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Edaphic entomofauna associated with coconut crops in the eastern Amazon

Entomofauna edáfica associada a lavouras de coqueiro na Amazônia oriental

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Highlights

Three insect groups were formed; Formicidae, most abundant, and less abundant insects.
Amazonian seasonality directly influenced the flow and insect dynamics.
The riparian forest area showed more diversity and less dominance than coconut crops.

Abstract

In the Eastern Amazon is the largest continuous coconut crop area in the world. This region is known for its high precipitation levels and an ecosystem of extensive insect biodiversity. It is important to know the local entomofauna and to know whether there is a balance between the different insect groups. This study aimed to understand the influence of seasonality on the dynamics of edaphic insect families, comparing the environment as a whole and in different commercial coconut crop areas and riparian forests in the Eastern Amazon. Forty pitfall traps were installed in the ground at an average distance of 1 m from the coconut stipe. They were filled with 200 ml of an aqueous solution of liquid neutral soap and 70% alcohol. Traps were installed in eight areas: an area of riparian forest (A1) and seven in commercial coconut crop areas (A2 to A8), in the Amazon dry and rainy season. The similarity between the insects was measured using Euclidean distance. The abundance of families in each collection area used qualitative similarity.

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For family dominance, quantitative similarity was used. Diversity analyses were performed to justify the similarities of the clusters through the Shannon and Simpson Indices. In total, 252,313 individuals, 118 families, and 9 orders were collected. There were many Formicidae in both climatic periods because it is a social insect and has edaphic habits. The families with the most individuals in the collections were Drosophilidae, Staphylinidae, Bostrichidae, Phoridae, Nitidulidae, Scolytidae, Tenebrionidae, Scarabaeidae, Ceratopogomidae, and Platyogastridae. The riparian forest area (A1) showed the greatest diversity and least dominance. The oldest cultivated areas A2 and A3 (7 years) showed the greatest diversity in the dry season. In the rainy season, the most diversified areas were those with the highest land slope (A6 and A7). The most dominant areas were A5 and A8, where the largest number of *Solenopsis* spp. were found. This study showed the importance of obtaining basic information about coconut entomofauna and conducting research on insect dynamics in agricultural crops in the Amazon region.
Key words: Abundance. Amazon seasonality. Diversity. Dominance. *Cocos nucifera* L.

Resumo

Na Amazônia Oriental, está localizado a maior área contínua de plantio de coqueiro do mundo. Essa região é conhecida por ter elevados índices de precipitação e um ecossistema de extensa biodiversidade de insetos. É importante conhecer a entomofauna do local, para saber se há equilíbrio entre os diferentes grupos de insetos. O objetivo deste estudo foi compreender a influência da sazonalidade na dinâmica das famílias de insetos edáficos, comparando o ambiente como um todo e diferentes áreas de plantios comerciais de coqueiro e mata ciliar na Amazônia Oriental. Foram instaladas no solo 40 armadilhas do tipo pitfall a uma distância média de 1 m do estipe, preenchidas com 200 ml com solução aquosa de sabão líquido neutro e álcool 70%, em oito áreas: uma área de mata ciliar (A1) e sete em áreas de lavoura comercial de coqueiro (A2 a A8) nos períodos seco e chuvoso amazônico. A similaridade entre os insetos foi medida através da distância Euclidiana. A abundância de famílias em cada área de coleta, utilizou a similaridade qualitativa. Para dominância de famílias utilizou similaridade quantitativa. Foram realizadas análises de diversidade para justificar as similaridades dos agrupamentos, através do Índice de Shannon e Índice de Simpson. Foram coletados 252.313 indivíduos, 118 famílias e 9 ordens. Houve um grande número de Formicidae em ambos os períodos climáticos, por se tratar de um inseto social e que tem hábitos edáfico. As famílias com maior número nas coletas foram: Drosophilidae, Staphylinidae, Bostrichidae, Phoridae, Nitidulidae, Scolytidae, Tenebrionidae, Scarabaeidae, Ceratopogomidae e Platyogastridae. A área de mata ciliar (A1) apresentou maior diversidade e menor dominância. As áreas cultivadas mais antigas A2 e A3 (7 anos) apresentaram a maior diversidade na estação seca. No período chuvoso, as mais diversificadas foram áreas que apresentaram maior declividade do terreno - A6 e A7. As áreas com maior dominância foram A5 e A8, onde o maior número de *Solenopsis* sp. foi encontrado. Esse estudo mostrou a importância de se obter informações base sobre a entomofauna associada à cocoicultura e de realizar pesquisas sobre dinâmica de insetos em lavouras na região amazônica.
Palavras-chave: Abundância. Sazonalidade Amazônica. Diversidade. Dominância. *Cocos nucifera L.*

Introduction

The coconut palm *Cocos nucifera* L. is originally from Southeast Asia, where the countries with the highest coconut production are found (Fontes, 2010). Brazil ranks fifth in the world in the amount produced and the first in yield of coconut fruit (Food and Agriculture Organization of the United Nations [FAOSTAT], 2018), with the North and Northeast regions holding 86% of Brazilian production. The state of Pará, located in the Eastern Amazon, occupies the fourth position in the national ranking, with 10.10% of the production (Instituto Brasileiro de Geografia e Estatística [IBGE], 2018).

In the Eastern Amazon is the largest continuous area of coconut planting in the world (Fróes, Aviz, Rebello, & Santos, 2019). It is known for having high precipitation levels and an ecosystem characterized by sustaining extensive biodiversity (Silva Dias, Cohen, & Gandú, 2005). According to Souza et al. (2016), this region stands out for having the largest area with the highest intensity of rainfall over the continent (between 4 and 10 mm / day). Seasonal rainfall averages in the Amazon clearly demonstrate that the rainy season occurs during the summer and autumn quarters (December to June) and the dry season in winter and spring (June to December).

There is a diversity of insects in the Amazon region, both in monocultures and in forest areas. These insects have great importance for the dynamics of the environment, mainly in monocultures, being agricultural pests, natural enemies, or/and decomposers. Thus, a strategy for monitoring these insects is to use fauna analyses, which characterize and delimit a community, measure the environmental impact of an area, determine the prevalent species, and compare areas based on insect species (Omoto, Silveira, & Morais, 2003).

For studies of diversity and abundance of terrestrial arthropods, one of the most studied standardized techniques is the use of trapdoor, drop, or pitfall traps, with or without bait. There are different designs for these types of traps; however, they are basically containers where bait is added, and in many cases, liquid to kill and preserve the specimen is also added. This trap model allows you to collect species with nocturnal and daytime habits (Aquino, Aguiar-Menezes, & Queiroz, 2006).

Entomofauna monitoring in coconut crops facilitates the identification of the best control and decision-making options, as well as generates information about the beneficial environmental entomofauna diversity (Thomazini & Thomazini, 2000) to conserve the ecological processes of arthropods and promote the correct management of habitats. This study aimed to understand the influence of seasonality on the dynamics of edaphic insect families, comparing the environment as a whole and different areas of commercial coconut crops and riparian forest in the Eastern Amazon.

Materials and Methods

The experiment was carried out in commercial dwarf coconut palm crops at Santa Isabel do Pará, Eastern Amazon (1° 13′42″S and 48° 02′57″W), with an average temperature of 26.7°C. According to Köppen's classification, this region is Af, and the annual rainfall is over 3000 mm (Secretaria do Estado e Meio Ambiente e Sustentabilidade [SEMAS], 2019). The insects were collected at the peak of the dry season of 2017 (July and August) and at the peak of the rainy season 2018 (February and March) (Figure 1).

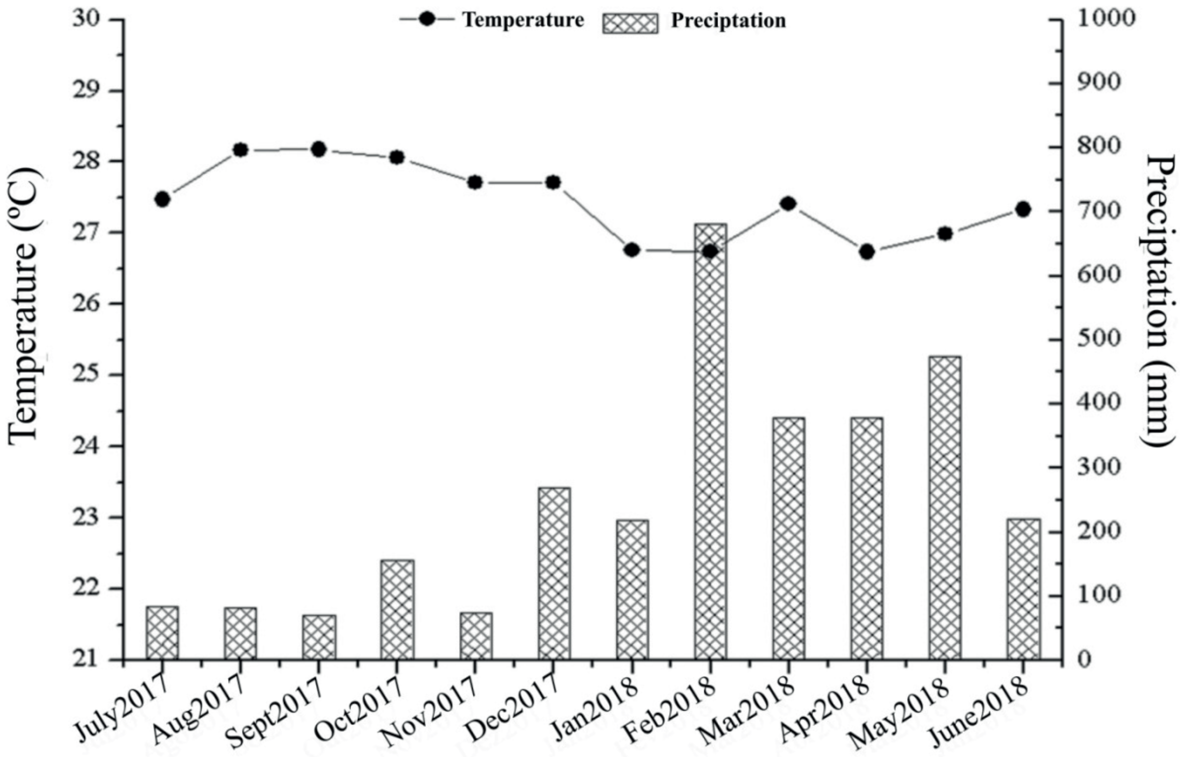

Figure 1. Average temperatures (°C) and rainfall (mm) in the collected years (2017 and 2018) on the Reunidas' farm, Sococo's Group, Santa Isabel do Pará- Eastern Amazon.

An area of riparian forest and seven commercial coconut crop areas (with different planting ages) were evaluated, where 40 traps/area were installed. The number of areas was selected proportionally according to the year of planting (2012 was the year with the most plantings carried out by the company; therefore, more areas with 6 years were monitored) and altitude levels (Table 1).

Table 1
Commercial *Cocos nucifera* L., green-dwarf variety coconut tree planting areas where insects were collected using pitfall traps in Eastern Amazon

Areas	Area type	Size (ha)	Age (years)	Tree height Minimum (m)	Tree height Average (m)	Tree height Maximum (m)
A1	Riparian forest	-	10	-	-	-
A2	Coconut palm planting	11.08	7	31	37	48
A3	Coconut palm planting	18.11	7	29	34	42
A4	Coconut palm planting	14.09	6	36	39	41
A5	Coconut palm planting	10.69	6	36	39	41
A6	Coconut palm planting	17.48	6	39	44	49
A7	Coconut palm planting	21.44	5	38	41	43
A8	Coconut palm planting	11.27	4	38	45	52

The pitfall traps were buried in the ground at an average distance of 1 m from the coconut stipe with a rain cover. The containers were made of plastic material with a capacity of 500 ml (6 x 13 cm), and one was buried with its edges at ground level. Then, they were filled with 200 ml of aqueous solution of neutral liquid soap and 70% alcohol to preserve the collected insects and increase the capture efficiency. Each trap was left for seven days in each area, both in the dry and rainy periods. Subsequently, they were sent to the Entomology Laboratory of the Federal Rural University of the Amazon, in Belém, PA, where the insects were screened, quantified, and identified to the family level with the aid of precision magnifiers and a dichotomous key by Borror, Triplehorn and Johson (2011). The most frequent ant genus was identified according to Baccaro et al. (2016).

Multivariate classifications were defined through cluster analysis for the total area in each period and for the different coconut planting areas. The similarity between insects considering the total area in the dry and rainy periods was measured using the Euclidean distance after Hellinger's transformation. To measure the abundance of families in each collection area, qualitative similarity was assessed using the Jaccard index. To assess the dominance of families in the areas, quantitative similarity was measured with the Bray-Curtis distance index. For the discrimination of similar groups, K-means were used. Diversity analyses were carried out to justify the similarities of the groupings obtained in the comparison of the planting areas through the Shannon and Simpson Indices. The analyses were performed using the statistical software PAST 3.25 (Hammer, Harper, & Ryan, 2001).

Results and Discussion

In total, 252,313 insects were collected, belonging to 9 orders and 96 families. The most abundant orders were Hymenoptera (46%), Coleoptera (34.69%), and Diptera (11.69%), followed by Blattodea (3.55%), Orthoptera (2.86%), Hemiptera (0.69%), Dermaptera (0.06%), Lepidoptera (0.05%), and Psocoptera (0.01%).

There were many individuals in the order Hymenoptera, family Formicidae, genus *Solenopsis* spp., which were responsible for 80% of the collected mirmecofauna, these results were similar to those of Acioli, Costa, Moura, Guimarães, Almeida and Miranda (2014). Ants have diversified eating habits, which exploit most terrestrial ecosystems (Hölldobler & Wilson, 1990); thus, the use of a soil trap guaranteed success in ant collection in edaphic areas. In addition, the collections were carried out in coconut crops, and there is an inherent relationship between palm trees in the Amazon region and ant communities. Although palm trees do not produce a specific substance, ants use leaf sheaths to build their nests (Santos, Harada, Alves, Santos, & Ribas, 2007). Notably, ants are social insects that have a recruiting habit; consequently, in monitoring analyses, ants are always in great quantity (Zéphirin, Leila, Chantal, & Champlain, 2019). This high number of ants was verified by the formation of isolated groups in climatic periods (Figure 2).

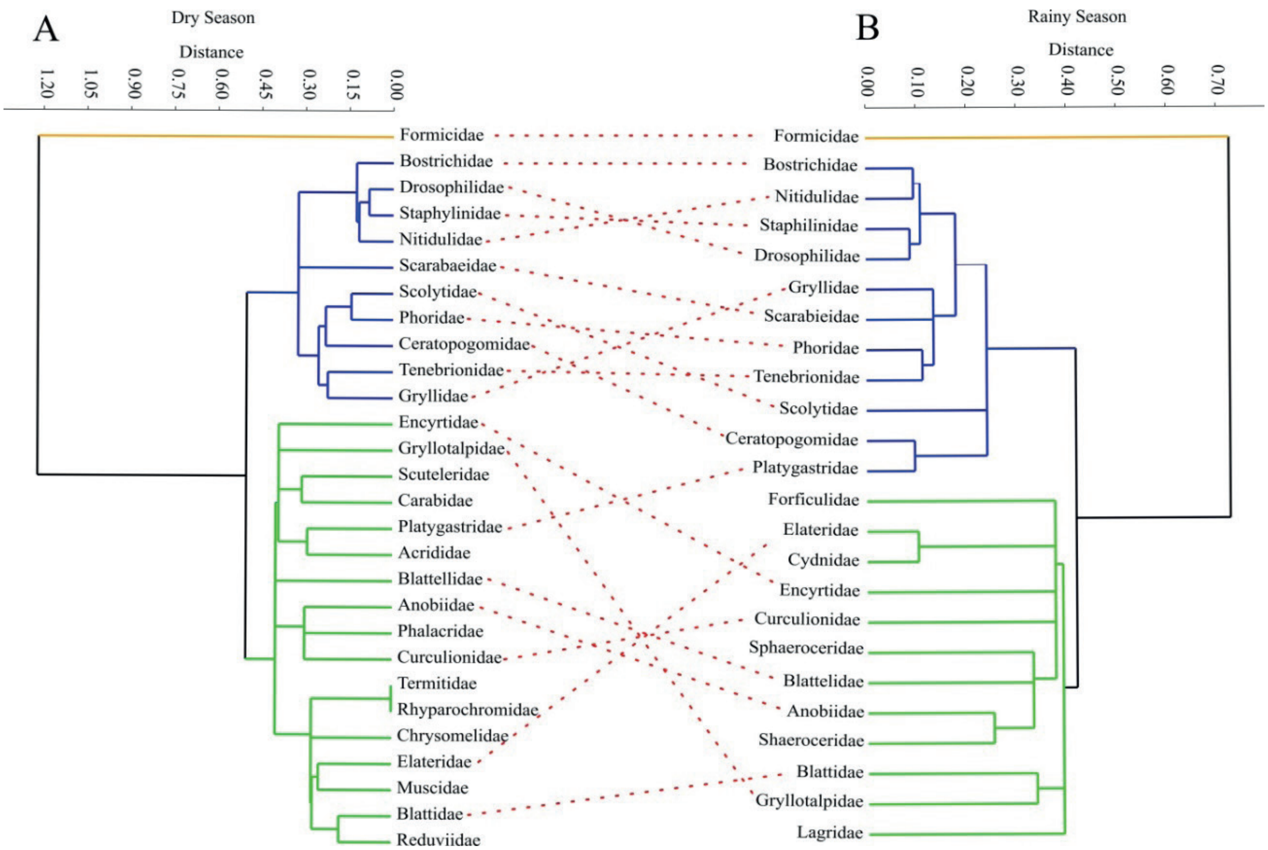

Figure 2. Dendrogram of similarity measured by the Euclidean distance of groups of families of edaphic insects, collected by pitfall traps in crops of coconut *Cocos nucifera* L., green dwarf variety, in the dry period (A) and in the rainy period (B). Eastern Amazon.

The similarity results (Figure 2) demonstrated the formation of three distinct groups; the first was formed only by the Formicidae family, the second group was formed by the most abundant insects, representing those of agricultural or environmental importance, and the third group comprised the insects that appeared less frequently.

A reduction of 81.86% was observed in the number of ants collected in the rainy season (February and March), which may have been influenced by the high rainfall in the Amazon region. Sucking insects that live in a symbiotic relationship with ants can be washed away from leaves, hence decreasing the ant population. This symbiotic relationship occurs because *Solenopsis* spp. ants lives with leaf-sucking Hemipteras, feeding on the sugary excretions that are released (Delabie & Fernández, 2003). In this relationship, plants are harmed, mainly in monocultures (Delabie, Ospina, & Zabala, 2003).

High rainfall in the rainy season and the decrease in the flow of ants is one of the reasons why the insect population in the second group of the dry season is smaller than that in the rainy season. When many ants live in a given habitat, they indirectly constitute a defense tactic for the plant, as noted by Perfecto and Sediles (1992), because Hemiptera can have greater longevity and less predation/parasitism due to the symbiotic relationship with the ants, which protect this group of insects from attack by natural enemies (Delabie et al., 2003).

The flow of Platygastridae parasitoids was influenced by their symbiotic relationship, occupying the third group in the dry period (July and August) and migrating to the second group in the rainy period. Parasitoid Hemiptera acts as an important mealybug controller, as noted by Teshiba, Kawano, Tokuda and Takagi (2019). Parasitoids in general are easily found in coconut cultivations, being associated not only with pests but also with weeds (Comércio, Onody, & Benassi, 2012).

The families Bostrichidae and Scolytidae are coleobrocas of great agricultural importance. According to Flechtmann, Couto, Gaspareto and Berti (1995), they are generally secondary pests attacking damaged trees. However, when the population of this pest is high, healthy trees can also be attacked (Silveira & Oliveira, 1988). In the coconut tree, the insect damages the stipe by forming holes and galleries, causing the plant to wilt with symptoms in the form of a closed umbrella, followed by death. The first report of this pest attacking green dwarf coconut crops was the species *Xyleborus affinis* in Sousa, PB in 2002 (Lopes, Brito, Batista, & Silva, 2010).

The family Staphylinididae is also found in the second group. This family of predatory habits (Pfiffner & Luka, 2000) is considered one of the most important insects in the soil entomofauna (Freitas, Leal, Uehara-Prado, & Iannuzzi, 2005). Coleoptera, Nitidulidae, and Tenebrionidae are also decomposers feeding on the sap of trees and fruits, especially fermented ones (Medri & Lopes, 2001).

Diptera plays an important role in the regulation of insect pest populations (Culik, Martins, Ventura, & Wolff, 2008). In the second group, in the two climatic periods, two families stood out: Drosophilidae, which comprises natural enemies and agricultural pests, and the Phoridae family, which, according to Almeida and Queiroz (2009), act as parasitoids of *Solenopsis invicta.* This parasitism relationship may explain why the large quantity of *Solenopsis* spp. and Phoridadae were always associated in the collections from coconut crops.

The third group families in the two climatic periods (Figure 2) were not characterized as edaphic pests or biological control agents due to their small number. However, they have been cited as agricultural and forestry pests and biological control agents, requiring periodic monitoring in the planting areas to evaluate the frequency of these insects.

In Table 2, the riparian forest area (A1) obtained the highest values of diversity and the lowest dominance, similar to those reported by Lima, Andreazze, Andrade and Pinheiro (2010). Due it is a more diversified environment when compared to monoculture. Such results have made the riparian forest used as a control. Therefore, the dominance and diversity values of each monoculture area differed according to their characteristics, with results closer or farther from the results of riparian forest area (Table 2).

In the dry season, the highest diversity values were between the riparian forest (A1) and the oldest plantings (A2 and A3). In the rainy season, they were between the riparian forest (A1), A4, A6, and A7 (Table 2). More diverse areas are propitious to be an environmental balance between species. This is because diversity contrasts with insect density (dominance), where variety rather than quantity determines diversity (Takhelmayum, Gupta, & Singh, 2013).

Table 2
Ecological indexes referring to the values of dominance (D) and diversity (H') of insect communities collected in the dry and rainy periods in commercial areas of coconut trees *Cocos nucifera* L., var. green dwarf in the Eastern Amazon

Period	Indexes	A1	A2	A3	A4	A5	A6	A7	A8
	Simpson (D)	0.04	0.04	0.05	0.06	0.10	0.07	0.07	0.10
D.S.	Shannon (H')	3.19	3.13	2.90	2.84	2.39	2.70	2.58	2.37
	Simpson (D)	0.04	0.05	0.06	0.04	0.06	0.05	0.05	0.06
R.S.	Shannon (H')	3.10	2.86	2.85	3.06	2.84	2.95	2.91	2.84

D.S.: Dry season; R.S.: Rainy season; A1: Riparian forest; A2-A8 Coconut palm planting areas.

These results were confirmed with similarity analyses. In the qualitative analysis, where the presence and absence were verified to evaluate the diversity of the areas, the similarity in the dry period occurred between the riparian forest (A1) and the older crops (A2 and A3) (Figure 3-A). In the rainy periods, the similarity occurred between riparian forest (A1), A6, and A7, which are among the areas with the highest altitude (Figure 3-B). In the quantitative analysis, the areas with the lowest diversity index (A5 and A8) in the two climatic periods were those that had the highest number of ants collected (Figure 3-B and C).

Areas A2 and A3 (Figure 3-A) had two characteristics in common that may have influenced the greater diversity in the dry period. The first characteristic was that they were found in the oldest crops (7 years old) among those evaluated in this study. Data obtained in the study of Beugre, Yao, Allou and

Dagnogo (2017) reported that the diversity of edaphic entomofauna of coconut was greater in areas of older crops with a tendency to have greater stability in insect flow. According to Issali, Konan, Lekadou, Allou and Et Zakra (2013), the majority of coconut insect pests, which generally decrease the diversity of the environment, attack young plants because of the tenderness of different organs. This explains the fact that even with a short age interval between the plantings evaluated, there was an influence on the flow of insects due to the age of planting. The second characteristic was that they were located in lower lands among those monitored. This characteristic, combined with the rains of the Amazon region, caused greater accumulation of water in the areas in the dry period, resulting in greater soil moisture, facilitating the survival of insects in the dry period.

Bandeira and Harada (1998) confirmed these results by stating that in tropical ecosystems, such as the Amazon, the edaphic fauna returns to the soil's organic surface when there is more moisture. However, in the rainy season, the amount of water that went down to these places was excessive, and some species of insects die with excess water or hide under the surface of the soil to complete their life cycle. As a result, there was a decrease in diversity in the lower areas (A2 and A3), making the A4, A6 and A7 areas (Figure 3-B), which had the highest altitude, more similar to the riparian forest (A1) in the rainy season.

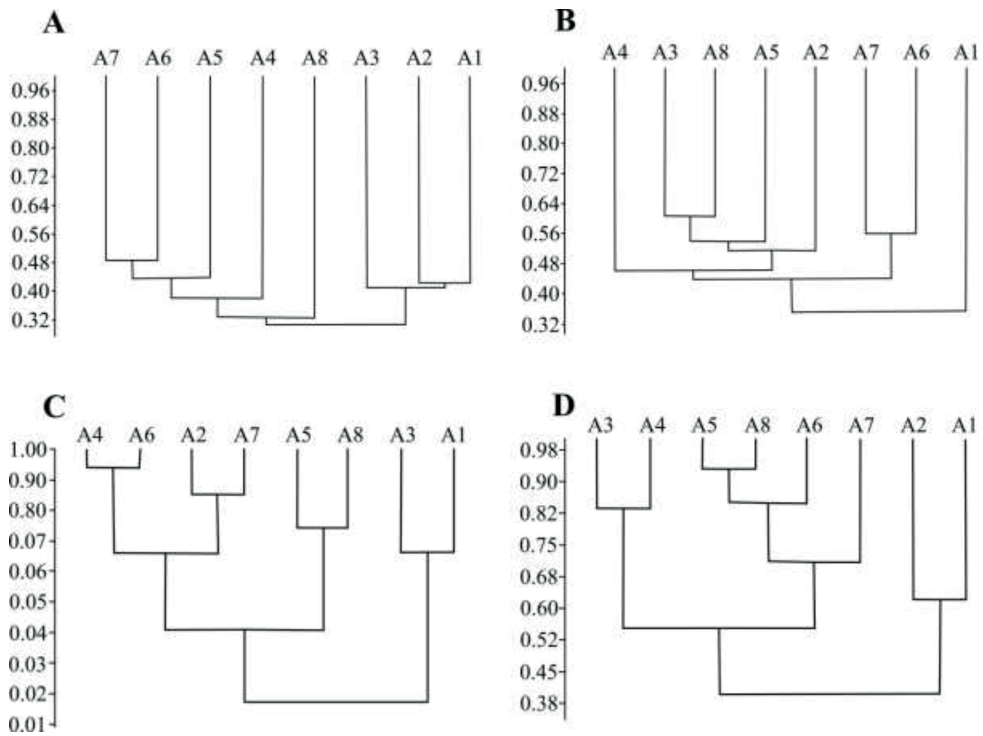

Figure 3. Dendrograms of similarity between entomofauna collection areas associated with commercial coconut crops: (A) Qualitative analysis - Amazonian dry season; (B) Quantitative analysis - Amazon rainy season; (C) Quantitative analysis - Amazonian dry season; (D) Quantitative analysis - Amazonian rainy season.

In the quantitative analysis (Figure 3-B and C), there was similarities between the areas that had the lowest diversity values and the highest dominance values (A5 and A8), both in the dry and rainy periods. In these areas, the most ants were collected. Ants in general tend to dominate the environment where they establish, mainly because their colonies have a recruiting habit (Zéphirin et al., 2019). Except for symbiotic insect pests, the consequence of ant dominance results in a decrease in the diversity of different insects in the environment in which the ant is installed. The dominance index is inversely proportional to the diversity index (Takhelmayum et al., 2013), so the low diversity of these areas can be directly linked to the large number of Formicidae in the environment.

Conclusion

Seasonality influenced the dynamics of insects in the collection areas, with the largest number of specimens and the smallest number of families in the dry Amazonian period (July and August). Seasonality also influenced the family dynamics of parasitoids, which are more frequent in the rainy season (February and March). Despite the decline in the amount collected in the dry period compared to the rainy period, *Solenopses* spp. were frequently collected in all areas. The riparian forest was more diversified than commercial coconut crops, independent of the climatic period. The older commercial coconut crop areas showed the highest levels of diversity in the dry period, and those with the highest altitude were the most diversified in the rainy season. The areas with the most ants obtained the highest dominance values and the lowest diversity values. This study showed the importance of conducting initial studies on entomofauna associated with coconut farming and developing research on insect dynamics in agricultural plantations in the Amazon region, showing the range of information that can be explored in future research.

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