Research Article

Sampling of the main hymenopteran parasitoids (Insecta: Hymenoptera) associated with sugarcane borer in organic and conventional farming systems[1]

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ABSTRACT

Hymenopteran parasitoids strongly associated with the sugarcane borer [*Diatraea saccharalis* (Lepidoptera: Crambidae)] may be found both in organic and conventional sugarcane farming systems. This study aimed to sample parasitoids associated with sugarcane borer in organic, organic near a forest fragment and conventional systems. Two colors of Moericke traps were used (yellow and white) to collect insect samples, and faunistic analyses were performed to determine the composition of parasitoids in each management type. A total of 287 insects were collected, with the most abundant families being Diapriidae (44.44 %), Eulophidae (37.5 %) and Braconidae (18.06 %). The most abundant genus in the organic system was *Omphale* (Eulophidae), *Omphale* (Eulophidae) in the organic system near the forest fragment, and *Omopria* and *Coptera* (Diapriidae) in the conventional system. The parasitoids were more abundant in the organic system (43.06 %), followed by the organic system near the forest fragment (36.81 %) and the conventional system (20.14 %). The yellow trap was the most effective in attracting parasitoids, which were generally more abundant in organic systems, regardless of proximity to forest fragments.

KEYWORDS: *Saccharum* spp., *Diatraea saccharalis*, Diapriidae, Eulophidae, Braconidae.

RESUMO

Amostragem dos principais himenópteros parasitoides (Insecta: Himenóptera) associados à broca da cana-de-açúcar em sistemas orgânicos e convencional

Parasitoides himenópteros intimamente associados à broca da cana-de-açúcar [*Diatraea saccharalis* (Lepidóptera: Crambidae)] podem ser encontrados tanto no cultivo orgânico quanto no convencional. Objetivou-se amostrar parasitoides associados à broca da cana-de-açúcar sob cultivo orgânico, orgânico próximo a um fragmento florestal e convencional. Armadilhas Moericke de duas cores (amarela e branca) foram usadas para amostrar os insetos, e análises faunísticas foram conduzidas para determinar a composição de parasitoides em cada tipo de manejo. No total, foram coletados 287 insetos, dos quais as famílias mais abundantes coletadas foram Diapriidae (44,44 %), Eulophidae (37,5 %) e Braconidae (18,06 %). O gênero mais abundante no cultivo orgânico foi *Omphale* (Eulophidae), *Omphale* (Eulophidae) no fragmento orgânico próximo à floresta e *Omopria* e *Coptera* (Diapriidae) no convencional. Os parasitoides foram mais abundantes no sistema orgânico (43,06 %), seguidos por orgânico + floresta (36,81 %) e convencional (20,14 %). A armadilha amarela foi mais atraente para os parasitoides, os quais foram, em geral, mais abundantes em sistemas orgânicos, independentemente da presença de fragmentos florestais.

PALAVRAS-CHAVE: *Saccharum* spp., *Diatraea saccharalis*, Diapriidae, Eulophidae, Braconidae.

INTRODUCTION

Sugarcane (*Saccharum* spp.; Poaceae) is extensively cultivated for products such as ethanol and sugar, driving high productivity demands in Brazil. According to the Conab (2023), the estimated yield for the 2023/2024 harvest is 637.1 million tons. Due to its favorable climate, Brazil's Southeast region accounts for 63.5 % of the national production, with São Paulo remaining the highest-yielding state, despite the competition for land use with other crops such as soybean and corn.

Yield losses are often linked to pest infestations, particularly by *Diatraea saccharalis* (Fabricius, 1794) (Lepidoptera: Crambidae), commonly known as sugarcane borer, a key pest in sugarcane cultivation (Parra 2014). Damage occurs during the larval stage, when the insect bores into plant stems, creating

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tunnels as it feeds. This leads to symptoms such as apical bud death and plant desiccation, resulting in substantial yield losses. Additionally, *D. saccharalis* can facilitate fungal infections by *Fusarium moniliforme* J. Sheld (1904) and *Colletotrichum falcatum* Went (1893), which contaminate the plant sap (Dinardo-Miranda et al. 2013, Rossato Júnior et al. 2013).

Various control methods have been employed to manage sugarcane borers, including plant resistance (Arruda 2012), chemical control (Wilson et al. 2022) and biological control (Parra 2014). Since organic farming prohibits the use of chemical insecticides (Siddiqui et al. 2023), biological control using natural enemies such as parasitoids and predators is the most viable, efficient and ecologically sustainable solution for managing *D. saccharalis* larvae (Bezerra et al. 2021).

In Brazil, hymenopteran parasitoids are commonly used in biological control programs targeting *D. saccharalis.* Endoparasitoids such as *Cotesia flavipes* (Cameron, 1891) (Hymenoptera: Braconidae) parasitize larvae, whereas *Trichogramma galloi* Zucchi, 1988 (Hymenoptera: Trichogrammatidae) targets eggs (Botelho et al. 1999, Martins et al. 2011, Parra 2014). Mass releases of these parasitoids, alone or in combination, enhance control efficiency and are widely recommended (Botelho et al. 1999). In addition to released parasitoids, naturally occurring species are crucial biological control agents, helping to maintain the ecosystem balance, as they specialize in different host developmental stages (Fernández & Sarkey 2006).

Moericke traps, often used to monitor aphids (Hussain et al. 2022), can be adapted to survey various insect groups, depending on trap color (Banaszak et al. 1994). They are also effective for sampling parasitoids (Silva et al. 2016), and their use for capturing bees and other pollinators has increased in recent decades (Krahner et al. 2024). This method is cost-effective, if compared to alternatives like sex pheromones (Bąkowski et al. 2013). Trap color significantly influences insect capture rates, with yellow being the most common one (Martins et al. 2010, Bąkowski et al. 2013). However, blue and white traps have also shown promise for capturing hymenopterans (McCravy 2018).

Research using Moericke traps to monitor parasitoids associated with the sugarcane borer remains limited. Therefore, this study aimed to identify hymenopteran parasitoids associated with the sugarcane borer under three different management systems: organic, organic near a forest fragment and conventional sugarcane, using Moericke traps of distinct colors.

MATERIAL AND METHODS

The study was conducted at the Santo Antônio sugar mill, in Sertãozinho, São Paulo state, Brazil, covering two consecutive harvests, from August 2019 to April 2021. The sugarcane variety used was RB966928, and three treatments were evaluated: organic sugarcane (T1) (21º11’38’’S and 47º93’98’’W), organic near a forest fragment (T2) (21º11’68’’S and 47º94’97’’W) and conventional management (T3) (21º12’96’’S and 47º96’33’’W). Each treatment had 40 replications: 20 yellow (Y) and 20 white (W) traps, with each pair representing one sampling site. One hectare was allocated per treatment, resulting in three distinct areas.

For insect sampling, yellow and white Moericke-type traps were used. These disposable plastic trays measured 15 cm in diameter and 4 cm in depth. The traps were placed near sugarcane plants and attached to bamboo stakes, and the trap height adjusted based on the plant growth, starting at 50 cm above the ground during the tillering stage. After 90 days, the traps were raised to 100 cm, remaining for 60 days, and finally reaching 150 cm until harvest. Each treatment used 20 traps of each color, with 20 trap sites per treatment. Each site included one yellow and one white trap, spaced 2 m apart, with 10 m separating adjacent sites, forming five rows of four trap sites.

The traps were filled with water and a few drops of detergent to reduce surface tension and remained in the field for 48 hours, and sampling was conducted monthly from the tillering stage to maturation, resulting in 16 collections. Insects were collected using soft-bristled brushes and voile fabric sieves, and then stored in plastic containers filled with 70 % ethyl alcohol. The samples were taken to the laboratory for screening and identification, and the parasitoids were identified to the lowest possible taxonomic level using keys from Gibson et al. (1997), Wharton et al. (1997), Masner & Garcia (2002) and Fernández & Sharkey (2006).

Insect abundance per site, per trap and family-specific abundance were analyzed using two-way

Anova, with means compared by the Tukey test ($\alpha = 0.05$). Non-parametric data were compared using the Dunn (multiple comparisons) or Mann-Whitney (single comparisons) tests ($\alpha = 0.05$). Statistical analyses were performed with GraphPad Prism v.9.0, and faunistic indices, including richness, Shannon diversity (H') and species abundance, were assessed using the Berger-Parker index in Past® software. Similarity analysis among cultivation types, trap color and insect families (organic, organic near a forest fragment and conventional) was performed using the DataTab® calculator, with results plotted in hierarchical clusters based on Euclidean distances.

RESULTS AND DISCUSSION

A total of 287 insects were collected, with the most abundant families being Diapriidae (44.44 %), Eulophidae (37.5 %) and Braconidae (18.06 %). The parasitoid abundance was higher in the organic system, followed by the organic + forest and the conventional system, accounting for 43.06, 36.81 and 20.14 %, respectively. Following Gollan et al. (2011), family-level data were log(x + 1) transformed for statistical analysis. First, the number of insects per site across both harvests was assessed. The cultivation system significantly influenced the insect presence (F2,114 = 6.00; p < 0.0001), whereas the harvest factor showed no significant effect on insect counts (F1,114 = 87.04; p = 0.567). During the first harvest, the organic and organic + forest systems had three times more parasitoids than the conventional system. In the second harvest, only the organic system showed a higher insect abundance (Figure 1).

When comparing the trap colors across organic and conventional crop systems during the first harvest, both variables had a significant influence on insect abundance (system: $F_{2,114} = 10.79$; $p < 0.0001$; color: $F_{1,114} = 99.32$; $p < 0.0001$), with a notable interaction between them ($F_{2,114} = 5.393$; $p = 0.0058$) (Figure 2A). Similarly, during the second harvest, both the system ($F_{2,114} = 6.00$; $p < 0.0033$) and trap color ($F_{1,114} = 87.04$; $p < 0.0001$) influenced the insect abundance, although no significant interaction was observed between the variables ($F_{2,114} = 1.164$; $p < 0.3159$) (Figure 2B). Notably, the yellow traps were more effective in capturing parasitoids across all cropping systems and both harvests (Figure 2). Therefore, yellow traps are the most suitable option for sampling parasitoids in sugarcane agroecosystems.

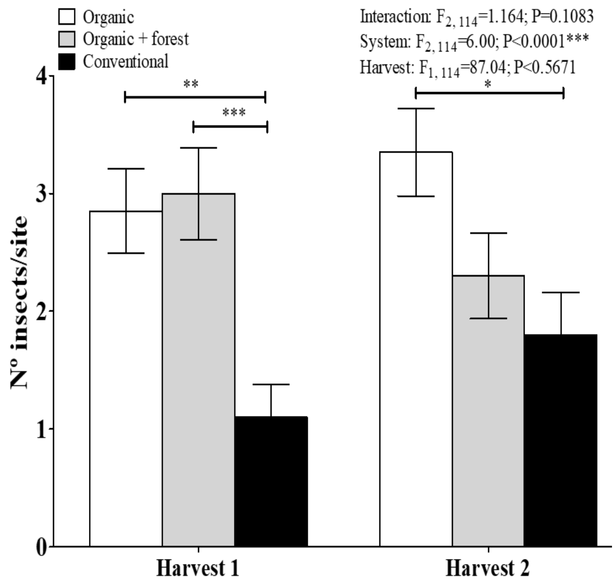

Figure 1. Average number of insects per site. Each site consisted of one yellow and one white Moericke trap. Bars represent the mean ± standard error of the mean. Asterisks indicate significant differences (* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$) based on the Tukey test.

Yellow is frequently selected because it tends to attract a higher number of insects (Perioto et al. 2002a, Abrahamczyk et al. 2010, Martins et al. 2010). Csanády et al. (2021) demonstrated that several insect orders, particularly Diptera, Hymenoptera and Coleoptera, show a preference for yellow. This preference has also been observed in studies by Perioto et al. (2002a, 2002b, 2004) and Souza et al. (2019), when surveying hymenopteran parasitoids in cotton, soybean, coffee and bell pepper crops. Additionally, yellow trays are favored in research on bee and other hymenopteran species abundance. For instance, Gollan et al. (2011) found that yellow trays captured more bees than white trays did.

In the first harvest, both the crop system ($F_{2,171} = 9.475$; $p < 0.0001$) and insect family ($F_{2,171} = 11.21$; $p < 0.0001$) had a significant effect on insect abundance, with a weak interaction between the variables ($F_{4,171} = 2.534$; $p = 0.0421$). The abundance of Diapriidae was not influenced by the environment, whereas Eulophidae showed a higher abundance in the organic and organic + forest systems. Additionally, Braconidae was approximately three times more abundant in the organic system, when compared to the others (Figure 3A). Overall, Diapriidae was more numerous in the organic + forest and conventional systems than the other families (Figure 3A).

The two harvests followed a similar pattern. System ($F_{2,171}$ = 4.576; p < 0.0116), family ($F_{2,171}$ = 10.21; p < 0.0001) and their interaction ($F4_{,171}$ = 3.418; p = 0.0102) significantly influenced the insect abundance (Figure 3B). During the second sampling, Diapriidae in the organic system was twice more abundant than in the organic + forest system. The Eulophidae family was approximately three times more abundant in both organic systems than in the conventional one. In the second harvest, Braconidae appeared to be unaffected by the cropping system (Figure 3B). In the conventional system, the three families had a similar abundance, with Eulophidae being especially more abundant than Braconidae in both organic systems (Figure 3B).

A total of 287 insects from 33 different genera, representing the hymenopteran families Braconidae, Diapriidae and Eulophidae, were collected in the sugarcane agroecosystem using Moericke trays. Yellow (Y) trays captured most parasitoids (252 individuals), whereas white (W) trays collected only 35 (Table 1). Comparing both harvests, the number of individuals varied across the treatments (T). In harvest 1 (H1), T1Y (organic; yellow) captured 50 individuals, T2Y (organic + forest; yellow) captured 54, and T3Y (conventional; yellow) collected 21. For the white trays, T1W captured seven, T2W collected six, and T3W had the fewest, with only one. In harvest 2 (H2), T1Y captured 55 individuals, T2Y collected 38, and T3Y had 34. In white trays during the second harvest, T1W collected 12, T2W captured eight, and T3W again had only one individual (Table 1).

Genera abundance varied across treatments. In the organic cultivation, *Omphale* (Eulophidae) was the most abundant, with 12 parasitoids; in the organic

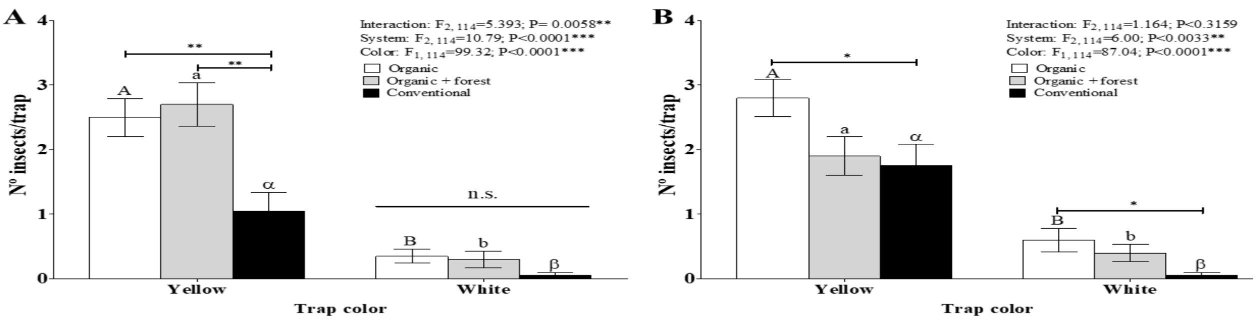

Figure 2. Average number of insects per trap across both harvests [A) harvest 1; B) harvest 2], based on trap color (yellow and white). Bars represent the mean ± standard error of the mean. Asterisks indicate significant differences within the trap color variable (* p < 0.05; ** p < 0.01; *** p < 0.001), based on the Dunn's test. Uppercase, lowercase and Greek letters denote statistical differences among the organic, organic + forest and conventional systems for different trap colors (Mann-Whitney test; α = 0.05).

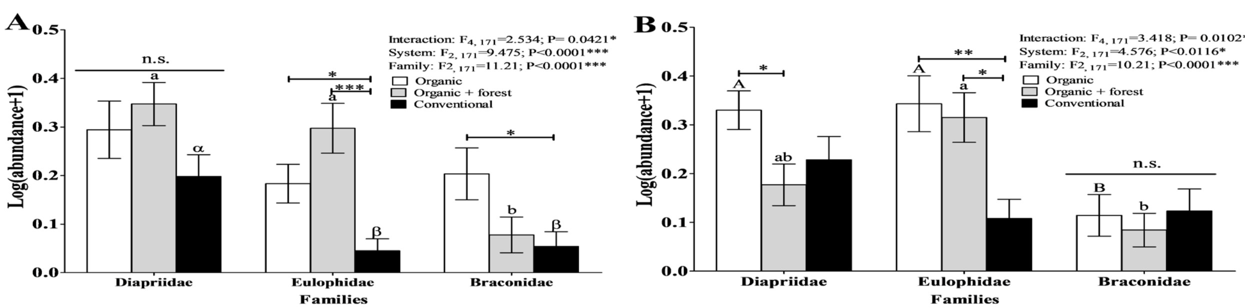

Figure 3. Insect abundance per site across both harvests [A) harvest 1; B) harvest 2], according to the three major families collected: Diapriidae, Eulophidae and Braconidae. Bars represent the mean ± standard error of the mean. Asterisks indicate significant differences within the trap color variable (* p < 0.05; ** p < 0.01; *** p < 0.001) based on the Tukey test (α = 0.05). Uppercase, lowercase and Greek letters denote statistical differences for family abundance across the organic, organic + forest and conventional cropping systems (Tukey test; α = 0.05).

Table 1. Abundance (n), frequency (f), species richness and Shannon diversity index (H') of parasitoid taxa in organic sugarcane cultivation, organic cultivation near forest fragments and conventional cultivation, comparing yellow and white Moericke traps.

Family/Genus	Organic								Organic near forest fragments								Conventional							
	Harvest 1				Harvest 2				Harvest 1				Harvest 2				Harvest 1				Harvest 2			
	Yellow		White		Yellow		White		Yellow		White		Yellow		White		Yellow		White		Yellow		White	
	n	f	n	f	n	f	n	f	n	f	n	f	n	f	n	f	n	f	n	f	n	f	n	f
Braconidae																								
Aleiodes	1	-	1	-	-	-	-	-	4	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Apanteles	4	0.01	1	-	2	0.01	1	-	-	-	-	-	-	-	-	-	2	0.01	-	-	1	-	-	-
Bentonia	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Chelonus	-	-	-	-	1	-	-	-	-	-	-	-	4	0.01	-	-	-	-	-	-	1	-	-	-
Cotesia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Cremnops	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Diolcogaster	4	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypomicrogaster	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0.01	-	-
Masona	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Microctonus	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	-	2	0.01	-	-
Rasivalva	5	0.02	-	-	1	-	-	-	2	0.01	-	-	-	-	-	-	1	-	-	-	1	-	-	-
Zele	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diapriidae																								
Basalys	2	0.01	-	-	6	0.02	-	-	5	0.02	-	-	3	0.01	-	-	5	0.02	-	-	2	0.01	-	-
Coptera	9	0.03	1	-	7	0.02	1	-	12	0.04	2	0.01	2	0.01	-	-	7	0.02	-	-	10	0.03	-	-
Entomacis	11	0.03	1	-	1	-	-	-	5	0.02	1	-	-	-	-	-	2	0.01	-	-	-	-	-	-
Monelata	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Omopria	9	0.03	1	-	7	0.02	1	-	12	0.04	2	0.01	2	0.01	-	-	7	0.02	-	-	10	0.03	-	-
Ortona	-	-	-	-	1	-	-	-	-	-	-	-	2	0.01	-	-	-	-	-	-	1	-	-	-
Pentapria	1	-	-	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Townesella	1	-	-	-	8	0.03	-	-	2	0.01	1	-	2	0.01	-	-	-	-	-	-	1	-	-	-
Trichopria	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	3	0.01	-	-
Eulophidae																								
Acrias	1	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Asecodes	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Baryscapus	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Ceranisus	1	-	-	-	2	0.01	4	0.01	-	-	-	-	4	0.01	7	0.02	-	-	-	-	3	0.01	-	-
Eprhopalotus	-	-	1	-	5	0.02	2	0.01	-	-	-	-	2	0.01	1	-	-	-	-	-	-	-	-	-
Euderus	1	-	-	-	2	0.01	-	-	-	-	-	-	2	0.01	-	-	-	-	-	-	-	-	-	-
Euplectrus	2	0.01	-	-	2	0.01	2	0.01	5	0.02	-	-	1	-	-	-	-	-	-	-	1	-	-	-
Horismenus	-	-	1	-	-	-	-	-	1	-	-	-	1	-	-	-	1	-	-	-	1	-	-	-
Neopomphale	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Omphale	3	0.01	1	-	12	0.04	-	-	13	0.04	2	0.01	5	0.02	-	-	1	-	-	-	1	-		-
Pediobius	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-		-
Tetrastichus	2	0.01	-	-	-	-	-	-	2	0.01	-	-	2	0.01	-	-	-	-	-	-	-	-	1	-
Total	50		7		55		12		54		6		38		8		21		1		34		1	
Richness	17		7		18		7		13		4		19		2		9		1		18		1	
H'	2.45		1.94		2.19		1.33		1.88		0		2.47		1.79		2.79		0.37		2.53		0	

system near a forest fragment it predominated again, with 13 individuals; whereas, in the conventional system, *Omopria* and *Coptera* (Diapriidae) were the most abundant ones, each with 10 parasitoids. A previous report identified *Omphale* as a parasitoid of the ber fruit fly in India (Narayanan & Chawal 1962). More recently, this genus has also been reported as a parasitoid of the brassica pod midge (Skellern et al. 2023). These findings highlight the need for further research into the ecology of *Omphale* spp. in organic sugarcane systems and its relationship with the sugarcane borer and other pests.

Overall, two of the most abundant genera collected (Table 1) belonged to the Eulophidae family, and one to the Diapriidae family. The most frequently collected genera were *Omopria* (Masner & Garcia 2002) and *Coptera* Say, 1836 (Diapriidae), both of which have a global distribution, predominantly in tropical regions and diverse habitats. *Omopria brevipalpis* Masner & Garcia (2002), the only species within the *Omopria* genus, has been collected using light traps in Brazil and Argentina, and is potentially associated with ants, although its actual hosts remain unknown (Masner & Garcia 2002, Comério et al. 2016). The *Coptera* genus parasitizes dipterans and plays a significant role in biological control, particularly against fruit flies. In Brazil, the *Coptera howardi* Loiácono, 1981 species was found in Surinam cherry fruits infested with *Anastrepha* Schnier, 1868 (Aguiar-Menezes et al. 2003). Although the *Coptera* genus is typically associated with fruit flies, it is also abundant in various agroecosystems, such as wild loquat, eucalyptus, miombo, loblolly pine (Tymochko et al. 2021) and sugarcane, as observed in this study.

In H1, the species richness was higher in yellow traps, with T1Y, T2Y and T3Y recording 17, 13 and 9 species, respectively, whereas the white traps T1W, T2W and T3W had 7, 4 and 1 species. In H2, the yellow traps recorded 18 species in T1Y, 19 in T2Y and 18 in T3Y, whereas white traps showed a similar richness to H1, with T1W having 7 species, T2W recording 2 and T3W with 1 species (Table 1). The highest species richness was observed in yellow traps placed in the organic system near a forest fragment during H2 (19 species), followed by both organic and conventional systems (18 species each).

In H1, the Shannon diversity index (H') was higher in the yellow trays, with T1Y showing the highest value (H' = 2.45), followed by T2Y (H' = 2.19) and T3Y (H' = 1.88). In the white trays, T1W recorded H' = 1.94, T2W had H' = 2.19, and T3W had the lowest diversity (H' = 0). In H2, the yellow trays recorded H' values of 2.47 in T1Y, 2.79 in T2Y (the highest overall), and 2.53 in T3Y. In the white trays, T1W had H' = 1.79, T2W recorded the lowest value (H' = 0.37), and T3W remained at H' = 0 (Table 1).

The organic farming and organic farming near forest fragments showed similar insect parasitoid populations, both differing from conventional practices. Santos et al. (2017) found that organic sugarcane cultivation supports a greater arthropod diversity and abundance due to more available food sources and shelter for natural enemies. In contrast, pesticides used in conventional systems negatively affect beneficial insects, reducing parasitoid longevity and parasitism rates (Valente et al. 2018).

Habitat manipulation can enhance monocultures by boosting predator and parasitoid populations (Prabowo et al. 2021). Furthermore, the presence of forest fragments near cultivation areas has been shown to support larger insect parasitoid populations. In this context, Silva et al. (2020) reported that, as the distance between cultivation and forest fragments increases, parasitoid populations decrease; however, a similar parasitoid abundance was found in both organic systems, regardless of proximity to forest fragments.

The hierarchical cluster analysis provided an insight into relationships between trap color and insect family based on the average number of individuals collected in each survey. Two main groups emerged, one for yellow and one for white traps, highlighting differences in insect abundance (Figure 4A). The cropping system influenced the creation of a distinct separation between clusters, indicating a clear differentiation between family groups, while the small distance within clusters suggests that the groups are homogeneous (Figure 4B). Comparing the three main clusters, it was noted that Diapriidae and Eulophidae are primarily responsive to organic systems.

Within the Braconidae family, 12 genera were identified, including two that are known parasitoids of *Diatraea saccharalis*: *Apanteles* Förster, 1862 and *Cotesia* Cameron, 1891 (Silva et al. 1968). *Apanteles* is a cosmopolitan genus and the largest within the Microgastrinae subfamily, serving as parasitoids of various lepidopteran species during their larval stage (Whitfield et al. 2009). Examples include *Apanteles impunctatus* Muesebeck, 1958 and *Apanteles vulgaris* (Ashmead, 1900), both of which parasitize the sugarcane borer during its immature phase (Silva et al. 1968).

The *Cotesia* genus is also a larval parasitoid of various Lepidopteran families and is important in controlling agricultural pests. *Cotesia flavipes* has been widely used in biological control programs for sugarcane borer in Brazil (Whitfield et al. 2009, Parra 2014). Despite its extensive release in sugarcane crops, only one *Cotesia* specimen was found, suggesting its limited survival in the field. Another hypothesis, supported by Volpe et al. (2014), is that

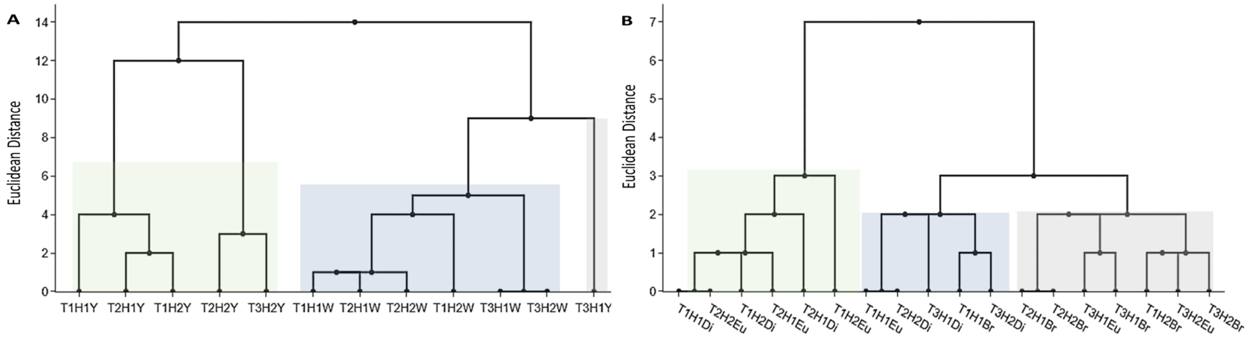

Figure 4. Similarity dendrogram of treatments based on insect abundance. A) trap color; B) insect families. T1: organic; T2: organic + forest; T3: conventional; H1: harvest 1; H2: harvest 2; Di: Diapriidae; Eu: Eulophidae; Br: Braconidae. The y-axis represents Euclidean distances.

C. flavipes may not be attracted to colored Moericke traps, as it showed little or no attraction to colors such as white, light blue, dark blue, light green, dark green, pink and yellow.

In the Eulophidae family, 12 genera were collected, with three being known to parasitize *D. saccharalis*, including *Horismenus* Walker, 1843, *Pediobius* Walker, 1846 and *Tetrastichus* Haliday, 1844 (Silva et al. 1968). *Pediobius* and *Tetrastichus* are recognized biological control agents (Gibson et al. 1997, Hanson & Gauld 2006), whereas *Pediobius* and *Horismenus* are often hyperparasitoids, many of which are facultative. *Pediobius furvus* (Gahan, 1928) has a variety of hosts, including *D. saccharalis* in its pupal stage. Although successful in the southern U.S.A. for sugarcane borer control, it struggled with parasitism in Brazil (Tambasco 1997, Endo et al. 2018).

Tetrastichus Haliday, 1844 parasitizes a wide range of hosts, including Coleoptera, Diptera, Lepidoptera and Hymenoptera (Gibson et al. 1997). One species, *Tetrastichus howardi* (Olliff, 1893), is notable for its parasitism plasticity (Vargas et al. 2011, Pereira et al. 2015, Endo et al. 2018). In studies by Vargas et al. (2011), *T. howardi* completed its development within about 23 days (from egg to adult), producing a progeny of over 170 individuals from a single *D. saccharalis* host and parasitizing both larvae and pupae. Pereira et al. (2015) found that *T. howardi* can also parasitize adult stages; therefore, its ability to parasitize larvae, pupae and adults makes it a promising candidate for mass rearing in laboratories to control *D. saccharalis* in crops such as corn, sorghum and sugarcane (Cruz et al. 2011, Pereira et al. 2015).

Within the Diapriidae family, the Diapriinae subfamily includes the *Trichopria* Ashmead, 1893 genus, which parasitizes the immature stages of Diptera, such as larvae and pupae. The *Trichopria cubensis* Fouts, 1926 species parasitizes the pupae of *Lydella minense*, *Paratheresia brasiliensis* and *Parthenoleskia parkeri* (Diptera: Tachinidae), all of which are parasitoids of *D. saccharalis* (Silva et al. 1968, Hughes et al. 1982, Loiácono & Margaría 2002).

Understanding the species involved in *D. saccharalis* biological control is crucial for effective pest management in the field. Organic agroecosystems support natural enemies by providing alternative hosts, favorable microclimates and nutritional resources (Gurr et al. 2017, Altieri & Nicholls 2019). Monocultures with ecological corridors often have a greater diversity of natural enemies, as they attract, preserve and disperse them into the cultivated area (Altieri & Nicholls 2019). Forest fragments offer a range of species and can provide ecological services to agricultural environments. These fragments function as reservoirs for natural enemies near monocultures, enhancing biological control.

CONCLUSIONS

1. The yellow Moericke traps were more attractive to parasitoids across all three cultivation systems. The results underscore the significance of organic systems in preserving entomological diversity in sugarcane agroecosystems and highlight the role of habitat manipulation and forest fragments in promoting parasitoid survival and abundance;

2. Certain parasitoid families, such as Diapriidae and Eulophidae, responded more to the Moericke traps in organic systems. However, key families for sugarcane pest control, like Trichogrammatidae and Platygastridae, were not captured by the Moericke traps.

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