



Composition and Functional Groups of Insects in Grain Crops from South-Ern Guanajuato

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ABSTRACT

Eight samplings were carried out in three-grain crops; corn, wheat, and barley, in El Capulín, Salvatierra, Gto., collecting 6,596 specimens of insects, from August to November 2018 and from February to May 2019. The entomofauna is made up of 11 orders and 59 families, of which, 53 are in corn, 25 in wheat, and 24 in barley. The entomofaunal community is grouped into two functional groups according to their ecological role, and their diet: 1) EFG's (ecological functional groups), it includes herbivores, predators, parasitoids, pollinators, vectors, decomposers, and generalists; 2) TFG's (trophic functional guilds) comprise phytophagous, insectivores, decomposers, polyphages, Necrophagist, hematophagous, carnivores, nectarivorous, and mycophagy. The principal component analysis for the EFG's indicated a close relationship and dominance of herbivores and predators in corn, unlike wheat and barley, while for the phytophagous and insectivorous TFG's presented the same relationship. As far as it can be said that in maize cultivation, both functional and trophic relationships are established by antagonistic groups of plant hosts and predators, the other groups in wheat and barley being non-specific and generalist groups. This shows dominance of insects adapted to the development, growth, and phenology cycles in the corn crop, in which the abundance values denote a relationship with demographic factors typical of phytophages, and a smaller number of families of the other groups. The agronomic management and other ecological interactions in the agroecosystems are factors that contribute to the composition of functional groups for entomofauna in the grain crops studied.

Keywords: Functional ecology, Guild insects, Agroecosystems, Agroecology.

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INTRODUCTION

Mexico, being a mega-diverse country, is represented by a high diversity of animal and plant species, an example is insects that represent 75% of known species [1], of which an estimated 47,768 species are described, the best-known insects are grouped in the orders Coleoptera, Hemiptera, Homoptera, Diptera, Lepidoptera Orthoptera, and Odonata, having families of economic and ecological importance in agriculture [2]. In addition to representing various forms of life and habits, they also form

diverse functional groups, including phytophages, predators, parasites, and decomposers, amongst others [3, 4].

The heterogeneity of the landscapes, the characteristics of the habitats that are part and in turn surround the agroecosystems, increase the diversity and have a significant influence on the organisms that are within the agroecosystem, particularly the insects, which can increase or decrease their ecological functions. Egerer *et al.* [5] found that the structure and diversity of the landscapes that surround an agroecosystem modify the abundance and diversity of predatory

insects. In their study, they found a greater diversity of coccinellids in the agroecosystems highly anthropized by human activities that increased the variety of landscapes. In turn, Oliveira *et al.* [6], reported that a secondary forest surrounding citrus crops harbored a greater abundance of parasites of the Braconidae family, compared to the edges of secondary forest-citrus plantation landscapes. The foregoing highlights the role that vegetation has on the diversity and composition of insects in agroecosystems, in addition to the ecosystem services they offer concerning the crops, some of them being: pollination, predation, and degradation of organic matter, among others.

Despite recognizing the important role of biodiversity in agroecosystems, there is a lack of information from experiments and observational studies to generate a theoretical overview of the biodiversity-agroecosystem interrelation. Muriel and Vélez [7] have provided evidence that suggests non-linear relationships between levels of diversity and ecological factors of agroecosystems such as the abundance, richness, and diversity of beneficial and/or harmful insects, as well as other aspects that have to do with sustainability. Leyva and Lores [8] also indicate the need for new methods that allow measuring agrobiodiversity from a comprehensive perspective. This suggests that research on agroecological phenomena requires more and new approaches.

The Mexican state of Guanajuato is located in the middle of the national territory, bordered by two biogeographic regions, the Nearctic and the Neotropical, which implies a remarkable natural wealth through endemism and the exchange of flora and fauna. However, according to CONABIO [9] in its anthropogenic transformation index, the state of Guanajuato has its ecosystems at a degree of unsustainable. Given the vocation and agricultural boom of the state, it is necessary to promote viable and sustainable agroecology production strategies with the environment and the agroecosystems themselves. For the Bajío and southern Guanajuato region, there are a few studies with an agroecological approach on the biological control of pests, the analysis of ecological aspects, and the diversity of insects associated with crops, for example, the works of Salas-Araiza *et al.* [10], Guzmán-Mendoza *et al.* [3], Ramos-Patlán *et al.* [11] and León-Galván *et al.* [12] in which aspects of the habits,

composition, and diversity of species are analyzed for some crops in the region, such as corn, sorghum, and carrot.

Thus, the absence of functional ecology studies expressed in the organization of guilds or ecological interactions of the agricultural entomofauna of a region of productive importance such as the state of Guanajuato is notable which implies the application of a little-explored approach [13] to address the issue of functional ecology applied to agroecosystems and understand the population dynamics of both pests and beneficial insects that interact in these environments. Therefore, this study aims to know the composition of insect families, as well as the functional groups that make up the entomofauna of three-grain crops (corn, wheat, and barley), in the community of El Capulín, Salvatierra, in the state of Guanajuato, Mexico. It is hypothesized that the composition of the entomofauna will be dominated by phytophages families, the presence of beneficial insects being low and that agronomic management plays an important role in this.

MATERIALS AND METHODS

Study site

The work was carried out in the town of El Capulín, municipality of Salvatierra, Guanajuato (**Figure 1**). The climate is semi-warm, subhumid with rains in summer, with lower humidity (67.3%), and temperate sub-humid with rains in summer with medium humidity (32.7%). The maximum temperature is 33.4 °C, the minimum of 2 °C and an annual average of 18.1 °C. Annual rainfall ranges from 700 to 800 mm. The characteristic soil types in the study site correspond to Vertisol (87.2%), Phaeozem (7.5%), and Solonchak (1.4%) [14]. Representative native vegetation is subtropical scrub and deciduous forest, which surround various grain and vegetable crops.

Field design and specimen collection

The fieldwork was carried out in three irrigation production systems with two sampling periods. The first from August to November 2018 and the second from February to May 2019. Before the collection of the insects, work transects were delimited in each of the crops: corn (2018 cycle), wheat, and barley (2019 cycle). For this case, five transects of 20 x 30 m² were drawn in the three

crops there was a total area of 9,000 m², an area considered adequate to understand abundance patterns of insect populations [5]. The samplings were systematic every 10 days, with a duration of one day, and the sampling technique consisted of doing zigzag-shaped walks on the entire surface of the transect with the possibility of

homogeneously collecting all insects, potentially found in the sampling site. In addition to the above, a distance of 10 meters was left between crops and transects to have data independence [15], also because transects are the most useful monitoring method [16].

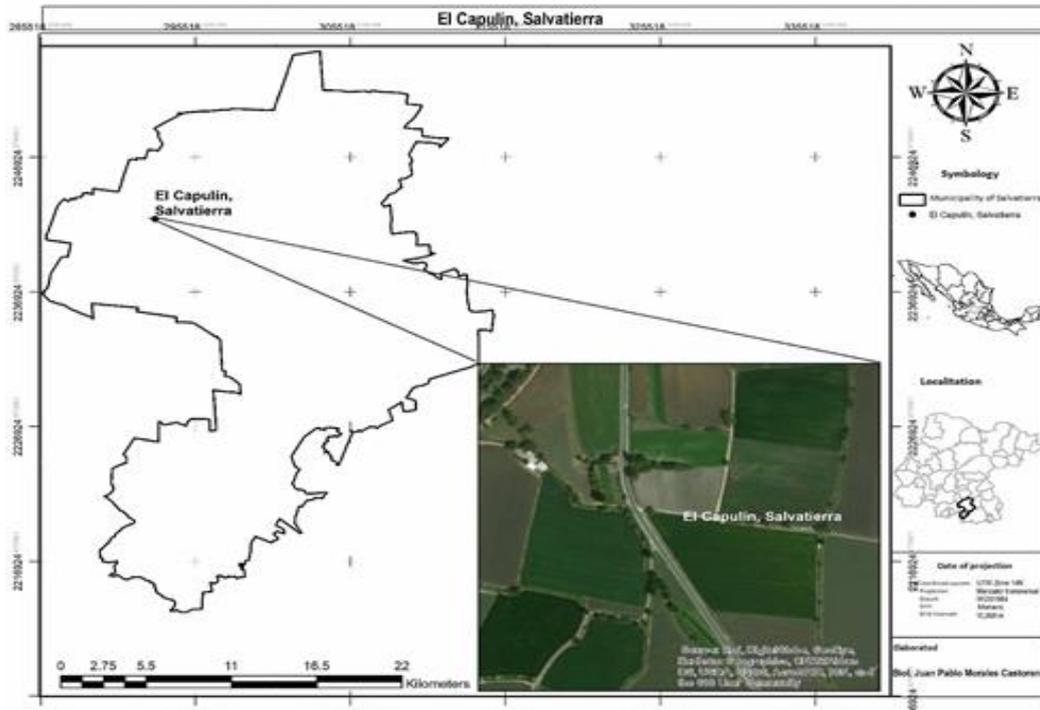


Figure 1. Location of the work area in El Capulin, Guanajuato, Mexico

Collection of specimens and treatment

The insects were collected with the help of aerial entomological and striking nets, as well as with stainless-steel tweezers, and in the case of small species (aphids), the collection was done with the help of brushes or with the use of vacuum cleaners. The collected insects were placed in 250 ml plastic bottles with 70% alcohol for their preservation. Each vial was labeled with the following information: place, date, crop, sampling type, transect, and time of day. Later, the specimens were transported to the Biology Laboratory of the Higher Technological Institute of Salvatierra, and the Entomology Laboratory of the University of Guanajuato, Irapuato-Salamanca campus. With the help of a stereoscopic microscope with a single objective lens and an integrated lamp, identification was made at the family level, working with higher-order taxa such as family, genus, or tribe. This facilitates the ordering of organisms into functional groups based on the feeding ecology,

which is useful to detect changes in the function of the ecosystem as suggested by Grimbacher *et al.* [17] and Gómez *et al.* [18], and this can be extrapolated to agroecosystems [19]. The functional groups were characterized according to the proposal by others such as Oliveira [20] and Cumbria and Rodríguez [21] of the Functional Food Groups (GFF's) and modified for this study. This consists of grouping insects based on their trophic relationships but does not take into account their ecological role. For this case, the insects were grouped into two groups: 1-EFG's (ecological functional groups), based on their ecological relationships and their functional role, characterizing seven EFG's: Herbivores (H), predators (D), parasitoids (PAR), pollinators (POL), vectors (V), decomposers (DES) and generalists (G), and 2- TFG's (functional guilds trophic), considering their diet. There are nine guilds: phytophages (P), insectivores (I), polyphagous (POF), necrophagous (N),

hematophagous (H), carnivores (C), nectarivores (NEC), and mycophagous (M).

Data analysis

The composition of the entomofauna in the crops was represented with range-abundance graphs or Whittaker curves, which order the species (in this case families), from the most to the least abundant, that is, they are based on the relative abundance of each family, Rank abundance curves are useful as biodiversity indices complement [22]. Finally, a principal component analysis was developed to see the relationship between the EFG and the TFG's and to see the behavior of the composition of the families of insects in the three crops. Statistical analysis was carried out with the Past version 4.0 statistical program.

RESULTS AND DISCUSSION

Abundance of insects

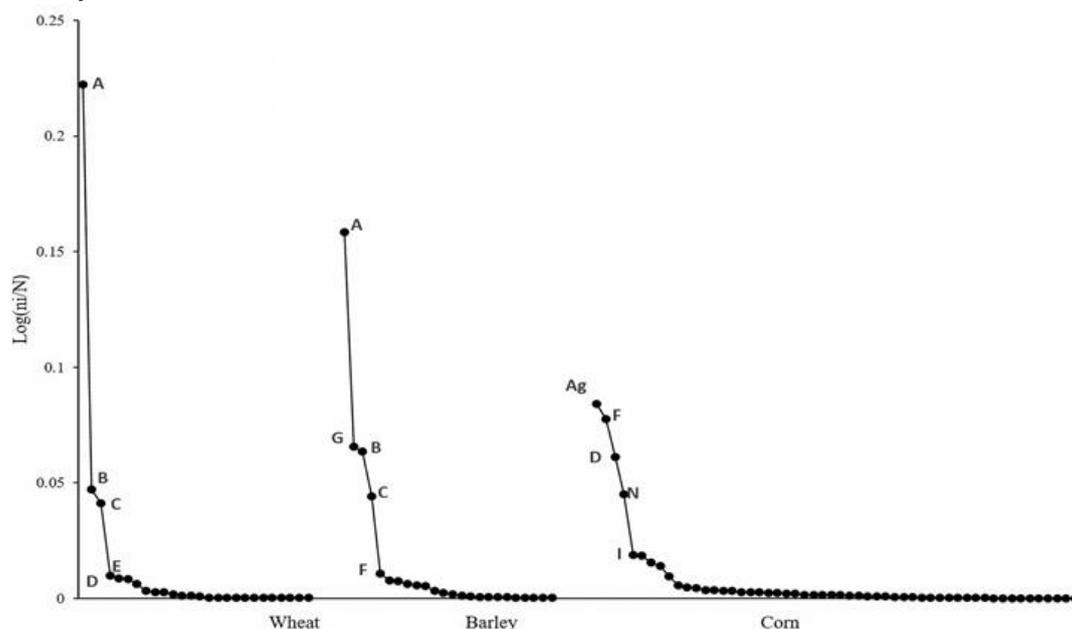


Figure 2. Range-abundance curves show the composition of the entomofauna in the agroecosystem. Only the most abundant families in individuals are presented for each crop, which is represented by letters. A = Aphididae, B = Braconidae, C = Coccinellidae, D = Chloropidae, E = Chironomidae, G = Miridae,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

Functional groups

The insects were grouped into two categories, depending on their ecological relationships, having a total of seven EFG's, and in nine TFG's; trophic guilds, depending on their diet. For the GFF's, the largest number of families was presented in corn, the most representative groups being herbivores, predators, and

A total of 6,596 specimens were collected, and 11 orders and 59 families were identified. The largest number of families, 53, was presented in corn, followed by wheat with 25 and barley with 24. **Table 1** shows the families found by order and their presence in the three crops. Diptera had the most families with 18, followed by Hemiptera with 13, and Coleoptera with 10.

Composition of families

The composition of families was represented by rank-abundance or Whittaker curves, and the families were ordered from the most to the least abundant. The corn crop presented the highest number of families ($n = 53$), with Labiidae being the most abundant with $n = 647$ individuals, followed by Cicadellidae ($n = 591$), Chloropidae ($n = 459$) and Culicidae ($n = 332$). In the case of the Aphididae family, there was a greater number of individuals in wheat ($n = 1,343$) and barley ($n = 632$ individuals) (**Table 1 and Figure 2**).

generalists. The TFG's had in corn, the highest abundance in phytophages, insectivores, entomophagous organisms, and polyphages (**Figure 3**).

The principal component analysis for EFG's, showed a relationship between the groups, explaining Component 1, 72.7% of the correlation, while Component 2, explained,

22.5%, giving 95.2% of the total variation explained, with a total correlation of 96.6%, and a cophenetic correlation coefficient of 0.997. Ecologically, it is defined in the crops that the presence of herbivores and predators are related to corn, while for barley and wheat, there is the presence of generalist insects and decomposers, and other groups (pollinators, parasites, and vectors) (Figure 4). For the TFG's, Component 1 explained a relationship of 97.6%, and

Component 2, 1.7%, with the total explained correlation being 99.3%, and the cophenetic correlation of 1.00. It is shown that the trophic groups for corn are composed of phytophages, insectivores, entomophages, and polyphages, while wheat and barley present a more diverse composition that includes nectarivores, ghouls, decomposers, carnivores, hematophagous, mycophagy, and decomposers (Figure 4).

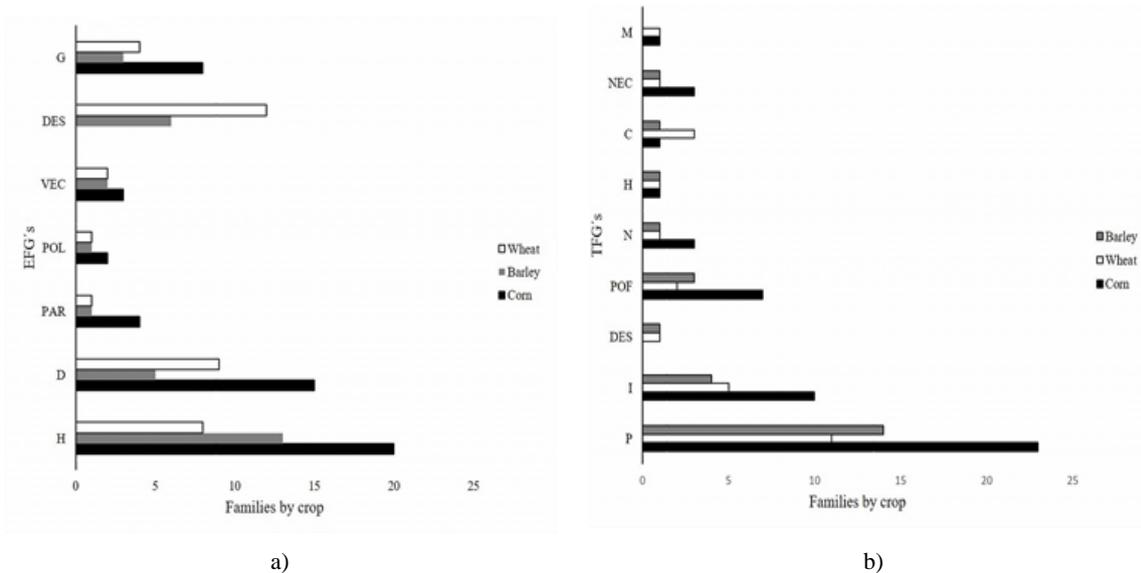
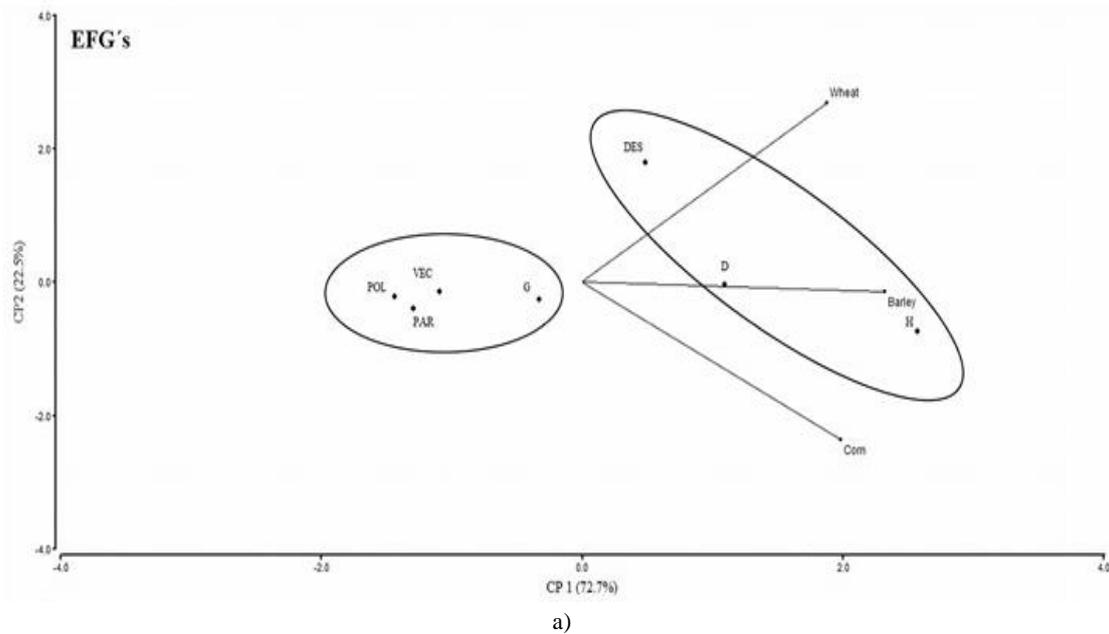
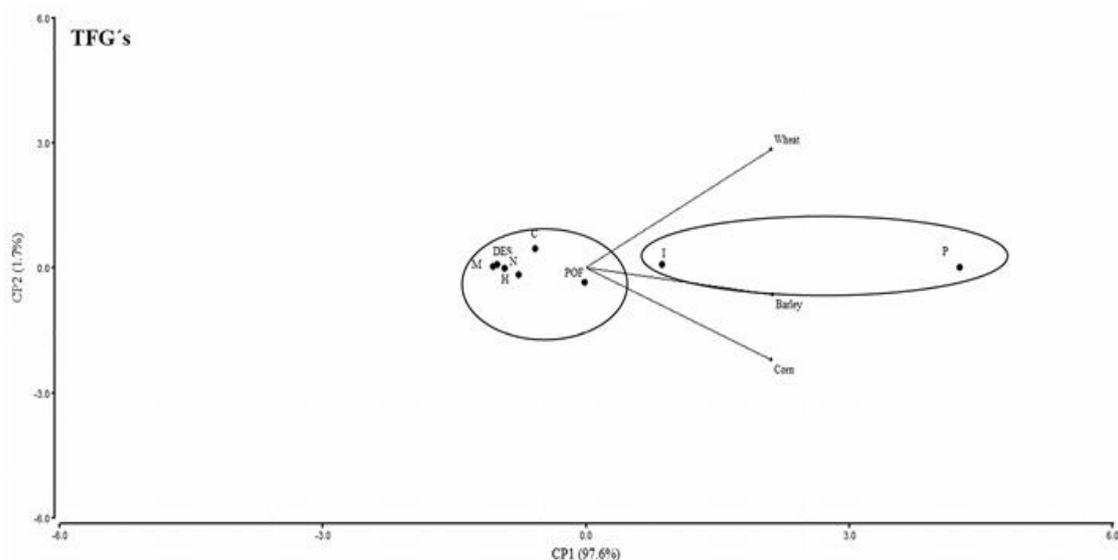


Figure 3. Abundance of functional guilds per family for each crop. EFG's = ecological functional guilds, TFG's = trophic functional guilds.





b)

Figure 4. Biplot of PCA showing the ordination for EFG's and TFG's, ecological and trophic functional traits of insects in three-grain crops.

Table 1. Registered families for the three crops. The numbers in the boxes are equal to the proportional abundance of families in each crop.

Taxa		Crops			Functional Groups		
Orden	Family	Corn	Wheat	Barley	EFG's	TFG's	
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	
	Dermoptera	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
	Tabinadae	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: EFG's: Herbivores = H, Predators = D, Parasitoids = PAR, Pollinators = POL, Vectors = V, Decomposers = DES and Generalist = G. TFG's: Phytophages = P, insectivores = I, decomposers = DES, polyphages = POF, ghouls = N, hematophages = H, carnivores = C, nectivorous = NEC, and mycophagous = M.

Richness and abundance

The diversity of insect families in this study was found alongside other studies in grain and vegetable crops in Guanajuato, such as León-Galván *et al.* [12], who registered 58 families for

corn, sorghum, and carrot crops in the municipality of Irapuato, while Piña-García and Leyte-Manrique [4], registered a similar number of families in six crops (sorghum, alfalfa, corn, beans, tomato, and tomato) from Urireo, in the

municipality of Salvatierra. These values of richness at the family level for insects, recorded in this study and reported in others for the region, can be considered high compared to other agroecosystems. For example, Díaz *et al.* [23] found 33 families of insects and more than 1500 individuals in an agroecosystem subject to agroecological production of vegetables and aromatic plants immersed in a dry forest landscape in Colombia. Even the value of family richness by functional group in this study is higher than that reported in other works. López *et al.* [24] reported six and nine families for pollinators and predators respectively, with a total abundance of around 540 specimens, in agroecosystems of vineyards surrounded by native vegetation. In a study reported for Cuba, in an organic agroecosystem embedded in an urban matrix, Duarte and López [25] found a richness of 23 families and just over 2,000 captured specimens. These results are interesting because they highlight a high level of diversity in their agroecosystems, possibly as a response to two important factors such as the management that is carried out on a local scale and the biogeographic position of Guanajuato, which is in the Nearctic and Neotropical regions limits. These results support the assertions of Suárez-Mota *et al.* [26] when considering the Bajío region as an important place from the ecological, biological, morphological points of view, with important plant taxonomic groups, such as the Asteraceae, which present a high percentage of endemism in Mexico. In this way, it is urgent to address the problem indicated by the CONABIO Natural Capital Index [9], which takes Guanajuato, as a place with unsustainable ecosystems, working with agroecosystem and agroecological approaches.

Insects in Guanajuato's agroecosystems

In the El Capulín ejido, cultural tasks are carried out to combat insects, such as the use and application of organic insecticides, which can have invasive effects on the entomofauna and their abundance and the presence of families. However, the site presented an entomofauna relatively like that recorded in other works for Guanajuato [27]. In addition, the variety of crops in the region is potentially refuge and feeding areas for the entomofauna, as has been suggested by others, where agricultural areas are providing

habitat for insects with specific requirements. In this sense, Ramos-Patlán *et al.* [11], found that the largest number of individuals and species of mantis are concentrated in sites with significant agricultural activity, mainly in places with high humidity and irrigation that are distributed from the center to the south of the State. In different studies, the refuge potential that agroecosystems offer to insects and small vertebrates have been reported, mainly in traditional agroecosystems where there is tolerance of weed vegetation and managements that promote organic fertility [28]. The diversity patterns showed significant differences between the crops. In the present study, the corn crop was the one that presented the greatest diversity of families, being Labiidae, Cicadellidae, and Chloropidae, which had high abundances and which contrasts with other works that record Aphididae, Cicadellidae, and Acrididae as characteristic families of this crop [4, 12] (**Table 1**). This may have repercussions on functionality. In this sense, both the management (fertilization, spatial arrangement, mono-polycultures) and the wild vegetation cover that surrounds the agroecosystems or that functions as biological [29] corridors, combine to influence the abundance and diversity of functional groups [30]. For example, in the experimental management of plant associations of *Leucaena leucocephala*-*Panicum maximum* generated new habitats provided by the plant structure of the branches and tillers, this increased the number of phytophagic and bioregulatory insects as predators and parasitoids [31]. In this study, corn, wheat, and barley crops, when presented in a system of associated crops (polycultures), increased their diversity in the agroecosystem [32], acting as a shelter for diversity of families, which is comparable to sylvan areas [33]. In addition, it is noteworthy the marked heterogeneity of the agricultural landscape of the region; Piña-García and Leyte-Manrique [4], registered for sorghum in a locality near to study area Coccinellidae, Chrysomelidae, and Pentatomidae as the representative insects, while in the present study, Coccinellidae, Aphididae, and Braconidae were found as abundant families. On the other hand, wheat and barley presented similar results in their entomofauna compared to corn. The families related to all the crops were Coccinellidae, Chloropidae, Culicidae, Meloidae,

Miridae, Miridae, Nabidae, Noctuidae, Pentatomidae, Tetrigidae, and Chrysomelidae, some of them commonly present in grain crops, given their plasticity and adaptability [34, 35].

Guilds differences

The principal component analysis showed a marked difference between crops, particularly for corn, for both EFG's and TFG's. Therefore, the functional ecological processes of the agroecosystem are different in corn, in this crop herbivores and predators predominate, which alludes to a high specialization of phytophages such as Aphididae, Chrysomelidae, Cicadellidae, Miridae, as well as predators such as Coccinellidae, and parasitoids in lower proportion, example, Braconidae. In this regard, Ghiglione *et al.* [29], mentions that one of the causes of the presence of certain functional groups depends on agronomic management, as observed in corn, in which foliar applications of chemicals such as Malathion were carried out, during three monthly repetitions throughout the cycle, observing a dominance of herbivores and predators, which alludes to the fact that the insects of these groups, despite the handling and, where appropriate, the control, have quasi resistance and therefore, their abundances and occurrence in the crops are higher, unlike the other groups that may be susceptible, and therefore move to these alternate crops of barley and wheat. In the case of TFG's, the trophic relationships allude to a differentiation between phytophages, insectivores, and nectarivores as related groups in corn cultivation, while for wheat and barley, the trophic relationships seem to be focused on energy flows due to evident decomposers presence.

CONCLUSION

The functional groups of EFG's and TFG's characterized in the studied grain crops (corn, wheat, and barley), are an indirect result of the handling carried out on each crop, being corn, the one that presented greater agronomic management, given its economic importance and planted area, unlike wheat and barley. Likewise, the functional components of the entomofauna, that is, the EFG's and the TFG's established a strong relationship between the functional role and trophic relationships, being as expected, the presence of phytophages, which establishes

relationships with other antagonistic groups as carnivores, and nectarivores, among others. Finally, the results of this study are considered a basis for carrying out future studies focused on the ecological aspects of the biological interchanges of prey-predator-parasitoids for the entomofauna of agricultural regions with conditions similar to the Bajío guanajuatense.

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