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Natural parasitism of *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae) in four departments in Paraguay

Parasitismo natural de *Spodoptera frugiperda* (Smith) (Lepidoptera: Noctuidae), en cuatro departamentos de Paraguay

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Abstract

The impact produced by natural enemies on culture pests is a very important factor to consider at the moment of evaluating control methods. In this context, the characteristic fauna of a region and its influence on a particular pest are relevant data. This paper records the occurrence of parasitoids naturally associated with the fall army worm *Spodoptera frugiperda* (Smith, 1797) and their percentual impact calculated from rearing larvae of the host collected during the period 2015 – 2016 in Paraguay in the departments of Caaguazú, Alto Paraná, Canindeyú and Itapúa. The parasitoids recorded were: *Dissomphalus* spp. (Hymenoptera: Bethylidae), *Exasticolus fuscicornis* Cameron (Hymenoptera: Braconidae), *Ophion* spp. (Hymenoptera: Ichneumonidae), *Archytas* spp. (Diptera: Tachinidae) and *Winthenia* spp. (Diptera: Tachinidae).

Key words:
percentage parasitism; parasitoid fauna; maize; fall army worm

Resumen

El impacto que los enemigos naturales producen sobre las plagas de cultivos es un factor importante a tener en cuenta en el momento de evaluar los métodos de control a aplicar. En este contexto, la fauna propia de una región y su influencia sobre una plaga en particular son datos relevantes. Este artículo reporta la ocurrencia de parasitoides asociados de manera natural al gusano cogollero *Spodoptera frugiperda* (Smith, 1797) y su impacto porcentual calculado en la base de cría de larvas del hospedero recolectados durante el período 2015 - 2016 en Paraguay en los departamentos de Caaguazú, Alto Paraná, Canindeyú e Itapúa. Los parasitoides registrados fueron: *Dissomphalus* spp. (Hymenoptera: Bethylidae), *Exasticolus fuscicornis* Cameron (Hymenoptera: Braconidae), *Ophion* spp. (Hymenoptera: Ichneumonidae), *Archytas* spp. (Diptera: Tachinidae) y *Winthenia* spp. (Diptera: Tachinidae).

Palabras clave:
porcentaje de parasitoidismo; fauna de parasitoides; maíz; gusano cogollero

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Introduction

The cultivation of maize (*Zea mays* L.) in Paraguay is second in importance after soybeans, both in surface area (950,000 ha) and in grain production (4,985,881 Mg). The departments of Alto Paraná, Canindeyú, Itapúa, and Caaguazú are the leading producers of maize, accounting for 74.8 % of the area sown (DCEA, 2015). One of the main phytosanitary problems of this crop is the armyworm (*S. frugiperda*). The most widely used control method is the application of chemical products, which is often inefficient, in addition to increasing production costs and generating problems such as pest resistance and environmental contamination. In the search for alternatives to control this pest, the use of parasitoids arises as a strategy and an opportunity to protect the crop.

There are registers of the presence of *Chelonus* sp., *Chelonus cautus* Cresson, 1872; *Chelonus insularis* Cresson, 1865; *Cotesia* sp .; *Cotesia marginiventris* Cresson, 1865; *Meteorus laphygmae* Vierecck, 1913 and *Exasticolus* sp. (Hym., Braconidae), *Pristomerus spinator* Fabricius, 1804; *Campoletis flavicincta* Ashmead, 1890 and *Ophion* sp. (Hym., Ichneumonidae) and *Archytas incertus* Giglio-Tos, 1893; *Archytas marmoratus* Townsend, 1915 and *Lespesia archippivora* Riley, 1871 (Dip., Tachinidae) (Dequech *et al.,* 2004; Figueireido *et al.,* 2006 a, b; Cruz *et al.*, 2009; Gutiérrez *et al.,* 2013; Estrada *et al.,* 2013). Because of the lack of information on parasitoid species associated with the armyworm in Paraguay, the objective of this study was to verify the occurrence of parasitoids that act as natural biological control agents of S. frugiperda larvae in the main maize producing departments.

Material and methods

Sampling points

Larvae of *S. frugiperda* from different instars were collected in corn crops in the 2014/2015 and 2015/2016 agricultural years, the number of larvae collected was variable. The collections were made in four departments: Caaguazú, Alto Paraná, Canindeyú and Itapúa, which are the central corn producing departments in Paraguay. The data of temperature, precipitation, altitude, localities sampled by department and number of samples collected are presented in table 1.

Table 1. Department, Temperature, precipitation, altitude, sampled localities and number of samples made in the agricultural years 2014/2015 and 2015/2016. Paraguay, 2018.

Department	Average temperature (°C)	Average precipitation (mm)	Average altitude (msnm)	Number of locations sampled and (number of samples)
Canindeyú	21.92	1587.95	268.37	10 (1009)
Caaguazú	22.06	1592.71	236.06	6 (1015)
Alto Paraná	21.22	1630.01	260.02	8 (905)
Itapúa	21.41	1720.16	180.65	10 (1115)

Larvae collection

The number of points sampled (table 1) was variable according to the presence of the pest. The gathering was carried out in each batch in a random manner, and an average of 100 *S. frugiperda* larvae was collected. The larvae collected in the field were identified in situ by morphological characteristics, then placed in 50 mL falcon tubes and placed in containers to be transferred to the Entomology laboratory of the Plant Protection Area of the Faculty of Agricultural Sciences of the Universidad Nacional of Asunción. Once in the laboratory, the larvae of *S. frugiperda* were reared in plastic tubes (4.5 cm diameter x 7.5 cm long), with a temperature of 25 ± 5°C, HR 70 ± 10 % and a photoperiod of 12 hours. The larvae were fed with corn leaves, which were replaced daily until the larvae completed their cycle or until the emergence of the parasitoids, the observations were made daily. The adult parasitoids were located in alcohol 70% labeled and identified.

Identification of parasitoids

The parasitoids were separated in order and family using the taxonomic keys of Evans (1964), Achtenberg (1979), Wharton *et al.* (1997), Brown *et al.* (2010), López-Martínez *et al.* (2011) and Rafael *et al.* (2012). Then the identification of gender and species was made in the laboratory of the Facultad de Ciencias Exactas y Naturales (FACEN, by its acronym in Spanish). The evaluations were based on the diversity and frequency of the parasitoid species emerged by location. The percentage of parasitism was calculated according to the formula proposed by García *et al.* (2013).

$$\% \text{ Parasitism} = \frac{\text{Number of Parasitized Larvae}}{\text{Number of useful Larvae (Total)}} * 100$$

Where:
Number of Useful Larvae: difference between larvae recollected and killed by handling, leak or disease.
Number of Parasitized Larvae: only from useful larvae, whether the parasitoid emerged or not.

Results and Discussion

In the surveys carried out in the different departments, seven species of parasitoids were identified (table 2), the species collected and the percentage of parasitism obtained varied, depending on the locality and department. The rates of parasitism varied between 1.85 and 38.46%, occurring parasitism in all the areas sampled. The highest number of species collected was obtained in the departments of Canindeyú and Caaguazú, and the lowest diversity was observed in Itapúa.

The average percentage of parasitism in the department of Canindeyú was 14.80 % (table 3), with similar percentages found by Murúa *et al.* (2006) with 15% parasitism in the Argentine Northwest and 13.22 % in Yucatan-Mexico by Delfín *et al.* (2007).

Table 2. Parasitoids of *S. frugiperda* in the agricultural years 2014/2015 and 2015/2016, in the departments of Alto Paraná, Canindeyú, Itapúa, and Caaguazú. 1. Alto Parana 2. Caaguazu 3. Canindeyu 4. Itapúa.

Orden	Family	Sub family	Species	Locality			
				1	2	3	4
Hymenoptera	Braconidae	Cheloninae	*Chelonus* sp.	x			
		Homolobinae	*Exasticolus fuscicornis*	x	x	x	
			Glyptapanteles militaris		x		
	Ichneumonidae	Ophioninae	*Ophion* sp.		x	x	x
	Bethylidae		*Dissomphalus* spp.			x	
Diptera	Tachinidae	Tachininae	*Archytas* sp.	x	x	x	x
		Goniinae	*Winthenia* sp.	x	x	x	x

The highest percentage of natural parasitism was 41.38 % in a harvest carried out by a small producer in the Curuguaty district. This higher percentage could be due to the fact that this producer had a polyculture in its premises and this regard, Figueiredo *et al.* (2006a) and Souza (2015), mention that a greater diversity of species of parasitoids is observed in polycultures, production system characteristic of small producers, however in large areas of monocultures an adverse influence is observed in relation to the presence of parasitoids. The species of parasitoids in the department of Canindeyu were: *Dissomphalus* spp. (Hymenoptera: Bethylidae), *Exasticolus fuscicornis* Cameron (Hymenoptera: Braconidae), *Ophion* spp. (Hymenoptera: Ichneumonidae), *Archytas* spp. (Diptera: Tachinidae) and *Winthenia spp*. (Diptera: Tachinidae) (table 2). *Dissomphalus* spp., Has not been reported as a parasitoid of *S. frugiperda*, this specimen constitutes the first record of this species associated with the armyworm in Paraguay. According to Redighieri and Azevedo (2006), *Dissomphalus* is the most abundant genus of the Bethylidae family in tropical forests and has a wide distribution in the Brazilian Atlantic Forest.

Table 3. Municipality, coordinates, number of larvae collected, number of useful larvae, parasitized and percentage of natural parasitism of *S. frugiperda* in the Department of Canindeyu, Paraguay. NLC = number of larva collected; ULN = useful larva number; % p = parasitism percentage.

Collection	Municipality	Coordinates	NLC	ULN	NLP	% P
1	Curuguaty	S -24°28'56.4" W -055°37'16.4"	79	53	8	15.09
2	Yvyrarovana	S -24°24'00.7" W -055°07'35.6"	111	48	17	35.42
3	Yvyrarovana	S -24°20´21.1" W -055°07´13.2"	105	47	4	8.51
4	Yvyrarovana	S -24°22´16.6" W -054°58´59.9"	125	78	12	15.38
5	Yvyrarovana	S -24°22´11.4" W -055°07´16.7"	75	59	2	3.39
6	Yvyrarovana	S -24°18´12.4" W -054°58´34.5"	95	36	5	13.89
7	Curuguaty	S -24°15´44.3" W -055°43´53.5"	90	54	1	1.85
8	Curuguaty	S -24°15´38.0" W -055°43´50.7"	115	70	9	12.86
9	Curuguaty	S -24°15´27.6" W -055°43´53.7"	114	29	12	41.38
10	Curuguaty	S -24°15´35.0" W -055°44´08.2"	100	80	12	15.00
Total			1009	554	82	14.80

In the Department of Caaguazú (table 4), the average percentage of parasitism was 20.25 %, similar to those found by Dequech *et al.* (2004), Murúa *et al.* (2006), Murúa *et al.* (2009), Silva *et al.* (2011), Ordóñez *et al.* (2015a) and Ordóñez *et al.* (2015b) who obtained parasitism of 22.01; 19.94; 18.93; 2.3; 18.20 and 22.08 % respectively, in countries of America. Meanwhile, it is considered low when compared to the works of García *et al.* (2013), who mention parasitism of 62.40 % and 48.46 % respectively in Mexico. The percentage varied between 15.32 % in the municipality from February 3 to 36.45 % in the town of Dr. J. M. Frutos, which could be considered as acceptable since a large amount of non-selective chemical products is used in the area. Of the total of 152 emerged parasitoids, with five identified species (table 2), the species *Glyptapanteles militaris* was the most common in the repatriation and February 3, *Archytas sp*. was the most abundant in Yhú and Campo 9, while in Dr. J. M. Frutos the species with the highest number of emerged parasitoids was *Winthenia* sp. and in Caaguazú the most abundant was *Ophion* sp.

In the department of Alto Paraná, there was natural parasitism of 16.73 % (table 5), varying from 2.56 % (Itakyry) to 38.46 %. The average value could be considered low when comparing the results presented by Dequech *et al.* (2004), Pérez (2008) and Ordoñez *et al.* (2015a). For the Alto Paraná localities, the most abundant species was *Exasticolus fuscicornis*, while the least abundant was *Chelonus* sp. (table 1).

The average percentage in the department of Itapúa was 19.3% (table 6), the value similar to those presented by Molina *et al.* (2004), Silva *et al.* (2011) and García *et al.* (2013). The lowest percentage of parasitism was obtained in the municipality of Pirapó (5.50 %) and Natalio (5.90 %), while the highest value was obtained in the municipality of Edelira (37.50 %), the Low values levels may be related to the use of non-selective chemicals applied continuously in the area. In the monitored localities, the most abundant species was *Whinthenia* sp. followed by *Archytas* sp., while the least abundant species was *Ophion* sp. These results agree with the works of Murúa *et al.* (2006), which mention the Tachinidae family as the most abundant in Argentina.

The species *Chelonus* sp., *Exasticolus fuscicornis*, *Glyptapanteles militaris*; *Ophion* sp *.; Archytas* sp. and *Winthenia* sp. found in this research, have already been reported as parasitoids of *S. frugiperda* and other noctuids (Cave, 1993; Dequech *et al.*, 2004; Estrada *et al.*, 2013; Gutierrez *et al.,* 2013), in countries such as Brazil, Mexico , Honduras, Cuba. The exception is the species *Dissomphalus* spp., This being the first record of parasitoids in larvae of *S. frugiperda*.

It should be noted that these species have been reported as natural parasitoids. However, they are not produced on a large scale, and basic studies are needed to determine their potential as biological controllers as a basis for mass production.

Table 4. Municipality, coordinates, number of larvae collected, useful larvae, parasitized and percentage of natural parasitism of *S. frugiperda* in the Department of Caaguazú. Paraguay. NLC = number of larva collected; ULN = useful larva number; % p = parasitism percentage.

Collection	Municipality	Coordinates	NLC	NLU	ULN	% P
1	Caaguazú	S -25°27'20.60''W -055°59''00.83''	190	138	24	17.39
2	Dr. Frutos	S -25°19'52.02'' W -055°51''12,48''	225	96	35	36.45
3	Yhú	S -25°17'08.60'' W -0 55°58'32.13''	215	96	17	17.70
4	Campo 9	S -25°22'53.14'' W -055°40'10.91''	120	56	9	16.07
5	Repatriación	S -25°32'07.51'' W -055°40'10.91''	55	30	6	20
6	3 de Febrero	S -55°13'40.47'' W -055°46'56.56''	210	137	21	15.32
Total			1015	553	112	20.25

Table 5. Municipality, coordinates, number of larvae collected, useful larvae, parasitized and percentage of natural parasitism of *S. frugiperda* in the Department of Alto Paraná Paraguay. NLC = number of larva collected; ULN = useful larva number; % p = parasitism percentage.

Collection	Municipality	Coordinates	NLC	ULN	NLP	% P
1	Dr. Mallorquin	S-25° 27' 19'' W-55° 13' 05''	38	26	6	7.69
2	Yguazú	S-25° 22' 40'' W-54° 55' 29''	15	6	5	6.41
3	Hernandarias	S -25° 16' 03'' W-54° 51' 13''	102	45	11	14.1
4	Itakyry	S -25° 01' 24'' W -55° 00' 09''	55	38	2	2.56
5	Mbarakayú	S -25° 05' 32'' W-54° 57' 26''	164	86	10	12.82
6	Minga Porã	S -24° 53' 42'' W -54° 56' 35''	285	130	30	38.46
7	San Alberto	S-24° 56' 15'' W -54° 56' 47''	84	41	5	6.41
8	Santa Fé	S -25° 16' 53'' W -54° 43' 23''	162	100	9	11.53
Total			905	472	78	16.73

Table 6. Municipality, number of larvae collected, useful larvae, parasitized and percentage of natural parasitoidism of *S. frugiperda* in the Department of Itapúa. Paraguay. NLC = number of larva collected; ULN = useful larva number; % p = parasitism percentage.

Collection	Municipality	Coordinates	NLC	ULN	NLP	% P
1	Pirapó	S -26°60'032'' W-055°41'29''	73	55	3	5.45
2	Capitán Miranda	S -27°02'972'' W- 055° 57'199''	29	18	4	22.22
3	Fram	S -27°09'001'' W -055°49'234''	60	40	10	25
4	La Paz	S-27°04'890'' W -055°30'742''	46	23	3	13.04
5	Obligado	S - 27°04'27'' W-055°38'18''	29	17	4	23.53
6	Hohenau	S -27°07'221'' W -055° 51'208''	77	39	5	12.82
7	Capitán Meza	S-26°50'06'' W -055°30'502''	37	27	5	18.52
8	María Auxiliadora	S-26° 46´20.17 W -055°16´34´´	318	231	27	14.33
9	Edelira	S -26°37'15.0'' W- 055°19'50''	39	24	9	37.50
10	Natalio	S -26°45''35'' W -055°10'20''	407	272	16	5.88
Total			1115	746	86	11.53

Conclusions

Based on the results in the different departments where the gathering was made, it can be concluded that the natural occurrence of parasitoids in the cultivation of corn constitutes essential components of the regulation of the pest population, and the conservation of the same, through ecological management.

Seven species of *S. frugiperda* parasitoids were found, represented by the following four families and their respective species, Braconidae*: Chelonus* sp., *Exasticolus fuscicornis, Glyptapanteles militaris;* Ichneumonidae: *Ophion* sp .; Bethylidae: *Dissomphalus* spp and Tachinidae: *Archytas* sp. and *Winthenia* sp.

Natural parasitism varied between departments, being 14.8 %; 20.25 %; 16.73 % and 11.53 % for the departments of Canindeyú, Caaguazú, Alto Paraná and Itapúa, respectively.

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