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Entomofauna associated to tropical pastures, *Cenchrus ciliaris*, *Chloris gayana*, and *Megathyrsus maximus*[1]

Entomofauna asociada a pasturas tropicales *Cenchrus ciliaris, Chloris gayana* y *Megathyrsus maximus*

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Abstract

Introduction. Pastures are the primary source of food in livestock systems and can be a suitable niche for insects with beneficial and harmful functions. **Objective.** To estimate the entomofauna associated with three species of pastures, *Cenchrus ciliaris*, *Chloris gayana*, and *Megathyrsus maximus*, in conditions of the Colombian Caribbean. **Materials and methods.** Ten samplings were carried out in two contrasting periods (August to October 2018 and January to March 2019), three forage species (*Cenchrus ciliaris*, *Megathyrsus maximus*, *Chloris gayan*a) within 1000 m^2 were used. Arthropods were identified by order and family and typified by functional groups. Diversity and abundance indices by pasture and season were estimated, as well as their correlation with climate. A simple correspondence analysis was performed. **Results.** A total of 380 insects from 7 orders and 35 families were collected, with the greatest abundance for Hemiptera and Coleoptera. The Shannon's diversity index was higher for all orders of *C. gayana*, except for Hemiptera in *C. ciliaris*. Phytophages were found in a higher percentage (66.84 %), followed by predators (27.11 %). Insect abundance was influenced by the interaction between season and pasture, showing an increase at low temperatures, except for *M. maximus*. Pastures represented adequate microenvironments to maintain the diversity of insects, the Hemiptera and Coleoptera orders being the most numerous and representative of the functional groups of phytophages and predators, respectively. **Conclusion.** The entomofauna of *C. gayana*, *C. ciliaris*, and *M. maximus* was similar in insect abundance and diversity, however, insect abundance depended on the influence of the season and pastures.

Keywords: biological control, crops, biological diversity.

Resumen

Introducción. Los pastos son la principal fuente de alimento en los sistemas ganaderos y pueden ser un nicho adecuado para insectos con funciones beneficiosas y dañinas. **Objetivo.** Estimar la entomofauna asociada a tres especies de pastos, *Cenchrus ciliaris*, *Chloris gayana* y *Megathyrsus maximus*, en condiciones del Caribe

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colombiano. **Materiales y métodos.** Se realizaron diez muestreos en dos estaciones contrastantes, de baja y alta precipitación (agosto a octubre de 2018 y enero a marzo de 2019), se utilizaron tres especies forrajeras (*Cenchrus ciliaris*, *Megathyrsus maximus*, *Chloris gayana*), en un área de 1000 m^2. Los artrópodos fueron identificados por orden y familia y tipificados por grupos funcionales. Se estimaron índices de diversidad y abundancia por pastos y estaciones, así como su correlación con el clima. Se realizó un análisis de correspondencia simple. **Resultados.** Se recolectaron 380 insectos de siete órdenes y 35 familias, con mayor abundancia para Hemiptera y Coleoptera. El índice de diversidad de Shannon fue más alto para todos los órdenes de *C. gayana*, excepto para Hemiptera en *C. ciliaris*. Los fitófagos se encontraron en mayor porcentaje (66,84 %), seguidos de los depredadores (27,11 %). La abundancia de insectos estuvo influenciada por la interacción entre la estación y el pasto, mostró un incremento a bajas temperaturas, excepto para *M. maximus*. Los pastos representaron microambientes adecuados para mantener la diversidad de insectos, los órdenes Hemiptera y Coleoptera fueron los más numerosos y representativos de los grupos funcionales fitófagos y depredadores, respectivamente. **Conclusión.** La entomofauna de *C. gayana*, *C. ciliaris* y *M. maximus* fue similar en abundancia y diversidad de insectos, sin embargo, la abundancia dependió de la influencia de la estación y de los pastos.

Palabras clave: control biológico, cultivos, diversidad biológica.

Introduction

Pastures are considered the primary food source in animal production systems, both for ruminants and minor species (Alothman et al., 2019). In Colombia, pasture and forage production is mainly focused on livestock, most are introduced or naturalized species (Negawo et al., 2020). The species *Chloris gayana, Cenchrus ciliaris*, and *Megathyrsus maximus* are native to Africa and naturalized in the tropics and subtropics. They have intrinsic characteristics such as tolerance to drought, adaptation to areas with annual rainfall regimes between 100 – 500 mm (Negawo et al., 2020).

Crops are agrosystems with many interactions between plants and animals, which perform maintains the balance between harmful and beneficial populations (Jarvis et al., 2011). In the case of entomofauna associated with pastures, it is necessary to know the functional groups to prove this relationship. The arthropods have role in the agroecosystem related to the consumer habit; as phytophages, they can act as pests for have a high colonization capacity and large populations. These are regulated by the group of consumers called "natural enemies" made up of predators and parasitoids (Alomar & Albajes, 2005). There are also decomposer, pollinator and omnivorous arthropods that play an essential role in agroecosystems (Caraballo-Gracia et al., 2019). Therefore, it is essential to determine biodiversity that exists in this type of production system to preserve natural habitats and guarantee the ecosystem services provided by beneficial insect populations against pests (Altieri & Nicholls, 2012). In this context, it is important to be aware of the interactions and relationships established by insects in an agroecosystem, accord to their trophic functions or consumption habits, especially those pest insects that produce adverse effects on growth, nutritional quality, and reproductive capacity of pastures, such as the froghoppers (commonly known as salivazo or *mion*) *Aeneolamia* sp., and *Zulia* sp. (Hemiptera: Cercopidae), considered the main pest for pastures that feed in livestock in tropical America (Valerio et al., 2001).

There are other pest insects, such as *Blissus leucopterus*, *B. insularis* (Hemiptera: Lygaeidae), *Collaria* sp. (Hemiptera: Miridae) (Giraldo et al., 2011), *Spodoptera* sp., *Mocis latipes* (Lepidoptera: Noctuidae), chrysomelids of the genus *Systena*, and *Epitrix*, ants of the genus *Atta* and *Acromyrmex*. On the other hand, the biological function of predatory insects such as flies (Syrphidae: *Salpingogaster nigra*), may beetles (Carabidae: *Leptotrachelus* sp.), bugs (Reduviidae: *Apiomerus lanipe*s), and various spiders (Salticidae) (Giraldo et al., 2011).

Insect diversity is quite relevant because it contributes to the structuring of communities in pastures, pollination, and nutrient cycling (Whiles & Charlton, 2006). By typifying the entomofauna, the harmful or beneficial behavior of arthropods can be generalized to a great extent, being essential to determine their functional role in agroecosystems of interest to devise comprehensive management strategies.

This study sought to determine the entomofauna associated with three species of pastures, *Cenchrus ciliaris*, *Chloris gayana* and *Megathyrsus maximus,* in conditions of the Colombian Caribbean.

Materials and methods

Research site

The study was carried out at the Motilonia Research Center of the Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), municipality of Agustín Codazzi, Cesar, Colombia. It is geographically located on the coordinates 10°01’55.5’ N and 73°13’30” W at an elevation of 106 m.a.s.l., with an annual rainfall of 1585 mm (1980 – 2017), average annual temperature of 27 °C, average relative humidity of 71 %, and sunlight of 6.9 hours/day (Instituto de Hidrología, Meteorología y Estudios Ambientales, 2020). The research site was 1000 m^2 paddocks for each specie (*C. ciliaris, M. maximus,* and *C. gayana*) from the germplasm bank of the alliance between Bioversity Internacional and the Centro Internacional de Agricultura Tropical (CIAT).

Entomofauna sampling and review

Ten samplings were carried out in two seasons of the year of the Colombian dry Caribbean region: the rainy season (August to October 2018) and the dry season (January and March 2019). The collections were made weekly; the collection method was direct with an entomological network, which consisted in four double passes over ten random points homogenized for each pasture. Some direct collections were also made on organs such as flowers and leaves, and roots were checked. The insects were organized at the Entomology Unit of the AGROSAVIA’s Motilonia Research Center (RC). Then, samples of the specimens were submitted to the “Luis Maria Murillo” National Insect Collection Department, attached to AGROSAVIA, for identification by specialists.

Definition of functional groups and beneficial relationship index

Functional roles in the collected entomofauna were identified based on bibliographic information Zumbado Arrieta and Azofeifa Jiménez (2018); and field observations of structural, physiological, morphological features or life habits. Therefore, the functional group was assigned by to the main consumption habit of most members of the family to which each collected specimen belonged. Given that some families have a broad functional diversity that could alter the results of the analysis, functional groups such as omnivores, represented by the Formicidae family, and pollinators, which reported small abundance, were not considered.

Entomofauna of the three pastures data analysis

The collected insect diversity was determined by abundance and richness from the quantification of the number of individuals of each family by taxonomic order. Orders were compared in a general way, and later, analyzed for each pasture. Matrices were constructed to estimate diversity by calculate specific richness with Margalef’s index (equation 1) (Margalef, 1956).

$$I = (S-1) / (\ln N - 1) \qquad (1)$$

Where *S* is the number of families and *N* the total number of individuals).

The abundance was calculate with the Shannon-Wiener's index (equation 2) (Shannon, 1948) and Simpson's dominance index (equation 3).

$$H' = -\sum pi Ln\, pi \qquad (2)$$

$$\lambda = \sum p_i^2 \qquad (3)$$

Where p_i is the number of individuals of the $_I$ family divided by the total number of individuals of the sample) (Simpson, 1949).

The predicted number of families was estimated non-parametric models of the Chao1 index (equation 4) (Moreno, 2001).

$$C = S + a2\ 2b - 1 \qquad (4)$$

Where C: Chao1, *S*: number of families in a sample, *a:* number of families represented by a single individual, and *b*: families with two individuals).

The indices were estimated through Paleontological Statistics, version 2.17c (Hammer et al., 2001), also they were also statistically compared using permutation and bootstrapping tests. Variance analysis was also performed to compare the orders at a general level, considering the parameters and diversity indices mentioned, using SAS, version 9.4.

Functional groups and beneficial insect relationship index data analysis

The insect abundance of the functional groups was estimated as a percentage in each pasture and season evaluated. At the same time, the typification of families by functional group allowed to calculate the beneficial functional relationship index (BRIN) of the entomofauna collected by pasture and season to establish the relationship between phytophages and consumers (predators and parasitoids). The BRIN was calculated from the equation 5.

BRIN= *ln*(number of phytophages / number of consumers) (5)

Where ln is the natural logarithm of the coefficient of the number of phytophages and the number of consumers (Diaz et al., 2017).

Relationship between insect abundance in pastures and climatic conditions data analysis

General and mixed linear models were used to analyze the relationship between insect abundance in pastures and climatic conditions. Insect abundance was evaluated as a response variable, and pastures, seasons, and their interaction as independent variables with fixed effects. Also, the samplings were included as variables with random effects. This procedure was performed whit R, version 4.0.0 (R Core Team, 2020), interface with Infostat (Di-Rienzo et al., 2020). Correlations were established with the Spearman's coefficient between entomofauna

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abundance and climatic conditions (accumulated rainfall, average temperature, and average relative humidity) with SAS, version 9.4 (Statistical Analysis System Institute, 2013). Finally, a simple correspondence analysis was carried out to define a multivariate level the relationship between the variable of abundance per family associated with the season and the pasture variables. The representativeness of each category to each component was defined through cosine squared with R.

Results

Entomofauna in *C. ciliairis*, *C. gayana*, and *M. maximus*

The results showed that 380 individuals were collected, distributed in seven orders and 35 families (Table 1). When analyzing insect diversity, a statistically significant difference between richness of the families (FR: number of families) grouped by order ($p<0.0001$) was noted, being greater in Hemiptera (10.66), followed by Coleoptera (6.66 FR), Hymenoptera (2.66 FR), and Diptera (1.66 FR). Abundance (Ab: number of individuals) results were similar, since Hemiptera was the most abundant (67.6 Ab), and Hymenoptera (4.00 Ab) the least (Table 2). When classifying insect abundance for each pasture, *C. gayana* had the most individuals (134 Ab), followed by *M. maximus* (127 Ab), and *C. ciliaris* (119 Ab). Hemiptera was the one with the highest number of individuals in the three pastures, being *C. gayana* the one with the highest average, following of Coleoptera mainly in *M. maximus* (Table 3).

Shannon's diversity index based on the relative abundance of families and Margalef's wealth index were higher in *C. gayana* for all orders (Coleoptera, Diptera, and Hymenoptera), except for Hemiptera, which had the highest diversity and richness index in *C. ciliaris*. The family structures in the three evaluated pastures had a number of predicted species similar to that observed under the Chao1 index, except for the families of the order Coleoptera in *C. ciliaris*, and Hemiptera in *M. maximus*, because they reported fewer families than those predicted for those pastures (Table 2).

Functional groups and beneficial insect relationship index

The abundance of phytophagous and predators insects was greater in the rain season that in the dry season, with the Cantharidae family standing out among the predators in the *C. ciliaris* and *C. gayana* with 12 and 5 individuals, respectively. In the *M. maximus* the most abundant was the Coccinellidae family with 14 individuals. On the other hand, the phytophagous family Nogodinidae stood out with greater abundance in most of the pastures, surpassed the Membracidae family by one specimen in *C. ciliaris*. In the dry season, the Pachygronthidae and Nogodinidae families were the ones with the highest abundance of phytophagous insects, each one with 12 individuals in the *C. gayana* and *M. maximus*. The abundance of predators was higher in the Coccinellidae family of the *M. maximus*. Lastly, the parasites Braconidae with two individuals (*M. maximus*), Chalcididae and Platygastridae with one individual each family (*C. gayana*) (Tables 4 and 5).

When considering the abundance percentage of the functional groups by season, the phytophages had the highest value, 67.28 % in the rainy season and 66.26 % in the dry season, while predators showed 29.04 % and 24.54 %, respectively. Besides, a more significant presence of decomposers (6.75 %) and parasitoids (2.45 %) was observed in the dry season, compared to the rainy season (decomposers with 3.23 % and parasitoids with 0.46 %).

The order Hemiptera was related to the functional group of phytophages (98.5 %), while Coleoptera reported the greatest diversity of functional groups with predators (61.6%) and parasitoids (38.4 %). Accordingly, phytophages and predators predominated in all pastures; however, *M. maximus* was the pasture with the highest

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Table 1. Insect abundance by order and families associated with three pastures (*C. ciliaris, C. gayana*, and *M. maximus*) in conditions of the Colombian dry Caribbean. Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Motilonia Research Center, Agustín Codazzi, Cesar, Colombia. 2019-2020.

Cuadro 1. Abundancia de insectos por orden y familias asociados a tres pasturas (*C. ciliaris, C. gayana* y *M. maximus*) en condiciones del Caribe seco colombiano. Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Centro de Investigación Motilonia, Agustín Codazzi, Cesar, Colombia. 2019-2020.

		Abundance by pastures			
Order	**Families**	***C. ciliaris***	***C. gayana***	***M. maximus***	**Total families**
Coleoptera	Bruchidae		3	5	8
	Buprestidae		2	1	3
	Cantharidae	20	8	2	30
	Carabidae	1			1
	Cerambycidae		2		2
	Chrysomelidae	11	8	14	33
	Coccinellidae	10	4	28	42
	Curculionidae	1	1		2
	Lampyridae	1	1	2	4
Diptera	Sarcophagidae	7	3	8	18
	Shyrphidae		1	1	2
Hemiptera	Cercopidae	3			3
	Cicadellidae	9	6	2	17
	Cixxidae	2	5	5	12
	Coreidae	3	2	4	9
	Dyctiopharidae			1	1
	Lygaeidae	2	3	1	6
	Membracidae	14	11	6	31
	Nogodinidae	18	44	20	82
	Pachygronthidae	2	4	12	18
	Pentatomidae	2	10		12
	Pyrrhocoridae			1	1
	Reduviidae	2		1	3
	Rhopalidae	1	4		5
	Thyreocoridae	2	1		3
Hymenoptera	Braconidae			2	2
	Chalcididae		2		2
	Crabronidae	1			1
	Platygastridae		1		1
	Tiphiidae	1			1
	Vespidae	3	1	1	5
Lepidoptera	Arctiidae	1			1
Neuroptera	Chrysopidae	2	5	8	15
Orthoptera	Acrididae		2	1	3
	Proscopiidae			1	1
	Total pastures	119	134	127	380

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Table 2. Diversity of the main insect orders present in three pastures (*C. ciliaris, C. gayana,* and *M. maximus*) in conditions of the Colombian dry Caribbean. Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Motilonia Research Center, Agustín Codazzi, Cesar, Colombia. 2019-2020.

Cuadro 2. Diversidad de los principales órdenes de insectos presentes en tres pasturas (*C. ciliaris, C. gayana* y *M. maximus*) en condiciones del Caribe seco colombiano. Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Centro de investigación Motilonia, Agustín Codazzi, Cesar, Colombia. 2019-2020.

Order	FR	Ab	SIn	MIn	SIn	CIn1
Coleoptera	6.66b	41.66b	1.45a	1.55b	0.69ab	7.77
Diptera	1.66c	6.66c	0.30c	0.39c	0.18c	1.66
Hemiptera	10.66a	67.6a	1.84a	2.31a	0.77a	11.66
Hymenoptera	2.66c	4.00c	0.87b	1.19b	0.54b	3.16
p value	< 0.0001	< 0.0004	< 0.0004	< 0.0013	< 0.0012	< 0.05
CV	16.8	38.3	22.72	26.59	21.14	
R2	0.95	0.88	0.88	0.84	0.84	

*Different letters indicate statistical significance. FR: family richness; Ab: abundance; SIn: Shannon's Index; MIn: Margalef's Index; SIn: Simpson's Index; CIn1: Chao1 Index. / * Letras diferentes indican significancia estadística. FR: riqueza de familias; Ab: abundancia; SIn: índice de Shannon; MIn: índice de Margalef; Sin: índice de Simpson; CIn1: índice Chao1.

Table 3. Abundance and insect diversity indices associated with three pastures (*C. ciliaris, C. gayana*, and *M. maximus*) and two seasons (dry, rainy) in conditions of the Colombian dry Caribbean. Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Motilonia Research Center, Agustín Codazzi, Cesar, Colombia. 2019-2020.

Cuadro 3. Abundancia e índices de diversidad de insectos asociados a tres pasturas (*C. ciliaris, C. gayana* y *M. maximus*) y dos estaciones (seca y lluviosa) en condiciones del Caribe seco colombiano. Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Centro de Investigación Motilonia, Agustín Codazzi, Cesar, Colombia. 2019-2020.

Order	Pasture/Season	FR	Ab	SIn	MIn	Sin	CIn1
	C. ciliaris	6.0	44.0	1.30	1.32	0.67	9.0
	C. gayana	8.0	29.0	1.82	2.07	0.80	8.3
Coleoptera	*M. maximus*	6.0	52.0	1.23	1.26	0.62	6.0
	Rainy	7.0	67.0	1.48	1.40	0.72	8.0
	Dry	6.0	58.0	1.50	1.23	0.75	6.0
	C. ciliaris	1.0	7.0	0.00	0.00	0.00	1.0
	C. gayana	2.0	4.0	0.56	0.72	0.37	2.0
Diptera	*M. maximus*	2.0	9.0	0.34	0.45	0.19	2.0
	Rainy	2.0	8.0	0.37	0.48	0.21	2.0
	Dry	2.0	12.0	0.28	0.40	0.15	2.0
	C. ciliaris	12.0	60.0	2.03	2.68	0.82	12.0
	C. gayana	10.0	90.0	1.71	2.00	0.72	10.0
Hemiptera	*M. maximus*	10.0	53.0	1.79	2.26	0.77	13.0
	Rainy	14.0	128.0	1.84	2.67	0.74	15.0
	Dry	11.0	75.0	1.97	2.31	0.82	17.0
	C. ciliaris	3.0	5.0	0.95	1.24	0.56	4.0
	C. gayana	3.0	4.0	1.04	1.44	0.62	3.5
Hymenoptera	*M. maximus*	2.0	3.0	0.63	0.91	0.44	2.0
	Rainy	4.0	7.0	1.15	1.54	0.61	7.0
	Dry	4.0	5.0	1.86	1.86	0.72	5.5

FR: family richness; Ab: abundance; SIn: Shannon's Index; MIn: Margalef's Index; SIn: Simpson's Index; CIn1: Chao1 Index. / FR: riqueza de familias; Ab: abundancia; SIn: índice de Shannon; MIn: índice de Margalef; Sin: índice de Simpson; CIn1: índice Chao1.

Table 4. Abundance of entomofauna by order and families according to its main trophic group associated with three pastures (*C. ciliaris, C. gayana*, and *M. maximus*) during rainy season in conditions of the Colombian dry Caribbean. Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Motilonia Research Center, Agustín Codazzi, Cesar, Colombia. 2019-2020.

Cuadro 4. Abundancia de entomofauna por orden y familia según su principal grupo trófico asociadas a tres pasturas (*C. ciliaris, C. gayana* y *M. maximus*), durante época de lluvias en condiciones del Caribe seco colombiano. Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Centro de Investigación Motilonia, Agustín Codazzi, Cesar, Colombia. 2019-2020.

			Abundance by pastures			
Order	**Families**	**Functional groups**	***C. ciliaris***	***C. gayana***	***M. maximus***	**Total**
Coleoptera	Buprestidae	Phytophagous		2	1	18
	Chrysomelidae		5	4	5	
	Curculionidae		1			
	Cantharidae	Predator	12	5	1	49
	Carabidae		1			
	Coccinellidae		10	2	14	
	Lampyridae		1	1	2	
Diptera	Sarcophagidae	Decomposer	7			7
	Shyrphidae	Phytophagous	1		1	
Hemiptera	Cercopidae	Phytophagous	3			126
	Cicadellidae		6	5		
	Cixxidae		1	4	1	
	Coreidae		3	1		
	Dyctiopharidae				1	
	Lygaeidae		2	3		
	Membracidae		14	7	3	
	Nogodinidae		13	32	13	
	Pachygronthidae		2	4		
	Pentatomidae			1		
	Pyrrhocoridae				1	
	Rhopalidae		1	3		
	Thyreocoridae		2			
	Reduviidae	Predator	2			2

percentage of decomposers (6.30 %) and parasitoids (2.00 %), contrary to *C. gayana* in which phytophages (81.34 %) dominated (Figure 1A). Similar proportions were also found between phytophages and predators, according to the BRIN. These results were found mainly in *C. ciliaris* (0.24 BRIN) and *M. maximus* (0.24 BRIN) during the rainy season (0.37 BRIN). The BRIN analysis between phytophages and parasitoids revealed a higher proportion of phytophages in the rainy season (2.16 BRIN), compared to the dry season (1.43 BRIN). In the case of pastures, very similar values among them were obtained (*C. ciliaris* = 1.57 BRIN, *M. maximus* = 1.57 BRIN, and *C. gayana* = 1.56 BRIN). A greater abundance of phytophages was registered in all the pastures and two seasons evaluated, which was reflected in a higher Shannon's diversity index, because most of the collected insects belonged to the Hemiptera order.

Relationship of insect abundance with pastures and climatic conditions

The analysis of the Generalized Linear Mixed Models (GLMM) was highly significant ($p<0.001$; $R^2=0.53$), with interaction between pastures and seasons ($p<0.05$). This result corroborates that insect abundance was

Table 5. Abundance of entomofauna by order and families according to its main trophic group associated with three pastures (*C. ciliaris, C. gayana*, and *M. maximus*) during dry season in conditions of the Colombian dry Caribbean. Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Motilonia Research Center, Agustín Codazzi, Cesar, Colombia. 2019-2020.

Cuadro 5. Abundancia de entomofauna por orden y familia según su principal grupo trófico asociadas a tres pasturas (*C. ciliaris, C. gayana* y *M. maximus*) durante época de sequía en condiciones del Caribe seco colombiano. Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Centro de Investigación Motilonia, Agustín Codazzi, Cesar, Colombia. 2019-2020.

Order	Families	Functional groups	Abundance by pastures			
			C. Ciliaris	***C. Gayana***	***M. Maximus***	**Total**
Hymenoptera	Chalcididae	Parasitoid		1		1
	Crabronidae	Predator	1			6
	Tiphiidae		1			
	Vespidae		3		1	
Lepidoptera	Arctiidae	Phytophagous	1			1
Neuroptera	Chrysopidae	Predator	1	2	3	6
Coleoptera	Bruchidae	Phytophagous		3	5	30
	Cerambycidae			2		
	Chrysomelidae		6	4	9	
	Curculionidae			1		
	Cantharidae	Predator	8	3	1	28
	Coccinellidae			2	14	
Diptera	Sarcophagidae	Decomposer		3	8	11
	Shyrphidae	Predator			1	1
Hemiptera	Cicadellidae	Phytophagous	3	1	2	74
	Cixxidae		1	1	4	
	Coreidae			1	4	
	Lygaeidae				1	
	Membracidae			4	3	
	Nogodinidae		5	12	7	
	Pachygronthidae				12	
	Pentatomidae		2	9		
	Rhopalidae			1		
	Thyreocoridae			1		
	Reduviidae	Predator			1	1
Hymenoptera	Braconidae	Parasitoid			2	4
	Chalcididae			1		
	Platygastridae			1		
	Vespidae	Predator		1		1
Neuroptera	Chrysopidae	Predator	1	3	5	9
Orthoptera	Acrididae	Phytophagous		2	1	4
	Proscopiidae				1	

influenced by the type of pasture, the rainfall, and drought conditions. In the rainy season, the average abundance was higher in *C. ciliaris* (18.60 ± 4.72 Ab), followed by *C. gayana* (15.60 ± 4.72 Ab), while in the dry season, the abundance was higher in *M. maximus* (16.20 ± 4.81 Ab). When the interaction occurred, the sources of variation were analyzed together. However, the abundance related to pastures (regardless of the season) registered the

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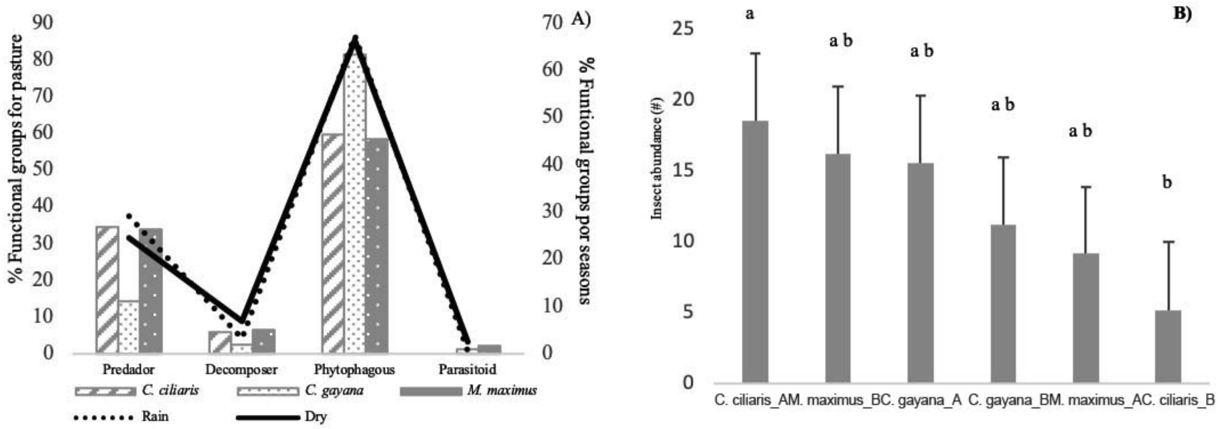

Figure 1. Entomofauna associated with three pastures (*C. ciliaris*, *M. maximus*, *C. gayana*) in two seasons (rainy: A and dry: B). **A)** Functional groups. **B)** Insect abundance. Different letters showed statistical differences (p<0.05). Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Motilonia Research Center, Agustín Codazzi, Cesar, Colombia. 2019-2020.

Figura 1. Entomofauna asociada con tres pasturas (*C. ciliaris*, *M. maximus*, *C. gayana*) en dos estaciones (Lluvioso: A y sequía: B) del centro de investigación Motilonia, Cesar, Colombia. **A)** Grupos funcionales. **B)** abundancia de insectos. Diferentes letras muestran diferencias estadísticas (p<0,05). Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Centro de Investigación Motilonia, Agustín Codazzi, Cesar, Colombia. 2019-2020.

highest average in *C. gayana* (13.40 ± 3.89 Ab), followed by *M. maximus* (12.70 ± 3.89 Ab), and *C. ciliaris* (11.90 ± 3.89 Ab) (p=0.92), while the abundance in the rainy season (14.75 ± 3.55 Ab) was higher than in the dry period (10.87 ± 3.55 Ab) (p<0.27) (Figure 1B). A significant inverse linear correlation was found between the average temperature and abundance, especially of phytophages (R=-0.41; p<0.02); however, there was no correlation between abundance and rainfall.

The simple correspondence analysis revealed that the percentages of accumulated variance were 60.8 % and 39.2 % for the first and second dimensions, respectively. The first dimension was represented mainly by *C. gayana* (0.75) and the second by *C. ciliaris* (0.71) and *M. maximus* (0.73). Also, the relationship with the rainy (A) and drought (B) seasons was considerable. The families of insects with the most significant association with *C. gayana*, from the functional group of phytophages, were *Cerambycidae*_B, *Curculionidae*_B, and *Pentatomidae* _B. The predator families were *Vespidae*_ B and *Chrysopidae*_B. Finally, two of the three families of parasitoids were recorded in this pasture (*Platygastridae*_B, *Chalcididae*_A and B).

In *C. ciliaris*, the phytophages families *Coreidae*_B, *Chrysomelidae*_B, and *Pachygronthidae*_B, were the most reported. The predators were *Reduvidae*_A *Cabronidae*_A, and *Tiphiidae*_A, and the family of decomposers *Sarcophagidae*_A was found in this pasture. However, this variation can be conditioned by multiple environmental factors. Moreover, in *M. maximus*, insect families of phytophages such as *Lygaeidae*_B, *Phyrrhocoridae*_A, and *Proscopiidae*_B, predators such as *Coccinellidae*_A and B, and *Reduviidae*_B, and parasitoids such as *Braconidae*_B, were identified mainly in the dry season (Figure 2).

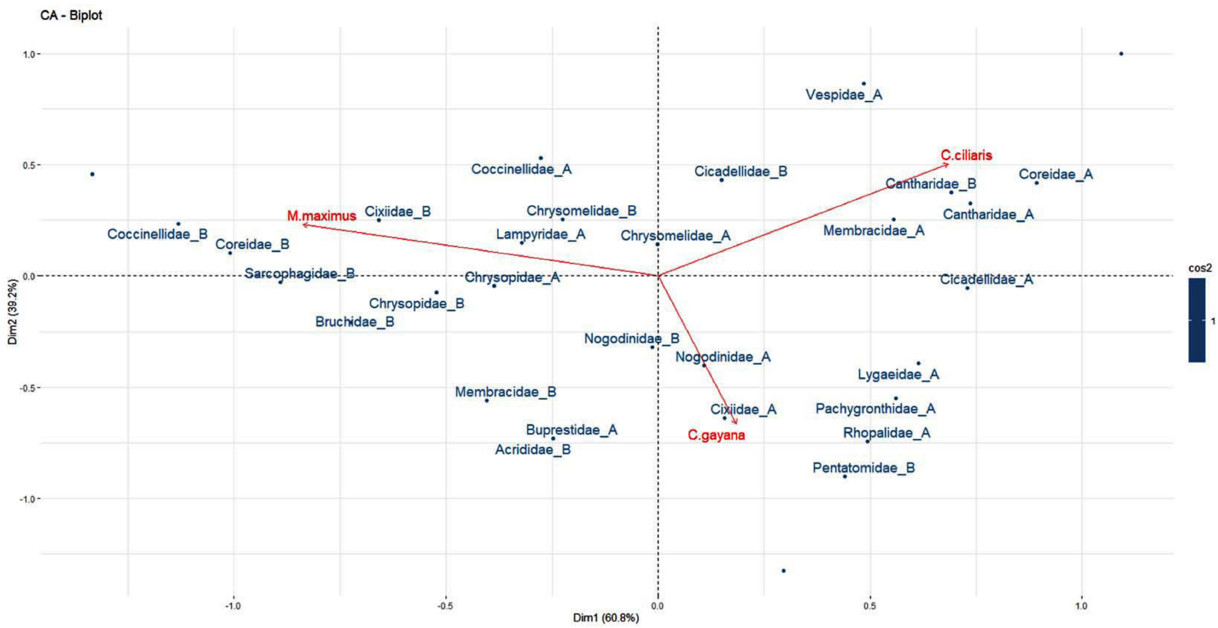

Figure 2. Map of factors that show the relationship among the three pastures (*C. ciliaris*, *M. maximus*, and *C. gayana*) in two seasons (rainy: A and dry: B), and the abundance of insects per family. Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Motilonia Research Center, Agustín Codazzi, Cesar, Colombia. 2019-2020.

Figura 2. Mapa de factores que presentan la relación entre tres pasturas (*C. ciliaris*, *M. maximus* y *C. gayana*) en dos estaciones (lluviosa: A y seca: B) y la abundancia de insectos por familia. Corporación Colombiana de Investigación Agropecuaria (AGROSAVIA), Centro de Investigación Motilonia, Agustín Codazzi, Cesar, Colombia. 2019-2020.

Discussion

The abundance of insects collected in this study of 380 individuals could be related to the collection method used by entomological network, because there are other more used and relevant methods for recording insect diversity, such as malaise traps that allow investigating communities of insects. Insects on large spatial and temporal scales, becoming important tools due to the large number of specimens collected through passive sampling (Uhler et al., 2022). Therefore, the insect collection method must be carefully selected, in order to potentiate sampling of individuals and estimate the diversity adequately.

In this research, the Coleoptera was considered as a representative order within the abundant entomofauna of the evaluated pastures, this finding could be due to the fact that coleopterans are the second largest and most diverse order in the planet (Rainio & Niemelä, 2003). Similarly, the high abundance of the order Coleoptera was similar to that reported by a study carried out in Tanzania, Africa, where a high diversity of the orders Hymenoptera and Coleoptera was found in *M. maximus* (Ojija et al., 2016).

According to the Shannon index obteined in this study, the order Coleoptera presented great abundance, this is possibly by having a greater availability of biomass in combination with climatic factors such as rain, coleopterans could easily develop considering their effects on the foliage as a pest and predatory behavior (Lee & Kwon, 2013). It could also be favorable to have a wide diversity of this order since many of them act as pest predators (New, 2019), as observed in this research in the Cantharidae and Coccinellidae families, which were very abundant in *C. ciliaris*, and *M. maximus*, respectively.

The orders Lepidoptera (one individual), Neuroptera (15 individuals from one family), and Orthoptera (three individuals from three families), registered few families and less abundance; therefore, it was not possible to calculate the diversity indices. Harmful or beneficial behavior of arthropods can be generalized to a great extent, being essential to determine their functional role in agroecosystems of interest to devise comprehensive management strategies. Some orders in this research were scarce, such as Orthoptera and Lepidoptera, which has been considered of high importance, mainly due the economic damage it may cause on pastures (New, 2019). For this order low values could be due to the active agricultural intervention in the surroundings of the research site, because the vast abundance of this order has been related to the restoration rates of some meadows (Rákosy & Schmitt, 2011).

The functional group of pollinators was not considered since only one individual was registered, nor the family Formicidae because it fulfills many functions for being omnivorous. The presence of pollinators was small, which agrees with the report of other evaluations in *M. maximus* (Ojija et al., 2016) and may be due to the limited availability of flowers during the evaluation period, or the preferred habit at the time of sampling (Collinge et al., 2003). Some orders of this functional group were also related to the functional group of parasitoids, which reported little abundance.

In this study, the abundance of arthropods found in the rainy season, which may be related to their adaptive capacity (Barnett & Facey, 2016). However, it has been reported that high levels of rainfall can also affect arthropod flight, limit feeding, and increase migration times (Kasper et al., 2008). In addition, it was found that in times of higher rainfall, grasses improve biomass availability, plant height, and soil cover, which favors the abundance and diversity of insects (Barnett & Facey, 2016).

The diversity of the Hemiptera order reported in this research may be due to the fact that the order has a great related adaptation within its evolutionary process, being considered one of the five most diverse orders (Szwedo, 2018). Likewise, their coevolution with grasses has been identified, and most of their families are characterized by being pests and vectors (Gullan & Cranston, 2014).

In *C. ciliaris*, was found that the highest abundance of the entomofauna was defined by the orders Orthoptera, Isoptera, and Hymenoptera (Patel, 2015), contrary to the results found in this study, since no Isoptera insects were reported and the abundance of the other orders was very limited not only in *C. ciliaris*. The plant component, depending on the use that insects make of it, may or may not favor the presence of pest and beneficial insects. It could also be considered that, in species highly adapted to drought conditions such as *M. maximus*, biomass availability could not be strongly compromised as it is a food source for insects in times of low rainfall (Barragán-Hernández & Cajas-Girón, 2019). This condition probably created a favorable environment and promoted a greater abundance of the entomofauna in this pasture during the dry season. The population dynamics of insects decreased when the average temperature increased (Yarupaita Echevarria, 2016).

The diversity in the rainy season could also be related to the lower temperatures recorded at this time, as shown by the negative relationship between temperature and insect abundance. This behavior was mainly detected in insects of the Hemiptera order, as happened in this study with Hemiptera, being the ones with the greatest abundance after Coleoptera. The effect of low temperature could account for the large number of insects collected during the rainy season in all pastures, except for *M. maximus*, which had the highest abundance during the dry season. So, even though insect abundance increased when the temperatures were low, it should be considered that pasture also influenced insect abundance.

Conclusion

The orders Coleoptera and Hemiptera stood out, which mostly represented the functional groups of predators and phytophages, respectively. The entomofauna of *C. gayana*, *C. ciliaris*, and *M. maximus* was similar in insect abundance and diversity. However, insect abundance depended on the influence of the season and pastures. Therefore, it is crucial to consider the biotic and abiotic factors that can affect the entomofauna associated with pastures to create preservation strategies for beneficial fauna and efficient pest management, thus maintaining a balance in the trophic relationships of the entomofauna associated with pastures, could be a useful tool and sustainably as an alternative to agroecological production systems by maintaining the natural balance and reducing the application of agrochemicals.

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Competing interests

The authors declare no conflict of interest.

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