

A SURVEY OF FALL ARMYWORM (LEPIDOPTERA: NOCTUIDAE) PARASITOIDS IN THE MEXICAN STATES OF MICHOACÁN, COLIMA, JALISCO, AND TAMAULIPAS

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ABSTRACT

Fall armyworm larvae, *Spodoptera frugiperda* (J. E. Smith) were collected from whorl stage corn or sorghum in the states of Michoacán, Colima, and Jalisco in August, and Tamaulipas, Mexico in September 1998. Eleven species of hymenopteran parasitoids were recovered representing 3 families: Ichneumonidae (*Ophion flavidus* Brulle, *Campoletis flavicincta* Ashmead, and *Pristomerus spinator* F.); Braconidae (*Aleiodes laphygmae* Viereck, *Cotesia marginiventris* Cresson, *Meteorus laphygmae* Viereck, *Meteorus* sp., *Chelonus insularis* Cresson, *Chelonus* sp. probably *cautus* Cresson, and *Chelonus* sp.); and Eulophidae (*Euplectrus platyhyphenae* Howard). The overall rate of parasitism was 11.3%, based on 2219 larvae collected. The highest rate of parasitism from a single collection was 26.5%, representing 6 species of parasitoids in Michoacán. The next highest rate of parasitism, 23%, was by a single species, *C. flavicincta*, in Michoacán. The most widely distributed species was *P. spinator*, occurring in 12 collections from 3 states. *Chelonus* sp. was collected from all four states in only 6 collections. The greater diversity of parasitoids and higher rates of parasitism in Michoacán may be related to the more diverse habitat with more forests, orchards, and pastures near the cornfields in that state.

Key Words: parasitoids, *Spodoptera frugiperda*, *Ophion*, *Campoletis*, *Pristomerus*, *Aleiodes*, *Cotesia*, *Meteorus*, *Chelonus*, *Euplectrus*, maize, corn, sorghum, Mexico

RESUMEN

Larvas de gusano cogollero, *Spodoptera frugiperda* (J. E. Smith) fueron colectadas de maíz y sorgo para grano en etapa de verticilio en los estados de Michoacán, Colima y Jalisco durante Agosto, y en Tamaulipas, México durante Septiembre de 1998. Once especies de parasitoides himenópteros se recuperaron y representaron a 3 familias: Ichneumonidae (*Ophion flavidus* Brulle, *Campoletis flavicincta* Ashmed, y *Pristomerus spinator* F.); Braconidae (*Aleiodes laphygmae* Viereck, *Meteorus* sp., *Chelonus insularis* Cresson, *Chelonus* sp. probablemente *cautus* Cesson, y *Chelonus* sp.); y Eulophidae (*Euplectrus platyhyphenae* Howard). La proporción general de parasitismo fue de 11.3%, basada en 2219 larvas colectadas. La proporción más alta de parasitismo proveniente de una colecta simple fue de 26.5%, representando 6 especies de parasitoides en Michoacán. La siguiente proporción más alta, 23%, fue para una especie simple, *C. flavicincta*, en Michoacán. La especie distribuida más ampliamente fue *P. spinator*, presentándose en 12 colectas hechas en 3 estados. *Chelonus* sp. se colectó en los cuatro estados sólo en 6 colectas. La diversidad más grande de parasitoides y proporciones más altas de parasitismo en Michoacán pueden estar relacionadas con los habitat más diversos con más bosques, huertas y pastizales cerca de los maizales en ese estado.

The fall armyworm, *Spodoptera frugiperda* (J. E. Smith), is an important economic pest of corn, sorghum, grasses, and occasionally other crops in North America, Central America and parts of South America (Luginbill 1928; Vickery 1929; Mitchell 1979; Andrews 1980, 1988). The fall armyworm lacks the ability to diapause during cold weather and thus spreads northward from over-

wintering habitats each year (Luginbill 1928). The seasonal migration of fall armyworm from Southern Florida and the Lower Rio Grande Valley has been studied by Westbrook and Sparks (1986), Pair et al. (1986, 1991), and Pair & Westbrook (1995). The potential for migration from other areas along the Mexican Gulf Coast was discussed by Raulston et al. (1986).

Early workers recognized the value of parasitoids in reducing larval populations of fall armyworm (Luginbill 1928; Vickery 1929). Andrews (1988) reviewed the Latin American research on fall armyworm including its parasitoids, and Ashley et al. (1989) reviewed the literature on fall armyworm. Biological control of this pest is desirable because of increasing economic and environmental concerns which have resulted in surveys of parasitoids and other natural enemies in different parts of its range (Hogg et al. 1982; Pair et al. 1986; Gross & Pair 1986; Castro & Pitre 1989). Ashley (1979) listed 53 species of fall armyworm parasitoids from 43 genera and 10 families and suggested that importations from Central and South America into Florida and Texas may significantly reduce overwintering populations. He also suggested that the number of parasitoids unique to either North or South America is indicative of the need for more larval collections so as to establish whether differences actually are present or are simply a function of inadequate records. Ashley (1986) reported the highest parasitism levels of fall armyworm were found for corn and that *Chelonus insularis* Cresson had the highest parasitism rates of all the parasitoids for North and Central America. Pair et al. (1986) found that the highest rates of parasitism were in overwintering areas of Mexico-Texas and south Florida and confirmed that *C. insularis* was the most common parasitoid. They presented evidence for differential distribution of some parasitoids as indicated by their native scarcity or abundance in defined

geographical areas. Riggin et al. (1993) concluded that the most efficient biological control programs for fall armyworm will be ones that use and amplify several parasitoid species rather than programs that rely on an individual natural enemy.

Biological differences (developmental rates, reproductive compatibility and susceptibility to insecticides) between populations of fall armyworm collected from corn in different areas of Mexico suggested some geographical isolation of populations (Lopez-Edwards et al. 1999). Therefore, we surveyed the natural enemies of fall armyworm in west-central and northeastern Mexico in an effort to find new parasitoids and to add to the knowledge of the distribution of known parasitoids of this pest.

MATERIALS AND METHODS

During August 1998, collections of fall armyworm larvae were made from whorl-stage corn and sorghum in the states of Michoacán, Colima, and Jalisco, and 1 collection was made from fruiting corn in Jalisco. A later collection was made from whorl-stage sorghum in Tamaulipas in September. No efforts were made to collect eggs or pupae. The larvae were placed individually in 30 cc plastic cups with pinto bean diet (Burton 1969) and held in the laboratory for emergence of parasitoids. Adult parasitoids were submitted to the USDA Systematic Entomology Laboratory, Beltsville, MD for identification. The dates and locations of collections are presented in Table 1.

TABLE 1. LOCATION, DATE, CROP, SAMPLE SIZE, AND TOTAL PERCENTAGE FALL ARMYWORM LARVAE PARASITIZED BY HYMENOPTERA, COLLECTED FROM CORN (C) OR SORGHUM (S) IN THE MEXICAN STATES OF MICHOACÁN (M), COLIMA (C), JALISCO (J), AND TAMAULIPAS (T).

Code	Location	Date	Crop	No. coll.	Percentage parasitized
M 1	Jazmin	08/07/98	C	25	4.0
M 2	El Batillero	08/07/98	C	26	23.0
M 3	La Sidra	08/07/98	C	84	6.0
M 4	La Sidra	08/08/98	C	89	9.0
M 5	El Hueso	08/08/98	C	102	26.5
M 6	Carreras	08/08/98	C	109	14.7
C 7	Mezcales	08/12/98	C	143	7.0
C 8	Los Clomos	08/12/98	C	84	2.4
C 9	Cerro Colorado	08/13/98	C	121	3.3
C 10	El Bordo	08/13/98	C	114	11.4
C 11	Crucero de Tapames	08/13/98	C	89	0
C 12	Peña Blanca	08/13/98	C & S	219	15.5
C 13	El Narajito	08/14/98	C	171	7.6
J 14	Los Pozos	08/19/98	C	81	8.6
J 15	Apastepe	08/19/98	C	89	7.9
J 16	Los Depositos	08/19/98	C	89	4.5
J 17	Sayula	08/19/98	C	89	2.2
J 18	Sayula	08/20/98	C & S	177	18.6
J 19	Sayula	08/20/98	C (ears)	18	0
T 20	El Mante	09/22/98	C	300	19.7

Collection size ranged from 25 to 300 fall armyworm larvae. Collections 12 and 18 comprise combinations of samples from adjacent fields of whorl-stage corn and sorghum. The number collected was corrected by subtracting the number that died from injury or unknown causes during the first few days after collection before calculating percent parasitism. Mortality due to pathogens and nematodes will be reported elsewhere.

RESULTS AND DISCUSSION

Out of 2219 fall armyworm larvae collected, 251 produced parasitoids, for a parasitism rate of 11.3%. This represented 11 species from 3 families of Hymenoptera: 7 Braconidae, 3 Ichneumonidae, and 1 Eulophidae. Only 2 of 20 collections produced no parasitoids: a collection from whorl-stage corn at C11 in Colima and a collection from ears of corn at J19 in Jalisco. The two highest rates of parasitism were found in Michoacán at M5 and M2 with 26.5 and 23% parasitism, respectively (Table 1). M5, C12, and C13, had the highest number of parasitoid species, 6 (Tables 2 and 3). In contrast, M2 had only a single species of parasitoid and represented the highest rate of parasitism by a particular species, 23%. The next most diverse collections of parasitoids were from M3 and M6 in Michoacán with 5 species each (Tables 2 and 3).

Pristomerus spinator F. was the most widely distributed parasitoid, being found in 12 collections from 3 states (Table 3). At nearly 13%, it showed the second highest rate of parasitism. *P. spinator* was listed as a parasite of fall armyworm from Nicaragua, Brazil, and Cuba by Andrews (1988). *P. spinator* was reported from Quintana Roo and Tamaulipas, México, by Carrillo (1980) and Pair et al. (1986) respectively. While this was the most widely distributed parasitoid in our collections, we did not find it in the single collection from Tamaulipas.

Campoletis flavicincta Ashmead was found in 8 collections from 2 states, occurring most abundantly in Michoacán in 5 of 6 collections and also had the highest rate of parasitism, 23% (Table 3). However, it was not found in collections from Colima and Tamaulipas. *C. flavicincta* was listed from several states of the U.S.A. and from Uruguay by Ashley (1979), and from Nicaragua, Uruguay, and Brazil by Andrews (1988).

Ophion flavidus Brulle was found in one collection in Michoacán and two collections from Colima, with the highest rate of parasitism (5%) in Colima. *O. flavidus* was listed from the U.S.A. by Ashley (1986) and from Honduras and Brazil by Andrews (1988).

Chelonus insularis was found in 9 collections from 3 states but always at less than 5%. Luginbill (1928) and Vickery (1929) indicated that *C. in-*

TABLE 2. PERCENTAGE OF FALL ARMYWORM LARVAE PARASITIZED BY EACH SPECIES OF BRACONIDAE AT EACH LOCATION.

Code*	Braconidae						
	<i>A. l.</i>	<i>C. i.</i>	<i>C. c.</i>	<i>C. sp.</i>	<i>C. m.</i>	<i>M. l.</i>	<i>M. sp.</i>
M 1	0	0	0	0	0	0	0
M 2	0	0	0	0	0	0	0
M 3	0	0	0	0	0	0	1.2
M 4	0	0	0	2.2	0	0	3.4
M 5	0	1.0	1.0	0	2.0	0	2.9
M 6	0	0.9	2.8	0	0	0	0
C 7	0	2.1	3.5	0	0	0.7	0
C 8	0	0	0	1.2	1.2	0	0
C 9	0	0.8	0	0	0	0	0
C 10	0	0.9	3.5	0	0.9	0	0
C 11	0	0	0	0	0	0	0
C 12	0	0	10.6	2.9	0	1.9	1.0
C 13	0	2.3	0.6	1.2	0	0.6	0
J 14	0	3.7	0	0	0	0	0
J 15	0	0	0	0	0	0	6.7
J 16	0	1.1	0	0	0	0	3.4
J 17	0	2.2	0	0	0	0	0
J 18	0	1.1	0	9.6	0	0	0
J 19	0	0	0	0	0	0	0
T 20	0.3	0	0	0.7	0	10.3	0

*Locations are described in Table 1. *A. l.* = *Aleoides laphygmae*, *C. i.* = *Chelonus insularis*, *C. c.* = *Chelonus* sp. prob. *cautus*, *C. sp.* = *Chelonus* sp., *C. m.* = *Cotesia marginiventris*, *M. l.* = *Meteorus laphygmae*.

TABLE 3. PERCENTAGE OF FALL ARMYWORM LARVAE PARASITIZED BY EACH SPECIES OF ICHNEUMONIDAE AND EULOPHIDAE AT EACH LOCATION.

Code*	Ichneumonidae			Eulophidae
	<i>C. f.</i>	<i>O. f.</i>	<i>P. s.</i>	<i>E. p.</i>
M 1	0	0	4.0	0
M 2	23.1	0	0	0
M 3	1.2	1.2	1.2	1.2
M 4	1.1	0	2.2	0
M 5	6.9	0	12.7	0
M 6	1.8	0	8.2	0.9
C 7	0	0	0.7	0
C 8	0	0	0	0
C 9	0	0	1.7	0
C 10	0	0	6.1	0
C 11	0	0	0	0
C 12	0	4.8	8.7	0
C 13	0	0.6	2.3	0
J 14	1.2	0	3.7	0
J 15	1.1	0	0	0
J 16	0	0	0	0
J 17	0	0	0	0
J 18	2.3	0	4.5	0
J 19	0	0	0	0
T 20	0	0	0	8.3

*Locations are described in Table 1. *C. f.* = *Camponotus flavicincta*, *O. f.* = *Ophion flavidus*, *P. s.* = *Pristomerus spinator*, *E. p.* = *Euplectrus platyphenae*.

sularis was important in controlling fall armyworm populations in its overwintering habitats of Florida and Southern Texas. Pair et al. (1986) confirmed the importance of *C. insularis* in these areas but found that it was of secondary importance elsewhere. *C. insularis* has been reported as an important parasite of fall armyworm in Latin America (Andrews 1988). Ashley (1986) reported that the Braconidae had the greatest impact on fall armyworm populations with *C. insularis* having the highest parasitism rates in Central and North America.

Chelonus sp. was found in 6 collections, representing all 4 states, and *Chelonus* sp. probably *cautus* was found in 6 collections, representing only 2 states (Table 2). The taxonomy of the genus *Chelonus* needs more study in Mexico (P. M. Marsh, pers. comm.). In our collections, *C. insularis* was most common in Colima and was not found in the single collection from Tamaulipas. When all *Chelonus* sp. are considered, they were found in 14 locations, representing all 4 states. While most of the collections had less than 5% parasitism by any member of the genus *Chelonus*, one collection in Colima had 11% parasitism by *Chelonus* sp. probably *cautus* and one collection from Jalisco had 10% parasitism by *Chelonus* sp. Thus, *Chelonus* spp. appear to be highly important as natural enemies of fall armyworm in Mexico.

Meteorus laphygmae Viereck was found in 4 collections, representing 2 states. It occurred at

only 1 to 2% in the three collections in Colima, but was the most abundant in Tamaulipas with 10%. *Meteorus* sp. was found in 6 collections, representing 3 states, with its highest rate of 7% in Jalisco. Ashley (1986) listed the genus *Meteorus* only from the continental U.S.A., stating that *M. laphygmae* in Texas had its greatest impact on fall armyworm feeding on grass. Andrews (1988) lists *M. laphygmae* from Surinam, Venezuela, and Colombia. Pair et al. (1986) list *Meteorus autographae* Musebeck from Mexico as well as several southern states of the U.S.A.

Aleiodes laphygmae Viereck (formerly *Rogas laphygmae*) was the only parasitoid limited to a single collection, in Tamaulipas. Ashley (1986) reported that *R. laphygmae* appeared to be confined to the continental U. S. and that the highest parasitism rates occurred in fall armyworm feeding on grass. Andrews (1988) listed *R. laphygmae* from Nicaragua.

Cotesia marginiventris Cresson (formerly *Apanteles marginiventris*) was found in 4 collections, representing only 2 states at rates of 2% or lower. *C. marginiventris* has often been reported as a parasitoid of fall armyworm in the U.S.A. (Ashley 1986). Andrews (1988) listed *A. marginiventris* from Lesser Antilles, Surinam, Venezuela, Brazil, and Nicaragua. Ashley (1986) reported that *C. marginiventris* appeared to have its greatest impact on fall armyworm feeding on grass. However, under experimental conditions of whorl-stage corn

infested with newly hatched fall armyworm, *C. marginiventris* can produce rates of parasitism up to 40% in Georgia (Hamm et al. 1994).

Euplectrus platyhyphenae Howard was the only member of the family Eulophidae collected. *E. platyhyphenae* was most abundant in Tamaulipas (8%), but occurred at very low levels in 2 collections from Michoacán. Ashley (1986) lists *E. platyhyphenae* from Lesser Antilles, Cuba, Barbados, Trinidad, Venezuela, and Colombia. Montoya-Burgos (1980) reported natural parasitism by *Euplectrus* sp. against second instar fall armyworm of about 15% in corn from Veracruz.

Due to technological advances in mass rearing, Lewis and Nordlund (1980) suggested *C. insularis* and *C. marginiventris* as candidates for "rear and release" approaches using either: (1) release throughout the overwintering zone, (2) early-season colonization, or (3) therapeutic release on target crops.

We did not sample eggs or pupae and therefore did not find any egg (except for *Chelonus* which is an egg-larval parasitoid) or pupal parasitoids. The rare incidence of tachinid parasitoids was probably due to the low incidence of large host larvae in our collections (Rohlf's & Mack 1985). *Archytas marmoratus* (Townsend) is an important parasitoid of both fall armyworm and corn earworm, *Helicoverpa zea* (Boddie), in whorl-stage corn in the U.S.A (Gross & Pair 1991). Pair et al. (1986) reported that *A. marmoratus* was the primary parasitoid attacking medium and large fall armyworm larvae in whorl-stage corn throughout the southern states during the spring of 1981-83. *Archytas* spp. have been reported attacking *S. frugiperda* in several areas in Latin America (Andrews 1988). The low incidence of *O. flavidus* may also have been influenced by the collection of mostly small larvae (Rohlf's & Mack 1985). Gross & Pair (1991) state that *O. flavidus* parasitized 4th, 5th, and 6th instar armyworm with equal success, but were minimally successful in completing development on late 6th instars. Although *O. flavidus* does not kill the host until the late prepupal or pupal stage, Rohlf's and Mack (1983) found that parasitized larvae consumed 17 to 22% less artificial diet than unparasitized larvae.

Results of this survey suggest a need for more taxonomic studies of parasitic hymenoptera in Mexico, especially for *Meteorus* sp., *Chelonus* sp., and *Chelonus* sp. prob. *cautus*. All of the determined species, except *Pristomerus spinator*, have ranges which extend into the U.S.A. However, they may not be evenly distributed throughout Mexico. This study was only a partial survey of these areas of Mexico within a defined time frame, during the rainy season when most corn is grown. A thorough survey would require sampling all developmental stages of fall armyworm to evaluate the importance of parasitoids that de-

velop in the egg, pupal, and adult stages throughout the growing season for corn and sorghum over several years to determine if the differences seen in this study were due to location, the developmental stage of the host crop, or the developmental stage of the fall armyworm larvae. Additional ecological studies are needed to determine where and how the fall armyworm and its various natural enemies survive the dry season when few crops are available.

ACKNOWLEDGMENTS

The authors express their gratitude to Robert W. Carlson, Paul M. Marsh, and Michael E. Schauff (USDA Systematic Entomology Laboratory, Beltsville, MD) for their assistance in the identification of specimens.

This project was supported in part by Specific Cooperative Agreement #58-6602-7-F101 between the United States Department of Agriculture, Agricultural Research Service and the Universidad de Colima, Mexico.

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