

Parasitoids associated with *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in corn in the State of Maranhão, Brazil

T. C. SILVA, R. N. S. LEMOS, A. A. MOREIRA, J. R. G. ARAUJO, F. R. MEDEIROS, M. A. CASTELLANI

Spodoptera frugiperda (Smith, 1797) (Lepidoptera: Noctuidae), the fall armyworm, is one of the main pests of corn, causing yield losses ranging from 17 to 38.7%. Its control is based on the use of chemical insecticides, which cause damages to the environment and man. This work aimed to identify and quantify the parasitoids emerged from larvae collected in agricultural fields in São Luís, Urbano Santos, and Formosa da Serra Negra (MA, Brazil), during the 2002/2003 and 2003/2004 cropping seasons. One thousand one hundred and seventy-three larvae were collected, with a parasitism percentage of 17.81%, which in 2002/2003 was about 12.42% and in 2003/2004 achieved 24.48%, representative values of the total mortality rate. The parasitoids that emerged belonged to orders Diptera and Hymenoptera, standing out *Chelonus insularis* (Cresson) (Cheloniidae), which appeared in 34.66% of the parasited larvae collected during 2003/2004, and the tachinids *Lespesia lanei* (Guimarães) and *Archytas incertus* (Macquard), which appeared in 25.92% and 24.07%, respectively, in 2002/2003. The rest of the parasitoids observed were the ichneumonid, *Eiphosoma laphygmae* (Costa Lima), the braconids *Chelonus texanus* (Cresson), *Cotesia* sp., *Macrocentrus* sp., and *Brachymeria* sp., and tachinids *Lespesia affinis* (Riley), *Archytas incansanus* (Townsend), and *Archytas* sp. The hymenopterans had a preference for first-instar larvae and the dipterans for the last instars and the pupal stage, this way avoiding the competition between both.

T. C. SILVA, R. N. S. LEMOS, J. R. G. ARAUJO, F. R. MEDEIROS. Programa de Pós-Graduação em Agroecologia/UEMA- Caixa Postal 9, CEP 65055-098, São Luís-MA, Brasil. E-mail: rlemos@cca.uema.br.
A. A. MOREIRA, M. A. CASTELLANI. Departamento de Fitotecnia e Zootecnia/ UESB- Caixa Postal 95, CEP 45083-900, Vitória da Conquista -BA, Brasil. *Persona de contacto: E-mail: aldenise.moreira@gmail.com.

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INTRODUCTION

Due to its productive potential, chemical composition, and nutritional value, corn (*Zea mays* L.) is listed as one of the most important agribusiness commodities in Brazil and worldwide (WALQUIL & VILELA 2003). Brazil ranks third among corn producers, with an average yield of 34.2 million tons, in an average area of 12.7 million hectares and a productivity near 2,700 kg/ha (VIANA & POTENZA, 2000; SILOTO, 2002; NEHMI FILHO, 2003).

The fall armyworm, *Spodoptera frugiperda* (Smith, 1797), is considered one of the main pests of corn, as it causes damages in practically all stages of corn development, destroying the whorl, reducing photosynthesizing area and yield (CRUZ *et al.*, 1995; SILOTO, 2002; MONTESBRAVO, 2004). Yield losses range from 17 to 38.7% (CRUZ *et al.*, 1995; POLANCZYK *et al.*, 2000; WAQUIL & VILELA, 2003; WISEMAN, 1999; POLANCZYK *et al.*, 2003), resulting in annual damages of over 400 million dollars (CRUZ *et al.*, 1996).

These losses mainly result from insecticide sprays (WAQUIL & VILELA, 2003).

In addition to these losses, another serious problem faced by farmers has been the development of populations that are resistant to the insecticides used (CRUZ, 2002). Studies have sought Integrated Pest Management (IPM) strategies for the control of *S. frugiperda* aimed at reducing the development of resistant populations to certain insecticides, especially those that take advantage of natural pest population suppression factors, such as predators and parasitoids.

Several studies have been conducted in order to identify and determine the effectiveness of fall armyworm natural enemies. CRUZ *et al.* (1997) evaluated the parasitism potential of *Campolletis flavicincta* (Ashmead) on larvae of different ages, and observed an oviposition preference for larvae between three and four days of age. A decreased corn leaf intake by *S. frugiperda* larvae parasitized by *Chelonus insularis* (Cresson) (REZENDE *et al.*, 1994), *Campolletis flavicincta* (CRUZ *et al.*, 1997), and *Telenomus remus* (Nixon) (FIGUEIREDO *et al.*, 1999) was observed. VALICENTE & BARRETO (1999) observed the occurrence of *Campolletis* sp. and *Archytas marmoratus* in Cascavel, Paraná, with parasitism rates of 47% and 15.4%, respectively. Confirming the great importance of natural biological control on *S. frugiperda* population suppression, FIGUEIREDO *et al.* (2006) observed that in the absence of natural enemies, dry matter yield losses amounted to 47.27%, while grain yield losses were 54.49%.

The development of studies that allow comparisons to be made between the effectiveness of parasitoids in agroecosystems with different habitat complexities will certainly be of help in outlining pest management projects (GARCIA, 1991) aimed at biological control.

Information on native natural enemies associated with *S. frugiperda* in regional agroecosystems in the State of Maranhão are still scarce and practically no data are avail-

able on the subject. Consequently, this research aimed to identify and quantify *S. frugiperda* parasitoids in agricultural areas of three municipalities in Maranhão, as well as to evaluate the relationship between the number of parasitized larvae and the number of collected larvae, and parasitoid preference for different stages of development of this pest.

MATERIAL AND METHODS

The *S. frugiperda* larvae were collected in commercial planting areas, located in the municipalities of São Luís, Formosa da Serra Negra, and Urbano Santos. Fifteen collections were performed in the three municipalities during the 2002/2003 and 2003/2004 cropping seasons.

In São Luís, collections were made in Andiroba (02°37'41"S and 44°12'18"W), Tajaçuba (02°37'20"S and 44°12'34"W), and at Universidade Estadual do Maranhão's School Farm - UEMA (02°35'04"S and 44°12'29"W). The soil in these regions is a yellow acric latosol, with a mean maximum temperature of 27°C, mean maximum relative humidity of 82%, and precipitation between 2,400 and 2,800mm. In the municipality of Urbano Santos, collections were made in agricultural fields of Mato Grande (03°11'54"S and 43°22'58"W) and Serraria (03°11'28"S and 43°22'31"W). The soil in these areas is a plinthosol, with a mean maximum temperature of 27°C, relative humidity between 79 and 82%, and precipitation between 2,400 and 2,800mm. In the municipality of Formosa da Serra Negra, collections were made in the locality of Chapada de Dentro (06°26'09"S and 46°11'19"W). In those areas, the soil is a structured red nitosol, with temperature between 25 and 26°C, relative humidity between 73 and 76%, and precipitation between 1,200 and 1,600 mm.

In each property, 100 corn plants (20 to 70cm in height) were collected at random (Clavijo, 1978). At the Entomology laboratory (UEMA), the *S. frugiperda* caterpillars

were isolated and placed in plastic containers 6.5 cm in height by 4 cm in diameter, with a snap-on plastic lid, containing artificial diet (NALIN, 1991). The experiment was conducted in an incubator maintained at 25°C, relative humidity $60 \pm 10\%$, and 14-hour photophase.

The larval instars were determined by head capsule measurements, using an ocular micrometer attached to a stereoscopic microscope. The caterpillars were maintained on the diet until the *S. frugiperda* adults or the parasitoids emerged.

Observations were made daily, and the emerged adult parasitoids were counted, placed in 70% alcohol, labeled, and sent for identification.

The evaluations were based on the frequency of parasitoid species emerged and on the distribution of parasitoids emerged in each instar of the host, location, and collection period, compared by the Chi-square test (SOKAL & ROHF, 1981).

RESULTS

We obtained 1173 *S. frugiperda* larvae, from which 209 parasitoids emerged, with a parasitism rate of 17.81%. In the 2002/2003 cropping season, a total of 475 *S. frugiperda* caterpillars was obtained, with a parasitism rate of 12.42%; the highest rates were obtained at Formosa da Serra Negra (18.42%

and 18.51%), while the smallest index occurred in the Mato Grande area at Urbano Santos, where only three parasitoids emerged, with 4.61% parasitism (Table 1).

In the 2003/2004 cropping season, we obtained a total of 698 caterpillars, with a parasitism rate of 21.48%, therefore higher than the values found in the previous year. The highest percentages were recorded in Andiroba and Formosa, with 32.45% and 34.09% respectively, while the smallest percentages were obtained in Serraria (12.35%) (Table 2). Of the parasitized caterpillars (59 in 2002/2003 and 150 in 2003/2004), 5 and 28 parasitoids did not reach the adult stage, respectively (Tables 1 and 2).

The mortality rate in 2002/2003 was 37.68%, comprising 179 larvae, of which 59 died by the action of parasitoids (12.42%) and 120 individuals died by other factors (fungi, bacteria, viruses, handling, and even the use of chemical insecticides). In 2003/2004, mortality was 44.12%, with a total of 308 dead larvae, of which 158 died due to other factors (22.63%) and 150 died due to parasitoids (21.48%) (Tables 1 and 2).

Parasitoids in the orders Diptera and Hymenoptera were obtained in both cropping seasons. In 2002/2003, only dipterans were identified in collections made at UEMA's School Farm.

In all, we obtained 11 parasitoid species emerged from *S. frugiperda* larvae, distrib-

Table 1. *Spodoptera frugiperda* mortality by parasitoids and other factors, in the municipalities of São Luís, Urbano Santos, and Formosa da Serra Negra-MA, during the 2002/2003 cropping seasons.

Locations	Plants collected	Larvae observed	Larvae parasitized		Parasitoids emerged		Deaths by other factors	
	n	n	n	%	n	%	n	%
São Luis	100	51	05	9.80	03	5.88	10	19.60
São Luis	100	51	06	11.76	03	5.88	10	19.60
Formosa S. Negra	100	76	14	18.42	14	18.42	33	43.42
Formosa S. Negra	100	54	10	18.51	10	18.51	21	38.88
Urbano Santos	100	65	03	4.61	03	4.61	17	26.15
Urbano Santos	100	93	11	11.82	11	11.82	13	13.97
Urbano Santos	100	85	10	11.76	10	11.76	16	18.83
Total	700	475	59	12.42	54	91.52	120	25.27

Table 2. *Spodoptera frugiperda* mortality by parasitoids and other factors, in the municipalities of São Luís, Urbano Santos, and Formosa da Serra Negra-MA, during the 2003/2004 cropping seasons.

Locations	Plants collected	Larvae observed	Larvae parasitized		Parasitoids emerged		Deaths by other factors	
	n	n	n	%	n	%	n	%
São Luís	100	85	13	15.29	09	10.58	21	24.70
São Luís	100	111	21	18.91	16	14.41	47	42.34
São Luís	100	114	37	32.45	28	24.56	14	12.28
São Luís	100	61	09	14.75	07	11.47	08	13.11
Formosa S. Negra	100	88	30	34.09	28	31.81	22	25.00
Formosa S. Negra	100	73	20	27.39	14	19.17	14	19.17
Urbano Santos	100	77	09	11.68	09	11.68	15	19.48
Urbano Santos	100	89	11	12.35	11	12.35	17	19.10
Total	800	698	150	21.48	122	81.33	158	22.63

Table 3. Parasitoids emerged at different *Spodoptera frugiperda* stages of development in the municipalities of São Luís, Urbano Santos, and Formosa da Serra Negra-MA, during the 2002/2003 and 2003/2004 cropping seasons.

Parasitoid species	Cropping seasons				Stage at emergence
	2002/2003		2003/2004		
	n	%	n	%	
Order Hymenoptera					
Ichneumonidae					
Cremastinae					
<i>Eiphosoma laphygmae</i> (Costa Lima)	00	00	11	7,33	3rd instar
Braconidae					
Cheloninae					
<i>Chelonus insularis</i> (Cresson)	05	8,47	52	34,66	3rd instar
<i>Chelonus texanus</i> (Cresson)	03	5,08	02	1,33	4th instar
Microgastrinae					
<i>Cotesia</i> sp.	02	3,38	02	1,33	3rd instar
Macrocentrinae					
<i>Macrocentrus</i> sp.	03	5,08	00	00	3rd instar
Chalcididae					
<i>Brachymeria</i> sp.	00	00	01	0,66	Adult
Order Diptera					
Tachinidae					
<i>Lespesia affinis</i> (Riley)	03	5,55	00	00	5th and 6th instars
<i>Lespesia lanei</i> (Guimarães)	14	25,92	24	19,67	5th and 6th instars
<i>Archytas incertus</i> (Macquard)	13	24,07	16	13,11	Pupa
<i>Archytas incansanus</i> (Townsend)	08	14,81	10	8,19	Pupa
<i>Archytas</i> sp.	03	5,55	04	3,27	Pupa

uted in two hymenopteran families: Ichneumonidae and Braconidae (Cheloninae, Microgastrinae, and Macrocentrinae), and one dipteran family: Tachinidae. The incidence of parasitoids indicated that in 2002/2003 the

dipteran species were abundant (75.92%), while in 2003/2004 hymenopterans had a higher index (54.90%) (Table 3).

In the 2003/2004 cropping season, the species *Chelonus insularis* (Cresson) occurred

Table 4. Frequency of parasitoids emerged at different *Spodoptera frugiperda* stages of development in the municipalities of São Luís, Urbano Santos, and Formosa da Serra Negra-MA, during the 2002/2003 cropping season.

Stages of development	Diptera		Parasitoids Hymenoptera		Total	
	n	%	n	%	n	%
2nd instar	—	—	01	1.86	01	1.86
3rd instar	—	—	08	14.81	08	14.81
4th instar	—	—	04	7.40	04	7.40
5th instar	08	14.81	—	—	08	14.81
6th instar	08	14.81	—	—	08	14.81
Pupa	25	46.30	—	—	25	46.30
Adult	—	—	—	—	—	—
Total	41	75.92	13	24.07	54	100.00

$\chi^2 = 13$ and $p = 2.33$

most abundantly, representing 42.62% of emerged parasitoids, while in 2002/2003 only 8.47% were observed. This parasitoid emerged from 3rd instar larvae (Table 4).

The most frequent parasitoids in 2002/2003 were dipterans in the family Tachinidae: *Lespesia lanei* (Guimarães), which occurred in 25.92% of the cases, always emerging from 5th and 6th instar larvae, and *Archytas incertus* (Macquard), which represented 24.07%, emerging from the pupal stage of *S. frugiperda*. In 2003/2004, they represented 19.67% and 13.11% respectively, occupying the second and third ranks in total number of parasitoids for that period (Table 3).

Only one individual per larva emerged from most parasitized caterpillars. However, we observed situations where more than two parasitoids of the species *Lespesia lanei* emerged from a single *S. frugiperda* caterpillar.

The tachinid *Archytas incansanus* (Townsend) also occurred in considerably high numbers, representing 14.81% in 2002/2003 and 8.19% in 2003/2004, ranking third and fourth in frequency, respectively, emerging at the pupal stage. The dipterans *Lespesia affinis* (Riley) and *Archytas* sp. occurred at a smaller frequency, with a 5.55% rate in 2002/2003. In the 2003/2004

cropping season, *L. affinis* did not occur, and *Archytas* sp. represented 3.27% (Table 4).

The hymenopterans *Chelonus texanus* (Cresson), *Cotesia* sp., and *Macrocentrus* sp. showed frequencies of 5.08%, 3.38%, and 5.08%, respectively, in 2002/2003. In 2003/2004 there was no record for *Macrocentrus* sp., while the others occurred in only 1.33% of the cases. These parasitoids emerged from 3rd and 4th instar larvae. The hymenopteran *Eiphosoma laphygmae* (Costa Lima) was observed only in the locality of Andiroba (São Luís), in the 2003/2004 cropping season, representing 7.33% of the parasitoids collected during that period (Table 3).

During the *S. frugiperda* collections in Andiroba in 2003/2004, one mobility-challenged adult (moth) was captured. In the laboratory, the species *Brachymeria* sp. (Chalcididae) emerged from its abdomen (Table 3).

In the 2002/2003 and 2003/2004 cropping seasons, there was an inversion in parasitoid emergence as larval development occurred, that is, parasitoid specificity was verified in relation to *S. frugiperda* larval development: parasitoids in the order Hymenoptera preferred the initial stages of development (1st, 2nd, 3rd, and 4th instars), while parasitoids in the order Diptera preferred the final stages (4th, 5th, and 6th instars and the pupal stage) (Tables 4 and 5).

Table 5. Frequency of parasitoids emerged at different *Spodoptera frugiperda* stages of development in the municipalities of São Luís, Urbano Santos, and Formosa da Serra Negra-MA, during the 2003/2004 cropping season.

Stages of development	Diptera		Parasitoids Hymenoptera		Total	
	n	%	n	%	n	%
2nd instar	—	—	04	3.27	04	3.27
3rd instar	—	—	59	48.36	59	48.36
4th instar	01	0.82	03	2.45	04	3.27
5th instar	09	7.38	—	—	09	7.38
6th instar	15	12.30	—	—	15	12.30
Pupa	30	24.60	—	—	30	24.60
Adult	—	—	01	0.82	01	0.82
Total	55	45.10	67	54.90	122	100.00

$\chi^2 = 65.3$ and $p = 0.0001$

Based on the application of the c^2 test, a significant difference was observed in relation to parasitoid emergence between the orders Diptera and Hymenoptera and the host's stage of development, with the following values: $c^2 = 13$ and $p = 2.33$, $c^2 = 65.3$ and $p = 0.0001$ for the 2002/2003 and 2003/2004 cropping seasons, respectively.

DISCUSSION

The parasitism rate results obtained in the cropping seasons and localities studied indicated a variable parasitism rate from one year to the next and from one locality to another, with an average value of 17.81%, near those found by SILVA *et al.* (1997), who observed 19.3% in the Triângulo Mineiro region -MG, DEQUECH *et al.* (2004), who recorded rates of 18.11% and 22.01% in Cachoeirinha-RS, and LUCCHINI & ALMEIDA (1980), who obtained 15.33% parasitism in Ponta Grossa - PR. Higher values were also recorded in Turrialba, Costa Rica, where MARENCO-MENDOZA & SAUNDERS (1993) reported a 65% larval mortality of *S. frugiperda* by parasitoids.

It was observed that 12.42% and 21.48% of *S. frugiperda* deaths were caused by parasitoids, which demonstrates their importance in controlling the pest population in the

agroecosystems studied. REZENDE *et al.* (1994) concluded that parasitizing caterpillars in the field helps maintain the injury level below the economic threshold, since they remain less time on the plant and consume less leaf area.

A preference of parasitoids in the order Diptera for the final stages of larval development and for the pupal stage of *S. frugiperda* was observed, which, according to NOTZ (1992) can be explained by the fact that these insects have greater feeding requirements, and when parasitism occurs during the first instars they do not reach the adult stage.

The differences observed in relation to the emergence of parasitoids of orders Diptera and Hymenoptera at different stages of larval development, according to SILVA *et al.* (1997), are justified by the fact that these orders do not compete for the same stage of development of the caterpillar.

The parasitoids most frequently found were the hymenopterans *Chelonus insularis* and the dipterans *Lespesia lanei*, *Archytas incertus* and *Archytas incansanus*. SILVA *et al.* (1997) found a greater frequency for the dipteran *Archytas incertus* and the hymenopterans *Chelonus texanus* and *Diadegma* sp. in the Triângulo Mineiro Region, MG; VALICENTE & BARRETO (1999), however, found a greater frequency for the dipteran *Archytas marmoratus* and for the

hymenopteran *Campeletis* sp. in the Cascavel Region, in Paraná. The results obtained in the present work and in other studies conducted at different regions of the country indicate variation in the dominance of parasitoid species, thus highlighting the necessity for knowledge on native natural enemies to enhance natural biological control and the development of parasitoids within applied biological control, adapted to different regional conditions.

The species *Chelonius insularis* occurred most frequently during the 2003/2004 cropping season, emerging from 3rd instar larvae. According to MOLINA-OCHOA (2003), this parasitoid has widespread distribution in the Americas and constitutes an important element for *S. frugiperda* control. Its egg-larval traits, as well as its high reproductive potential, have led to studies on its mass pro-

duction and release in production areas (MONTESBRAVO, 2004); it may represent a key parasitoid against this pest species.

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RESUMEN

SILVA, T. C., R. N. S. LEMOS, A. A. MOREIRA, J. R. G. ARAUJO, F. R. MEDEIROS, M. A. CASTELLANI. 2008. Parasitoides asociados con *Spodoptera frugiperda* (Lepidoptera: Noctuidae) en maíz en el estado de Maranhão, Brasil. *Bol. San. Veg. Plagas*, **34**: 493-500.

Spodoptera frugiperda (Smith, 1797) (Lepidoptera: Noctuidae), gusano cogollero, es una de las principales plagas del maíz, provocando pérdidas que varían de 17 a 37%. Su control se basa en el uso de insecticidas químicos, los cuales provocan daños al medio ambiente y al hombre. Este trabajo tuvo como objetivo cuantificar los parasitoides emergentes de larvas recogidas en campo en São Luis Urbano Santos, y Formosa da Serra Negra (MA, Brasil), durante las campañas agrícolas 2002/2003 y 2003/2004. Se recogieron 1173 larvas, con un porcentaje total de parasitismo de 17.81% que en la campaña 2002/2003 se situó en el 12.42% y en la de 2003/2004 llegó al 24.48%, valores representativos de la tasa de mortalidad. Los parasitoides que emergieron pertenecían a los órdenes Diptera e Hymenoptera, sobresaliendo *Chelonius insularis* (Cresson) (Cheloniidae), que apareció en el 34.66% de las larvas parasitadas recogidas durante el periodo de 2003/2004, y los taquinídeos *Lespesia lanei* (Guimarães) y *Archytas incertus* (Macquard), que aparecieron en 25.92% y 24.07% respectivamente, de las correspondientes al periodo 2002/2003. El resto de parasitoides observados fueron el icneumónido *Eiphosoma laphygmae* (Costa Lima), los braconídeos *Chelonius texanus* (Cresson), *Cotesia* sp., *Macrocentrus* sp., *Brachymeria* sp., y los taquinídeos *Lespesia affinis* (Riley), *Archytas incansanus* (Townsend), y *Archytas* sp. Los himenópteros manifiestan preferencia por los primeros estadios larvarios de *Spodoptera frugiperda* y los dípteros por los últimos y por el estado de pupa de este modo evitan la competencia entre ambos.

Palabras clave: Gusano cogollero, Control Biológico, Control Integrado, Parasitismo.

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