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Original Article

Potential of weed for Acrididae pest control in a maize agroecosystem

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Abstract

In a rainfed maize crop agroecosystem, the effects of weeds on acridid pests were evaluated. There were three types of vegetation namely tithonia (T), grassland (Z), and maize crop (M). Sampling of plants/acridids was conducted weekly in 33 quadrants, from September to October 2021. The data were standardized to compare abundances, diversity (H'), and species composition (SC). Correlation coefficients between abundance and diversity of acridids, and vegetation and environment factors, were calculated. Vegetations did not differ in abundance, but SC indicated T (H'= 1.88) as the most diverse, and diversity was the highest in M (D = 0.38). The Acrididae differed in abundance, diversity, and dominance, being the highest in Z and T (5.0 ±2.2; T 5.0 ±2.9); Z (H' = 1.56); and T (D = 0.77), respectively, and also SC was different. M and T had positive correlations for acridids-abundance-vegetation dominance, but Z with t°-RH. The weeds have potential for use in a strategy to control acridids in crops.

Keywords: acridids, agricultural landscape, agrobiodiversity, agroecology, weeds

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1. Introduction

Acridids are widely distributed herbivorous insects that contribute to the functioning of ecosystems through the recycling of organic matter (Mancini & Mariottini, 2021) and through their role as herbivorous prey (De Gracia & 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* and *Brachystola magna* (Barrientos-Lozano, 2003), able to damage industrial, fruit, basic, and ornamental crops, and severe 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, & Torres-Castillo, 2021). Despite the above, there are reports that grasshoppers consume wild plants like the four o'clock flower (*Mirabilis jalapa*), sunflower (*Helianthus laciniatus*), cuahuilotillo (*Croton adspersus*), tlacote (*Salvia mexicana* L.), and quintonil (*Amaranthus hybridus*) (Ramírez-Méndez, González-Villegas, & 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 grasshopper population density. Nonetheless, it has been seen that taxonomic composition and physical structure of vegetation play important roles in areas occupied by grasshoppers (Branson, Joern, & Sword, 2006) and that the habitat types not only influence the presence of species but also their abundance (Kemp, Harvey, & 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*; these

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results indicate the 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, & Samways, 2016).

Because of the close relationship between the habitat characteristics and the structure of acridid 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 appropriately (Zhang, 2011; Zhang, Lecoq, Latchininsky, & Hunter, 2019) and agroecologically, but they have been little explored in Mexico. The intensive agricultural activity dependent on insecticides has led the crop fields of Guanajuato to have losses 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 (Landis, 2017; Martin & Osorio, 2012; Nicholls, 2008). Hence, it is crucial to understand how plant diversity influences insect pests as a basis for agroecological regulation strategies of harmful insects. This work evaluated the effects of the weed vegetation abundance, diversity, and species composition in a maize agroecosystem on pest acridids' abundance, diversity, and species composition. Furthermore, the ecological traits of the insect population were correlated with those of vegetation and the environment (T° and relative humidity) in the agroecosystem.

2. Materials and Methods

2.1 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 a relative humidity of 30.28%. The soil in the area is vertisol, with a clay texture. Industrial agriculture in Guanajuato, promoted since the 40's of the last century, is characterized by use of 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, & Tristán-Martínez, 2017).

2.2 Experimental plot

A 2,000 m^2 plot was established with rainfed maize 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 maize planted was brand Pioneer, at a density of 80000 plants/ha. The management of the crop followed commercial practices in rainfed crops. 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.

2.3 Vegetation sampling

Thirty-three 5 m^2 quadrants distributed randomly were established, 11 in T, 11 in Z, and 11 in M, where sampling was carried out to obtain data on species, abundances, and composition of vegetation. The sampling was carried out during the months of September and October in 2021, with weekly visits. The plants were identified with the taxonomic keys of the group (Calderón de Rzedowski, & Rzedowski, 2004; Espinosa & Sarukhán, 1997) and deposited in the Herbarium of the Life Sciences Division of the Department of Agronomy from University of Guanajuato.

2.4 Grasshopper sampling

From September to October 2021, weekly insect collections were made in the previously mentioned quadrants 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 50 cm, and a handle that was 50 cm in length. Captures were done by one person, who avoided being registered by grasshoppers and quickly executed 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.

2.5 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, in 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 using 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 with the transform to (x-mean)/sd.

3. Results and Discussion

3.1 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 differed by 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 structures of weeds present in the three types of vegetation in agroecosystem were different. For example, in hierarchical order in M, there were: *Cenchrus echinatus*, *Z. mays*, and *Parthenium hysterophorus;* in Z: *S. adhaerens*, *Sorghum halepense*, *Tinantia erecta*, *Portulaca oleracea*, and *Jaltomata procumbens*; and in T: *T. tubaeformis* and *Chloris gayana* (Figure 1).

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

Family	Species	Maize (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	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

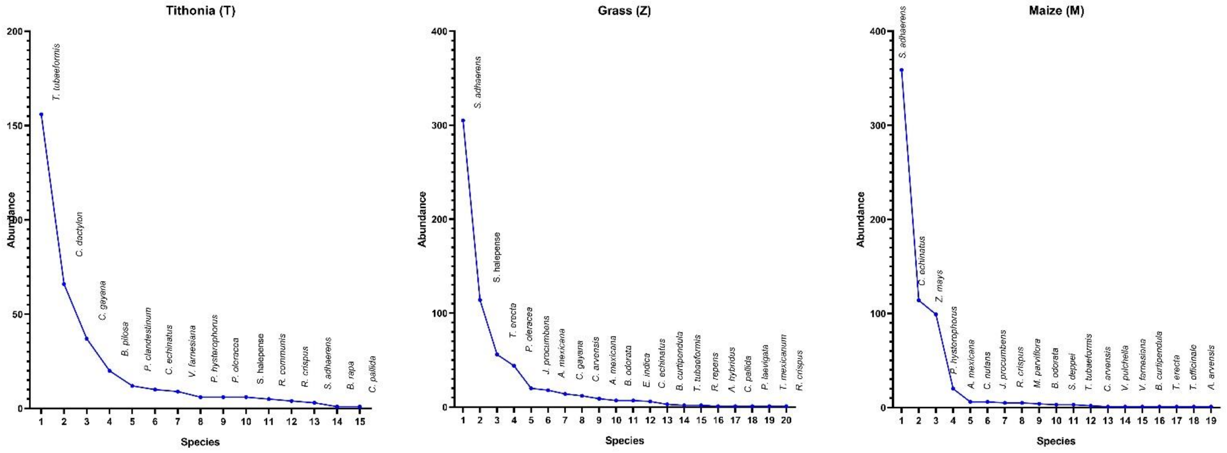

Figure 1. Abundance rank accumulation curves for plant species from three communities within an agroecosystem

The results suggest that weed plants respond sensitively to microenvironmental conditions and culture management (Mahaut, Gaba, & Fried, 2019). Guzmán-Mendoza, Hernández-Hernández, Salas-Araiza, and Núñez-Palenius (2022) found significant differences in diversity values and in 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 crust on soil, while *Cyperus esculentus* and *Cyperus rotundus* (Cyperaceae) have a positive correlation with clay in the soil (Ramírez-Santoyo, Guzmán-Mendoza, Leyte-Manrique, & Salas-Araiza, 2021).

Regarding the diversity values, they decreased in rank order T, H’ = 1.88; Z, H’ = 1.67 and M, H’ = 1.36. The comparison indicates 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 greatest dominance: D = 0.38. These results correspond inversely with the evenness, where the vegetation of the crop (M) was the one with the least value (Table 2). An interesting feature of weed communities is that abundance, diversity, and richness are influenced by some physicochemical traits of the soil. For example, previous research near the study site by León-Galván *et al*. (2019) found that the abundance, richness, and diversity of weeds in maize crops have a negative correlation, while in sorghum, calcium and potassium are negatively correlated with diversity; also, species like *C. album* and *C. rotundus* are associated with salt crust and soil clay, respectively (Ramírez-Santoyo *et al*., 2021). Many of these edaphic conditions can influence the plant composition coupled with culture management such as selective weeding.

The multidimensional scaling indicates that each plant community was different from the others. The test suggests similarity levels for M-Z as 0.40, M-T as 0.04, and Z-T as 0.03 (Figure 2). The separation of groups is observed in the first dimension that had a coefficient of determination of R^2 = 0.63. This highlights the differentiation in the composition of the species by 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, & Bàrberi, 2009). Regarding this, 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 a local scale.

3.2 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 differentialis* 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, & 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 explain this result. In contrast, *S. admirabilis* stands out due to its low abundance, since it has been an abundant species in the study area (Salas-Araiza *et al*., 2003). The ANOVA indicated significant differences in the abundance of grasshoppers (F = 8.49, p = 0.001). The Tukey test showed that the least number of insects was recorded in M (avg. = 2.1 ± SD = 1.5), while T and Z had similar average amounts (5.0 ±2.2 and 5.0 ±2.9, respectively).

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

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

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

Diversity value/site	Maize	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

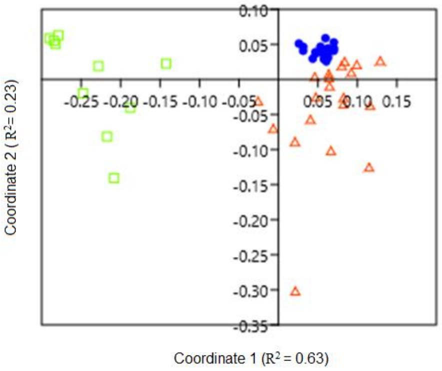

Figure 2. Non-parametric multidimensional scaling of three plant communities of a maize agroecosystem calculated through the Bray-Curtis index. The value of the effort index is 0.12. The communities are presented with green (T), red (Z), and blue (M) markers. R^2 in coordinate 1 = 0.63, and R^2 in coordinate 2= 0.23.

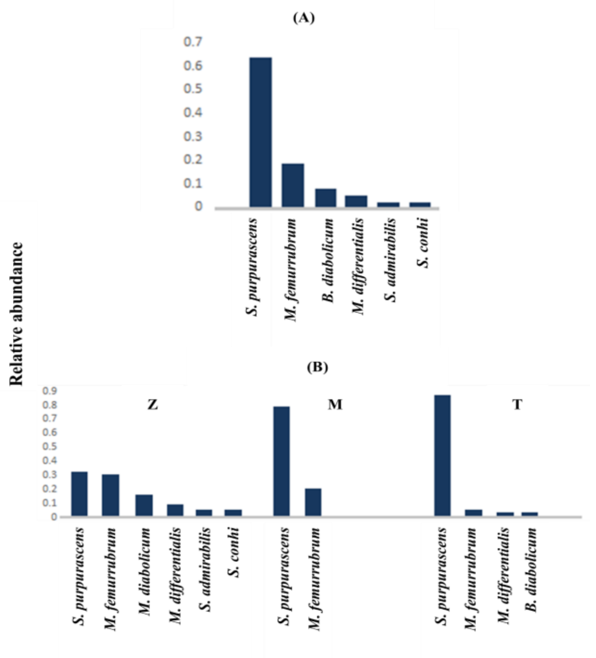

Figure 3. Total relative abundance (A) and abundance by type of vegetation (B) of acridids. Z = grassland, M = crop, and T = tithonia

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

Diversity value/site	Maize	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

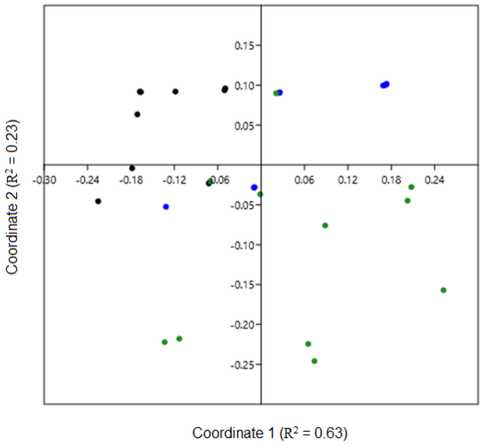

Figure 4. Non-parametric multidimensional scaling for acrid species through the Bray-Curtis index. The value of the effort index is 0.12. The communities are represented by green (T), black (Z), and blue (M) markers.

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, & Veidela, 2019). In addition, the environmental heterogeneity provided by these plants means ecosystem benefits for crops (Ghiglione, Zumoffen, Dalmazzo, Strasser, & 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 maize (Salas-Araiza & 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, & Maldonado, 2006). Something similar was observed in this study because all the acridid 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 in T and Z, but not the identity of the species.

3.3 Environmental-insect variables

The correlations between the different attributes of the populations of acridids, of plants and the physical variables presented significant differences 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 average temperature and relative humidity (Table 4).

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

Vegetation	Acridids-plants	Environment
Crop (M)	(A) insects - (A) plants: -0.65/0.03 (S) insects - (A) plants: -0.75/0.01 (D) insects - (A) plants: 0.75/0.01 (H’) insects - (A) plants: -0.75/0.01 (J’) insects - (A) plants: -0.75/0.01	-
Tithonia (T)	(S) insects - (D) plants: -0.86/0.0001 (D) insects - (D) plants: 0.78/0.0001 (H’) insects - (D) plants: -0.84/0.0001 (J’) insects - (D) plants: -0.69/0.02	-
Grassland (Z)	-	(A) insects - °C: 0.66/0.03 (A) insects - RH: -0.71/0.01

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 *M. sanguinipes* (Olfert, Weiss, Giffen, & Vankosky, 2021). Nevertheless, in the system studied here, biotic factors related to weedy vegetation, such as diversity, composition, and other elements associated with plant cover, 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 to diminishing the pressure from herbivory on 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.

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