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

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Diversity and abundance of edaphic arthropods associated with conventional and organic sugarcane crops in Brazil

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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 organicamente, 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 pertencentes a 190 morfo-espécies. No sistema convencional 4964 espécimens foram coletados e representaram 122 morfo-espécies, 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. 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.

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Materials and Methods

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 exclusive categories known as super-dominant, super-abundant, and super-frequent. The dominance was calculated by the equation DL = (1 / S) × 100, where DL = dominance limit and S = total number of species per sample. The abundance was calculated using the standard deviation and confidence interval of the arithmetic mean at 1 and 5% probabilities. For frequency, the equation F = (*n* / *N*) × 100 was adopted, where F = frequency (%), *n* = number of specimens of each species collected, and *N* = total number of specimens of the collected species. For constancy, the equation C = (P / *N*) × 100 was used, where C = constancy, P = number of samples containing the species, *N* = total number of samples collected (Silveira Neto et al. 1976).

Diversity was assessed using the species diversity indices of Shannon–Wiener (H') and Margalef (α). The equitability index (E) was calculated to evaluate the uniformity of the captures and how the individuals are distributed in the sample, using the ANAFAU software (Moraes & Haddad 2003). The similarity index assessed the number of species shared between the 2 cropping systems.

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 *Crematogaster* 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.

		Conventional						Organic						
Taxon	Morphospecies	No. Individuals Captured	No. collections	Dominance	Abundance	Frequency	Constancy	No. Individuals Captured	No. collections	Dominance	Abundance	Frequency	Constancy	Functional Group
Blattodea														
Blatellidae	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	.	.	.	.	.	.	Predator
	Pseudabarys sp.1	.	.	.	.	.	.	2	2	ND	R	LF	Z	Predator
	Pseudabarys sp.2	.	.	.	.	.	.	1	1	ND	R	LF	Z	Predator
	Pseudabarys sp.3	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
Cincidelinae	*Megacephala* sp.1	2	2	ND	R	LF	Z	1	1	ND	R	LF	Z	Predator
	Cincidelinae sp.1	4	1	ND	R	LF	Z	20	7	D	C	F	Y	Predator
	Cincidelinae sp.2	4	3	ND	R	LF	Z	.	.	.	.	.	.	Predator
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
Elateridae	*Conoderus scalaris*	4	3	ND	R	LF	Z	.	.	.	.	.	.	Herbivore
	Conoderus sp.1	.	.	.	.	.	.	2	2	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	*Ataenius* sp.1	1	1	ND	R	LF	Z	.	.	.	.	.	.	Detritivore
	Ataenius sp.2	1	1	ND	R	LF	Z	.	.	.	.	.	.	Detritivore
	Canthon sp.1	11	6	ND	C	F	Y	.	.	.	.	.	.	Detritivore
	Canthon sp.2	.	.	.	.	.	.	3	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.

		Conventional						Organic						
Taxon	Morphospecies	No. Individuals Captured	No. collections	Dominance	Abundance	Frequency	Constancy	No. Individuals Captured	No. collections	Dominance	Abundance	Frequency	Constancy	Functional Group
Staphylinidae	Staphylinidae sp.1	3	2	ND	R	LF	Z	1	1	ND	R	LF	Z	Predator
	Staphylinidae sp.2	165	2	D	VA	VF	Z	1	1	ND	R	LF	Z	Predator
	Staphylinidae sp.3	.	.	.	.	.	.	1	1	ND	R	LF	Z	Predator
	Staphylinidae sp.4	16	6	ND	C	F	Y	81	6	D	VA	VF	Y	Predator
	Staphylinidae sp.5	1	1	ND	R	LF	Z	1	1	ND	R	LF	Z	Predator
	Staphylinidae sp.6	.	.	.	.	.	.	3	2	ND	R	LF	Z	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	115	3	D	VA	VF	Z	Predator
	Forficulidae sp.2	.	.	.	.	.	.	1	1	ND	R	LF	Z	Predator
Labiduridae	*Labidura* sp.	15	5	ND	C	F	Y	1	1	ND	R	LF	Z	Predator
Diptera														
Agromyzidae	Agromyzidae sp.1	.	.	.	.	.	.	24	3	D	A	VF	Z	Herbivore
Asilidae	Asilidae sp.	5	2	ND	R	LF	Z	.	.	.	.	.	.	Predator
Culicidae	Culicidae sp.1	.	.	.	.	.	.	2	2	ND	R	LF	Z	Omnivore
	Culicidae sp.2	7	1	ND	D	LF	Z	.	.	.	.	.	.	Omnivore
Dolichopodidae	*Condylostylus* sp.	2	1	ND	R	LF	Z	.	.	.	.	.	.	Predator
	Dolichopodidae sp.1	2	1	ND	R	LF	Z	7	4	ND	D	LF	Y	Predator
Drosophilidae	Drosophilidae sp.1	1	1	ND	R	LF	Z	1	1	ND	R	LF	Z	Detritivore
	Drosophilidae sp.2	.	.	.	.	.	.	21	6	D	C	F	Y	Omnivore
	Drosophilidae sp.3	8	2	ND	D	LF	Z	1	1	ND	R	LF	Z	Omnivore
	Drosophilidae sp.4	.	.	.	.	.	.	1	1	ND	R	LF	Z	Omnivore
	Drosophilidae sp.5	.	.	.	.	.	.	1	1	ND	R	LF	Z	Omnivore
Muscidae	Muscidae sp.1	5	1	ND	R	LF	Z	2	1	ND	R	LF	Z	Omnivore
	Muscidae sp.2	.	.	.	.	.	.	1	1	ND	R	LF	Z	Omnivore
Mycetophilidae	Mycetophilidae sp.1	.	.	.	.	.	.	2	2	ND	R	LF	Z	Omnivore
	Mycetophilidae sp.2	.	.	.	.	.	.	2	1	ND	R	LF	Z	Omnivore
Phoridae	Phoridae sp.1	11	6	ND	C	F	Y	60	11	D	VA	VF	W	Detritivore
	Phoridae sp.2	12	5	ND	C	F	Y	53	12	D	VA	VF	W	Detritivore
	Phoridae sp.3	7	4	D	D	LF	Y	40	7	D	VA	VF	Y	Detritivore
	Phoridae sp.4	8	3	ND	D	LF	Z	8	2	ND	C	F	Z	Detritivore
	Phoridae sp.5	.	.	.	.	.	.	15	6	D	C	F	Y	Detritivore
	Phoridae sp.6	.	.	.	.	.	.	1	1	ND	R	LF	Z	Detritivore
	Phoridae sp.7	.	.	.	.	.	.	1	1	ND	R	LF	Z	Detritivore
	Phoridae sp.8	3	3	ND	R	LF	Z	1	1	ND	R	LF	Z	Detritivore

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.

		Conventional						Organic						
Taxon	Morphospecies	No. Individuals Captured	No. collections	Dominance	Abundance	Frequency	Constancy	No. Individuals Captured	No. collections	Dominance	Abundance	Frequency	Constancy	Functional Group
Piophilidae	Piophilidae sp.1	.	.	.	.	.	.	6	4	ND	D	LF	Y	Omnivore
Psychodidae	Psychodidae sp.1	.	.	.	.	.	.	1	1	ND	R	LF	Z	Omnivore
Sciaridae	Sciaridae sp.1	.	.	.	.	.	.	3	2	ND	R	LF	Z	Omnivore
	Sciaridae sp.2	1	1	ND	R	LF	Z	6	3	ND	D	LF	Z	Omnivore
	Sciaridae sp.3	3	3	ND	R	LF	Z	20	6	D	C	F	Y	Omnivore
	Sciaridae sp.4	.	.	.	.	.	.	1	1	ND	R	LF	Z	Omnivore
	Sciaridae sp.5	8	3	ND	D	LF	Z	43	4	D	VA	VF	Y	Omnivore
	Sciaridae sp.6	3	2	ND	R	LF	Z	32	3	D	VA	VF	Z	Omnivore
	Sciaridae sp.7	.	.	.	.	.	.	1	1	ND	R	LF	Z	Omnivore
	Sciaridae sp.8	.	.	.	.	.	.	1	1	ND	R	LF	Z	Omnivore
	Sciaridae sp.9	2	1	ND	R	LF	Z	1	1	ND	R	LF	Z	Omnivore
	Sciaridae sp.10	2	1	ND	R	LF	Z	1	1	ND	R	LF	Z	Omnivore
	Sciaridae sp.11	1	1	ND	R	LF	Z	1	1	ND	R	LF	Z	Omnivore
	Sciaridae sp.12	1	1	ND	R	LF	Z	.	.	.	.	.	.	Omnivore
Sphaeroceridae	Sphaeroceridae sp.1	.	.	.	.	.	.	23	3	D	A	VF	Z	Omnivore
	Sphaeroceridae sp.2	.	.	.	.	.	.	7	2	ND	D	LF	Z	Omnivore
	Sphaeroceridae sp.3	.	.	.	.	.	.	3	1	ND	R	LF	Z	Omnivore
	Sphaeroceridae sp.4	.	.	.	.	.	.	1	1	ND	R	LF	Z	Omnivore
	Sphaeroceridae sp.5	1	1	ND	R	LF	Z	1	1	ND	R	LF	Z	Omnivore
Tachinidae	Tachinidae sp.1	11	4	ND	C	F	Y	6	1	ND	D	LF	Z	Omnivore
Ulidiidae	Ulidiidae sp.1	1	1	ND	R	LF	Z	.	.	.	.	.	.	Omnivore
	Diptera sp.1	.	.	.	.	.	.	2	1	ND	R	LF	Z	Omnivore
	Diptera sp.2	.	.	.	.	.	.	1	1	ND	R	LF	Z	Omnivore
	Diptera sp.3	3	2	ND	R	LF	Z	1	1	ND	R	LF	Z	Omnivore
	Diptera sp.4	.	.	.	.	.	.	9	1	ND	C	F	Z	Omnivore
	Diptera sp.5	.	.	.	.	.	.	1	1	ND	R	LF	Z	Omnivore
	Diptera sp.6	.	.	.	.	.	.	1	1	ND	R	LF	Z	Omnivore
	Diptera sp.7	.	.	.	.	.	.	1	1	ND	R	LF	Z	Omnivore
	Diptera sp.8	1	1	ND	R	LF	Z	2	1	ND	R	LF	Z	Omnivore
Hemiptera														
Aphididae	Aphididae sp.1	24	2	D	C	F	Z	11	3	ND	C	F	Z	Herbivore
Aetalionidae	Aetalionidae sp.1	.	.	.	.	.	.	4	3	ND	R	LF	Z	Herbivore
Cercopidae	*Mahanarva fimbriolata*	2	2	ND	R	LF	Z	11	5	ND	C	F	Y	Herbivore
Coreidae	Coreidae sp.	1	1	ND	R	LF	Z	.	.	.	.	.	.	Herbivore
Cydnidae	*Scaptocoris castanea*	2	2	ND	R	LF	Z	90	11	D	VA	VF	W	Herbivore
	Cyrtomenus mirabilis	3	2	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.

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		Conventional						Organic						
Taxon	Morphospecies	No. Individuals Captured	No. collections	Dominance	Abundance	Frequency	Constancy	No. Individuals Captured	No. collections	Dominance	Abundance	Frequency	Constancy	Functional Group
Reduviidae	*Rasahus* 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
	Acromyrmex sp.	21	8	D	C	F	W	10	5	ND	C	F	Y	Herbivore
	Anochetus sp.	2	2	ND	R	LF	Z	.	.	.	.	.	.	Predator
	Atta sp.1	.	.	.	.	.	.	2	2	ND	R	LF	Z	Herbivore
	Atta spp.	33	9	D	VA	VF	W	22	8	D	A	VF	W	Herbivore
	Brachymyrmex spp.	253	14	D	VA	VF	W	498	15	D	VA	VF	W	Omnivore
	Camponotus spp.	184	14	D	VA	VF	W	622	15	SD	SA	SF	W	Omnivore
	Crematogaster spp.	145	8	D	VA	VF	W	1,749	15	SD	SA	SF	W	Predator
	Dolichoderus spp.	63	2	D	VA	VF	Z	8	2	ND	C	F	Z	Predator
	Dorymyrmex spp.	988	15	SD	SA	SF	W	1,026	15	SD	SA	SF	W	Predator
	Ectatomma spp.	66	12	D	VA	VF	W	62	10	D	VA	VF	W	Predator
	Gnamptogenys spp.	25	7	D	A	VF	Y	17	5	D	C	F	Y	Predator
	Hypoponera sp.	8	1	ND	D	LF	Z	9	2	ND	C	F	Z	Predator
	Odontomachus sp.	26	6	D	A	VF	Y	8	5	ND	C	F	Y	Predator
	Pachycondyla sp.	1	1	ND	R	LF	Z	4	2	ND	R	LF	Z	Predator
	Paratrechina sp.	.	.	.	.	.	.	3	2	ND	R	LF	Z	Predator
	Pheidole spp.	2,032	15	SD	SA	SF	W	2,716	15	SD	SA	SF	W	Omnivore
	Pseudomyrmex sp.	1	1	ND	R	LF	Z	3	3	ND	R	LF	Z	Predator
	Solenopsis sp.	.	.	.	.	.	.	1	1	ND	R	LF	Z	Omnivore
	Tapinona sp.	98	2	D	VA	VF	Z	7	1	ND	D	LF	Z	Predator
	Trachymyrmex sp.	1	1	ND	R	LF	Z	.	.	.	.	.	.	Herbivore
	Wasmania sp.	.	.	.	.	.	.	10	1	ND	C	F	Z	Predator
	Formicidae sp.1	3	1	ND	R	LF	Z	2	2	ND	R	LF	Z	Predator
Vespidae	Vespidae sp.1	2	2	ND	R	LF	Z	1	1	ND	R	LF	Z	Predator
Isoptera														
Termitidae	Termitidae sp.1	3	3	ND	R	LF	Z	26	5	D	VA	VF	Y	Detritivore
Lepidoptera														
Hesperiidae	Hesperiidae sp.1	5	2	ND	R	LF	Z	4	2	ND	R	LF	Z	Herbivore
	Hesperiidae 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.

		Conventional						Organic						
Taxon	Morphospecies	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	80	2	D	VA	VF	Z	Herbivore
	Lepidoptera sp.3 (immature)	2	2	ND	R	LF	Z	.	.	.	.	.	.	Herbivore
Neuroptera														
Chrysopidae	*Chrysoperla externa*	1	1	ND	R	LF	Z	.	.	.	.	.	.	Herbivore
Hemerobiidae	Hemerobiidae sp.1	2	2	ND	R	LF	Z	.	.	.	.	.	.	Omnivore
Orthoptera														
Acrididae	Acrididae sp.1	11	6	ND	C	F	Y	107	11	D	VA	VF	W	Herbivore
	Acrididae sp.2	12	3	ND	C	F	Z	.	.	.	.	.	.	Herbivore
Gryllidae	*Gryllus assimilis*	71	13	D	VA	VF	W	3	2	ND	R	LF	Z	Herbivore
Thysanoptera														
	Thysanoptera sp.1	2	1	ND	R	LF	Z	.	.	.	.	.	.	Herbivore
Araneae														
Araneidae	Araneidae sp.1	1	1	ND	R	LF	Z	.	.	.	.	.	.	Predator
Corinnidae	*Corinna* sp.	14	7	ND	C	F	Y	81	9	D	VA	VF	W	Predator
	Corinnidae sp.1	.	.	.	.	.	.	58	5	D	VA	VF	Y	Predator
	Castianeirinae sp.1	3	1	ND	R	LF	Z	3	3	ND	R	LF	Z	Predator
Ctenidae	Ctenidae sp.1	.	.	.	.	.	.	1	1	ND	R	LF	Z	Predator
Gnaphosidae	Gnaphosidae sp.1	1	1	ND	R	LF	Z	.	.	.	.	.	.	Predator
	Gnaphosidae sp.2	2	1	ND	R	LF	Z	.	.	.	.	.	.	Predator
Hahniidae	Hahniidae sp.1	1	1	ND	R	LF	Z	.	.	.	.	.	.	Predator
	Hahniidae sp.2	1	1	ND	R	LF	Z	.	.	.	.	.	.	Predator
	Hahniidae sp.3	.	.	.	.	.	.	4	3	ND	R	LF	Z	Predator
Linyphiidae	*Lepthyphantes* sp.	1	1	ND	R	LF	Z	3	3	ND	R	LF	Z	Predator
	Meioneta sp.1	1	1	ND	R	LF	Z	2	2	ND	R	LF	Z	Predator
	Meioneta sp.2	.	.	.	.	.	.	1	1	ND	R	LF	Z	Predator
	Linyphiidae sp.1	.	.	.	.	.	.	1	1	ND	R	LF	Z	Predator
Lycosidae	*Lycosa* sp.	2	1	ND	R	LF	Z	1	1	ND	R	LF	Z	Predator
	Lycosidae sp.1	6	5	ND	R	LF	Y	11	7	ND	C	F	Y	Predator
	Lycosidae sp.2	.	.	.	.	.	.	2	1	ND	R	LF	Z	Predator
Miturgidae	*Teminius insularis*	2	2	ND	R	LF	Z	23	8	D	A	VF	W	Predator
	Miturgidae sp.1	1	1	ND	R	LF	Z	7	4	ND	D	LF	Y	Predator
Oonopidae	Onopinae sp.1	.	.	.	.	.	.	2	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. (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						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	Predator
	Berlandiella sp.2	.	.	.	.	.	.	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	.	.	.	.	.	.	Predator
	Salticidae sp.2	1	1	ND	R	LF	Z	.	.	.	.	.	.	Predator
	Salticidae sp.3	1	1	ND	R	LF	Z	.	.	.	.	.	.	Predator
	Salticidae sp.4	.	.	.	.	.	.	1	1	ND	R	LF	Z	Predator
	Salticidae sp.5	.	.	.	.	.	.	2	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 ytu	1	1	ND	R	LF	Z	.	.	.	.	.	.	Predator
	Scytodidae sp.1	2	2	ND	R	LF	Z	.	.	.	.	.	.	Predator
Tetragnathidae	Tetragnathidae sp.1	3	2	ND	R	LF	Z	.	.	.	.	.	.	Predator
Theridiidae	*Coleosoma* sp.1	3	2	ND	R	LF	Z	5	4	ND	R	LF	Y	Predator
	Coleosoma sp.2	3	3	ND	R	LF	Z	.	.	.	.	.	.	Predator
	Dipoena sp.1	7	2	ND	D	LF	Y	5	5	ND	R	LF	Y	Predator
	Dipoena sp.2	5	4	ND	R	LF	Z	29	8	D	VA	VF	W	Predator
	Dipoena sp.3	1	1	ND	R	LF	Z	.	.	.	.	.	.	Predator
	Theridiidae sp.1	.	.	.	.	.	.	2	2	ND	R	LF	Z	Predator
Titanoecidae	*Goeldia* sp.1	4	2	ND	R	LF	Z	9	4	ND	C	F	Y	Predator
	Goeldia sp.2	.	.	.	.	.	.	7	2	ND	D	LF	Z	Predator
Opiliones	Opiliones sp.1	1	1	ND	R	LF	Z	20	2	D	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.

Table 2. Distribution of morphospecies in relation to faunistic indices of dominance, abundance, frequency, and constancy captured in pitfall traps in conventional and organic sugarcane systems in Brazil (2011/12 and 2012/13 growing seasons).

		No. of morphospecies (%)		Total no. of individuals (%)	
Faunistic index	Classification	Conventional	Organic	Conventional	Organic
Dominance	SD	2 (1.6)	4 (2.8)	3,020 (60.84)	6,110 (73.8)
	D	17 (14)	30 (21.2)	1,577 (31.76)	1,825 (22.04)
	ND	103 (84.4)	108 (76)	367 (7.4)	345 (4.16)
Abundance	SA	2 (1.65)	4 (2.8)	3,020 (60.84)	6,110 (73.8)
	VA	11 (9.1)	19 (13.4)	1,450 (29.21)	1,598 (19.3)
	A	2 (1.6)	5 (3.5)	51 (1.03)	114 (1.38)
	C	16 (13.2)	19 (13.4)	218 (4.39)	238 (2.87)
	D	7 (5.7)	9 (6.3)	53 (1.07)	60 (0.72)
	R	84 (68.8)	86 (60.6)	172 (3.46)	160 (1.93)
Frequency	SF	2 (1.6)	4 (2.8)	3,020 (60.84)	6,110 (73.8)
	VF	13 (10.6)	24 (16.9)	1,501 (30.24)	1,712 (20.68)
	F	16 (13.2)	19 (13.4)	218 (4.4)	238 (2.87)
	LF	91 (74.6)	95 (66.9)	225 (4.52)	220 (2.65)
Constancy	W	11 (9)	16 (11.3)	3,832 (77.2)	7,253 (87.6)
	Y	16 (13.2)	23 (16.2)	193 (3. 89)	457 (5.52)
	Z	95 (77.8)	103 (72.5)	939 (18.91)	570 (6.88)

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 system, 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

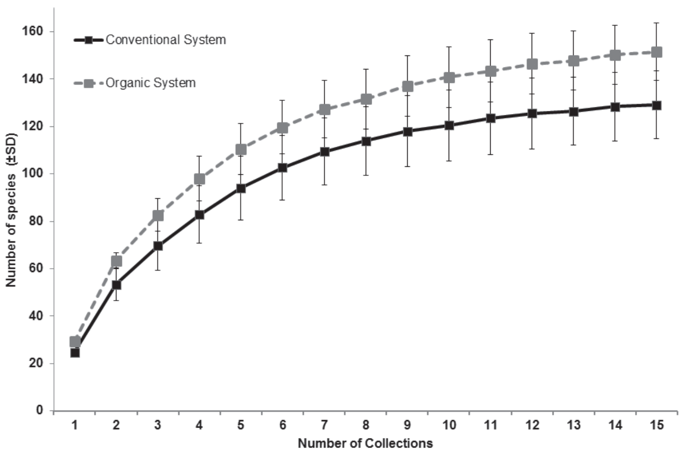

Fig. 1. Curve estimating species richness of edaphic arthropods in conventional and organic sugarcane fields in Jaboticabal, São Paulo, Brazil. Error bars represent the standard deviation.

(86.7%) out of 15 from the conventional field presented positive values (Fig. 2). Therefore, the communities were different both quantitatively and qualitatively. Ants generally were the most abundant species found on both systems, but they were more abundant in the organic than the conventional system.

Discussion

Twice as many soil-dwelling arthropods were captured in the organic 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 hymenopteran predators in the organic system. These predators are reported 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).

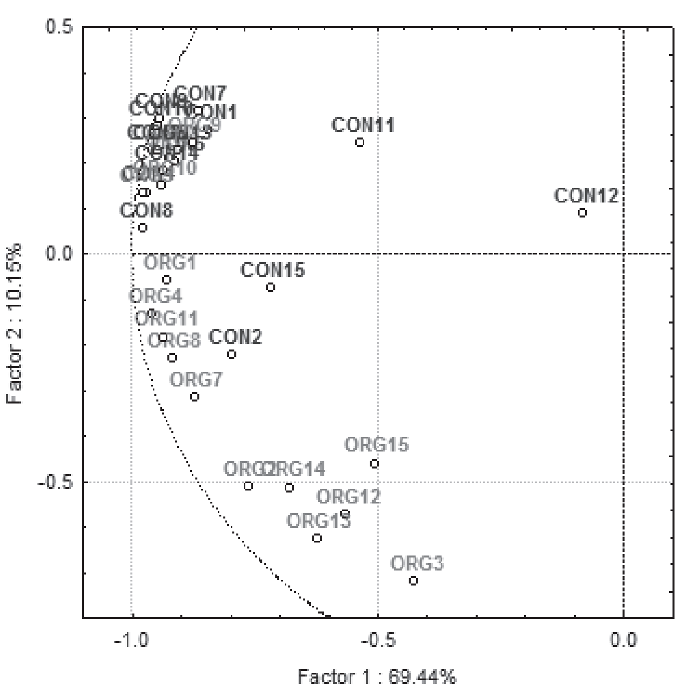

Fig. 2. Principal component analysis of the arthropod communities in organic (ORG) and conventional (CON) sugarcane fields.

Our results also suggest that compared with the conventional system, the organic system could provide greater availability and abundance 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 appropriate 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 *Crematogaster*, *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 spiders 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-dominant species in the conventional system. Thus, even with the disruption caused 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 contributed to the high abundance, frequency, and constancy in the conventional 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 *Camponotus* spp.) may be related to the nesting strategy of these species. According 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 reduced 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 crops (Chiverton & Sotherton 1991). Arthropod predators and parasitoids also can utilize these weeds to supplement their diet by feeding on pollen and nectar. Thus, herbicides can affect biodiversity, either by acting directly (on herbivores) or indirectly (on predators and omnivores).

In spite of the higher species richness in the organic than the conventional system, both the faunistic and diversity indices were generally similar. We hypothesize that this finding may be related to surrounding 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, allowing the reoccupation of the disturbed environment more quickly.

The study of arthropod biodiversity may allow us to identify important 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 sugarcane improves the abundance and diversity of arthropods (especially predators and omnivores) relative to conventional management.

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