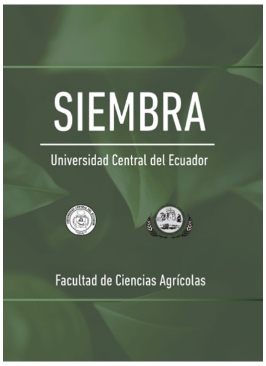
Prospecting of coccinelides associated with maize cultivation (Zea mays L.)

Prospección de los coccinélidos asociados al cultivo de maíz (Zea mays L.)



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Abstract

Maize is considered the third most important grain crop in the world due to its economic, food and industrial interest. Throughout its phenology this crop is attacked by pests and diseases, which could have adverse effects on production. In order to control these problems, conventional management is generally used, causing ecological imbalances. For this reason, it is necessary to consider sustainable alternatives based on the knowledge of beneficial entomofauna. This research aimed to conduct a prospective analysis of the coccinelides associated with maize cultivation in the canton of Santa Ana, Ecuador. For this purpose, the coccinelides present under two different conditions were evaluated; with and without insecticide application. Five sampling techniques were used according to the research protocol and taxonomic classification was carried out. The data were interpreted using descriptive statistics, in addition, alpha and beta diversity was assessed. In the study, 297 individuals were found, gathered to: 1 order,1 family, 13 genera and 11 species. The greatest abundance was found in undisturbed conditions, determining that the most efficient trapping technique for their capture was the use of chromatic traps. This type of research is important to derive biological control programs in economically important crops.

Keywords: control, conventional, diversity, entomofauna, traps.

Resumen

El maíz es considerado el tercer cultivo de grano más importante del mundo debido a su interés económico, alimentario e industrial. A lo largo de su fenología este cultivo es atacado por plagas y enfermedades, que pueden generar efectos adversos sobre la producción. Para el control de estos problemas, generalmente se acude al manejo convencional, los cuales ocasionan desequilibrios ecológicos. Por esta razón, es necesario considerar alternativas sostenibles fundamentadas en el conocimiento de la entomofauna benéfica. Esta investigación tuvo por objetivo realizar un análisis prospectivo de los coccinélidos asociados al cultivo de maíz en el cantón Santa Ana, Ecuador. Para su efecto, se evaluaron los coccinélidos presentes en dos condiciones distintas: con y sin aplicación de insecticida. Se utilizaron cinco técnicas de muestreo, de acuerdo con el protocolo de investigación, y se procedió con la clasificación taxonómica. Los datos fueron interpretados mediante estadística descriptiva; además, se valoró la diversidad alfa y beta. En el estudio se encontraron 297 individuos, congregados a: 1 orden,1 familia, 13 géneros y 11 especies. La mayor abundancia se presentó en condiciones no intervenidas, determinándose que la técnica de trampeo más eficiente para su captura fueron las trampas cromáticas. Este tipo de investigación es importante para derivar programas de control biológico en cultivos de importancia económica.

Palabras clave: control, convencional, diversidad, entomofauna, trampas.

1. Introduction

Maize (*Zea mays* L.) represents the most important grain crop in the world, due to its contributions in several contexts: food, economic, social and environmental, i.e., it is part of the human and animal diet, it generates economic income, it is the basis for the production of industrial by-products, and it creates jobs for many families that depend on this crop, improving their quality of life and also contributes to the production of biofuels (Tanumihardjo et al., 2020; Erenstein et al., 2022).

According to the FAO database, in 2021 world production of maize was estimated at 1,210,235,135 tons, being the United States and China the main producing countries (FAOSTAT, 2023). In Ecuador, the harvested area was 366,138 ha with a production of 1,699,369 tn, with Los Ríos, Manabí and Guayas as the main producing provinces at the national level (Instituto Nacional de Estadística y Censos [INEC], 2023).

Throughout its cycle, this graminacea can be affected by pests and diseases that damage different organs of the plant, which could cause yield losses close to 30 %; in this sense, more than 70 species of insect pests associated with maize have been reported; however, six species are economically important (Hernández-Trejo et al., 2019). In order to reduce their incidence, chemical insecticides are mainly used (Barreto Carbajal et al., 2022), without considering that their indiscriminate use can affect the health of farmers and consumers, as shown by previous studies in Ecuador (Fernández Aravena, 2021; Vargas Sunta & Moyano Calero, 2022). Additionally, they cause ecological imbalances in some agricultural pests, resulting -among others-, in substantial increase in pest population, as well as resistance problems (Zelaya-Molina et al., 2022).

Nature offers biological alternatives based on natural enemies which are used in biological control programs and are validated as a profitable, and sustainable strategy (Corrales Paredes, 2021). In this context, within the group of insects with recognized bioregulatory activity are the coccinellids, noted for their predatory activity on many agricultural pests in economically important crops (Cevallos Cevallos et al., 2021; Taranto et al., 2022).

Some of the research advances as to biological control have been developed in crops such as: sweet chili (Rocca et al., 2021), cabbage (Askar, 2021), nopal (Ascencio Contreras, 2021), cotton (Geethu et al., 2022), soybean (Gesraha & Ebeid, 2022) and others (Rondoni et al., 2021).

In Ecuador, biological control studies have been very limited, especially in the maize crop, which is why deeper knowledge of natural enemies is necessary; within this context, particularly, as to coccinellid predators. The objective of this research was to carry out a prospective analysis of coccinellids associated with maize cultivation in the Santa Ana canton, Manabi province, Ecuador.

2. Materials and Methods

2.1 Location and characterization of the study site

This research was conducted at the end of the dry season of 2015-2016, on the premises of the Faculty of Agricultural Engineering at Technical University of Manabi [UTM], Lodana parish, Santa Ana canton, province of Manabi (Ecuador), located at 01°09’51’’S latitude and 80°23’24’’W longitude, with an altitude of 60 m a.s.l.

2.2 Evaluation of coccinellids associated with the maize crop

The chosen study area was 2,000 m^2, and we used seeds of white maize variety INIAP-528 with a planting density equivalent to 40,000 plants ha^{-1}. The lot was then divided into two plots, one of which was subjected to chemical treatment.

During the slow growth phase (25 das), high populations of leafhopper (*Dalbulus maidis* DeLong) emerged, these were controlled with CETAMISEN® SP insecticide (Acetamiprid 250 g i.a kg^{-1}), 15 g of commercial product diluted in 20 L of water were applied at early morning (7:30 am) on a single occasion.

The use of other insecticides was not required as –after the first treatment- very low populations of the plague remained and did not exceed the economic threshold, with the only exception of *D. maidis*, whose threshold was higher than 0.7 individuals, according to the average established by Anasac (2023).

The insects collected were adults, and five sampling techniques were used: yellow traps, suction traps, roundup, light traps and pitfall traps. In each study plot we placed five 0.76 m x 1.25 m yellow traps, permanently located at five different points on the field (“X”), and avoiding the edge effect. Vegetable grease was placed on each trap to allow the insects to adhere.

The suction traps consisted of 12 cm x 4.5 cm plastic bottle-shaped collectors, whose upper end was provided with two tubes; one short measuring 26 cm x 0.5 cm (obstructed with mesh), and one long measuring 36.5 cm x 0.5 cm, which allowed suctioning and capture of the insect, even when located in places of difficult access on the plant. Each plot was sampled by zigzag walking, considering 5 plants per sampling site, so that 25 plants were evaluated in each plot.

Sampling was carried out using an entomological net; the tool was provided with a metal handle and a very fine mesh to trap the arthropods. Ten rows of plants were evaluated by making movements in the shape of an “8”. This type of evaluation was carried out from 15 days after crop (emergence) until the slow growth stage (4^{th} week), in order to avoid possible mechanical damage.

Light traps measuring 15 cm x 10 cm were used in each study plot. The trap was placed in the center, and it was provided with a 1.2 v 800 mAh photocell charged with solar energy during the day, and projecting ultraviolet light at night; additionally, it had a short wire coating that emitted light electricity discharges. A metal cone measuring 35 cm in length, with upper and lower openings of 28 and 7 cm respectively, was then attached to a container (14 cm x 7.5 cm) that served as a “water reservoir”, and was used to trap the insects.

The pitfall traps consisted of polyethylene containers (bottles) with their upper end inverted in the form of a cone, five units were used for each plot. We made 14 cm x 7.5 cm holes in the ground (the size of the trap) to place the traps at surface level, and put 300 mL of natural attractant (stock solution consisting of 2,700 mL of water, and 300 mL of molasses) in each trap. The mixture was renewed every week of sampling.

The evaluation and collection of the samples corresponding to each trapping method was carried out every 7 days and at a specific time (7:30 a.m.), during eight consecutive weeks. Subsequently, samples were moved to a suitable physical space to be stripped of impurities, separated from other arthropods that were not object of research, and preserved in 90 % alcohol. Finally, they were mounted and placed in their respective entomological boxes.

The information obtained weekly was recorded in a matrix, the values of each collection date were summed for each study plot at the end of the week; then, the respective formulas were applied as described below.

2.3 Taxonomic classification

The insects were taxonomically classified at the Entomology Laboratory-UTM. Bibliographic materials from the authors; Iannacone and Perla (2011), Leeper (2016), and Bustamante-Navarrete (2020) were used to facilitate the study. Databases such as; Centro de Biociencia Agrícola Internacional (CABI, 2021), the Invertebrate Collection of the Museo de Zoología QCAZ of the Pontificia Universidad Católica del Ecuador (PUCE, 2021) and the Insect Collection of the Museo de Entomología of the Universidad del Valle (Posso Gomez, 2013). Synoptic collections available on the website “Coccinellidae del Ecuador” (González, 2015) were also used. The samples were corroborated by the Universidad Nacional Agraria La Molina of Peru.

2.4 Data analysis

The data were analyzed using descriptive statistics and alpha and beta diversity indices were calculated.

To determine the number of individuals, their relative abundance and percentage estimates, first, we calculated the sum of each of the species present in each study plot, then the relative abundance [RA] was calculated by dividing the value obtained (corresponding to the individuals of each species) by the total number of individuals of all the species in the study plot multiplied by 100 (equation [1]). Percentage estimates were also obtained for all species recorded in the area to achieve a generalized visualization.

$$AR = {}^{n}/_{N} * 100 \quad [1]$$

The Margalef richness index [DMg] was calculated using equation [2]. Where *S* represents the number of species found, *ln* the natural logarithm and *N* the total number of individuals present at the site.

$$DMg = \frac{(S-1)}{\ln(N)} \quad [2]$$

Simpson's 1-D (dominance) index [λ] was calculated using equation [3]. Where ∑ represents the summation of individuals, *pi* the number of individuals of species "*i*" divided by the total number of individuals in the sample ($pi = {}^{ni}/_{N}$).

$$\lambda = \sum pi^2 \quad [3]$$

The Shannon-Wiener Index [H'] was calculated using equation [4]. Where *pi* corresponds to the relative abundance, which consists of the division of the number of individuals of each species by the total number of individuals of all species in the study plot multiplied by 100; while ln represents the natural logarithm and ∑ the summation.

$$H' = \sum_{i=1}^{S} \rho_i ln(\rho_i) \quad [4]$$

The Pielou equitability index [J] was calculated using equation [5]. Where *H' max = ln(S)*, i.e., *H'* corresponds to the Shannon-Wiener Index, *H'max* represents the maximum expected diversity, ln is the natural logarithm and S is the number of species found.

$$J = \frac{H'}{H'max.} \quad [5]$$

The Jaccard index [JI] was calculated using equation [6]. Where *A* represents the number of species present at site *A*; *B* the number of species present at site *B* and *C* the number of common species present at both sites *A* and *B*.

$$JI(\%) = \frac{C}{A+B-C} x\ 100 \quad [6]$$

Sorensen's Index [SI] was calculated using equation [7]. Where *A* represents the number of species found in community *A*; *B* the number of species found in community *B* and *C* the number of common species in both localities *A* and *B*.

$$SI = \frac{2\,C}{A+B} x\ 100 \quad [7]$$

3. Results and Discussion

We found 297 individuals (Coleoptera: Coccinellidae) distributed in 5 subfamilies (Coccinellinae, Coccidulinae, Epilachninae, Ortaliinae and Scymninae) with 13 genera and 15 species (Figure 1). The highest abundance corresponds to the following species: *Cheilomenes sexmaculata* Fabricius with 93 individuals (31.31 %), followed by Hyperaspis festiva Mulsant with 63 (21.21 %) and *Cycloneda sanguinea* Linnaeus with 36 individuals (12.12 %) (Table 1).

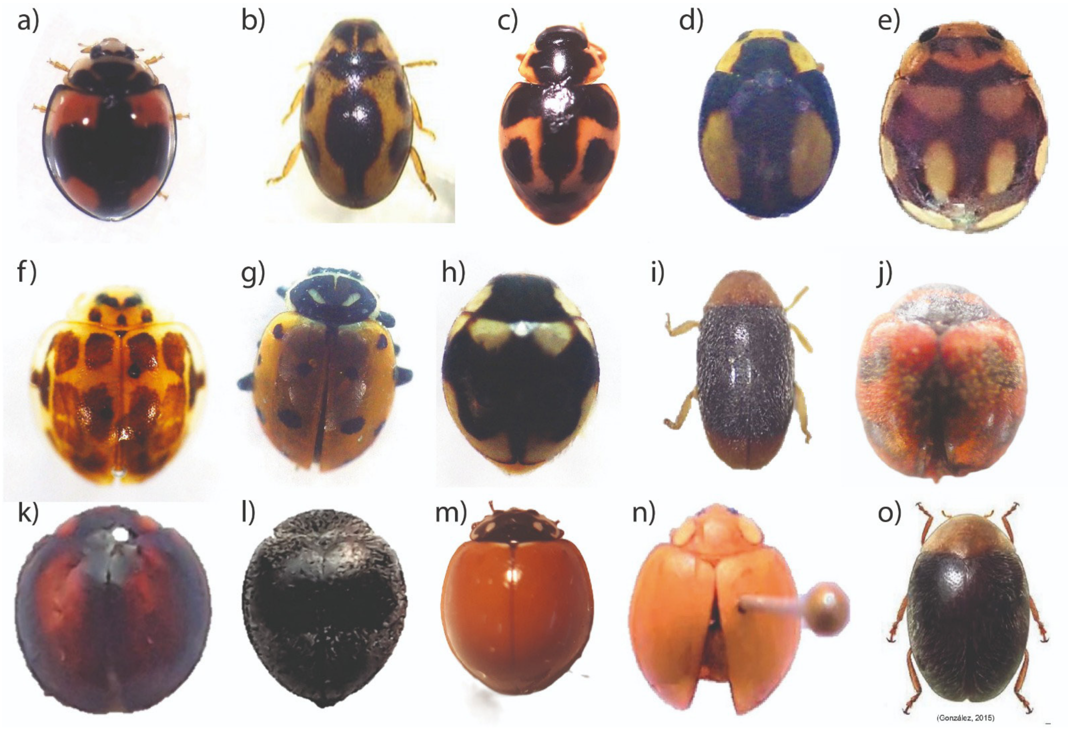

Figure 1. a) *Cheilomenes sexmaculata*. b) *Hyperaspis onerata*. c) *Hyperaspis festiva*. d) *Hyperaspis esmeraldas*. e) *Cyrea alma*. f) *Psyllobora confluens*. g) *Hippodamia convergens*. h) *Tenuisvalvae bromelicola*. i) *Diomus apollonia*. j) *Rodolia cardinalis*. k) *Mada synemia*. l) *Azya orbigera ecuadorica*. m) *Cycloneda sanguinea*. n) *Paraneda pallidula guticollis*. o) *Scymnus cerinotum.*

Table 1. Number of individuals, relative abundance and percentage estimation of coccinellids associated with maize crop, at the "La Teodomira" experimental campus, Santa Ana, Ecuador.

Subfamily	Species	N.° individuals*			Relative Abundance (%)*		
		NI	WI	Total	SI	CI	Total
	Cheilomenes sexmaculata Fabricius	64	29	93	31,37	31,18	31,31
	Hippodamia convergens Guérin-Méneville	15	3	18	7,35	3,23	6,06
Coccinellinae	*Psyllobora confluens* Fabricius	5	2	7	2,45	2,15	2,36
	Cycloneda sanguinea Linnaeus	26	10	36	12,75	10,75	12,12
	Paraneda pallidula guticollis Mulsant	1	1	2	0,49	1,08	0,67
Coccidulinae	*Azya orbigera ecuadorica* Gordon	0	1	1	0,00	1,08	0,34
Epilachninae	*Mada synemia* Gordon	7	6	13	3,43	6,45	4,38
Ortaliinae	*Rodolia cardinalis* Mulsant	1	0	1	0,49	0,00	0,34
	Tenuisvalvae bromelicola Sicard	14	8	22	6,86	8,60	7,41
	Hyperaspis onerata Mulsant	3	3	6	1,47	3,23	2,02
	Hyperaspis esmeraldas Gordon y González	2	0	2	0,98	0,00	0,67
Scymninae	*Hyperaspis festiva* Mulsant	38	25	63	18,63	26,88	21,21
	Scymnus cerinotum Gordon	11	2	13	5,39	2,15	4,38
	Cyrea alma Gordon & Canepari	16	3	19	7,84	3,23	6,40
	Diomus apollonia Gordon	1	0	1	0,49	0,00	0,34
	Summation	**204**	**93**	**297**	**100**	**100**	**100**

* NI: Without insecticide application; WI: With insecticide application.

In the plot without insecticide application [NI], 204 individuals were observed, distributed in 12 genera and 14 species, *Ch. sexmaculata* with 64 individuals (31.37 %), *H. festiva* with 38 (18.63 %) and *C. sanguinea* with 26 individuals (12.75 %) (Table 1). In the insecticide-applied [WI] plot, 93 individuals, 11 genera and 12 species were found, with *Ch. sexmaculata* standing out with 29 individuals (31.18 %), *H. festiva* with 25 (26.88 %) and *C. sanguinea* with 10 individuals (10.75 %) (Table 1).

The results showed lower abundance of coccinellids in the plot treated with insecticide. Cardoso De Sousa et al. (2021) and Skouras et al. (2022) argue that the family Coccinellidae is strictly affected by agrochemical applications, which threaten the survival of these generalist predators. In this sense, ladybugs are exposed to insecticides by three different ways; direct contact with treated surfaces, ingestion of contaminated prey and by residual contact, to which larvae and eggs can be persistently exposed. Corresponding to the above, there are some studies detailed below that argue the toxicity of insecticides with respect to this type of biological controller:

Cheng et al. (2022) determined the toxicity and risk assessment of nine pesticides on natural, non-target predators of *Harmonia axyridis*, using seven insecticides (imidacloprid, dinotefuran, thiamethoxam, acetamiprid, bifenthrin, dimethoate and emamectin benzoate), and two fungicides (tebuconazole and myclobutanil). The study found that almost all the insecticides used represented high mortality risk for the coccinellid, with the exception of emamectin benzoate and the two fungicides, which reported lower risk for the predator.

Dai et al. (2021) evaluated the transgenerational effects of imidacloprid and the insecticide sulfoximine on the larch ladybug (*H. axyridis*). The results showed that hatching, survival and larval emergence rates were significantly decreased, and the egg and instar stages of the F1 generation could apparently be prolonged when their parental F0 generation was exposed to those insecticides at concentrations of LC 20 and LC 50. Therefore, it suggests that they should be used with caution in IPM programs against *A. gossypii*, otherwise, the ecological service and efficacy of harlequin ladybugs will be reduced.

Similar results were obtained by Pavithrakumar et al. (2022) who evaluated the toxicity of some insecticides on the stages of *Ch. sexmaculata* under laboratory conditions. In acute toxicity bioassays, conducted at recommended field doses, showed that dimethoate was harmful to all life stages with 100 % mortality. Thiamethoxam was also found to be safe up to the egg stage; however, it was harmful to larvae, pupae and adults. While neem oil was harmful to non-feeding stages (eggs and pupae), completely inhibiting egg hatching and adult emergence; furthermore, it was harmless or slightly harmful to feeding stages. On the other hand, it was found that flubendiamide and spinosad presented a mortality > 10 % in eggs, larvae and pupae and 12.5 % for adults. There are also other contributions where the effect of insecticides is evaluated, whose purpose is to ensure those that can have greater pest control and less impact on beneficial insects, in this context, it is supported by the research developed by Barbosa et al. (2018), da Silva et al. (2022), Skouras et al. (2022) and You et al. (2022).

In relation to the species highlighted in the study (*Ch. sexmaculata*, *H. festiva* and *C. sanguinea*), it was attributed that they could be favored by the environmental conditions of the site, such as: average annual temperature of 27.7 °C, accumulated annual rainfall of 544 mm and relative humidity ranging between 70-80 %. Another important factor is the surrounding vegetation, for example, short-cycle crops (solanaceae and legumes), perennial crops such as cocoa and citrus, it was also common to find weeds as main hosts of aphids and whiteflies, constituting prey to ensure the survival and abundance of coccinellids. The results of this research coincide with the studies conducted by Sruthi et al. (2021), Martínez Chiguachi (2018) and Erráez Aguilera et al. (2020), who reported higher abundance of these species in varied crops (eggplant, cowpea, chili bell pepper, citrus and other crops).

3.1 Alpha and beta diversity

The Margalef index focuses on the richness of species found in a given population. In each plot, values corresponding to 2.44 (NI) and 2.43 (WI) were obtained with 14 and 12 species, respectively. According to Duarte-Goyes et al. (2019), these values fall within the ranges 2 and 2.7, interpreted as agroecosystems of medium diversity. Martínez Chiguachi (2018) argues that this condition is attributed to anthropogenic factors, such as pesticide applications, lack of rotation, associated crops, etc.

Simpson's index allows to know the probability that two individuals of a community sample belong to the same species (Wu et al., 2022). The values found in this research (0.82 NI and 0.80 WI), suggest high diversity and indicate low dominance (0.17 NI and 0.19 WI), being an inversely proportional index according to the scale mentioned by Kunda et al. (2022), whose interpretation range varies between 0 and 1. Similar studies have been found with the work done by Cisneros Puma (2021), who evaluated the diversity and abundance of coccinellids associated with alfalfa and maize crops in the province of Arequipa (Peru), and found a greater dominance of species in both crops during the rainy season in relation to the dry season, a condition attributed mainly to climatic factors. Opposite results have been obtained with the research of Cuello Catalán (2022) who studied the interannual variation of native and exotic coccinellids in the last decade, and their relationship with climate change in the metropolitan region of Santiago, Chile. He found greater diversity during 2010 and 2011; however, in 2012 to 2021, significantly low levels of diversity were observed, due to climate change, which threatens biodiversity, together with pollution, habitat destruction, biological invasions, and other anthropogenic factors.

The Shannon-Wiener index, based on species richness and proportional abundance, reported calculated values of 2.06 (NI) and 1.94 (WI) in the studied plots, which are within the ranges between 1.5 and 3.5 according to that proposed by Kunda et al. (2022), who associate it with agroecosystems of medium diversity. This information agrees with the research developed by Rasheed and Buhroo (2018), who studied the diversity of coccinellid beetles in three districts of southern Kashmir, India, demonstrating values of 2.29, 2.30 and 2.33, determining agroecosystems of medium diversity among the sites studied.

The Pielou index showed an equitable behavior of the species present in the research, with results of 0.78 for each plot studied (Table 2), which was within the range referred to by Kunda et al. (2022), who suggest a scale ranging from 0 to 1, with results close to 1 indicating equitable communities.

Table 2. Alpha and beta diversity of coccinellids associated with maize crop, at the "La Teodomira" experimental campus, Santa Ana, Ecuador.

Parameters	Plots*	
	NI	WI
Total number of individuals (N)	204	93
Total number of species (S)	14	12
Margalef index	2,44	2,43
Shannon index	2,06	1,94
Simpson's diversity	0,82	0,80
Simpson's dominance	0,17	0,19
Pielou index	0,78	0,78
Jaccard index (%)		73,33
Sorensen index (%)		84,62

* NI: Without insecticide application; WI: With insecticide application.

Regarding the similarity indexes of Jaccard and Sorensen, they showed that in both plots there is high similarity of species found, reporting values of 73.33% (JI) and 84.62% (SI), Ramirez et al. (2015) argue that values close to 1 indicate high similarity. This research coincides with the study developed by Cisneros Puma (2021), who found high similarity of coccinellids in the alfalfa crop, reporting values of 78 and 88 % using the Jaccard and Sorensen index, respectively, in the localities of Cayma and Polobaya, Peru (dry season), while in the rainy season they reached values of 45 % (JI) and 63 % (SI).

3.2 Abundance of coccinellids according to sampling techniques

It was determined that the sampling technique that captured the greatest number of coccinellids were the chromatic traps (yellow), with a total of 275 individuals, followed by the suction trap and the roundup. These are important strategies for monitoring arthropods; however, their efficiency will depend on the type of arthropod to be captured, type of trap, color to be used, height, type of crop, among others. Ikemoto et al. (2021) evaluated the efficiency of different types of traps for attracting three Orders of insects (Hymenoptera, Diptera and Coleoptera), and found that the highest abundance of Coleoptera was in yellow sticky traps, proving high effectiveness; in this sense, insect reactions to color are generated by their visual systems, and ecological characteristics such as habitat and food. Phytophagous insects and their predators or parasitoids are generally attracted to yellow color, probably because this color represents an outstanding stimulus related to foliage.

On the other hand, Mahalakshmi et al. (2022) state that yellow sticky traps can be beneficial for capturing pests, but detrimental to non-target insects, such as coccinellids, which is why they should be used with caution, except in the case of implementing this technique as a measure to generate more ecological knowledge about predatory species (Table 3).

Table 3. Traps used to capture coccinellids associated with maize crop, at the "La Teodomira" experimental campus, Santa Ana, Ecuador.

Traps	NI*	WI*	Total
Yellow Stickers	195	80	275
Raid	1	7	7
Suction	8	6	14
Pitfall	0	0	0
Light	0	0	0
Summation	**204**	**93**	**297**

* NI: Without insecticide application; WI: With insecticide application.

3.3 Biological aspects of the principal coccinellids recorded in the survey

According to Merlin et al. (2022), the feeding and reproductive potential of predators is influenced by plants due to the direct effect on the quality of their prey and also by environmental conditions, which influence their life cycle, representing a determining factor for their mass breeding. Rodríguez et al. (2019) report that the biological and reproductive parameters of natural enemies are important attributes, that provide guidelines to be considered within biological control programs. Some aspects related to the life cycle of the main species highlighted in the study are mentioned below:

3.3.1 *Cheilomenes sexmaculata*

Ashwini and Shukla (2022) evaluated the life cycle of *Ch. sexmaculata* fed with the aphid *Aphis craccivora* (Koch) under laboratory conditions at 27.18 ± 1.45 **°C** and 49.80 ± 7.64 % relative humidity. The results revealed that the mean incubation period of the said predator was 1.64±0.72 days, the mean hatching percentage of eggs was 89.25±3.97 %, the mean duration of the first, second, third and fourth larval instar was 1.26±0.44; 1.68±0.59; 2.28±0.54 and 2.44±0.61 days, respectively. The total larval period was 7.66±1.61 days. The mean prepupal and pupal period was 1.04±0.20 and 2.18±0.48 days, independently. The mean adult emergence percentage was 89.48±4.44 % with a sex ratio of 1:1.40. Mean pre-oviposition, oviposition and post-oviposition were 3.48±0.77, 16.40±1.29 and 3.00±0.87 days, respectively. The fecundity of a gravid female was 363.32±76.32 eggs. Longevity in adult males and females was 17.12±1.44 days and 22.54±2.38 days, respectively. The total life expectancy of males was 29.64±2.59 while that of females was 35.06±3.17 days.

There are other contributions such as that of Abbas et al. (2020) who evaluated the biological cycle of *C. sexmaculata* under controlled conditions (25 ± 2 ºC and 60 ± 5 % relative humidity), which was fed with four aphid species (*Lipaphis erysimi* Kaltenbach, *Myzus persicae* Sulzer, *Aphis nerii* Boyer de Fonscolombe and *Diuraphis noxia* Mordvilko) and found that the most appropriate host for coccinellid feeding was *D. noxia*. In this context, he detailed the information obtained about biological and reproductive parameters: the duration of the egg stage was 3.30±0.16 days; the first instar was 1.00±2.19 days; the second instar was 1.10±0.7 days; the third instar was 1.47±1.12 days; the fourth instar was 2.47±0.12 days; the pupa had a duration of 2.65±3.48 days; the egg to adult stage was 12.42±0.35 days; the longevity of the male and female was 26.33±2.19 and 28.00±0.83 days, respectively; the pre-oviposition, oviposition and post-oviposition were 5.33±1.33, 14.70±1.33 and 7.33±1.70 days, independently, and the fecundity reached 316.80±25.07 eggs per female.

3.3.2 Hyperaspis spp.

Ascencio Contreras (2021) established the mean duration of the biological stages of four coccinellids fed with adult females of the wild grana (*Dactylopius opuntiae* Cockerell). The biological parameters of *Hyperaspis trifurcata* Schaeffer were evaluated under controlled conditions (28 ± 2 °C and 50 % relative humidity), resulting in the following data: egg stage (5.41 days), larva I-IV (16.48 days), pre-pupa (1.33 days), pupa (7 days), adult (39.5 days).

3.3.3 Cycloneda sanguinea

Rodríguez et al. (2019) evaluated the biological aspects and population parameters of *C. sanguinea* fed on the *Aphis aurantii* Boyer aphid from Fonscolombe, recording at the laboratory level (25 ± 2 °C and 70 ± 10 % relative humidity) the following longevity; the egg stage reached 3.78 days, larval development I-IV 10.34 days, pre-pupa 1.74 days, pupa 3.46 days, adult males and females 58.37 and 61.71 days, respectively, pre-oviposition took 3.9 days, where each female laid 882.2 eggs throughout her life, reaching an oviposition rate of 34.6 eggs/female/day. The average duration of the egg-adult phase was 19.32 days.

Santos-Cividanes et al. (2022) evaluated the survival and fecundity of *C. sanguinea* fed the green bug *Schizaphis graminum* Rondani under controlled conditions (25 ± 1 °C and 70 ± 10 % relative humidity), and determined that females laid eggs between 3-4 days after adulthood, the oviposition period extended from day 18 to day 105 and reached its peak on day 24 with a total of 17.6 eggs per female. As a consequence, the survival rate of adults gradually decreased from day 33, reaching maximum survival at day 92.

Rodríguez-Palomera et al. (2015) argue that biological and reproductive parameters may vary depending on the type of food to which coccinellids are exposed, together with environmental factors, which implies that their life cycle could be lengthened, or shortened. Islam et al. (2022), and Su et al. (2023) argue that when the food ingested is scarce or of lower quality, development time usually increases, while the reproductive rate decreases.

4. Conclusions

We determined that beneficial insects from the Coccinellidae family are sensitive to the application of agrochemicals, having an impact on their abundance and diversity.

The Margalef index obtained in the study plots was 2.44 (NI) and 2.43 (CI) with 14 and 12 species, respectively. These values are included within ranges 2 and 2.7, and are interpreted as agroecosystems of medium diversity.

We found that the Simpson indices shown in this research (0.82 NI and 0.80 WI) suggest high diversity, and low dominance (0.17 NI and 0.19 WI).

The Shannon-Wiener index, based on the species richness and proportional abundance in the plots under study, reported calculated values of 2.06 (NI) and 1.94 (WI). These are within the ranges comprised between 1.5 and 3.5, thus classifying as an agroecosystem of medium diversity.

The Pielou index showed that the communities presented an equitable behavior with a value of 0.78 for each plot under analysis since the index value is approaching 1.

Regarding the similarity indices of Jaccard and Sorensen, which reported values of 73.33 % (IJ) and 84.62 % (IS), they show that in both plots there exists a high similarity of species found as the values are close to 1.

The most efficient technique for the capture of coccinellids was the chromatic trap, which represents an advantage to carry out studies based on the expertise of this type of predator; however, it would be recommended to use it with caution since this trapping method is usually used for pest capture in the field, which is why it would be important to consider other criteria such as the color to be used, type of pests that need to capture or reduce their field population, type of crop, dimensions of the trap, among other parameters, which minimize the attraction of beneficial insects.

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Contributor roles

- Jessica Daniela Zambrano Mero: resources, conceptualization, investigation, methodology, writing – original draft.
- Nexar Emiliano Vega Lucas: resources, writing – review & editing.
- Ariolfo Leonardo Solís Bowen: supervision, writing – review & editing.
- Dorys Terezinha Chirinos Torres: validation, writing – review & editing.
- Diego Rodolfo Perla Gutiérrez: investigation (taxonomic processing of insects).
- Alex Gabriel Delgado Párraga: data curation.
- Sofía Lorena Peñaherrera Villafuerte: formal analysis.

Ethical implications

Ethics approval not applicable.

Conflict of interest

The authors declare that they have no affiliation with any organization with a direct or indirect financial interest that could have appeared to influence the work reported.

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