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An approach to the entomofauna in agroecosystems of the Salvatierra, Guanajuato, Mexico

Una aproximación a la entomofauna en agroecosistemas de Salvatierra, Guanajuato, México

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Abstract: The municipality of Salvatierra, in Guanajuato, Mexico, develops an agricultural activity of national and regional importance. However, despite this, there needs to be more information on ecologically and economically important faunal groups, such as insects. Therefore, the objective of this study was to have an approximation of the entomofauna in four crops: sorghum, alfalfa, maize, and beans, as well as their composition and the characterization of the functional groups of insects in a dry seasonal tropical environment of the municipality of Salvatierra. The entomofauna for the four crops is composed of nine orders: Coleoptera, Diptera, Dermaptera, Hemiptera, Hymenoptera, Lepidoptera, Mantodea, Neuroptera, and Orthoptera, and 53 families. The highest Simpson Wealth Index value was for alfalfa (0.91) and the lowest for beans (0.84). On the other hand, in terms of its structure and composition, the entomofauna is represented by eight functional groups: Herbivores = H, Predators = D, Parasitoids = PAR, Pollinators = POL, Vectors = V, Decomposers = DES, Xylophages = XIL, and Generalists = G. Phytophagous insects (pests), predators and parasitoids are the most common and abundant in crops. The present work generates new data on the entomofauna present in the agroecosystems of the community of Urireo in the municipality of Salvatierra, Guanajuato state, informing the development of specific studies of demography and ecological interactions between insect-plant and insect-insect.

Keywords: Agroecology, tropical deciduous forest, diversity, functional groups, insects.

Resumen: El municipio de Salvatierra en el estado de Guanajuato México, desarrolla una actividad agrícola de importancia regional y nacional. Sin embargo, existe una falta de información sobre grupos faunísticos de importancia ecológica y económica, como los insectos. Por ello, el objetivo del presente estudio fue tener una aproximación de la entomofauna en cuatro cultivos: sorgo, alfalfa, maíz y frijol, así como su composición, y la caracterización de los grupos funcionales de insectos en un ambiente tropical estacional seco del municipio de Salvatierra. La entomofauna para los cuatro cultivos está compuesta por nueve ordenes: Coleoptera, Diptera, Dermaptera, Hemiptera, Hymenoptera, Lepidoptera, Mantodea, Neuroptera, y Orthoptera, y 53 familias. El valor del índice de riqueza de Simpson más alto fue para alfalfa (0,91) y el menor para frijol (0,84). Por otro lado, en cuanto a su estructura y composición la entomofauna está representada por ocho grupos funcionales: Herbívoros = H, Depredadores = D, Parasitoides = PAR, Polinizadores = POL, Vectores = V, Descomponedores = DES, Xilófagos = XIL, y Generalistas = G. Siendo insectos fitófagos (plagas), depredadores y parasitoides los de mayor ocurrencia y abundancia en los cultivos. El presente trabajo genera nuevos datos de la entomofauna presente en los agroecosistemas de la comunidad de Urireo en el municipio de Salvatierra, estado Guanajuato, dando la pauta al desarrollo de estudios puntuales de demografía e interacciones ecológicas insecto-planta e insecto-insecto.

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Palabras clave: Agroecología, bosque tropical caducifolio, diversidad, grupos funcionales, insectos.

Introduction

The richness of insect species in Mexico is around 40 thousand to 350 thousand species, comprised of 34 large orders known to date (Salas-Araiza et al., 2002). They are found in a wide range of habitats, climates, and plant communities, including modified environments such as agricultural systems (Benton et al., 2003; Mace & Baillie, 2007; Mace et al., 2012; Salas-Araiza et al., 2015). Agricultural systems play an important role in the diversity, richness and, composition of insect species that inhabit them, providing shelter to various species (Meena et al., 2017; Pustai et al., 2016; Santos-Murgas et al., 2009). Agricultural systems promote complex networks of ecological interactions (Aparicio et al., 2003; Ríos-Casanova et al., 2010) and many environmental services beyond food production (Altieri, 1999). In this context, the study of ecological interactions in functional groups of insects is a basis for understanding the role they play, from a functional point of view that allows the identification of insect-insect and plant-insect relationships, in order to generate *a priori* management of them in agroecosystems (Leyte-Manrique et al., 2021). Furthermore, insects have extraordinary species richness and abundance, all make themselves key elements for the functioning of ecosystems. The insect diversity and abundance are sensitive to environmental changes at the landscape level, which have an influence on functional characteristics in the insect communities (Ramírez-Ponce et al., 2019); furthermore, González-González et al. (2020) found guilt differences in phytophagous, and scavengers scrab due to management in the crops. In this context, the relationship between the components of agroecosystems, such as water, soil, plants, and fauna, are key factors in the balance and diversity of species within agroecosystems (Salazar & Salvo, 2007; Sans, 2007).

Salvatierra belongs to Bajío Guanajuatense and, due to its topographic and climatic conditions, allows the development of activities such as agriculture and planting systems of monocultures and polycultures such as beans, lettuce, maize, sorghum, wheat, tomato, amongst others (Forlin, 2012). However, production can be affected by different causes that reduce plants quality and state of health. Amongst these causes are viruses, bacteria, fungi, and phytophagous insects (Aguilar-García & Holguín-Peña, 2013; Flores et al., 2008; Medina-Gaud, 1997). In many cases, the latter are usually considered pests due to the direct damage they cause to plants, through feeding or oviposition. As well as indirect damage, these insects may transmit viral diseases that damage crops, causing economic losses to farmers (Aguilar-García & Holguín-Peña, 2013). Added to this problem is that insect studies concerning ecological interactions are incipient, particularly those related to biodiversity in ecological studies in agroecosystems (León-Galván et al., 2019; Martínez-Aguirre et al., 2020; Miranda-Cornejo & Guzmán-Mendoza, 2020; Ramos-Patlán et al., 2018). Therefore, this study aimed was to describe and compare the diversity and composition of insects (at the order and family level) present in agricultural crops in the municipality of Salvatierra, an area with little knowledge about the entomofauna.

Material and methods

Study area. This work was carried in three sampling periods from October to December 2017, January to March 2018, and August to November 2018 with a total of 11 visits to maize (*Zea mays* L.), sorghum (*Sorghum* sp.), alfalfa (*Medicago sativa* L.), and bean (*Phaseolus vulgaris* L.) farms located in the community of Urireo, municipality of Salvatierra, in the state of Guanajuato, Mexico. Urireo is found at 20°13′32.07″ N and 100°51′ 36.72″ W, 1756 m a.s.l. (Figure 1). The vegetation type corresponds to tropical dry deciduous forest with some cultivated areas (Rzedowski, 2006). The climate is mild and humid throughout the year. The maximum temperature is 33.4 °C, the minimum temperature is 2 °C, and the annual average temperature is 18.1 °C. The annual rainfall is 730 mm (García, 1973; INEGI, 2009).

Collection of specimens. Before collecting of samples, three quadrants of 20 x 20 m^2 per crop were delimited and ordered homogeneously in each of them (Krebs, 1999). The crops were sellecting according to the planting cycles for each of them. The production system is rainfed. In sorghum and corn, it was from August to December; in alfalfa and beans, from March to November. The total area sampled was 10 hectares (2.5 for each crop). The samplings were carried out by three people, this being six man hours per day, and for the 11 departures it was 198 hours. The search and collection of the insects was carried out during the day, which was from 08:00 to 14:00 hours, considered for this purpose activity (Márquez-Luna, 2005).

It should be noted that the production system in Urireo is rainfed, and insecticides (Parathion, applied in sorghum, maize, and bean) were applied to two times in the crops during the time that the samplings were carried out. For this purpose, four quadrants of 20 x 20 m^2 were established per crop, distributed homogeneously, and then the free search was carried out in each crop by means of zig-zag walks and until the surface of each quadrant and crop was covered (Krebs, 1999; Leyte-Manrique et al., 2021; Márquez-Luna, 2005). These were collected with the help of entomological nets, entomological tweezers and by hand, as suggested by Márquez-Luna (2005). These were placed and preserved in 250 and 500 ml plastic bottles with 70 % alcohol. Subsequently, the specimens were transferred to the Biology Collections Laboratory of the Technological Institute of Salvatierra and Laboratory of Entomology of the University of Guanajuato, where identified at the family and order level with the help of taxonomic keys and guides of insects (For example: Borror & White, 1970), and a digital monocular stereoscopic microscope. The use of information obtained from higher taxonomic levels of order and families –together with morphospecies– information has been recommended for rapid analysis of the diagnosis of the state of a place's biodiversity (Grimbacher et al., 2008). This has shown evidence of reliability, with the advantage of the reduction of taxonomic and logistic limitations observed in conventional taxonomic treatments, such as the identification of species, that for some groups, the taxonomy is incomplete and with few collections, and in addition, it addresses the urgency of evaluating changes in diversity caused by the rapid modification of ecosystems (Mace & Baillie, 2007). The guilds were made on bases of taxonomic information in the keys reported for adults.

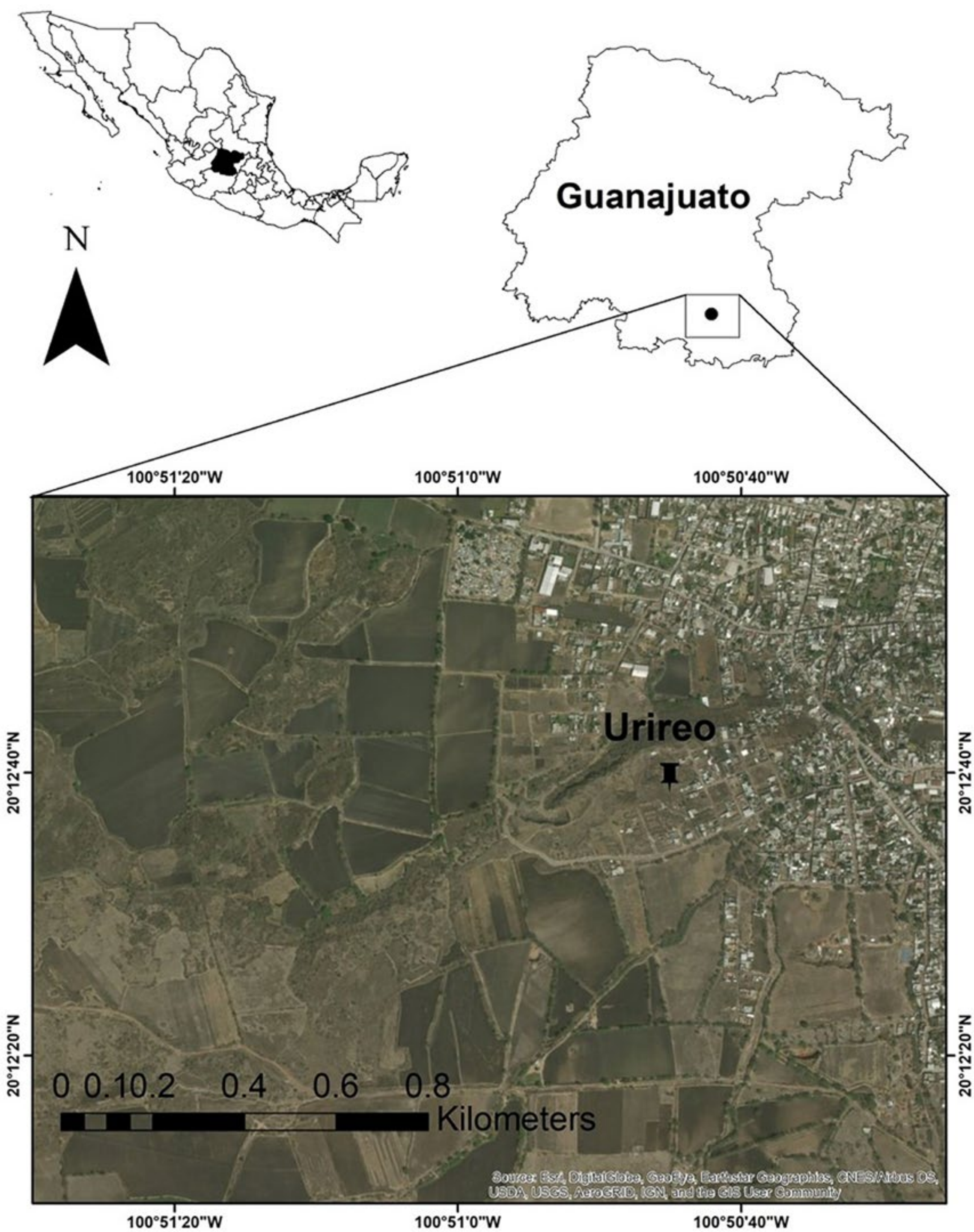

Figure 1. Study site in Urireo, Salvatierra, Guanajuato.

Checklist and functional groups. With the field and family records, a list of the insect families present in alfalfa, sorghum, corn, and bean crops were generated, and the functional groups of the insects were characterized in relation to their ecological and trophic roles. This was done in accordance with the proposal of Oliveira et al. (2020) on functional groups, which was modified for this study. For this case, they were grouped into eight types: Herbivores = H, Predators = P, Parasitoids = PAR, Pollinators = POL, Vectors = V, Decomposers = DES, Xilophages = XIL, and Generalists = G.

Data analysis. With records obtained from the field study, a database was created using Microsoft Excel. On the other hand, the richness of morphospecies, for that matter, at the level of families and orders, was obtained using the Simpson index, $\lambda = \Sigma pi^2$; where: pi = proportional abundance of species (in the case, families) i, that is, the number of individuals of the species i divided by the total number of individuals in the sample. This index interprets values of dominance, taking into account the representativeness of the species with the highest value of importance without evaluating the contribution of the rest of the species (Magurran, 2004; Moreno, 2001), and it is one of the useful indexes to evaluate biological diversity and its reverse is a good indicator (Salmerón-López et al., 2017). The Simpson index was generated with the help of the software PAST (2022) version 4. A nonparametric ANOVA from Kruskal-Wallis was carried out to see if there were differences between crops for the richness values. Finally, range-abundance or Whitaker curves were drawn to identify the composition of species, as well as their abundance and representativeness between crops. Range-abundance curves rank species from the most to the least abundant (Moreno, 2001).

Results

A total of 2,477 organisms belonging to nine orders and 53 insect families were collected. In terms of families, the most representative were: Coleoptera (13), Diptera (8), Hemiptera (15), Hymenoptera (7), and Lepidoptera (5). Those with the fewest number of families were Orthoptera and Neuroptera, with two, and Dermaptera, Hemiptera, and Mantodea, with one each (Table 1).

Table. 1. Recorded families in the four crops. In the box, the abundance values for each family are presented, as well as the characterized functional groups.

Taxa		Crops				Functional groups
Orders	**Families**	**Sorghum**	**Alfalfa**	**Maize**	**Bean**	
Coleoptera (13)	Cantharidae	20	16	8	0	P
	Carabidae	3	1	0	0	H, DES
	Cerambycidae	1	0	0	0	XIL
	Chrysomelidae	70	67	55	4	H
	Coccinellidae	167	103	47	36	P
	Cucujidae	2	0	0	0	G
	Curculionidae	0	0	8	0	H
	Latriididae	0	2	0	0	G
	Lycidae	0	0	2	0	G
	Melyridae	5	0	5	0	P
	Meloidae	1	2	4	12	G
	Phalacridae	1	2	0	0	G
	Cantharidae	8	4	24	9	H, XIL
Dermaptera (1)	Forficulidae	13	0	2	0	P
Diptera (8)	Asilidae	2	0	2	0	P
	Dolichopodidae	0	27	0	0	H
	Sarcophagidae	0	3	0	0	PAR
	Syrphidae	6	36	4	3	POL
	Tabanidae	8	2	0	3	PAR
	Tachinidae	1	0	0	0	PAR
	Tephritidae	2	0	0	0	H
	Trichoceridae	0	1	0	0	V
Hemiptera (15)	Aleyrodidae	0	0	0	78	H
	Alydidae	2	0	0	4	H
	Aphididae	166	59	0	0	H
	Cercopidae	0	77	0	0	H
	Cicadellidae	0	127	6	11	H
	Coreidae	11	7	2	5	H
	Flatidae	0	14	0	0	H
	Lygaeidae	19	4	2	0	H
	Membracidae	3	101	0	0	H
	Miridae	27	37	4	1	H
	Nabidae	5	43	0	0	P
	Pentatomidae	108	24	12	7	H

Taxa		Crops				Functional groups
Orders	Families	Sorghum	Alfalfa	Maize	Bean	
	Pyrrhocoridae	4	10	7	3	H
	Reduviidae	0	0	2	0	P
	Rhopalidae	0	0	0	2	H, XIL
Hymenoptera (6)	Apidae	5	0	2	6	POL
	Braconidae	0	8	0	0	PAR
	Ichneumonoidea	1	1	0	0	PAR
	Formicidae	0	0	0	3	H, G
	Pompilidae	2	0	0	7	POL
	Tiphiidae	0	4	0	0	PAR
Lepidoptera (5)	Erebidae	30	0	0	0	H
	Noctuidae	26	5	27	5	H
	Nymphalidae	3	0	2	2	H
	Pieridae	3	1	2	6	H
	Pyralidae	1	0	0	0	P
Mantodea (1)	Mantidae	1	1	0	0	P
Neuroptera (2)	Chrysopidae	45	3	0	0	P
	Ascalaphidae	2	0	0	0	P
Orthoptera (2)	Acrididae	313	55	37	55	H, P
	Tettigoniidae	1	7	0	0	H
Total = 9	**53**	**1092**	**855**	**266**	**264**	**2477**

Note: Insects functional groups, characterized according to their ecological function: Herbivores = H, Predators = P, Parasitoids = PAR, Pollinators = POL, Vectors = V, Decomposers = DES, Xilophages = XIL, and Generalists = G.

Richness

The Simpson index showed that alfalfa cultivation presents a value of richness of 0.91, followed by maize at 0.87, sorghum at 0.85, and beans at 0.84. The Kruskal-Wallis test, showed that there are significant differences (H = 19.51, P = 0.0001) of families' richness between crops (Figure 2).

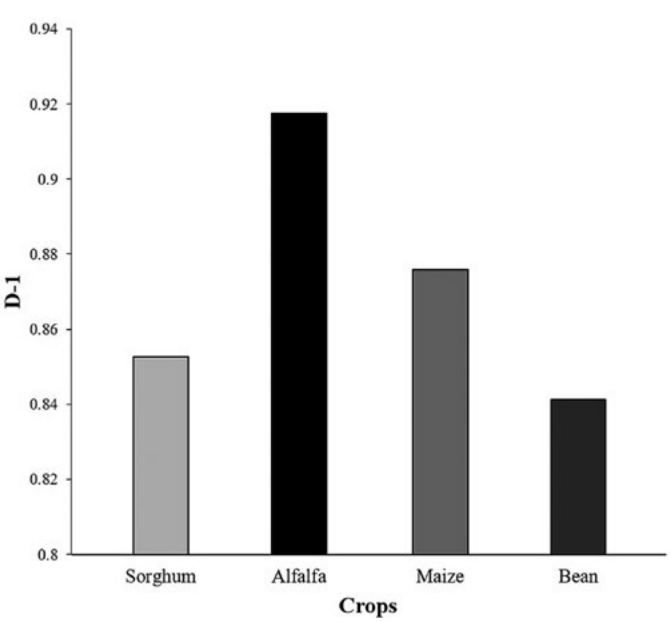

Figure 2. Index Simpson values by crops analyzed.

Composition of the entomofauna and Functional groups

The dominant orders for their abundance were Coleoptera and Hemiptera in practically all the evaluated crops, the maize (corn) crop where there was a marked dominance in the composition of their entomofauna (Figure 3).

Alfalfa and sorghum presented a higher diversity of families and abundance of individuals concerning other crops. For sorghum, the greatest diversity of families was for Acrididae, Coccinellidae, Aphididae, and Pentatomidae. In alfalfa were Chrysomelidae, Coccinellidae, Cercopidae, Membracidae and Cicadellidae. For maize, Coccinellidae, Acrididae, and Chrysomelidae, and in the case of beans, Aleyrodidae, Chrysomelidae, and Coccinellidae (Table 1; Figure 3). The differences in the structures of the insect populations expressed in their abundances undoubtedly take place due to the management behavior and the type of crop, such as fumigations, beneficial insect release, and perennial character, as in the cases of alfalfa.

On the other hand, eight functional groups were characterized: Hervibores (H), Predators (D), Parasitoids (PAR), Pollinators (POL), Vectors (V), Decomposers (DES), Xhylophages (XIL), and Generalists (G) (Table 1). In the graph of family abundance by functional group (Figure 4), it is shown that herbivores had the highest number of families in the cultivation of sorghum (20) and alfalfa (18). At the same time, for beans (14) and maize (11), it was lower. For predators in sorghum, there was the highest number of families (11), in the case of parasitoids in alfalfa, 5 families were recorded, and three for pollinators in sorghum and beans.

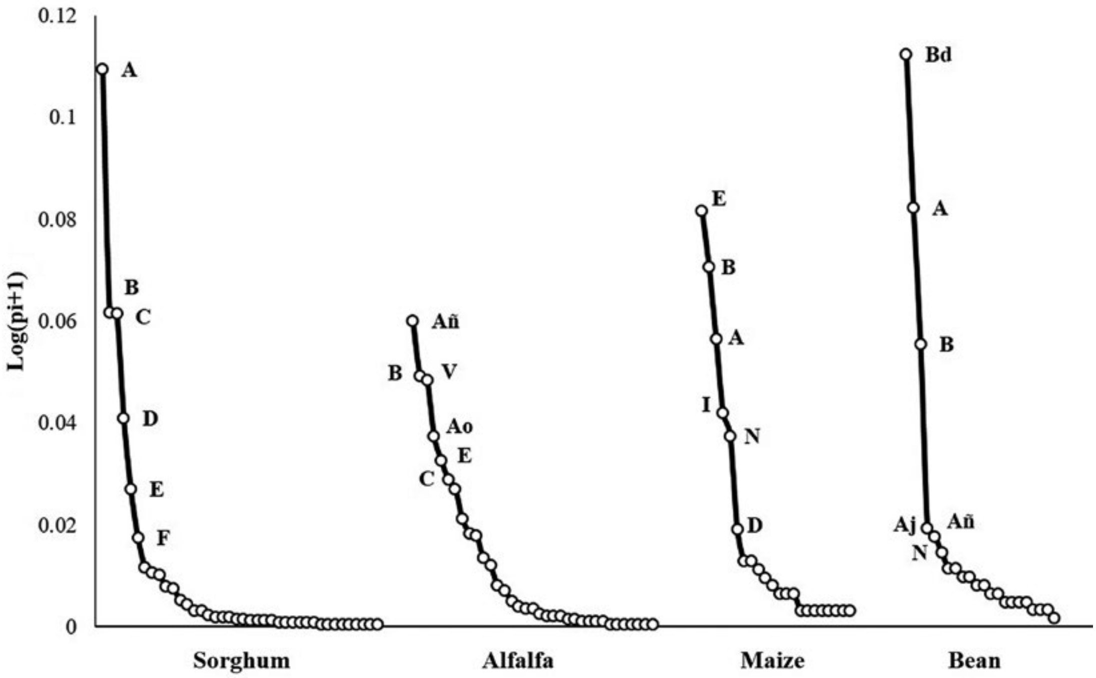

Figure 3. Whitaker rank-abundance curves. Acronyms: A = Acrididae (Caelifera: Orthoptera), B = Coccinellidae (Polyphaga: Coleoptera) C = Aphididae (Sternorrhyncha: Hemiptera), D = Pentatomidae (Heteroptera: Hemiptera), E = Chrysomelidae (Cucujiformia: Coleoptera), F = Chrysopidae (Neuroptera), N = Scarabaeidae (Polyphaga: Coleoptera), V = Membracidae (Cicadomorpha: Hemiptera), Aj = Meloidae (Polyphaga: Coleoptera), Añ = Cicadellidae (Cicadoidea: Hemiptera), Ao = Cercopidae (Cicadomorpha: Hemiptera) y Bd = Aleyrodidae (Sternorrhyncha: Hemiptera: Aleyrodidae).

Note. The acronyms of the most abundant families in each crop are presented, and they express their composition.

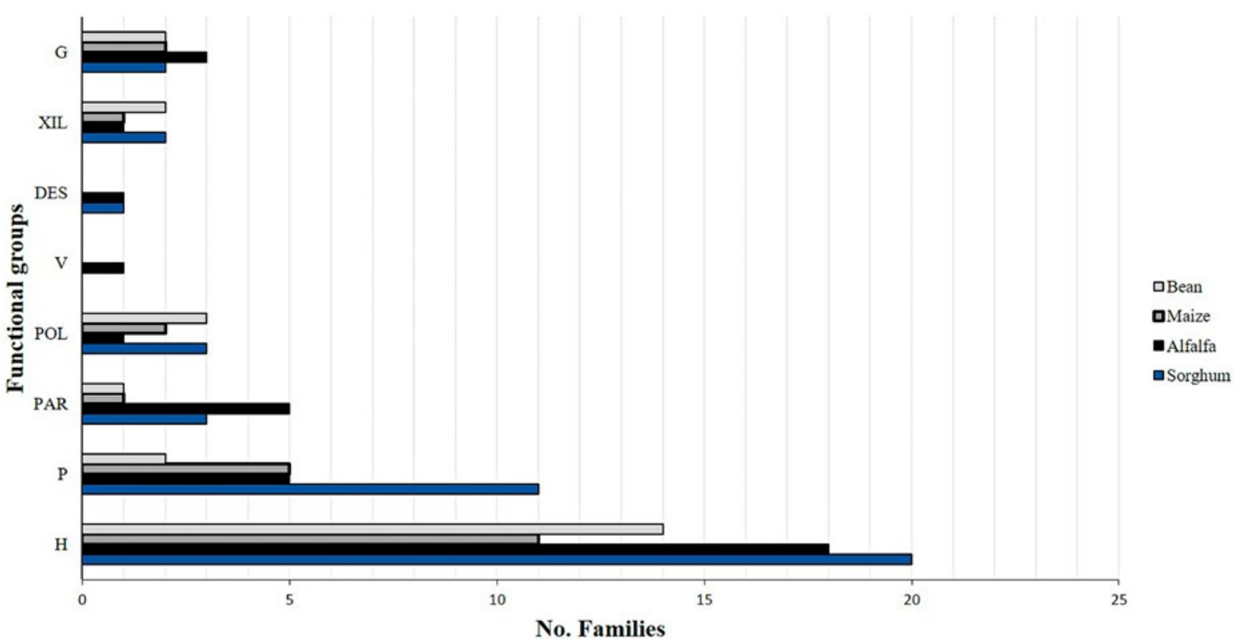

Figure 4. Families by functional groups in the crops.

Discussion

About to the families of insects found in this study and contrasting with others (Egerer et al., 2016; Martínez-Jaime et al., 2014, 2016; Medina-Gaud, 1997) in which, both Coleoptera and Hemiptera have been recorded as the most abundant groups in sorghum and corn, this study illustrates that the highest abundance was found in alfalfa (Table 1). This is probably because this crop can provide a refuge and constant food to these insects, as is the case of alfalfa, which, before being harvested, has several cuts during its cycle; the perennial nature of this type of culture influences the patterns of abundance and diversity of the species present (Grimbacher et al., 2008).

In this context, we observed a greater diversity of insect families in alfalfa with respect to beans, corn and sorghum, which means that being alfalfa an annual crop (in the study area) gives a more significant presence of different taxa and groups of insects, and that it may also be determined by the management of the crops in Urireo since they are made of these, bimonthly or quarterly cuts. This implies two things: 1-A greater diversity with respect to the other three crops, which have shorter life cycles. Therefore, in this case, comparing crops with differential life cycles may have implications on the values of abundance and diversity of insects, as well as the presence of functional groups throughout the year, and 2-Agronomic crop management can be the result of the diversity of families and groups, something already mentioned by authors such as Ramírez-Ponce et al. (2019), who alluded to and compared technified systems concerning to traditional ones in corn agroecosystems. In the case of Uriero, the production systems are rustic rainfed systems, and although insecticide applications were carried out, they did not reflect a negative effect on insect diversity. Since for example, in the case of corn, which was the second richest crop in families, being a plant that usually has the presence of a wide diversity of insects and functional groups, in which in addition to insects of phytophagous habits, predatory species such as the beetles of the family Coccinellidae are usually found; parasitoid wasps of the family Braconidae, and pollinators of the family Vespidae (Matienzo-Brito et al., 2011).

The abundance of families, the orders Coleoptera, Hemiptera, and Diptera, were mainly phytophagous insects for the first two, while for the third, they were mostly predatory or frugivorous. This agrees with that reported by Salas-Araiza et al. (2011, 2017) in which these families are the most representative of crops such as sorghum and corn. The antagonistic families of Coleoptera, Coccinellidae (predators) and Chrysomelidae (phytophagous), showed the highest abundance level with 353 and 196 individuals, respectively (Table 1). The sorghum and alfalfa crops manifested the most frequency, in this sense, we observe a pattern and relationship between the presence of both groups of beetles, in which not only their structures but also their function highlights their roles, one as phytophagous and the other as predatory, occurring in crops common to both (Egerer et al., 2016).

Thus, giving an expected interaction, prey-predator, having in this case a high abundance in the members of the family Coccinellidae, an atypical pattern, since what is registered in most of the studies is a high abundance and diversity of phytophagous species in relation to the predators (Piña-Garcia & Leyte-Manrique, 2017; Pustai et al., 2016; Salas-Araiza et al., 2017; Santos-Murgas et al., 2009). However, the high number of predators recorded here responds to biological control strategies recommended for the region, where producers make frequent releases of beneficial insects to attack pests. In the case of Hemiptera, the family Pentatomidae (phytophagous insects) had the highest occurrence in the four crops, and with the greatest abundance (151 individuals) in sorghum. For the Hemiptera, the family Aphididae presented an abundance of 225 individuals, having its highest occurrence and abundance in sorghum with 166 individuals, and in alfalfa with 59 (Table 1). Although, the abundance level obtained was low compared to other studies (Salas-Araiza et al., 2011, 2017), the prevalence of aphids was maintained throughout the study.

One of the reasons why low abundance is attributed is that the area was fumigated during several periods of growth, which could cause high mortality of individual species. In this regard, authors such as Montañez and Amarillo-Suárez (2014) have pointed out that the application of insecticides reduces the diversity of insects, mainly the benefits, as found in the present study. For Orthoptera, the family Acrididae had the highest abundance, with 460 insects, and high occurrence in all crops. For Lepidoptera, members of the family Noctuidae were the most abundant, with 63 individuals, and they had an occurrence in all the crops. Finally, for Hymenoptera, represented by pollinators, parasitoids, and predators, there was a high abundance in the Apidae and Vespidae families.

Richness

The values of richness found in alfalfa could be related to the lack of fumigation activities during their cultivation cycle, unlike sorghum and maize (these fumigations were not contemplated for the investigation), a crop under effects of herbicides to control pests. Perfecto et al. (1997), pointed out that traditional agroecosystems (with limited access to agronomic technologies) may contain a greater richness of species than those that are technified, so diversity may be affected, positively or negatively, by agricultural practices (Diaz et al., 2018; Forlín, 2012), the pattern observed in sorghum is interesting and it needs to be reviewed in order to know how management factors have influenced in the ecological interactions that makes an increase of taxonomic richness. In the region where the study was made, there is a great conserved vegetation coverage, has been observed an influence of the natural matrix of vegetation on diversity inside of the crops basically on beneficial species, such as pollinating insects (Balam-Pech et al., 2023; Lilheström et al., 2002). Finally, a consistent pattern was observed for all crops with few orders very abundant families, and many rare and little abundances. In all the crops studied, the phytophagous species were more abundant than the parasitoids and predators (Leyte-Manrique et al., 2021). This may be due to their gregarious habits, high reproductive rate, and greater egg-laying capacity, as well as their ability to adapt to climatic conditions or their more excellent resistance to the insecticides applied in each crop (Salazar & Salvo, 2007). In contrast to the beneficial insects, which are more susceptible to changes in their environment, as well as to their habitats, which in most species are solitary, observed only in greater quantity, during the reproductive season or in feeding areas or foraging, in this sense it has been reported that activities such as tillage or intensification in management affect the presence and abundance of certain groups of insects such as ants and flies (Grimbacher et al., 2008).

Composition of insects in crops and functional groups

These results suggest sensible differences in the networks of ecological interactions for functional groups of insects (eight) that arise with the development of the crop and that need to be evaluated in their detail to understand the directions the frequency, and identity of the types of interaction that are present and that are susceptible to the aspects temporary as the cultivation phenology (Diaz et al., 2018; Leyte-Manrique et al., 2021; Salas-Araiza et al., 2006; Salazar & Salvo, 2007). This information will allow us to understand how agricultural systems work from an ecosystem approach that generates agroecological production strategies, which inhibit the exponential growth of insect pest populations and benefit biodiversity services.

Conclusions

While this study only contemplated the analysis of diversity at the level of families 55 and orders 11 of the associated entomofauna in the four crops analyzed, it gives an example and idea of the structure and function of the presence of phytophagous, predator, and parasitoid functional groups. Likewise, it was observed that the cultivation of alfalfa presented the highest values of richness, which can be explained by the phenology and reproductive cycle of the plant; that is, its cycle is longer and allows a greater availability of food and shelter, unlike the other crops. As expected, there was a greater diversity of insect pests compared to the beneficial ones. The results presented here contribute to generating new knowledge about the diversity, composition, and functional groups of insects in the agroecosystems of the Guanajuato state. In addition to that they serve as a guide to the implementation of viable and sustainable alternatives in the management of beneficial insects, as it is the case of predators and parasitoids, that profits an integrated management of pests using their natural controllers of the phytophagous species, that they contribute to the integrated pest management by means of natural controllers making use of the knowledge of the ecological.

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Author Contribution

The first author stated the objectives of the research, contributed to the analysis of the data and the writing of the article.

The second author supported the writing and data analysis, together with the first author.

The third author contributed to the review of insect families and writing in general.

Conflict of Interest

The authors declare that they have no conflict of interest.