Eurasia Specialized Veterinary Publication

Entomological Research Letters

ISSN: 3108-639X

2022, Volume 2, Issue 2, Page No: 37-46

Available online at: www.esvpub.com/

Ecological Roles and Composition of Insect Assemblages in Southern Guanajuato Cereal Fields

Maria Ramirez[1]*, Jun B. Brown[1], Ingrid Smith[1], Anna N. Hassan[1]

[1]Department of Entomology and Zoology, Faculty of Natural Sciences, National Autonomous University of Mexico, Mexico City, Mexico.

***E-mail** ✉ mramirez@outlook.com

ABSTRACT

Between August to November (2018) and February to May (2019), 8 insect collections were made across three-grain crops—corn, wheat, and barley—at El Capulín, Salvatierra, Gto., totaling 6,596 specimens. The insect fauna included 11 orders and 59 families, of which 53 families are found in corn, 25 in wheat, and 24 in barley. The entomofauna was classified into two main functional groups based on their ecological roles and diets: 1) EFGs (ecological functional groups), which include predators, herbivores, parasitoids, vectors, decomposers, pollinators, and generalists; and 2) TFGs (trophic functional guilds), including phytophages, insectivores, decomposers, polyphages, necrophages, hematophages, carnivores, nectarivores, and mycophages. Principal component analysis of the EFGs showed that herbivores and predators dominated corn, while wheat and barley showed a more balanced distribution. Similarly, the phytophagous and insectivorous TFGs followed a similar trend. In maize cultivation, both trophic relationships and functional were shaped by antagonistic groups of predators and plant hosts, while in barley and wheat, more generalist groups were non-specific and prevailed. This suggests that corn favors the insect's dominance adapted to its developmental cycles, with abundance associated with demographic factors typical of phytophagous species and fewer families of other groups. Agronomic practices and ecological interactions in agroecosystems play important roles in shaping the composition of functional groups in the insect communities in the studied grain crops.

Keywords: Guild insects, Agroecology, Functional ecology, Agroecosystems

Received: 07 November 2022
Revised: 20 December 2022
Accepted: 21 December 2022

How to Cite This Article: Ramirez M, Brown JB, Smith I, Hassan AN. Ecological Roles and Composition of Insect Assemblages in Southern Guanajuato Cereal Fields. Entomol Res Lett. 2022;2(2):37-46. https://doi.org/10.51847/EvKsMvXrgns7

Introduction

Mexico, renowned for its high biodiversity, is home to a vast array of plant species and animals, with insects accounting for approximately 75% of the known species [1]. An estimated 47,768 insect species have been described, with the most studied insects classified into orders like Coleoptera, Homoptera, Hemiptera, Diptera, Orthoptera, Lepidoptera, and Odonata, which include families of significant ecological and economic importance to agriculture [2]. Insects exhibit a wide range of life forms and behaviors, and they occupy various functional groups such as herbivores, parasites, predators, and decomposers [3, 4].

The diversity of landscapes, combined with the characteristics of surrounding habitats, significantly impacts the biodiversity within agroecosystems. This, in turn, affects the insects inhabiting these environments, influencing their ecological functions. Egerer *et al*. [5] suggest that the diversity and structure of landscapes surrounding agroecosystems altered the abundance and diversity of predatory insects. Their study observed a higher diversity of coccinellids in agroecosystems that were heavily influenced by human activities, which increased landscape variety. Similarly, Oliveira *et al*. [6] noted that secondary forests surrounding citrus crops supported a greater abundance of Braconidae parasitoids compared to landscapes formed by citrus plantations and forest edges. These findings underline the importance of vegetation in shaping the composition and diversity of insect populations in agroecosystems, offering essential ecosystem services like pollination, predation, and organic matter decomposition.

While the role of biodiversity in agroecosystems is widely acknowledged, there remains a lack of experimental and observational studies that provide a comprehensive theoretical framework for understanding the biodiversity-agroecosystem relationship. Muriel and Vélez [7] have suggested that there are non-linear relationships between diversity levels and ecological factors such as the abundance, richness, and diversity of beneficial and harmful insects, as well as sustainability-related aspects in agroecosystems. Additionally, Galan and Perez [8] emphasized the need for innovative methods to assess agrobiodiversity from a holistic perspective. This highlights the necessity for new approaches to studying agroecological phenomena.

Guanajuato, a state located centrally in Mexico, lies at the crossroads of 2 biogeographic regions, the Nearctic and Neotropical, offering significant natural wealth through endemism and species exchange. However, according to the CONABIO [9] anthropogenic transformation index, the ecosystems in Guanajuato are facing unsustainable levels of degradation. Given the state's strong agricultural sector, it is crucial to adopt sustainable agroecological practices that are in harmony with both the agroecosystems and the environment. Although there have been some studies in the Bajío and southern Guanajuato regions focusing on pest biological control, ecological aspects, and insect diversity in crops like sorghum, corn, and carrot (Salas-Araiza *et al*. [10], Guzmán-Mendoza *et al*. [3], Ramos-Patlán *et al*. [11], and León-Galván *et al*. [12]), functional ecology research that addresses insect guilds and ecological interactions is still scarce [13]. This gap points to the need for a novel approach to understanding functional ecology within agroecosystems to better comprehend the dynamics of both pest and beneficial insect populations.

This research aims to explore the composition of insect families and the functional groups that constitute the entomofauna of three-grain crops in El Capulín, Guanajuato, Salvatierra, Mexico. It is hypothesized that the entomofauna composition will be dominated by herbivorous families, with fewer beneficial insects, and that agronomic management will play a significant role in this composition.

Materials and Methods

Study area

The study was conducted in El Capulín, a town located in the municipality of Salvatierra, Guanajuato **(Figure 1)**. The region experiences a semi-warm, subhumid climate with summer rainfall, accompanied by a low humidity level of 67.3%. It also has a temperate sub-humid climate, with medium humidity at 32.7%. The temperatures range from a maximum of 33.4°C to a minimum of 2 °C, with an average annual temperature of 18.1 °C. Annual rainfall varies between 700 and 800 mm. The types of soil in the study area predominantly include Vertisol (87.2%), Phaeozem (7.5%), and Solonchak (1.4%) [14]. The surrounding native vegetation consists of deciduous forest and subtropical scrub which coexist with different grain and vegetable crops.

Field layout and specimen collection

Fieldwork was conducted across three irrigation-based production systems over 2 sampling periods: the 1st from August to November 2018, and the 2nd from February to May 2019. Before insect collection, transects were established within each crop: wheat, corn (2018 cycle), and barley (2019 cycle). A total of five transects, each measuring 20 x 30 m^2, were set up for each crop, covering a combined area of 9,000 m^2, a suitable size for assessing insect population abundance patterns [5]. Sampling was conducted systematically every ten days, with each session lasting one day. The sampling method involved walking in a zigzag pattern across the entire transect to ensure a uniform collection of insects throughout the area. To maintain data independence [15] and ensure effective monitoring [16], a 10-meter gap was maintained between crops and between transects.

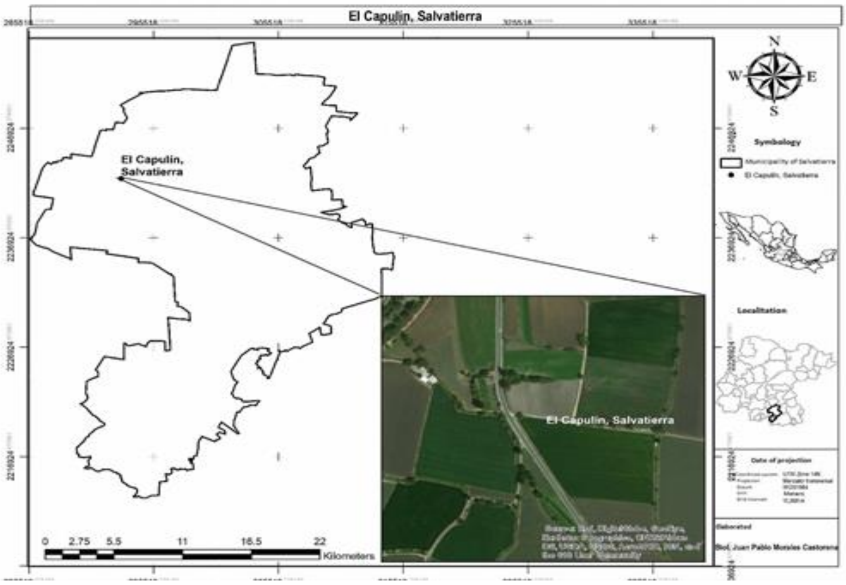


Figure 1. Location of the work area in El Capulin, Guanajuato, Mexico

Collection and processing of specimens

Insects were gathered using a combination of aerial entomological nets, striking nets, and stainless-steel tweezers. For smaller species, such as aphids, brushes or vacuum devices were utilized. After collection, the specimens were stored in 250 ml plastic bottles containing 70% alcohol to preserve them. Each vial was carefully labeled with key details, including the location, date, crop type, transect, sampling method, and time. The preserved samples were transported to the Biology Laboratory at the Higher Technological Institute of Salvatierra and the Entomology Laboratory at the University of Guanajuato, Irapuato-Salamanca campus. Identification of the specimens was performed under a stereomicroscope with an integrated lamp, focusing primarily on family-level identification, though genus and tribe were also considered when appropriate. This allowed the classification of insects into functional groups based on their feeding ecology, which helps detect shifts in ecosystem functions, as proposed by Grimbacher *et al*. [17] and Gomez Pamies *et al*. [18] and applicable to agroecosystems [19]. In this study, functional groups were defined following the classifications by Oliveira *et al*. [20] and Cumbrera and Rodríguez [21], modified for this research. The insects were divided into two main categories: 1) EFGs (Ecological Functional Groups) based on their ecological roles and interactions, including herbivores (H), decomposers (DES), predators (D), pollinators (POL), parasitoids (PAR), generalists (G), and vectors (V); 2) TFGs (Trophic Functional Guilds) based on their feeding habits, which included insectivores (I), phytophages (P), polyphages (POF), necrophagous (N), carnivores (C), hematophagous (H), mycophagous (M)and nectarivores (NEC).

Data analysis

The composition of the insect community across the crops was visualized using range-abundance graphs, also known as Whittaker curves, which display species (family-level) in order of abundance, from the most to the least abundant. These rank-abundance curves serve as complementary biodiversity indices [22]. Furthermore, a principal component analysis (PCA) was conducted to explore the relationships between EFGs and TFGs, as well as to examine the overall composition of insect families in the 3 crops. All statistical analyses were performed using the Past version 4.0 software.

Results and Discussion

Insect abundance

A total of 6,596 insect specimens were collected and identified, representing 11 orders and 59 families. The highest diversity of families was found in corn, with 53 families, followed by wheat with 25, and barley with 24. **Table 1** outlines the families found by order, highlighting their presence across the 3 crops. Diptera was the most diverse order, containing 18 families, followed by Hemiptera with 13, and Coleoptera with 10 families.

Family composition

The distribution of insect families was analyzed using rank-abundance (Whittaker) curves, where families were ranked based on their abundance from highest to lowest. Corn exhibited the greatest variety of families (n = 53), with the Labiidae family being the most numerous, totaling 647 individuals. Other abundant families in corn included Chloropidae (n = 459), Cicadellidae (n = 591), and Culicidae (n = 332). Meanwhile, the Aphididae family showed a higher abundance of wheat (n = 1,343) and barley (n = 632), as shown in **Table 1 and Figure 2**.

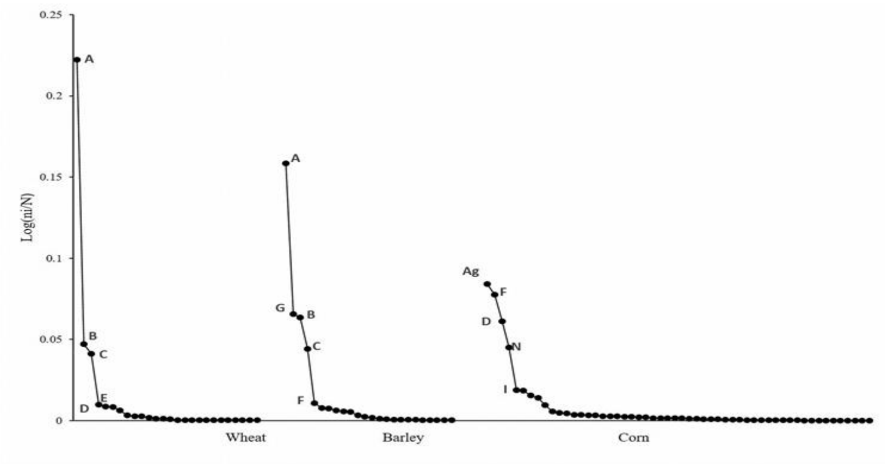


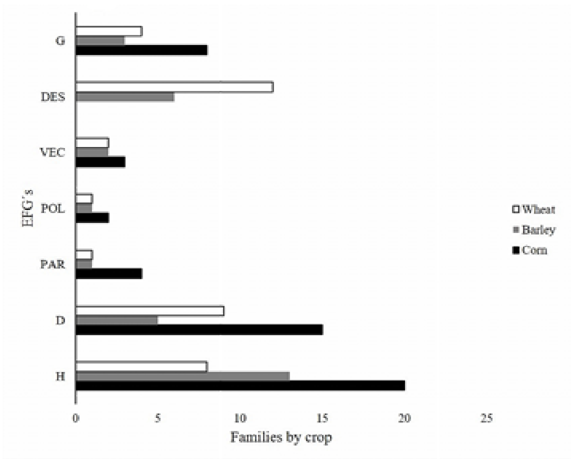
Figure 2. Range-abundance curves show the composition of the entomofauna in the agroecosystem. Only the most abundant families in individuals are presented for each crop, which is represented by letters. A = Aphididae, B = Braconidae, C = Coccinellidae, D = Chloropidae, E = Chironomidae. G = Miridae, F = Cicadellidae, I = Entomobryidae, N = Culicidae, and Ag = Labiidae

Functional groups

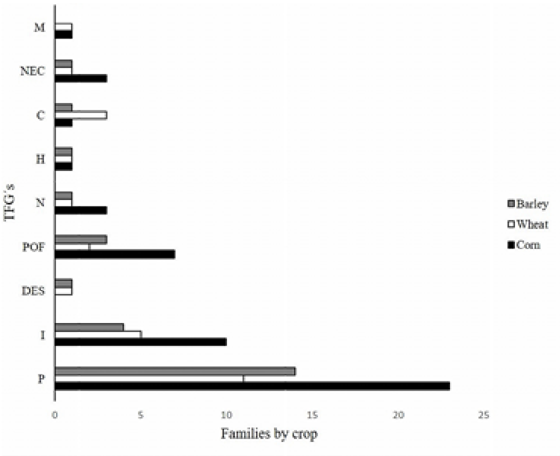
The insect specimens were categorized into two primary groups based on their ecological interactions: seven ecological functional groups (EFGs) and nine trophic functional guilds (TFGs), according to their dietary habits. In terms of EFGs, corn supported the highest diversity of families, with predators, herbivores, and generalists being the most dominant groups. When looking at TFGs, the corn crop showed the greatest abundance of phytophages, polyphages, entomophagous organisms, and insectivores **(Figure 3)**.

Principal component analysis (PCA) for EFGs revealed a strong correlation between the groups. Component 1 accounted for 72.7% of the total correlation, while Component two explained 22.5%, contributing to 95.2% of the total variance, with an overall correlation of 96.6% and a cophenetic correlation coefficient of 0.997. Ecologically, the analysis showed that herbivores and predators were predominantly linked to corn, when barley and wheat hosted a greater presence of decomposers and generalist insects, along with other groups such as parasites, pollinators, and vectors **(Figure 4)**.

For the TFGs, component 1 explained 97.6% of the variation, while component 2 contributed 1.7%, leading to an overall explained correlation of 99.3% and a perfect cophenetic correlation of 1.00. The analysis indicated that trophic groups in corn were primarily composed of phytophages, entomophages, insectivores, and polyphages. In contrast, wheat and barley exhibited a broader diversity, including nectarivores, necrophagous, decomposers, carnivores, hematophagous species, and mycophages **(Figure 4)**.

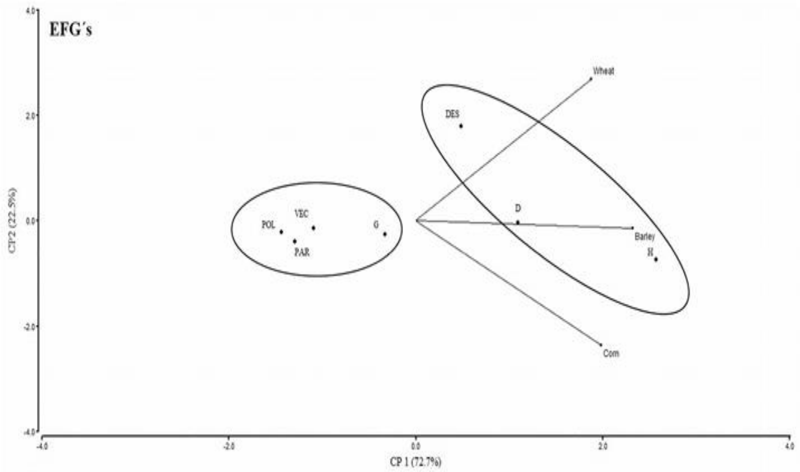


a)

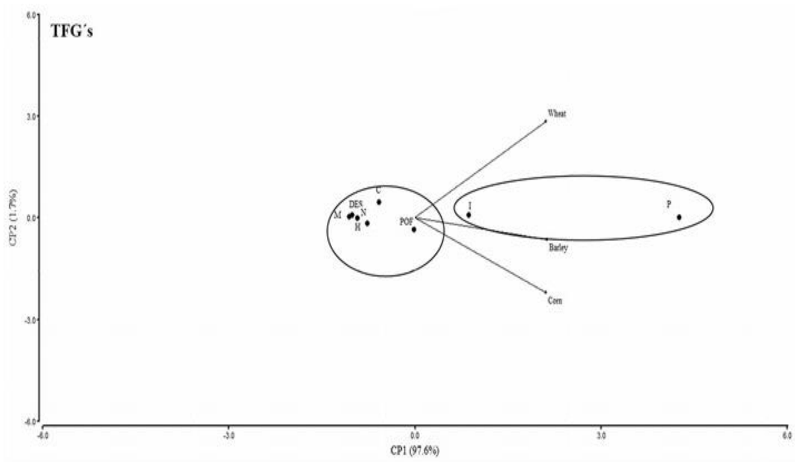


b)

Figure 3. Abundance of functional guilds per family for each crop. EFG´s = ecological functional guilds, TFG´s = trophic functional guilds.



a)



b)

Figure 4. Biplot of PCA showing the ordination for EFGs and TFGs, ecological and trophic functional traits of insects in three-grain crops.

The table displays the families identified in each of the three crops, with the numbers indicating the proportional abundance of these families. The insect families are categorized according to their functional groups (EFGs and TFGs).

Table 1. Insect Families Recorded Across Three Crops

Taxa	Family	Corn	Wheat	Barley	EFGs	TFGs
Collembola	Entomobryidae	134	19	0	D	M
Coleoptera	Chrysomelidae	133	0	1	H	P
	Cicadellidae	591	39	36	D	I
	Coccinellidae	2	200	154	D	I
	Cucujidae	8	0	0	G	POF
	Curculionidae	11	0	2	H	P
	Lagriidae	10	0	0	G	POF
	Languriidae	1	0	0	G	POF
	Lathridiidae	100	6	19	G	POF
	Leiodidae	1	0	0	G	POF
	Meloidae	20	2	1	G	POF
Dermaptera	Labiidae	647	0	0	D	I
Diptera	Asilidae	1	2	0	D	I
	Asteiidae	2	0	0	D	I
	Bombyliidae	1	0	0	POL	NEC
	Calliphoridae	18	0	0	D	I
	Chironomidae	0	41	25	D	C
	Chloropidae	459	46	26	VEC	H
	Culicidae	4	4	11	VEC	P
	Dolichopodidae	16	0	0	H	I
	Drosophilidae	31	0	0	D	C
	Lauxaniidae	39	1	0	G	C
	Lonchopteridae	1	0	0	G	POF
	Muscidae	0	6	2	G	H
	Scatopsidae	5	0	0	D	N
	Syrphidae	4	2	2	POL	NEC
	Tabinidae	2	0	0	PAR	P
	Therevidae	24	0	0	D	I
	Tephritidae	1	0	1	H	P
	Tipulidae	68	0	0	D	H
Ephemeroptera	Ephemeridae	0	12	6	DES	DES
Hemiptera	Alydidae	7	0	0	H	P
	Aphididae	26	1343	632	H	P
	Cercopidae	1	0	0	H	P
	Cicadellidae	591	39	36	D	I
	Coreidae	5	0	0	H	P
	Corimelaenidae	2	0	0	H	POF
	Lygaeidae	3	0	1	H	P
	Membracidae	0	2	0	H	P
	Miridae	0	29	234	H	P
	Nabidae	7	9	21	D	I
	Pentatomidae	19	1	6	H	P
	Reduviidae	1	1	1	D	I
	Scutelleridae	33	0	6	H	P

Hymenoptera	Braconidae	111	231	226	PAR	I
	Ceraphronidae	1	0	0	P	P
	Formicidae	0	0	2	H	POF
	Ichneumonidae	1	0	0	PAR	DES
	Scelionidae	25	0	0	P	P
	Vespidae	15	0	0	PAR	DES
Lepidoptera	Arctiidae	6	0	3	H	P
	Noctuidae	10	2	8	H	P
	Pyralidae	17	1	0	D	P
Neuroptera	Chrysopidae	8	16	18	D	I
Odonata	Coenagrionidae	0	1	0	D	C
	Libellulidae	3	0	0	D	DES
Orthoptera	Acrididae	3	0	4	H	P
	Gryllidae	15	0	0	H	P
	Tetrigidae	23	1	3	H	P
	Tettigoniidae	2	0	0	H	P
Subtotal		53	25	24		

Note: EFGs represent: Herbivores (H), Predators (D), Parasitoids (PAR), Pollinators (POL), Vectors (V), Decomposers (DES), and Generalists (G). TFGs represent: Phytophages (P), Insectivores (I), Decomposers (DES), Polyphages (POF), Necrophagous (N), Hematophagous (H), Carnivores (C), Nectarivores (NEC), and Mycophagous (M).

Insect richness and abundance

The insect family diversity observed in this study aligns with findings from other research conducted on vegetable crops and grains in Guanajuato. For instance, León-Galván *et al*. [12] documented 58 insect families across sorghum, corn, and carrot crops in Irapuato, while Piña-García and Leyte-Manrique [4] found a comparable number of families in 6 different crops (sorghum, alfalfa, tomato, corn, beans, and tomato) in Urireo, Salvatierra. These family-level richness values for insect populations in our study, as well as those reported by other regional studies, are notably high when compared to other agroecosystems. For example, Díaz *et al*. [23] identified 33 insect families and over 1,500 individuals in an agroecosystem engaged in agroecological production of aromatic plants and vegetables within a dry forest landscape in Colombia. Even the richness of families by functional group in this research exceeds the numbers found in previous research. López *et al*. [24] reported just 6 families of pollinators and 9 predators, with an abundance of approximately 540 specimens, in agroecosystems within vineyards surrounded by native vegetation. Meanwhile, a Cuban study conducted by Duarte and Almirall [25] in an organic agroecosystem within an urban matrix found 23 families and over 2,000 individuals. These findings are significant as they underscore the high biodiversity within these agroecosystems, potentially in response to two key factors: local management practices and Guanajuato's biogeographical position at the intersection of the Nearctic and Neotropical regions. These results support Suárez-Mota *et al*. [26] claims regarding the Bajio region's ecological, biological, and morphological significance, particularly with important plant families such as the Asteraceae, which exhibit a high degree of endemism in Mexico. Consequently, addressing concerns raised by the CONABIO Natural Capital Index [9] is essential, as it highlights Guanajuato as an area with unsustainable ecosystems, emphasizing the importance of agroecological and agroecosystem approaches.

Insects in Guanajuato's agroecosystems

In the El Capulín ejido, agricultural practices, including the use of organic insecticides, are employed to control insect populations. However, these measures can have unintended consequences, potentially affecting insect diversity and family abundance. Despite this, the entomofauna at the site remains similar to that found in other areas of Guanajuato [27]. Furthermore, the region's variety of crops provides a potential refuge and food source for insects, as suggested by other studies. Agricultural areas can serve as habitats for insects with specific needs. For example, Ramos-Patlán *et al*. [11] observed that sites with significant agricultural activity, particularly those with high irrigation and humidity, support large populations of mantises. Multiple studies have highlighted the refuge potential of agroecosystems for small vertebrates and insects, particularly in traditional systems where weed vegetation is tolerated and management practices foster organic soil fertility [28].

Results and Discussion

Diversity patterns

The study revealed notable differences in insect family diversity across the crops. Corn stood out as the crop with the highest diversity of insect families, dominated by Cicadellidae, Labiidae, and Chloropidae, which had particularly high populations. This contrasts with previous studies where Cicadellidae, Aphididae, and Acrididae were identified as the characteristic families of corn **(Table 1)** [4, 12]. This discrepancy may have functional implications. Various factors, such as crop management techniques (fertilization, planting arrangement, monocultures vs. polycultures), as well as surrounding wild vegetation that serves as biological corridors, play a role in shaping the abundance and diversity of functional groups [29, 30]. For instance, experimental plant associations, like Leucaena leucocephala-Panicum maximum, created new habitats through the structural complexity of branches and tillers, increasing the number of phytophagous and bioregulatory insects such as predators and parasitoids [31]. The present study found that growing corn, wheat, and barley together as part of a polyculture system boosted diversity within the agroecosystem [32], providing a habitat for a variety of insect families similar to those found in forested areas [33]. Additionally, the region's agricultural landscape is notably heterogeneous, which may contribute to the diversity observed. For example, Piña-García and Leyte-Manrique [4] recorded Coccinellidae, Chrysomelidae, and Pentatomidae as dominant families in sorghum crops nearby, while the current study observed Coccinellidae, Aphididae, and Braconidae as the most abundant families. Wheat and barley displayed similar insect populations to corn. In all three crops, shared families included Coccinellidae, Chloropidae, Culicidae, Meloidae, Miridae, Nabidae, Noctuidae, Pentatomidae, Tetrigidae, and Chrysomelidae. These families are common in grain crops due to their adaptability and flexibility [34, 35].

Guild differences

Principal component analysis differentiated the functional groups between crops, with corn showing distinct characteristics for both EFGs and TFGs. In corn, herbivores and predators were dominant, highlighting the specialization of phytophagous groups like Aphididae, Chrysomelidae, Cicadellidae, and Miridae, along with predators like Coccinellidae and a lower proportion of parasitoids, such as Braconidae. Ghiglione *et al*. [29] noted that the presence of specific functional groups can be influenced by agronomic practices. For corn, the use of chemical applications like Malathion throughout the growing cycle was linked to the dominance of predators and herbivores, suggesting that these insects might have developed resistance to certain treatments. This would explain their higher abundance and persistence in the crop, while other groups, potentially more susceptible, move to crops like wheat and barley. Regarding TFGs, trophic relationships in corn pointed to a stronger presence of insectivores, phytophages, and nectarivores, while in wheat and barley, the relationships appeared more oriented around energy flow, with decomposers being more evident.

Conclusion

The functional groups of EFGs and TFGs identified in the grain crops (wheat, corn, and barley) were largely influenced by the management practices applied to each crop. Corn, due to its economic importance and larger cultivated area, received more intensive agronomic management compared to wheat and barley. The study also revealed a strong connection between the functional roles and trophic relationships of the insect communities. As known, the presence of phytophages established interactions with other antagonistic groups, such as carnivores and nectarivores. These findings lay the foundation for future research focusing on the ecological dynamics of predator-prey-parasitoid interactions in agricultural areas similar to the Bajio Guanajuatense region.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

References

1. Loxdale HD. Insect science- a vulnerable discipline? Entomol Exp Appl. 2016;159(2):121-34. doi:10.1111/eea.12421
2. Stork NE. How many species of insects and other terrestrial arthropods are there on earth? Annu Rev Entomol. 2018;63:31-45. doi:10.1146/annurev-ento-020117-043348
3. Guzmán-Mendoza R, Calzontzi-Marín J, Salas-Araiza MD, Martínez-Yáñez R. La riqueza biológica de los insectos: análisis de su importancia multidimensional. Acta Zool Mex. (Nueva Serie). 2016;32(3):370-9.
4. Piña-García JA, Leyte-Manrique A. Diversidad, riqueza y composición de la entomofauna en cultivos hortícolas de Urireo, (Salvatierra, Guanajuato). Jóvenes Cienc. 2017;3(2):55-9.
5. Egerer MH, Bichier P, Philpott SM. Landscape and local habitat correlates of lady beetle abundance and species richness in urban agriculture. Ann Entomol Soc Am. 2017;110(1):97-103. doi:10.1093/aesa/saw063
6. Oliveira GB, Gadelha SS, Teles BR. Composition of Braconidae (Hymenoptera) fauna in citrus orchards surrounded by Amazonian secondary forest. Biodivers Int J. 2017;1(5):00025. doi:10.15406/jaccoa.2017.01.00025
7. Muriel SB, Vélez LD. Evaluando la diversidad de plantas en los agroecosistemas Como estrategia para el control de plagas. Manejo Integr. Plagas Agroecología (Costa Rica). 2004;71:13-20.
8. Galan AL, Perez AL. Nuevos índices para evaluar la agrobiodiversidad. Agroecología. 2012;7(1):109-15.
9. CONABIO. Índice de capital natural; 2020. (cited 2021 Sep 5). Available from: https://www.biodiversidad.gob.mx/pais/indice_capnat
10. Salas-Araiza MD, Guzmán-Mendoza R, Martínez-Jaime OA, González-Márquez MA, López FA. Species richness of noctuid moths (Lepidoptera: Noctuidae) from the State of Guanajuato, Mexico. Fla Entomol. 2015;98(4):1262-5. doi:10.1653/024.098.0444
11. Ramos-Patlán FD, Salas-Araiza MD, Guzmán-Mendoza R, Pérez-Moreno L, Martínez-Jaime OA, Núñez-Palenius HG. Notas sobre la presencia y distribución de especies de mantis en Guanajuato. Entomol Mex. 2018;5:118-24.
12. León-Galván del Carmen G, Guzmán-Mendoza R, Salas-Araiza MD, Felipe L, Ramírez-Santoyo LP, Núñez-Palenius HG. Patrones de riqueza y diversidad de insectos en tres cultivos de la localidad de El Copal, Irapuato, Guanajuato, México. Entomol Mex. 2019;6:69-74.
13. Montañez MN, Amarillo-Suárez Á. Impacto de los cultivos orgánicos en la diversidad de insectos: una revisión de investigaciones recientes. Rev Colomb Entomol. 2014;40(2):131-43.
14. INEGI. Prontuario de información geográfica municipal de los Estados Unidos Mexicanos, Salvatierra, Guanajuato. Clave Geo estadística. 2009;11028.
15. Vite-Silva V, Ramírez-Bautista A, Hernández-Salinas U. Diversidad de anfibios y reptiles de la Reserva de la Biosfera Barranca de Metztitlán, Hidalgo, México. Rev Mex Biodivers. 2010;81(2):473-85.
16. Sanderson C, Braby MF, Bond S. Butterflies Australia: a national citizen science database for monitoring changes in the distribution and abundance of Australian butterflies. Aust Entomol. 2021;60(1):111-27. doi:10.1111/aen.12513
17. Grimbacher PS, Catterall CP, Kitching RL. Detecting the effects of environmental change above the species level with beetles in a fragmented tropical rainforest landscape. Ecol Entomol. 2008;33(1):66-79. doi:10.1111/j.1365-2311.2007.00937.x
18. Gomez Pamies DF, Godoy Guglielmone MC, Coronel JM. Macrofauna edáfica en ecosistemas naturales y agroecosistemas de la ecorregión Esteros del Iberá (Corrientes, Argentina. Cienc. Suelo (Argentina). 2016;34(1):43-56.
19. Jankielsohn A. The importance of insects in agricultural ecosystems. Adv Entomol. 2018;6(2):62-73. doi:10.4236/ae.2018.62006
20. Oliveira JBBS, Faria ML, Borges MAZ, Fagundes M, De Araujo W. Comparing the plant-herbivore network topology of different insect guilds in Neotropical savannas. Ecol Entomol. 2020;45(3):406-15. doi:10.1111/een.12808

21. Cumbrera A, Rodríguez V. Estructura trófica a nivel de grupos funcionales de alimentación de la comunidad de insectos acuáticos y calidad biológica del agua en la parte media-Baja del río Cardenillo, Veraguas. Visión Antataura. 2018;2(1):16-40.
22. Zubair M, Jamil A, Hussain SB, Haq Ul A, Hussain A, Zahid DM, et al. Diversity of medicinal plants among different tree canopies. Sustainability. 2021;13(5):2640. doi:10.3390/su13052640
23. Díaz, JL, Moreno-Elcure F, Jaramillo C. Estudio de la diversidad funcional entomológica asociada a agroecosistemas con manejo agroecológico. Cuad. Agroecología. 2018;13(1):1-6.
24. López García GP, Mazzitelli ME, Fruitos A, González M, Marcucci B, Giusti R, et al. Biodiversidad de insectos polinizadores y depredadores en agroecosistemas vitícolas de Mendoza, Argentina. Consideraciones para el manejo del hábitat. Rev Fac Cienc Agrar Univ Nac Cuyo. 2019;51(1):309-22.
25. Duarte S, Almirall AL. Diversidad de insectos asociados a siete cultivos en el sistema de cultivo organopónico “1ro de Julio” de La Habana. Rev Científica Agroecosistemas. 2020;8(2):58-65.
26. Suárez-Mota ME, Villaseñor JL, López-Mata L. La región del Bajío, México y la conservación de su diversidad florística. Rev Mex Biodivers. 2015;86(3):799-808. doi:10.1016/j.rmb.2015.06.001
27. Salas-Araiza MD, López-Gutiérrez DR, Martínez-Jaime OA, Guzmán-Mendoza R. Parasitoids of sugarcane aphid, Melanaphis sacchari, at Irapuato, Guanajuato, México. Southwest Entomol. 2017;42(4):1091-3. doi:10.3958/059.042.0403
28. Huaman Pilco AF, Leiva Espinoza ST, Oliva Cruz SM, Hernández May MA. Insectos asociados al agroecosistema de café bajo sombra en Milpuc, Amazonas, Perú. UNED Res J. 2020;12(2):e3144. doi:10.22458/urj.v12i2.3144
29. Ghiglione C, Zumofeen L, Dalmazzo M, Strasser R, Attademo AM. Diversidad y grupos funcionales de insectos en cultivos de arroz y sus bordes bajo manejo convencional y agroecológico en Santa Fe, Argentina. Ecol Austral. 2021;31(2):261-76.
30. Martín JA, Osorio ÁA. Efectos de la biodiversidad en el control biológico dentro de los agroecosistemas. Inventum. 2012;7(13):30-5. doi:10.26620/uniminuto.inventum.7.13.2012.30-35
31. Alonso O, Lezcano JC, Suris M. Composición trófica de la comunidad insectil en dos agroecosistemas ganaderos con Leucaena leucocephala (Lam.) de Wit y Panicum maximum Jacq. Pastos Forrajes. 2011;34(4):433-44.
32. Santiago-Pacheco G, García-García MA, Martínez-Martínez L. Diversidad de arañas (Chelicerata: Araneae) en cultivos de maíz en San Andrés Huayapam, Oaxaca, México. Entomol Mex. 2017;4:15-20.
33. Orozco-Peón O, González-Moreno A, Ruíz-Sánchez E, Tun-Suárez JM, Palacios-Vargas J. Comunidades y gremios de parasitoides (Hymenoptera: Ichneumonidae) en cultivo de maíz y selva Baja caducifolia circundante. Ecosistemas Rec Agropecu. 2019;6(17):195-205. doi:10.19136/era.a6n17.1977
34. Reyes-Prado H, Segura AJ, Martínez-Peralta C, Sosa PR. Non-target insects captured in sex pheromone traps of Spodoptera frugiperda in sorghum surrounded by other crops and weeds. Southwest Entomol. 2020;45(3):643-8. doi:10.3958/059.045.0307
35. Rodríguez-Vélez JM, Uribe-Mu CA, Sarmiento-Cordero MA, Rodríguez-Vélez B, Cruz-Rodríguez JA, Contreras-Ramos A, et al. Relationships among Melanaphis sacchari, its predator insect communities, and weather conditions in sorghum crops at Colima, Mexico. Southwest Entomol. 2021;46(1):47-58. doi:10.3958/059.046.0104