Entomofauna associated with *Spodoptera frugiperda* in a maize agroecosystem in San José de las Lajas, Cuba

Entomofauna asociada a *Spodoptera frugiperda* en un agroecosistema de maíz en San José de las Lajas, Cuba

Yaisys Blanco Valdés[1], Tien Vo Minh[2], Alexis Lamz Piedra[3]*, Josefina Victoria Gómez Piñar[2], Fernando Arredondo Ruiz[4], Omar Enrique Cartaya Rubio[1], and Neisy Castillo[2]

ABSTRACT

The cultivation of maize (*Zea mays* L.*)* is of significant global economic importance as it is the third most widely grown cereal worldwide. Numerous harmful organisms affect this crop, impacting its yields. Among these, the "fall armyworm" *Spodoptera frugiperda* J. E. Smith, a corn pest, is the main culprit causing substantial economic losses because of its damage. Besides this pest, various beneficial insects are associated with the maize crops that play a crucial role in its control. The present research was conducted at the National Institute of Agricultural Sciences (INCA) in Cuba to list the insects associated with *S. frugiperda* in the maize agroecosystem with a 'MAIG-Diamante' cultivar. One hundred randomly selected plants were sampled in a zig-zag pattern, and the inner whorl leaves and other parts of the plants were examined. Seven samplings were carried out weekly. Classification of species was done using taxonomic keys. In the agroecosystem, insects belonging to 7 orders, 22 families, and 28 species were found. These were categorized according to their habits as 15 phytophagous, 11 predators, 1 parasitoid, and 1 pollinator species. *Spodoptera frugiperda*, *Zelus longipes, Zelus* sp.*, Nezara viridula, Peregrinus maidis, Oxymerus aculeatus*, an unspecified species of beetle, *Brachiacantha decora, Doru* sp., and *Apis mellifera* were very frequent. In contrast, the rest of the remaining species were somewhat frequent.

Key words: phytophage, beneficial insects, predators, parasitoids.

RESUMEN

El cultivo del maíz (*Zea mays* L.) tiene gran importancia económica a nivel mundial por ser el tercer cereal más extendido en todo el mundo. Sobre dicho cultivo inciden numerosos organismos nocivos, afectando su rendimiento, siendo *Spodoptera frugiperda* J. E. (Smith), la "palomilla del maíz", la principal plaga causante de grandes pérdidas económicas. Asociados a esta plaga existen diversos insectos benéficos que juegan un papel importante en su regulación. El presente trabajo se realizó en el Instituto Nacional de Ciencias Agrícolas (INCA) en Cuba, con el objetivo de catalogar la entomofauna asociada a *S. frugiperda* en un agroecosistema de maíz cultivar 'MAIG-Diamante'. Para el inventario se muestrearon 100 plantas seleccionadas al azar en forma de zig-zag y se revisaron los cogollos en su interior y otras partes de la planta. Se realizaron un total de 7 muestreos con una frecuencia semanal. La clasificación de las diferentes especies se realizó mediante diferentes claves taxonómicas. Se recolectaron insectos pertenecientes a 7 órdenes; 22 familias y 28 especies. Estos fueron ubicados según sus hábitos alimentarios en: 15 fitófagos, 11 depredadores, 1 parasitoide y 1 polinizador. Las especies *Spodoptera frugiperda, Zelus longipes, Zelus* sp.*, Nezara viridula, Peregrinus maidis, Oxymerus aculeatus,* especie de escarabajo no determinada, *Brachiacantha decora*, *Doru* sp. y *Apis mellifera* resultaron ser muy frecuentes; mientras que el resto de las especies fueron frecuentes.

Palabras clave: fitófago, insectos benéficos, depredadores, parasitoides.

Introduction

Maize (*Zea mays* L.) is a crop of significant economic and nutritional importance and is considered one of the most cultivated cereals alongside rice (*Oryza sativa* L.) and wheat (*Triticum sativum* L.) (Chura *et al*., 2019). It is the most worldwide crop, cultivated in 170 countries, with over 200 million ha harvested in 2018 (Díaz *et al*., 2022). This crop serves as food for humans, livestock, poultry, and raw materials in various industries (Rodríguez-Soto *et al*., 2018).

In Cuba, maize holds a strong tradition as a crop. It is used for human and animal consumption, as an associated crop, living fence, and reservoir of insect predators, among other

Received for publication: June 13, 2024. Accepted for publication: August 30, 2024. Doi: 10.15446/agron.colomb.v42n2.115031

[1] Instituto Nacional de Ciencias Agrícolas, San José de las Lajas, Mayabeque (Cuba).
[2] Universidad Agraria de la Habana, San José de las Lajas, Mayabeque (Cuba).
[3] Centro de Investigación en Alimentación y Desarrollo, Cuauhtémoc, Chihuahua (Mexico).
[4] Universidad Autónoma de Chihuahua, Santo Niño, Chihuahua (Mexico).
Corresponding author: alamzp@gmail.com

roles (Gigato-Toledo *et al*., 2018). However, various harmful organisms affect this crop. During fall, armyworm *Spodoptera frugiperda* J. E. Smith is the most important pest that causes significant economic losses (MRI, 2019). Yield reductions of up to 0.8 t ha^{-1} of dry maize grain, equivalent to 40% of the production in Cuban conditions, can occur (Blanco & Leyva, 2009). The highest infestations occur during the vegetative stage when the larva feeds on the leaf tissues (Mirabal *et al*., 2018).

Associated with *S. frugiperda* are various beneficial insects that contribute to the natural regulation of its populations in crops. The conservation and management of these beneficial insects are paramount, as they provide valuable ecological services for farmers at no cost. They aid in the regulation of harmful organisms and reduce the use of pesticides that are detrimental to humans, animals, and the environment (DGSV-CNRF, 2021; García González *et al*., 2022).

In Cuba, maize is one of the most fundamental crops cultivated in spring. Many details are known about the insect fauna present in maize during the spring in different locations and associated with various varieties. However, data from this specific cultivar in a low-rainfall period are scarce. This research aimed to list the insects associated with *S. frugiperda* in maize crops of the 'MAIG-Diamante' (conventional) cultivar. We determined the relative percentage frequency of occurrence of each detected insect species on the Las Papas Farm of the National Institute of Agricultural Sciences (INCA). This data will contribute fundamental and essential knowledge for this crop's agroecological pest management approach.

Materials and methods

Experimental area

This research was conducted from October to January 2021-2022 in experimental areas of the National Institute of Agricultural Sciences (INCA) in San José de las Lajas, Mayabeque Province, Cuba, 3.5 km along the road to Tapaste. The geographic coordinates of the area are 22°59'40.79" N and 82°8'21.88" W at an altitude of 138 m a.s.l.

The agroecosystem where the experiment was conducted is characterized by a short duration of low rainfall from November to March (Gil-Reyes *et al*., 2020).

The monthly climatic variables recorded were precipitation (mm), average monthly temperature (°C), and relative air humidity (%), using the meteorological station number 78374, located 350 m away from the experimental area.

The average monthly temperatures during the research period ranged from 21.9°C to 28.3°C, corresponding to the cooler and drier months (November to April). Monthly precipitation varied from 90 mm in the drier period to 20.9 mm in the cooler period. Notably, the highest precipitation occurred in October and December, when precipitation was limited, necessitating artificial irrigation (sprinkling) (MINAG, 2013). Relative air humidity ranged from 77% to 93% during the experimental period.

The soil of the experimental area was a typical eutrophic leached Red Ferralitic soil, characterized by medium to high fertility (Hernández Jiménez *et al*., 2015). According to this author, the soil is deep with an acidic pH; it has a low percentage of organic matter and a high percentage of phosphorus and calcium. However, potassium and magnesium are deficient (Tab. 1). Soil analyses were carried out using the methodologies described by Paneque *et al*. (2010).

TABLE 1. Chemical characteristics of the soil where an inventory of the entomofauna associated with the maize cultivar 'MAIG-Diamante' was carried out.

Depth (cm)	pH (H_2O)	OM (%)	P (mg kg^{-1})	K^+	Ca^{2+}	Mg^{2+}
				($cmol_c$ kg^{-1})		
0-20	6.4	2.11	234	0.52	9.93	1.80

OM: soil organic matter.

Experimental program

The maize cultivar 'MAIG-Diamante' was used and is characterized by having a medium growth cycle of 120 d to harvest maturity (MINAG, 2013). The crop reaches a height between 220 and 230 cm, with 12-16 thick and erect leaves. It is resistant to lodging, has a tassel and stigma, and its grains are yellow. Its potential yield is 5 t ha^{-1}.

The experimental area was 0.1 ha; the preceding crop was sweet potato (*Ipomoea batata* L.). Sowing of maize was carried out manually with a spacing arrangement of 0.90 m between rows and 0.30 m between plants. Nitrogen fertilization was applied at the time of planting at a rate of 50 kg ha^{-1} using urea, and potassium was applied at 100 kg ha^{-1} using potassium chloride.

Inventory of the insects associated with *S. frugiperda* in maize agroecosystem

To evaluate the entomofauna associated with *S. frugiperda* in maize crops, a detailed examination of the inner whorl leaves and other plant parts was conducted on 100

randomly selected plants in a zig-zag pattern using the simple systematic method. This was performed weekly, starting from 21 d after planting (from 14 to 56 d post-emergence), for 7 samplings.

Smaller insects (<3.0 mm) were collected using a handheld aspirator to gently collect insects. The insects were placed in labeled vials indicating the sampling site and date. In the case of highly mobile insects, an entomological net was used for collection at an angle of 90° in diagonal form.

Larger insects were stored in glass jars with 70% ethanol for preservation. All samples were taken to the Entomology Laboratory at the Faculty of Agronomy of the Agrarian University of Havana (UNAH). Species identification was done using a Novel stereoscopic microscope (PRC) with a magnification of 1.5-2. Taxonomic determination was performed using the keys of Cave (1993), Fernández (2002), Gordon (1985), and Nájera and Souza (2010).

Parasitoids were taken to the laboratory of the National Center for Agricultural Health (CENSA) for classification by specialized personnel using the guidelines proposed by Cave (1993). For each sampling, 20 larvae of *S. frugiperda* at different development stages were taken, placed separately in Petri dishes, and fed with leaves of *Sorghum halepense* (L.) Pers. until their life cycle was completed or until the emergence of parasitoids, which were placed in containers of ethanol at 70% for their identification.

Additionally, the samples were compared with specimens from the insect collection at the Entomology Laboratory of the Plant Health Department, Faculty of Agronomy of the Agrarian University of Havana.

Determination of the relative frequency index

The relative frequency index for each species was determined based on the data obtained from each weekly sample for each detected species. The following equation was used:

$$Rf = \left(\frac{Mi}{Mt}\right) * 100 \quad (1)$$

where

Rf = relative frequency of species occurrence (%);

Mi = total number of samplings with the species i;

Mt = total number of samplings.

The assessment of relative frequency (Rf) values was carried out using the scale of Masson and Bryant (1974), which indicates that a species is considered very frequent if Rf > 30, frequent if 10 ≥ Rf ≤ 30, and rare if Rf < 10.

Results

Inventory of the insects associated with *S. frugiperda* in a maize agroecosystem

In the maize agroecosystem, various insect species were detected belonging to seven orders, 22 families, and 28 species, of which 25 were identified (Fig. 1). The orders with the highest number of species were Coleoptera, Hemiptera, and Hymenoptera, with 10, 8, and 4 species, respectively.

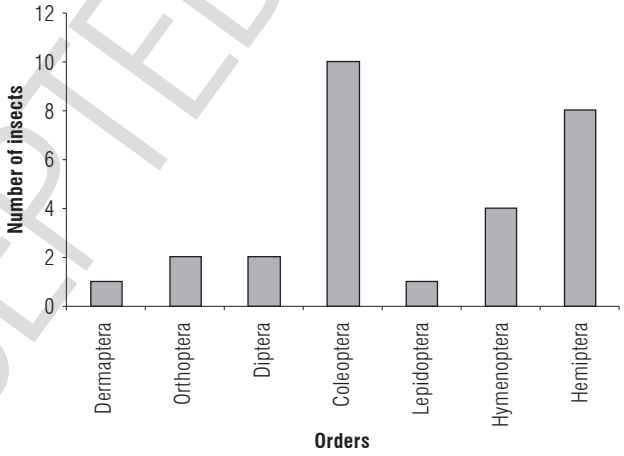

FIGURE 1. Number of species detected in each insect order in the maize cultivar 'MAIG-Diamante'.

List of phytophagous insects associated with maize crop

Table 2 lists the species of phytophagous insects distinguished from the 7 samples. Specifically, in this cultivar, 15 harmful species were identified. Among these, the primary species found and recognized in the literature as a pest capable of causing significant damage was *Spodoptera frugiperda*. Other insect species considered phytophagous for the crop were also recorded, including *Anasa andresii* Guér., *Nezara viridula* L., *Peregrinus maidis* Ashm., *Typophorus nigritus* Fabricius, *Diabrotica balteata* Le Conte, *Coptocycla guttata* Boheman, *Oxymerus aculeatus lebasi* Dup., *Cylas formicarius* Fabricius, *Atta insulares* Guér., *Conocephalus fasciatus* De Geer, *Gryllus assimilis* Fabricius, *Euxesta* sp., and two unidentified species from the order Coleoptera (Scarabaeidae and Curculionidae families).

TABLE 2. List of phytophagous insect species observed in the maize crop of the cultivar 'MAIG-Diamante'.

Order	Family	Species
Lepidoptera	Noctuidae	*Spodoptera frugiperda* J. E. (Smith)
Hemiptera	Coreidae	*Anasa andresii* Guér.
	Pentatomidae	*Nezara viridula* L.
	Delphacidae	*Perigrinus maidis* Ashm.
Coleoptera	Chrysomelidae	*Typophorus nigritus* Fabricius
		Diabrotica balteata Le Conte
		Coptocycla guttata Boheman
	Cerambycidae	*Oxymerus aculeatus lebasi* Dup.
	Scarabaeidae	Undetermined species
	Curculionidae	Undetermined species
	Brentidae	*Cylas formicarius* Fabricius
Hymenoptera	Formicidae	*Atta insulares* Guér.
Orthoptera	Tettigonidae	*Conocephalus fasciatus* De Geer
	Gryllidae	*Gryllus assimilis* Fabricius
Diptera	Otitidae	*Euxesta* sp.

The species *P. maidis* belonging to the order Hemiptera and the family Delphacidae was found in the nymphal stage on the flag leaves and the plant's tassel, 14 d after plant emergence (sampling 1). Concerning this delphacid, individuals were not detected forming colonies but rather were isolated on the leaves. In the last sample, one species of adult Diptera (*Euxesta* sp.) was detected on the maize crop.

List of beneficial insects associated with maize crop

Table 3 presents the beneficial insect species recorded in the maize crop during the research period.

TABLE 3. List of beneficial insect species associated with *Spodoptera frugiperda* in the maize agroecosystem.

Order	Family	Species
Predators		
Coleoptera	Coccinellidae	*Cycloneda sanguinea limbifer* Casey
		Brachiacantha decora Casey
		Brachiacantha sp.
Hymenoptera	Formicidae	*Pheidole* sp.
	Vespidae	*Polistes* sp.
Hemiptera	Reduviidae	*Zelus longipes* L.
		Zelus sp.
	Anthocoridae	*Orius insidiosus* Say
	Nabidae	Undetermined species
	Miridae	*Nesidiocoris tenuis* Reuter
Dermaptera	Forficulidae	*Doru* sp.
Diptera (Parasitoid)	Tachinidae	*Archytas marmoratus* Townsend
Hymenoptera (Pollinator)	Apidae	*Apis mellifera* L.

Thirteen species considered beneficial were identified as natural enemies of some harmful insects. Among these, 11 species exhibit predatory habits, while one is a parasitoid insect. Additionally, one species functions as a pollinator. These species spanned five orders and were represented in 10 families (Tab. 3).

The beneficial insects identified belonged to the orders Coleoptera, Hymenoptera, Hemiptera, Dermaptera, and Diptera, with Hemiptera having the highest number of species (5). In the study crop, the Coleoptera had three species from the family Coccinellidae: *Cycloneda sanguinea limbifer, Brachiacantha decora,* and *Brachiacantha* sp.

Only the parasitoid Archytas marmoratus in the adult stage was detected in field conditions. However, no parasitoid emerged when *S. frugiperda* larvae were placed in Petri dishes in the laboratory. Since the crop was established at a non-optimal time, the climatic conditions might not have been conducive to the development of parasitoid species.

Determination of the relative frequency index

Table 4 shows the relative frequency of the different species found in the studied crop. All the species detected in the research were determined as highly frequent and frequent.

TABLE 4. Relative frequency of entomofauna associated with the maize cultivar 'MAIG-Diamante'.

Species	Relative frequency (%)
S. frugiperda	100.0 VF
A. andresii	14.28 F
Z. longipes	85.71 VF
Zelus sp.	71.42 VF
O. insidiosus	14.28 F
Undetermined species (Nabidae)	14.28 F
N. tenuis	14.28 F
N. viridula	42.85 VF
P. maidis	100.0 VF
T. nigritus	14.28 F
D. balteata	28.57 F
C. guttata	14.28 F
O. aculeatus	57.14 VF
Undetermined species (Scarabaeidae)	71.42 VF
Undetermined species (Curculionidae)	14.28 F
C. formicarius	14.28 F
C. sanguinea	14.28 F
B. decora	57.14 VF
Brachiacantha sp.	28.57 F

Continued

Species	Relative frequency (%)
A. insularis	14.28 F
Pheidole sp.	28.57 F
Polistes sp.	28.57 F
C. fasciatus	14.28 F
G. assimilis	14.28 F
Doru sp.	85.71 VF
A. marmoratus	28.57 F
A. mellifera	42.85 VF
Euxesta sp.	28.57 F

Abbreviations: VF – Very frequent; F – frequent; R – rare. * Very frequent if Rf >30, frequent if $10 \geq Rf \leq 30$, and rare if $Rf < 10$.

The species *S. frugiperda, Z. longipes, Zelus* sp., *N. viridula, P. maidis, O. aculeatus*, and the undetermined beetle species *B. decora*, *Doru* sp., and *A. mellifera* were very frequent. The remaining species were frequent in the crop.

Discussion

According to Blanco Valdes (2016), research focused on establishing coexistent relationships between associated insects and crops is a relatively underexplored topic despite its significant importance for safeguarding economic crops. These authors mention that the diversity of colors and scents attracts entomofauna, benefiting economic crops.

The insect orders with the most detected species associated with maize crops were Coleoptera, Hemiptera, and Hymenoptera. These results align with those obtained by Mirabal *et al.* (2018). When assessing the insects associated with different maize agroecosystems across various San José de las Lajas farms, those authors found that these orders exhibited the highest number of species. The authors pointed out that the orders Coleoptera, Hemiptera, and Hymenoptera showcased the greatest diversity of families and species in maize crops. Merino (2016) reports the orders Coleoptera, Hemiptera, Diptera, Orthoptera, Hymenoptera, and Lepidoptera as the most representative in maize diagnostics, while Blanco and Leyva (2009) identify 7 orders, including Coleoptera, Dermaptera, Diptera, Hymenoptera, Lepidoptera, Orthoptera, and Hemiptera.

Spodoptera frugiperda larvae were found in all the samples taken. Simón and Golik (2018) suggest that the larvae are active day and night, feeding on tender tissues, leaves, and shoots. By the IV instar, they measure 11 to 15 mm and enter the plant's tassel, making their control difficult due to their lack of exposure. So, application or control measures should be conducted up to the third instar of the larvae (Fernández, 2002). Merino (2016) states that damage is inflicted during the initial days of crop development by devouring the plant close to the ground, defoliating it wholly or partially, and sometimes even leading to its death. In the later stages, these insects feed on the tassel and ear's rolled tender leaves, occasionally consuming the grains.

Varón *et al.* (2022) mention that *P. maidis* females primarily lay their eggs on the veins of the flag leaves. Many individuals can also be found in the tassel and areas where water accumulates. The highest incidence of this delphacid occurred from October to March, coinciding with data obtained by Padrón Padrón *et al.* (2008). The fact that *P. maidis* individuals were found isolated rather than in colonies on the leaves could be attributed to the planting season and various natural enemies, notably ladybirds and predatory bugs. This aspect agrees with results obtained by Mirabal *et al.* (2018), who report these natural enemies as regulators of *P. maidis* populations and other phytophagous insects in the crop.

Other hemipterans found were *N. viridula* and *A. andresii* (Hemiptera: Heteroptera). Simón and Golik (2018) point out that the damage caused by stink bugs and squash bugs is inflicted by the adult insects and nymphs from the fourth to fifth instar. In late plantings, more significant damage is typically observed.

In the order Coleoptera, the species *T. nigritus, C. guttata*, and *C. formicarius*, belonging to Chrysomelidae and Brentidae, were detected. These species are phytophagous pests of sweet potato crops, and their presence in the maize crop might be attributed to the preceding crop, which in this case was sweet potato.

Mirabal *et al.* (2018) suggest that the larvae of chrysomelid beetles *D. balteata* and *Cerotoma ruficornis* (Coleoptera: Chrysomelidae) feed on maize plant roots, affecting leaf development. The adults consume foliage and stamens, resulting in semi-empty cobs and reduced productivity.

Adult specimens of a longhorn beetle, morphologically matching the description of *O. aculeatus*, were also captured. This beetle is known to cause damage to plant species. In ordinary language, insects from this family are called borers, longhorn beetles, or sawyers, among other names. In studies conducted by Martins *et al.* (2011), specimens of *O. aculeatus* were found in maize crops at the Federal University of Viçosa, Minas Gerais state, Brazil, during the flowering period; these caused damage to the plant's reproductive parts.

Atta insularis (Hymenoptera: Formicidae) (leaf-cutting ants) is another species found in the crop. These are the primary herbivores in the Neotropics and are responsible for significant defoliation (Molina-Ochoa *et al*., 2004).

Conocephalus fasciatus and *G. assimilis* of the order Orthoptera are insects that impacted this experimental maize crop. However, their population values were low, possibly attributed to the timing of the research (October-January), a period of low rainfall. In this context, Huerta *et al*. (2014) indicate that these species' nymph and adult stages cause severe damage, consuming almost half of their body weight in green forage in a single day. Generally, they invade crops from July to September.

Adult insects of the order Diptera observed in the crop corresponded to those described for the genus *Euxesta* (Diptera: Otitidae), formerly considered secondary pests that cause severe damage to maize (Martos, 1983). The larvae of this dipteran species start by damaging the silks, leading to the emptying of the grains, especially the apical ones. However, the damage can extend to the entire ear. The activity of these larvae also serves as a gateway for saprophytic microorganisms, resulting in product loss and preventing its direct consumption (Rojas Borrel *et al*., 2017).

In studies conducted by Camacho-Báez *et al*. (2012), these flies are sometimes associated with grain rot where some type of pathogen is present; Rojas Borrel *et al*. (2017) found that the damage caused by the fall armyworm *S. frugiperda* can attract these flies.

Camacho-Báez *et al*. (2012), in their study of natural enemies of maize silk flies in Mexico, noted that the pirate bug *O. insidiosus* preys on larvae of these dipterans and is considered promising for use as a biological control agent. It has also been observed that the pirate bug feeds on lepidopteran eggs. Considering this element is of utmost importance given the very scarce number of these flies captured, with only three specimens found. Thus, *O. insidiosus* could have contributed to the natural control of their populations. In this regard, Blanco and Leyva (2009) stated that *O. insidiosus* feeds on silk fly eggs during the autumn-winter agricultural cycle.

Tchao *et al*. (2022) report in a study conducted in maize that the main predator insects belong to four orders and one suborder within Hemiptera, which are Hymenoptera, Hemiptera, Coleoptera, Dermaptera, and the suborder Heteroptera. These results agree with the findings of the present research.

Among the species identified in the studied agroecosystem, assassin bugs, *Zelus* sp., and *Z. longipes*, of the Reduviidae family were found. These are generalist predators that contribute to the natural control of phytophagous insects. These two species stand out as being highly prevalent on cultivated plants. Some prey items for these predators include larvae of lepidopterans, phytophagous mites, and aphids (Ordáz-Silva *et al*., 2014). Cuesta (2011), in a study conducted in Cienfuegos Province, Cuba, report that *Z. longipes* and *Coleomegilla cubensis* Casey play a significant role within maize crops as predators of *S. frugiperda*.

The species from the Nabidae family (unidentified) and the bug *Nesidiocoris tenuis* from the Miridae family detected in the experiment are considered predators by various authors. Species from the Nabidae family prey on and consume aphids, thrips, mites, whiteflies, and small lepidopteran caterpillars in their early stages, among other insects (Romero Sueldo *et al*., 2014).

In the studied agroecosystem, three species from the family Coccinellidae were detected within the order Coleoptera: *C. sanguinea limbifer*, *B. decora*, and *Brachiacantha* sp. This finding is consistent with the results obtained by Mirabal *et al*. (2018). In a national survey conducted in Cuba, Milán Vargas *et al*. (2008) report the presence of 14 genera and 22 species of ladybugs (coccinellids), which are considered widespread biocontrol agents for eggs and early larval instars of insects, especially Hemiptera. Moreover, Gordon (1985) highlights Coccinellidae as the second most represented family of entomophagous insects associated with the corn earworm with 11 species. Carabidae and Reduviidae were the leading families, with 16 species each, collectively accounting for 76.1% of the total biocontrol agents.

Another group of insects in the study were earwigs in the order Dermaptera. These insects are primarily predators of lepidopteran larvae (Jaraleño *et al*., 2020). In maize fields, both nymphs and adult earwigs feed on eggs and larvae of *S. frugiperda*, making them one of the most effective natural controls for *S. frugiperda*. Earwigs can also prey on other insects associated with maize crops, such as *Diatraea saccharalis* Fabricius and *Rhopalosiphum maidis* Fitch, which can serve as alternative prey if the corn earworm population decreases due to the action of these predators or pesticide application (Romero Sueldo *et al*., 2014).

During our research, two species from the order Hymenoptera were detected, one from the family Formicidae, *Pheidole* sp., and another from the family Vespidae, *Polistes* sp. These Hymenoptera species are considered another group

of predators in agricultural systems, and their role is crucial in regulating harmful organisms (Molina-Ochoa *et al*., 2004). An adult of *A. marmoratus*, a tachinid fly (Diptera: Tachinidae) associated with the fall armyworm, was also found. In this regard, Rojas Borrel *et al*. (2017) researched the natural enemies of *S. frugiperda* in maize crops in Ciego de Ávila. They found 9 species of parasitoids from the orders Hymenoptera and Diptera, among which they also included *A. marmoratus*. Molina-Ochoa *et al*. (2004) emphasize *A. marmoratus* as a significant parasitoid for the corn earworm.

Another species found in our research was the honeybee (*A. mellifera*). These hymenopterans are the most important pollinators, especially the domestic honeybee (*A. mellifera*) (Mendoza Betancourt *et al*., 2021). Genaro and Loriga (2018) state that *M. beecheii* and *A. mellifera* are the only two species of social bees living on the island, where they are raised and managed by humans for their products and services in agricultural crop pollination.

Various Cuban and international researchers and authors have reported all the species recorded who have studied pests and beneficial organisms related to maize and bean crops (Mendoza Betancourt *et al*., 2021).

All the species detected in the maize crop were very frequent or frequent, which agrees with the results obtained by Mirabal *et al*. (2018). This element in our population dynamics study plays a significant role in managing harmful and beneficial organisms, as it provides information about their incidence in different crop phenological stages. This information is essential for making decisions regarding their management.

In the case of *S. frugiperda*, the main maize pest, the insect was found to be very frequent, similar to the beneficial species that naturally control it, such *as Doru* sp. This predator is recognized as a highly efficient predator of the corn earworm. These findings correspond to Romero Sueldo *et al*. (2023), who highlight this dermapteran as frequent in untreated maize fields.

Two species from the *Zelus* genus were widespread, consistent with Álvarez Hernández *et al*. (2004). In their study on natural enemies of the lepidopteran *Heliothis virescens* F. in tobacco cultivation across four locations in Villa Clara, they report *Z. longipes* as very frequent.

Conclusion

Several phytophagous insects were detected in the agroecosystem of maize cultivar 'MAIG-Diamante'. Experimental crops and beneficial species contributed to the natural regulation of their populations in agricultural systems. Hence, their conservation and proper management are essential for establishing an agroecological management program for *Spodoptera frugiperda* in maize cultivar 'MAIG-Diamante'.

Conflict of interest statement

The authors declare that there is no conflict of interests regarding the publication of this article.

Author's contributions

YBV, NC, and JVGP designed the experiments. TVM carried out the field research, YBV, JVGP, NC, and ALP conceptualization, research, original draft, visualization, writing, and editing. FAR and OECR contributed to the data analysis. All authors have read and approved the final version of the manuscript.

Literature cited

Álvarez Hernández, U., Gómez Sousa, J., Grillo Ravelo, H., Danta Iglesia, C., & Guzmán Piñero, L. (2004). Enemigos naturales de *Heliothis virescens* (F.) (Lepidoptera: Noctuidae) en la provincia de Villa Clara, Cuba. *Centro Agrícola*, *31*(3-4), 113–114. http://cagricola.uclv.edu.cu/index.php/es/volumen-31-2004/numero-4-2004/732-enemigos-naturales-de-heliothis-virescens-f-lepidoptera-noctuidae-en-la-provincia-de-villa-clara-cuba

Blanco Valdes, Y. (2016). El rol de las arvenses como componente en la biodiversidad de los agroecosistemas. *Cultivos Tropicales*, *37*(4), 34–56. https://ediciones.inca.edu.cu/index.php/ediciones/article/view/1292

Blanco, Y., & Leyva, Á. (2009). Las arvenses y su entomofauna asociada en el cultivo del maíz (*Zea mays* L.) posterior al periodo crítico de competencia. *Cultivos Tropicales*, *30*(1), 11–17. https://ediciones.inca.edu.cu/index.php/ediciones/article/view/138

Camacho-Báez, J. R., García-Gutiérrez, C., Mundo-Ocampo, M., Armenta-Bojorquez, A. D., Nava-Pérez, E., Valenzuela-Hernández, J. I., & González-Guitrón, U. (2012). Enemigos naturales de las moscas de los estigmas del maíz: *Euxesta stigmatias* (Loew), *Chaetopsis massyla* (Walker) y *Eumecosommyia nubila* (Wiedemann) en Guasave Sinaloa, México. *Ra Ximhai*, *8*(3), 71–77. https://dialnet.unirioja.es/descarga/articulo/7865504.pdf

Cave, R. D. (1993). Parasitoides larvales y pupales de *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) en Centro América con una clave para las especies encontradas en

Honduras. *Ceiba*, *34*(1), 33–56. https://bdigital.zamorano.edu/handle/11036/3712

Chura, J., Mendoza-Cortez, J. W., & de la Cruz, J. C. (2019). Dosis y fraccionamiento de nitrógeno en dos densidades de siembra del maíz amarillo duro. *Scientia Agropecuaria*, *10*(2), 241–248. https://doi.org/10.17268/sci.agropecu.2019.02.09

Díaz-Chuquizuta, P., Hidalgo-Meléndez, E., Cabrejo-Sánchez, C., & Valdés Rodríguez, O. A. (2022). Respuesta del maíz (*Zea mays* L.) a la aplicación foliar de abonos orgánicos líquidos. *Chilean Journal of Agricultural & Animal Sciences*, *38*(2), 144–153. https://doi.org/10.29393/chjaa38-14rmpo40014

DGSV-CNRF. (2021). *Gusano cogollero Spodoptera frugiperda (J. E. Smith)* (Lepidoptera: Noctuidae). *Ficha Técnica*. Servicio Nacional de Sanidad, Inocuidad y Calidad Agroalimentaria. Dirección General de Sanidad Vegetal- Centro Nacional de Referencia Fitosanitaria. Tecámac, México. https://www.gob.mx/cms/uploads/attachment/file/635234/Gusano_cogollero_en_ma_z_y_arroz.pdf

Fernández, J. L. (2002). Estimación de umbrales económicos para *Spodoptera frugiperda* J. E. (Smith) (Lepidoptera: Noctuidae) en el cultivo del maíz. *Investigación Agraria. Producción y Protección Vegetales*, *17*(3), 468–472. https://dialnet.unirioja.es/servlet/articulo?codigo=283657

García González, M. T., Rodríguez Coca, L. I., Rodríguez Jáuregui, M. M., & Fernández Cancio, C. Y. (2022). Policultivos para el manejo de *Spodoptera frugiperda* (J Smith) y la entomofauna benéfica asociada en el maíz (*Zea mays* L.). *Revista de la Universidad del Zulia*, *13*(37), 262–276. https://www.produccioncientificaluz.org/index.php/rluz/article/view/38056/42020

Genaro, J. A., & Loriga, W. (2018). *Melipona beecheii* Bennett (Hymenoptera: Apidae): origen, estudios y meliponicultura en Cuba. *Insecta Mundi*, *643*, 1–18. http://digitalcommons.unl.edu/insectamundi/1148

Gigato-Toledo, A., Ferro-Valdés, E. M., & Mirabal-Báez, E. (2018). Consecuencias de la reducción foliar sobre cuatro descriptores del grano de maíz (*Zea mays*, Lin). *Revista Márgenes*, *6*(2), 48–59. https://revistas.uniss.edu.cu/index.php/margenes/article/view/704/665

Gil-Reyes, L., González-García, I., Hernández-González, D., & Álvarez-Guerrero, M. (2020). Extremos climáticos de temperatura y su relación con patrones atmosféricos de teleconexión durante el invierno. *Revista Cubana de Meteorología, 26*(4), 1–11. https://eqrcode.co/a/03yfcN

Gordon, R. D. (1985). The Coccinellidae (Coleoptera) of America north of Mexico. *Journal of the New York Entomological Society*, *93*(1), 1–912. https://www.jstor.org/stable/i25009450

Hernández Jiménez, A., Pérez Jiménez, J. M., Bosch Infante, D., & Castro Speck, N. (2015). *Clasificación de los suelos de Cuba*. Instituto Nacional de Ciencias Agrícolas. Ediciones INCA. https://ediciones.inca.edu.cu/files/libros/clasificacionsuelos-cuba_%202015.pdf

Huerta, A. J., Espinoza, F., Téllez-Jurado, A., Maqueda Gálvez, A. P., & Arana-Cuenca, A. (2014). Control biológico del chapulín en México. *BioTecnología*, *18*(1), 28–49. https://smbb.mx/wp-content/uploads/2017/10/Revista_2014_V18_N1.pdf

Jaraleño-Teniente, J., Lomeli-Flores, J. R., Rodríguez-Leyva, E., Bujanos-Muñiz, R., & Rodríguez-Rodríguez, E. S. (2020). Egg parasitoids survey of *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) in maize and sorghum in Central Mexico. *Insects, 11*(3), Article 157. https://doi.org/10.3390/insects11030157

Martins, E., Moreira, I., Alvarenga, M., Alfredo, J., Pinto, R., & Cola, J. (2011). *Oxymerus aculeatus* (Coleoptera: Cerambycidae) causing damage on corn plants (*Zea mays*) in Brazil. *Revista Colombiana de Entomologia*, *37*(1), 82–83.

Martos, A. (1983). Status de *Euxesta* spp. como plaga y relación de otros insectos de las mazorcas del maíz. *Revista Peruana de Entolomogía*, *26*(1), 41–45. https://sisbib.unmsm.edu.pe/BVRevistas/entomologia/v26/contenido.htm

Masson, S. F., & Bryant, R. J. (1974). The structure and diversity of the animal communities in a broadland reedswamp. *Journal of Zoology*, *172*(3), 289–302. https://doi.org/10.1111/j.1469-7998.1974.tb04106.x

Mendoza Betancourt, E. O., Vargas Batis, B., Quiala, Plana Quiala, A., Ranos García, Y. M., Cobas Magdariaga, Manuel, & Martínez González, R. (2021). Diversidad de insectos benéficos asociada a la flora existente en fincas suburbanas en Santiago de Cuba, Cuba. *Revista Chilena de Entomología*, *47*(1), 121–145. https://doi.org/10.35249/rche.47.1.21.13

Merino Cisneros, F. L. (2016). Sistema experto para diagnóstico de plagas insectiles de maíz (*Zea mays* L.) en Centro América. *Agronomía Mesoamericana*, *2*, 80–88. https://doi.org/10.15517/am.v2i0.25232

Milán Vargas, O., Cueto Zaldívar, N., Hernández Pérez, N., Ramos Torres, T., Pineda Duvergel, M., Granda Sánchez, R., Peñas Rodríguez, M., Díaz del Pino, J., Caballero Figueroa, S., Essen Campbell, I., Corona Santos, T., Rodríguez Ramírez, L. A., de Armas Garola, J. L., Montalvo Guerrero, J. M., & Delís Hechavarría, E. (2008). Prospección de los coccinélidos benéficos asociados a plagas y cultivos en Cuba. *Fitosanidad*, *12*(2), 71–78. https://www.redalyc.org/articulo.oa?id=209115682001

MINAG. (2013). *Guía técnica para el cultivo del maíz*. Instituto de Investigaciones de Granos, La Habana, Cuba: Agroecológica.

Mirabal, L., Crisanto R., Gómez, J., Pérez, N., Castillo, N., González, C., & Amador, A. (2018). Entomofauna asociada a un agroecosistema de *Zea mays* L., en San José de las Lajas, Mayabeque, Cuba. *Boletín de la Sociedad Entomológica Aragonesa*, (62), 259–264. https://dialnet.unirioja.es/servlet/articulo?codigo=7975999

Molina-Ochoa, J., Carpenter, J. E., Lezama-Gutiérrez, R., Foster, J. E., González-Ramirez, M., Angel-Sahagún, C. A., & Farías-Larios, J. (2004). Natural distribution of hymenopteran parasitoids of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) larvae in Mexico. *Florida Entomologist*, *87*(4), 461–472. https://doi.org/10.1653/0015-4040(2004)087[0461:NDOHPO]2.0.CO;2

MRI (Programa Manejo de Resistencia de Insectos). (2019). Cogollero (*Spodoptera frugiperda*) en el cultivo de maíz. Bases para su manejo y control en sistemas de producción. *Aapresid*, *10*, 4–24. https://issuu.com/aapresid/docs/cogollerorem_final

Nájera Rincón, M. B., & Souza, B. (2010). *Insectos benéficos. Guía para su identificación*. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias, México. https://www.ciaorganico.net/documypublic/551_INSECTOS_BENEFICOS_Guia_(2).pdf

Ordáz-Silva, S., Chacón-Hernández, J. C., Hernández-Juárez, A., Cepeda-Siller, M., Gallegos-Morales, G., & Landeros-Flores, J.

(2014). Depredación de *Pselliopus latispina* Hussey (Hemiptera: Reduviidae) sobre *Tetranychus urticae* Koch (Acari: Tetranychidae). *Acta Zoológica Mexicana*, *30*(3), 500–507. https://doi.org/10.21829/azm.2014.30374

Padrón Padrón, W. R., Marín Hautrive, L. R., & Yero Mosquera, Y. (2008). Ecología de *Peregrinus maidis* Ashm. en plantaciones de maíz; localidad de Potrerillo, municipio de Cruces, Cienfuegos. *Centro Agrícola, 35*(2), 59–64. http://cagricola.uclv.edu.cu/descargas/pdf/V35-Numero_2/cag112081608.pdf

Paneque, V. M., Calaña, J. M., Calderón, M., Borges, Y., Hernández, T., & Caruncho, M. (2010). *Manual de técnicas analíticas para análisis de suelo, foliar, abonos orgánicos y fertilizantes químicos*. Instituto Nacional de Ciencias Agrícolas. https://studylib.es/doc/7492787/manual-de-t%C3%A9cnicas-anal%C3%ADticas-para-an%C3%A1lisis-de-suelo--foliar#google_vignette

Rodríguez-Soto, J. C., Salazar Castillo, M. L., & Contreras Quiñones, M. (2018). Efecto de diferentes surfactantes sobre larvas III de *Spodoptera frugiperda* Smith bajo condiciones de laboratorio y de campo. *Arnaldoa*, *25*(3), 1041–1052. https://doi.org/10.22497/arnaldoa.253.25315

Rojas Borrel, Y., Iparraguirre Cruz, M., & Rodríguez, D. (2017). Enemigos naturales de *Spodoptera frugiperda* en el cultivo del maíz en Ciego de Ávila. *Universidad & Ciencia*, *6*(2), 27–41. https://revistas.unica.cu/index.php/uciencia/article/view/427

Romero Sueldo, M., Dode, M., & Virla, E. G. (2014). Depredación de *Doru luteipes* y *D. lineare* (Dermaptera: Forficulidae) sobre *Rhopalosiphum maidis* (Hemiptera: Aphididae) en condiciones de laboratorio. *Acta Zoológica Lilloana*, *58*(1), 73–79. https://ri.conicet.gov.ar/bitstream/handle/11336/17140/CONICET_Digital_Nro.5639_A.pdf?sequence=2

Romero Sueldo, G. M., Virla, E. G., Contarini, M., Van NIeuwenhove, G. A., & Speranza, S (2023). Evaluación de la efectividad de *Doru lineare* (Dermaptera: Forficulidae) contra *Spodoptera frugiperda* (Lepidoptera: Noctuidae) y su potencial protección de plántulas de maíz. *Revista de la Sociedad Entomológica Argentina*, *82*(2), 46–53. https://doi.org/10.25085/rsea.820206

Simón, M. R., & Golik, S. I. (Eds.) (2018). *Cereales de verano*. Facultad de Ciencias Agrarias y Forestales. Universidad Nacional de La Plata, Argentina. https://ri.conicet.gov.ar/bitstream/handle/11336/133607/CONICET_Digital_Nro.ac0248c9-411a-4ca1-a013-49a527b60484_K.pdf?sequence=5&isAllowed=y

Tchao, M., Tounou, A. K., Agboka, K., Tchein, G., Matotiloa, T., Gnamkoulamba, A., & Sanda, K. (2022). Literature review on the natural enemies of *Spodoptera frugiperda* J. E. (Smith) (Lepidoptera: Noctuidae) and the effectiveness of their use in the management of this pest in corn (*Zea mays* L.). *International Journal of Multidisciplinary Research and Analysis*, *5*(7), 1591–1601. https://doi.org/10.47191/ijmra/v5-i7-01

Varón de Agudelo, F., Rodríguez Chalarca, J., Villalobos Saa, J. C., & Parody Restrepo, J. (2022). *Manual de enfermedades y plagas del maíz*. Dubai: Advanta Seed International. https://hdl.handle.net/10568/119166