33:
7–18.

Silva Lusitana 14: 85–100.

Tanaka R. 1998. Conserving biology, lessons for conserving natural enemies,
pp. 305–325 in Pimentel D, Zayed A (eds.), Encyclopedia of plant resources, pp. 305–325
Wäckers FR.. 2001. The role of biocontrol in reducing the damage caused by the
olive moth, Prays oleae (Lepidoptera: Plutellidae) in Portugal. Biocontrol Science and Techno-
logy 14: 653–664.

Wilkinson TK, Landis DA. 2005. Habitat diversification in biological control: the role
of plant resources, pp. 305–325 in Wäckers FL, van Rijn PCJ, Bruin J [eds.], Plant-
Provided Food for Carnivorous Insects. A Protective Mutualism and its Applications.
Cambridge University Press, Cambridge, United Kingdom.