Potential of weed for Acrididae pest control in a corn agroecosystem

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Abstract

In a rainfed corn crop agroecosystem, was evaluated the effect of weeds on acridid pests; there were three types of vegetation: tithonia (T), grassland (Z), and corn crop (M). Samplings of plants-acridids were conducted weekly in 33 quadrants from September to October. The data were standardized to compare abundances, diversity (H'), and species composition (SC). Correlation coefficients between the abundance-diversity of acridids and vegetation-environment factors were calculated. Vegetation was not different in abundance, but it was in SC and diversity being T (H'= 1.88) the most diverse, and M (D = 0.38) the most dominant. The Acrididae were different in abundance, diversity, and dominance, being the highest Z and T (5.0 ±2.2; T 5.0 ±2.9); Z (H' = 1.56); T (D = 0.77), respectively, also SC was different. M and T showed positive correlations: acridids-abundance-

vegetation dominance, but Z with t°-RH. The implementation of weeds is a potential strategy to control acridids in crops.

Keywords: Acridids, agricultural landscape, agrobiodiversity, agroecology, weed.

1. Introduction

Acridids are widely distributed herbivorous insects that contribute to the functioning of ecosystems through the recycling of organic matter (Mancini and Mariottini, 2021) and their role as prey and herbivorous (De Gracia and Murgas, 2021). In Mexico, there are 920 species, outstanding pest species such as *Boopedon nubilum nubilum*, *Mermiria bivittata*, *Melanoplus differentialis, M. mexicanus*, *M. sanguinipes sanguinipes* y *Brachystola magna* (Barrientos-Lozano, 2003), able to damage industrial, fruit, basic and ornamental crops, where important damages have been reported in Tlaxcala, Puebla, Hidalgo, Estado de México, Durango, Zacatecas, and Guanajuato, with consumption ranges from 50 to 60% in basic grains, and affectations from 30 to 40% in forage production (Barrientos-Lozano, Song, Rocha-Sánchez and Torres-Castillo, 2021). Despite the above mentioned, there are reports that point grasshoppers consume wild plants like the four o'clock flower (*Mirabilis jalapa*), sunflower (*Helianthus laciniatus*), cuahuilotillo (*Croton adspersus*), tlacote (*Salvia mexicana* L.), quintonil (*Amaranthus hybridus*) (Ramírez-Méndez, González-Villegas and Nájera-Rincón, 2019), among other weed species. Grasshopper populations depend on abiotic factors like weather, soil, and altitude (Joern, 2000) and biotic factors like habitat vegetation conditions. Kistner-Thomas, Kumar, Jech and Woller (2021) measured 72 environmental variables and found that precipitation is a good predictor of population density. Nonetheless, it has been seen that taxonomic composition and physical structure of vegetation play an important role in areas occupied by grasshoppers (Branson, Joern, and Sword, 2006) and that the habitat types not only influence the presence of species but also their abundance (Kemp, Harvey and O´Neill, 1990) and diversity. Squiter and Capinera (2002) found that throughout a landscape, there are species typical of crops, such as *Melanoplus sanguinipes, Schistocerca americana,* and *Spharagemon cristatum,* and others from grasslands like *Chortophaga australior* and *Dichromorpha viridis*; those results show species' sensitivity to vegetation conditions. Therefore, the heterogeneity of the habitat is essential to regulate the abundance and patterns of diversity of acridids (Adu-Acheampong, Bazelet, and Samways, 2016).

Because of the close relationship between the habitat characteristics and the structure of acridids populations, it is necessary to explore ecological aspects that regulate population of grasshopper pests in an agroecosystem, since these results are the first steps for setting control schemes, regulation, and pest control from a sustainable perspective (Zhang, 2011; Zhang, Lecoq, Latchininsky and Hunter, 2019) and agroecological, which has been little explored in Mexico. The intensive agricultural activity dependent on insecticides has led the crop fields of Guanajuato to simplicity in their agrobiodiversity, decreasing the services of the agroecosystem that are key for the protection of the crops, such as the regulation of pests and pollination (Nicholls, 2008; Martin and Osorio, 2012; Landis, 2017). Hence, it is crucial to understand how plant diversity influences insect pests as a basis for agroecological regulation strategies for harmful insects. This work evaluated the effect of the weed vegetation's abundance, diversity, and species composition from a maize agroecosystem on pest acridids' abundance, diversity, and species composition.

Furthermore, the ecological traits of the insects' population were correlated with those of vegetation and the environment (T° and relative humidity) of the agroecosystem.

2. Materials and Methods

Study area. The work was carried out in an area of intensive agriculture in the community of El Copal, Irapuato. The climate is temperate-warm, with an average rainfall of 692 mm and an average temperature of 16.4 °C, and relative humidity of 30.28%. The soil in the area is vertisol, with a clay texture. Industrial agriculture in Guanajuato, promoted since the ‘40s of the last century, is characterized by using pesticides to control pests. Of the 29 active ingredients reported, 50% are hazardous and forbidden in other countries; endosulfan, methamidophos, and carbofuran are among them (Pérez-Olvera, Navarro-Garza, Flores-Sánchez, Ortega-García and Tristán-Martínez, 2017).

Experimental plot. A 2,000 m^2 plot was established with rainfed corn to the irrigation peak, where the growth of weed vegetation was promoted through selective pruning, which would originate three different vegetation conditions: one called grassland (Z) due to the dominance of grasses that proliferated in 400 m^2, and another one called tithonia (T) dominated by broadleaf weeds in 600 m^2; in the remaining 1,000 m^2, the growth of the crop was promoted (M). The corn planted was brand Pioneer, at a density of 10 thousand plants/ha. The management of the crop followed the commercial activities. Within each of these areas inside the plot, monitoring was carried out from September to October of 2021 to obtain data on the abundance, richness, and diversity of grasshopper species.

Vegetation sampling. Thirty-three 5 m^2 quadrants distributed randomly were established. 11 in T, 11 in Z and 11 in M, where samplings were carried out to obtain data from species, abundances and composition of vegetation. These samplings were carried out during the months of September-October 2020, with weekly visits. The plants were identified with the taxonomic keys of the group (Calderón de Rzedowski and Rzedowski, 2004, and Espinosa and Sarukhán, 1997) and deposited in the Herbarium of the Life Sciences Division of the Department of Agronomy from University of Guanajuato.

Grasshopper sampling. From September to October 2021, weekly insect collections were made in the previously mentioned quadrants sorted as indicated from 8:00 to 10:00 am UTC-6. The capture of insects was carried out by using an entomological net with a ring opening of 30 cm, a funnel length of the net of 50 cm, and a handle of 50 cm in length. Captures were done by one person, who avoided being registered by grasshoppers and quickly given five strikes with the net. The captured specimens were transported in vials with 70% alcohol to the Entomology Laboratory of Universidad de Guanajuato, where they were identified at the species level by comparing them with the list of Salas-Araiza, Salazar-Solís, and Montesinos-Silva (2003) and were quantified for their abundance and diversity by vegetation zone.

Statistical analysis. The data on the number of plants and insects were normalized and standardized to be compared among the established areas in the agroecosystem with an ANOVA. In case of significant differences, the Tukey mean comparison test was used, using the Infostat program. To represent the similarities among the plant communities identified, a multidimensional scaling nonparametric analysis was performed with PAST program, using the Bray-Curtis index. This test comes with an effort index that measures the fit between the configuration distances and the model fit disparities, the higher the value, the better the model representation.

Both for plants and insects, the Shannon Diversity indices were calculated and compared to Hutchenson's t-test. In addition, a Spearman correlation analysis was performed between abundance, diversity richness, grasshopper-plant equity, and environmental variables: average temperature, relative humidity, wind speed, and solar radiation. The data were standardized prior to analysis to get ease the comparison among variables in this case the formula was: x-mean/sd.

3. Results and Discussion

Habitat characterization. *17* families and 34 species of plants were found. The families with the highest number of species and present in the three types of vegetation grass (Z), *Tithonia* (T) and maize crop (M) were Poaceae (n = 10) and Asteraceae (n = 5) (Table 1). The average plant abundance among plant communities was not statistically different in T (41.3 ±19.5), Z (41.7 ±15.5) and M (42.25 ±SD = 10.7).

The species composition was different in each type of vegetation. In T *Tithonia tubaeformis* was abundant, while in M and Z it was *Setaria adhaerens*. Moreover, according to the accumulation curves, the floristic structure of the weeds present in the three types of vegetation of the agroecosystem was different. For example, in hierarchical order in M, there are: *Cenchrus echinatus*, *Z. mays,* and *Parthenium histerophorus*; in Z: *S. adhaerens*, *Sorghum halepense*, *Thinantia erecta*, *Portulacacea oleracea,* and *Jaltomata procumbens*; and in T: *T. tubaeformis* and *Chloris gayana* (Figure 1).

The results suggest that weed plants respond sensitively to microenvironmental conditions and cultural management (Mahaut, Gaba, and Fried, 2019). Guzmán-Mendoza, Hernández-Hernández, Salas-Araiza, and Núñez-Palenius (2022) found significant differences in terms of diversity values and the composition of the weed plant structure in three grain monocultures. Likewise, it is suggested that many of these species may have bioindicator characteristics; some of them are common in the study area, such as *Chenopodium album* (Chenopodiaceae), which is associated with sodium bicarbonate crusts in soils, while *Cyperus esculentus* and *Cyperus rotundus* (Cyperaceae) have a positive correlation with clays in the soil (Ramírez-Santoyo, Guzmán-Mendoza, Leyte-Manrique and Salas-Araiza, 2021).

Regarding the diversity values, it presented the gradient T, H' = 1.88; Z, H' = 1.67 and M, H' = 1.36. The comparison indicated significant differences (T-M t = 6.19, p <0.0001; T-Z t = 2.50, p = 0.012; M-Z t = 4.21, p <0.0001). The vegetation T presented the lowest dominance value: D = 0.25; followed by Z: D = 0.30; and M presented the highest dominance: D = 0.38. These results corresponded inversely with the evenness, where the vegetation of the crop (M) was the one with the lowest value (Table 2). An interesting feature of weed communities is that the values of abundance, diversity, and richness are influenced by some physicochemical traits of the soil. For example, previous research near to study site León-Galván *et al*. (2019) found that the abundance, richness, and diversity of weeds in corn crops have a negative correlation, while in sorghum, calcium and potassium are negatively correlated with diversity; also, species like *Chenopodium album* and *Cyperus rotundus* are associated with salt crusts and soil clay respectively (Ramírez-Santoyo *et al*., 2021). Many of these edaphic conditions can influence the plant composition coupled with cultural management such as selective weeding.

The result of the multidimensional scaling found that each plant community was different from each other. The test suggests that the similarity between M-Z was 0.40, M-T 0.04 and Z-T 0.03 (Figure 2). The separation of the groups is observed in the first dimension that had a coefficient of determination of R^2 = 0.63. This result highlights the differentiation in the composition of the species that constituted each type of weed vegetation, which indicates that both the abundances and the equality of the weed populations contribute to the heterogeneity observed in the agroecosystem environment (Dornelas, Moonen, Magurran and Bàrberi, 2009). Regarding to that, Gaba, Chauvel, Dessaint, Bretagnolle and Petit (2010) point out that the weed flora can respond sensitively to environmental conditions in radii of up to 200 m^2, because the environmental factors that influence the richness and diversity of weeds are more important at local scale.

Herbivorous insect community. Six species of grasshoppers were recorded. The most abundant were *Sphenarium purpurascens* (n= 86, avg. = 2.60 S.E. = ±0.19), dominant in central and southern Mexico, causing significant damage to corn crops (Romero-Arenas *et al*., 2020) and *Melanoplus femurrubrum* (25, 0.75 ±0.25) common in North America. *S. purpurascens* and *M. femurrubrum* were present in the three types of vegetation.

Regarding the richness of species in T (S = 4), *S. purpurascens* was presented as the dominant one, followed by *M. femurrubrum*, *Melanoplus diferenttialis* and *Boopedon diabolicum*, Z (S = 6). In addition to those registered in T, *Schistocerca cohni* and *Syrbula admirabilis* were found. In M there were two species (Figure 3). The presence of *S. cohni* in Z suggests a high capacity for adaptation because it is an abundant species in less anthropized environments, where native vegetation is important in the landscape (García, Fontana, Martínez, Escudero and Carrasco, 2010). The proximity of the study site to a forest area and the fact that there is still native weed vegetation (Guzmán-Mendoza *et al*., 2022) may be explaining this result. In contrast, *S. admirabilis* stands out due to its low abundance, since it has been an abundant species for the study area (Salas-Araiza *et al*., 2003).

The ANOVA result indicated significant differences in the abundance of grasshoppers ($F = 8.49$, $p = 0.001$). The Tukey test showed that the lowest number of insects was recorded in M (avg. = 2.1 ± SD = 1.5), while T and Z had the same average amount (5.0 ±2.2, 5.0 ±2.9, respectively).

The diversity indices indicate that Z had significantly the highest diversity of grasshoppers (Z-M: $t = 7.25$, $p<0.0001$; Z-T: $t= 6.47$, $p<0.0001$), while the diversity between M and T did not have significant differences (Table 3).

Nonparametric multidimensional scaling analysis shows a clear differentiation in species composition of acridids between T and Z, with M being an intermediate site (Figure 4).

The results indicate that the composition of the plant communities of the agroecosystem modifies the abundance and diversity of grasshopper species, which highlights the importance of weed vegetation for regulating phytophagous populations (Rojas, Rossetti and Veidela, 2019). In addition to the fact that the environmental heterogeneity provided by these plants means ecosystem benefits for crops (Ghiglione, Zumoffen, Dalmazzo, Strasser and Attademo, 2021). In this case study, the pressure of herbivores on the crop was reduced, softening the potential negative effect on production since grasshoppers are an important pest for corn (Salas-Araiza and Martínez-Jaime, 2018).

Previous studies indicate a direct relationship between the presence and composition of acridids and certain plant species, mainly grasses such as *Bouteloua* spp. and *Aristida adscensionis* (Gutiérrez, Hernández, García, Reyes and Maldonado, 2006). Something similar was observed in this study because all species observed in this study were found in grass. However, we observed that grasses influenced the abundance and composition of the grasshopper species, since the abundances were similar both in T and Z, but not the identity of the species.

Environmental-insect variables. The correlations between the different attributes of the populations of acridids, of plants and the physical variables presented significant differences differently according to the type of vegetation of the agroecosystem. In M, the attributes of diversity in acridids were significantly correlated with the abundance of plants; in T, the attributes mentioned for grasshoppers were significantly correlated with plant dominance, while in Z only the abundance of acridids was correlated with the physical variables of average temperature and relative humidity (Table 4).

In this way, in Z, the abundance of grasshoppers is positively influenced by temperature and negatively by humidity; In contrast, in M and T, biotic factors affect the populations of acridids. Prinster, Resaco and Nufio (2020), found that diversity was modified by physical factors such as altitude and temperature, the latter being considered important for the development of species, like *Melanoplus sanguinipes* (Olfert, Weiss, Giffen and Vankosky, 2021). Nevertheless, in the system studied here, biotic factors related to weedy vegetation, such as diversity, composition, and other elements associated with plant covers, like humidity, temperature regulation, and the presence of predators or food resources offered by the microenvironments influence the patterns of abundance and richness observed in grasshopper populations.

4. Conclusions

The types of vegetation were clearly different in the agroecosystem, and the six species of acridids reacted differently regarding abundances, diversity, and species composition. In this sense, the abundance of grasshoppers was higher in T and Z; furthermore, the richness and diversity of grasshopper species were higher in Z. The populations of acridids can be modified by the differences in weedy vegetation covers that have a potential of diminishing the pressure of herbivory in the crop; in addition, vegetation as a biotic factor can regulate the population patterns of acridids in sites such as M and T, but in environments like Z, abiotic factors influence the species of acridids.

Acknowledgments

To Consejo Nacional de Ciencia y Tecnología (CONACYT) for the scholarship given to Francisco Ramos, student of the Biociencias postgraduate program.

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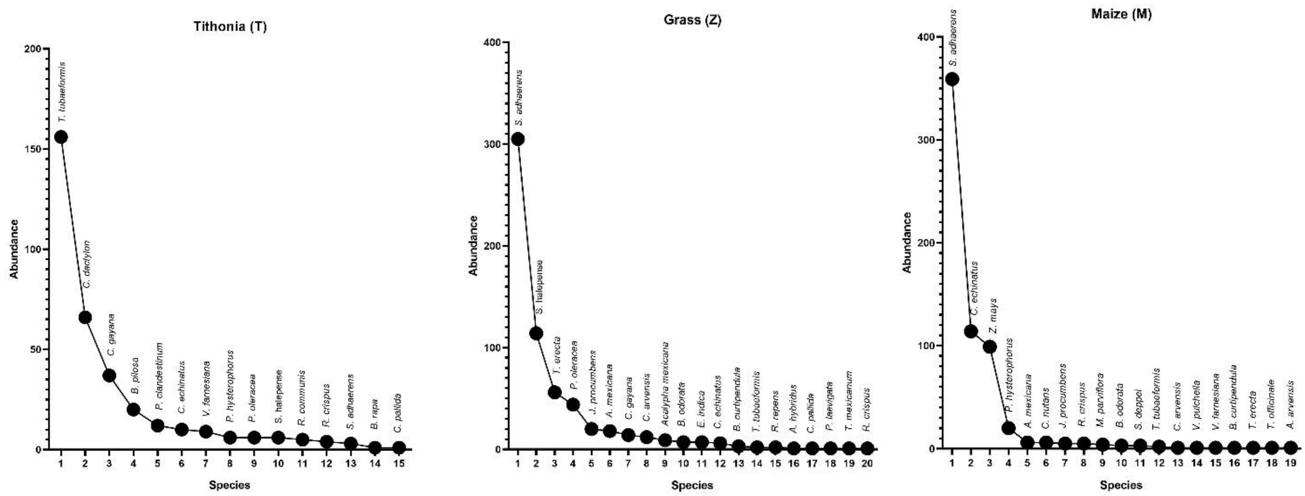

Figure 1 Abundance rank accumulation curves for plant species from three communities within an agroecosystem.

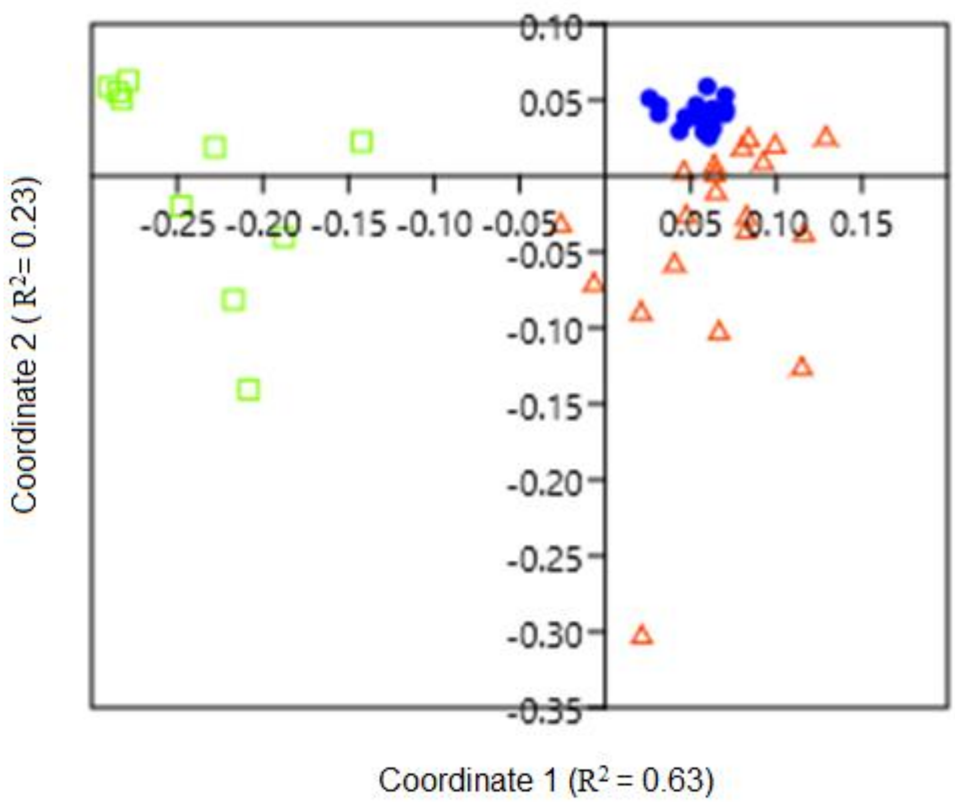

Figure 2 Non-parametric multidimensional scaling ordering of three plant communities of a corn agroecosystem calculated through the Bray-Curtis index. The value of the effort index is 0.12. Green (T), red (Z), blue (M). R2 coordinate 1 = 0.63, R2 coordinate 2= 0.23.

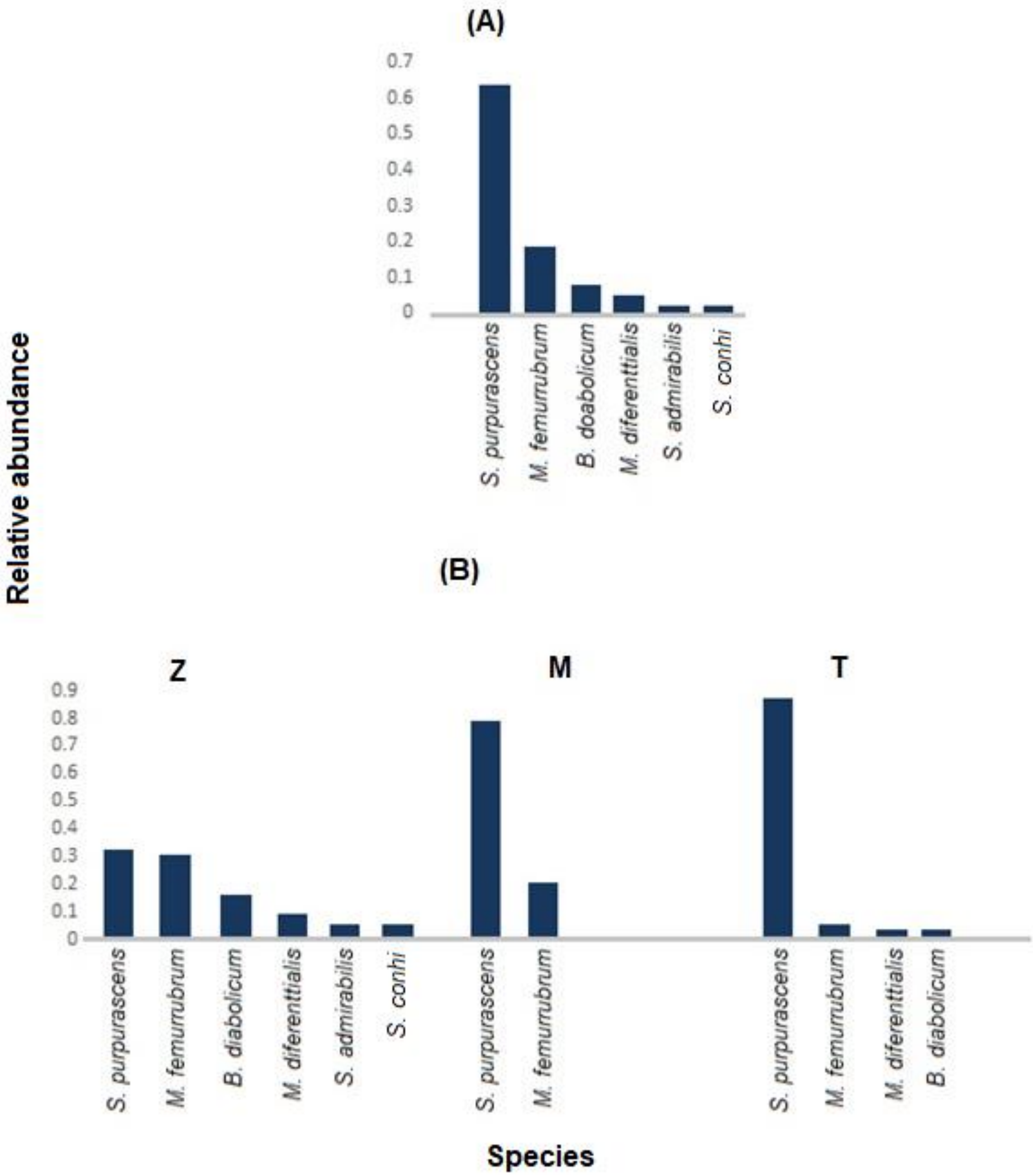

Figure 3 Total relative abundance (A) and by type of vegetation (B) of acridids. Z = grassland, M = crop, T = *Tithonia*.

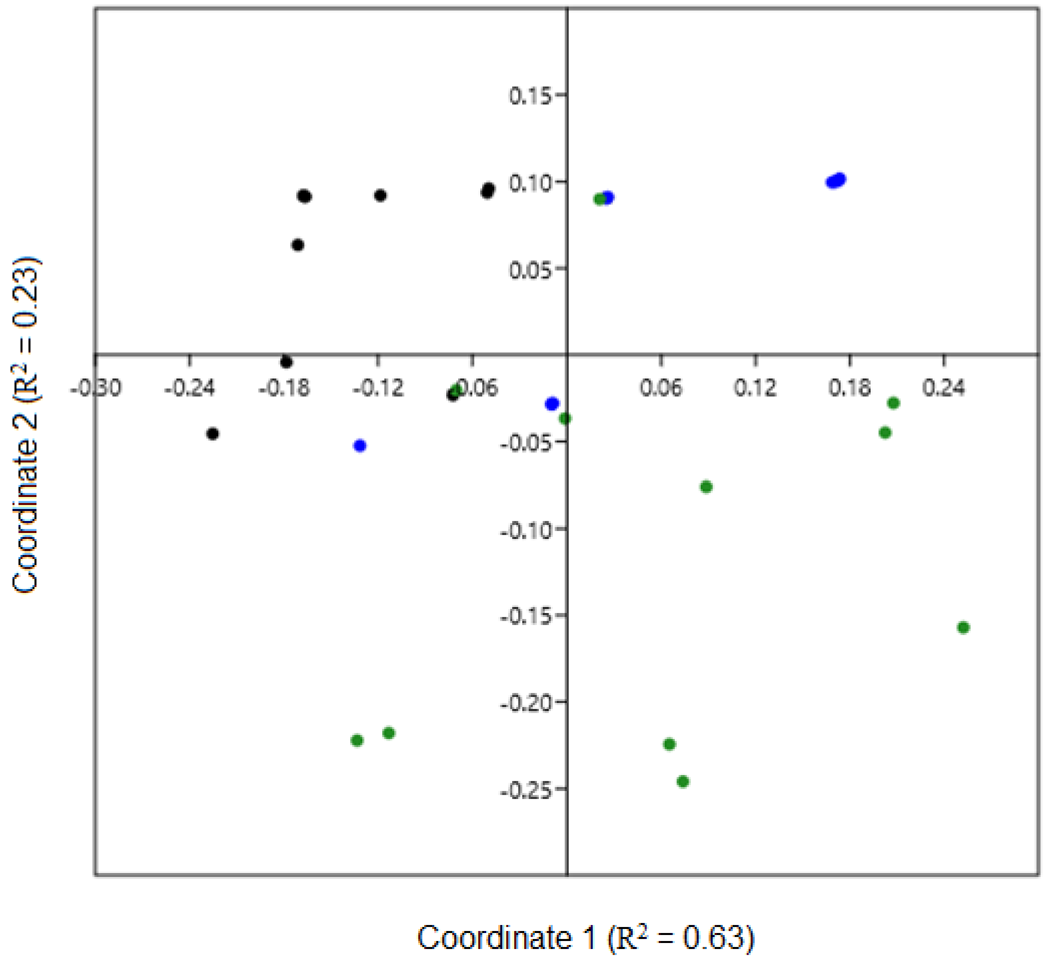

Figure 4 Non-parametric multidimensional scaling ordering for acrid species through the Bray-Curtis index. The value of the effort index is 0.12. green (T), black (Z), blue (M).

Table

1

Families	Species	Corn (M)	Tithonia (T)	Grassland (Z)
Amaranthaceae	*Amaranthus hybridus*	0	0	1
Asteraceae	*Bidens odorata*	3	0	7
	Bidens pilosa	0	20	0
	Parthenium hysterophorus	20	6	0
	Taraxacum officinale	1	0	0
	Tithonia tubaeformis	2	156	2
Brassicaceae	*Brassica rapa*	0	1	0
Cannabaceae	*Celtis pallida*	0	1	1
Caryophyllaceae	*Cerastium nutans*	6	0	0
Convolvulaceae	*Convolvulus arvensis*	1	0	12
Commelinaceae	*Tinantia erecta*	1	0	56
Cucurbitaceae	*Sicyos deppei*	3	0	0
Euphorbiaceae	*Acalypha mexicana*	0	0	9
	Ricinus communis	0	5	0
Fabaceae	*Prosopis laevigata*	0	0	1
	Trifolium mexicanum	0	0	1
	Vachellia farnesiana	1	9	0
	Vicia pulchella	1	0	0
Malvaceae	*Malva parviflora*	4	0	0

Papaveraceae	*Argemone mexicana*	6	0	18
Poaceae	*Bouteloua curtipendula*	1	0	3
	Cenchrus echinatus	114	10	6
	Chloris gayana	0	37	14
	Cynodon dactylon	0	66	0
	Eleusine indica	0	0	7
	Melinis repens	0	0	2
	Pennisetum clandestinum Hochst.	0	12	0
	Setaria adhaerens	359	3	305
	Sorghum halepense	0	6	114
	Zea mays	99	0	0
Polygonaceae	*Rumex crispus*	5	4	1
Portulacaceae	*Portulaca oleracea*	0	6	44
Primulaceae	*Anagallis arvensis*	1	0	0
Solanaceae	*Jaltomata procumbens*	5	0	20

Table 1 List of families, species, and the number of plants by type of vegetation in the corn agroecosystem.

Community	S	H’	D - J’
Corn	19	1.36	D = 0.38, J’ = 0.46

Grassland	19	1.67	D = 0.30, J’ = 0.56
Tithonia	17	1.88	D = 0.25, J’ = 0.66

Table 2 Values of species richness (S), Shannon diversity (H'), dominance (D), and evenness (J') by plant community of a corn agroecosystem.

Diversity value/site	Corn	Grassland	Tithonia
S	2	6	4
H’	0.51	1.56	0.51
D	0.67	0.24	0.77
J’	0.73	0.87	0.36

Table 3 Values of richness (S), diversity (H'), dominance (D), and evenness (J') of acridids in three types of vegetation.

Vegetation	Acridids-Plants	Environment
	(A) insects - (A) plants: -0.65/0.03	
Crop	(S) insects - (A) plants: -0.75/0.01	
(M)	(D) insects - (A) plants: 0.75/0.01	-
	(H’) insects - (A) plants: -0.75/0.01	
	(J’) insects - (A) plants: -0.75/0.01	
	(S) insects - (D) plants: -0.86/0.0001	-
Tithonia	(D) insects - (D) plants: 0.78/0.0001	

(T)	(H’) insects - (D) plants: -0.84/0.0001	
	(J’) insects - (D) plants: -0.69/0.02	
Grassland	-	(A) insects - °C: 0.66/0.03
(Z)		(A) insects - RH: -0.71/0.01

Table 4 Significant correlation coefficients (α= 0.05) of Spearman/probability, between abundance (A), richness (S), dominance (D), diversity (H'), equity (J') of acridids-plants and variables environmental: °C = temperature, RH = relative humidity.