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Authors: Molina-Ochoa, Jaime, Carpenter, James E., Lezama-Gutiérrez, Roberto, Foster, John E., González-Ramírez, Martín, et al.

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NATURAL DISTRIBUTION OF HYMENOPTERAN PARASITOIDS OF *SPODOPTERA FRUGIPERDA* (LEPIDOPTERA: NOCTUIDAE) LARVAE IN MEXICO

JAIME MOLINA-OCHOA[1], JAMES E. CARPENTER[2], ROBERTO LEZAMA-GUTIÉRREZ[1], JOHN E. FOSTER[3], MARTÍN GONZÁLEZ-RAMÍREZ[1], CÉSAR ANDRES ANGEL-SAHAGÚN[1] AND JAVIER FARÍAS-LARIOS[1]
[1]Universidad de Colima, Facultad de Ciencias Biológicas y Agropecuarias
Apartado postal 36, Tecomán, Colima 28100, México

[2]United States Department of Agriculture, Agricultural Research Service
Crop Protection & Management Research Laboratory, P.O. Box 748, Tifton, GA 31793-0748, USA

[3]University of Nebraska Lincoln, Department of Entomology
312F Plant Industry Building, Lincoln, NE 68583-0816, USA

ABSTRACT

A survey of parasitoids of fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), larvae was conducted in six Mexican states during August and September 2000. Thirteen genera of hymenopteran parasitoids were recovered representing the following 3 families, Braconidae: *Aleoides*, *Chelonus*, *Cotesia, Glyptapanteles*, *Homolobus*, and *Meteorus*; Ichneumonidae: *Campoletis*, *Eiphosoma*, *Ophion*, and *Pristomerus*; and Eulophidae: *Aprostocetus*, *Euplectrus,* and *Horismenus*. Out of 5591 FAW larvae collected, 772 produced parasitoids, for a parasitism rate of 13.8%. The highest rate of parasitism from a single collection was 42.2%, representing three species of parasitoids in Michoacán. *Chelonus insularis* Cresson was the most widely distributed species occurring in 45.3% of the locations. *Pristomerus spinator* (F.), and *Meteorus laphygmae* (Viereck), exhibited the highest rates of parasitism for a single collection with 22.2% and 22.1%, in Sinaloa, and Michoacán, respectively. The results supported the hypothesis that natural distribution and rates of parasitism of FAW larvae may be related to more diverse habitats with more forests, orchards, and pastures near to cornfields.

Key Words: fall armyworm, *Chelonus*, *Pristomerus*, *Meteorus*, *Ophion*, *Campoletis*, corn, survey.

RESUMEN

Se llevó a cabo un inventario de parasitoides de larvas del gusano cogollero, *Spodoptera frugiperda* (J. E. Smith) (FAW) colectadas principalmente de maizales en estado de verticilio en seis estados mexicanos durante Agosto y Septiembre de 2000. Trece géneros de parasitoides himenópteros fueron recuperados, representando a tres familias, Braconidae: *Aleoides*, *Chelonus*, *Cotesia*, *Glyptapanteles*, *Homolobus*, y *Meteorus*); Ichneumonidae: *Campoletis*, *Eiphosoma*, *Ophion*, y *Pristomerus*; y Eulophidae: *Aprostocetus*, *Euplectrus*, y *Horismenus*. De un total de 5591 larvas colectadas, 772 produjeron parasitoides, para una tasa de parasitismo de 13.8%. La tasa de parasitismo más alta para una colecta simple fué de 42.2%, representando a tres especies de parasitoides in Michoacán. La especie más ampliamente distribuida fué *Chelonus insularis* Cresson, presentándose en 45.3% de las localidades inventariadas. *Pristomerus spinator* (F.), y *Meteorus laphygmae* (Viereck), mostraron las tasa más altas de parasitismo para una colecta simple con 22.2% y 22.1%, en Sinaloa, y Michoacán, respectivamente. Los resultados apoyan la hipótesis de que la distribución natural y las tasas de parasitismo pueden estar relacionadas a lo diverso de los hábitat con la cercanía de más bosques, huertas y pastizales a los maizales.

Translation provided by the authors.

The therapeutic approach of killing pest organisms with toxic chemicals has prevailed as a pest control strategy for over 50 years (Lewis et al. 1997). In the 1950s environmental effects of persistent organochlorine insecticides such as DDT began to be observed. Currently, in agricultural pest control, the adverse effects of the use of insecticides are leading scientists to search for alternatives to chemical control of insect pests based on health, environmental, wild life, and economic concerns (Johnson et al. 1998; Mattsson et al. 2000; Solomon & Schettler 2000).

Native insects and pathogens are normal parts of functioning agro-ecosystems and can profoundly influence the agricultural structure, species composition, and diversity. Agro-ecosystems exhibit high biodiversity, mainly influenced by crops, weeds, microorganisms, and arthropods, but these factors are also influenced by geographical location, soil, and climatic characteristics, as well as human factors. Scientific evidence suggests that biodiversity can be used for improved pest management (Altieri 1991). The increased use of beneficial insects and interference with the colonization of fall armyworm in multiple cropping systems have prevented outbreaks in Latin America (Altieri 1994).

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), is a voracious pest inflicting damage to a multiplicity of annual crops in the Americas, and it is commonly controlled with synthetic insecticides, although insecticide resistance has been observed and is a concern (Yu 1991, 1992). Moreover, two strains of FAW have been identified according to their host preference, a corn-associated strain that feeds principally on corn, and a rice-associated strain that feeds primarily on forage grasses and rice (Pashley et al. 1987). Both FAW strains exhibited differences in resistance to chemical and biological insecticides (Adamczyk et al. 1997; López-Edwards et al. 1999), and have differences in their genetic population structure and population ecology (Pashley 1988; Lu & Adang 1996; Bossart & Prowell 1998; Levy et al. 2002; Meagher & Gallo-Meagher 2003; Nagoshi & Meagher 2003). These differences between FAW strains complicate the management of this pest.

Biological control is a highly desirable alternative to insecticides for controlling FAW infestations (Gross & Pair 1986). The value of parasitoids in reducing larval populations of this noctuid has long been recognized (Luginbill 1928; Vickery 1929). In order to develop a better understanding of the natural distribution of the FAW parasitoid complex and natural enemies, surveys have been carried out in different regions of Mexico (Carrillo 1980; Lezama-Gutiérrez et al. 2001; Molina-Ochoa et al. 2001, 2003a).

Here, we report the natural distribution of parasitoids of FAW larvae collected from whorl-stage corn, grain sorghum, forage sorghum, and Sudan grass fields from five Mexican states in the Pacific coast and one state in the Gulf of Mexico, during the summer of 2000.

Materials and Methods

During August and September of 2000, *S. frugiperda* larvae were collected from whorl-stage corn, grain and forage sorghum, and Sudan grass fields in 64 locations in the Mexican Pacific coast states of Sinaloa, Nayarit, Jalisco, Colima, and Michoacán, and in the Gulf of Mexico state of Veracruz. Egg masses and pupae were not collected.

FAW larvae were individually placed into 30-cc plastic cups with pinto bean diet (Burton & Perkins 1989), and held in the laboratory (Laboratory of Biological Control, Universidad de Colima, Facultad de Ciencias Biológicas y Agropecuarias, Tecomán, Colima, México) for emergence of parasitoids (Molina-Ochoa et al. 2001). Adult parasitoids were placed in 70% ethanol and then submitted to the USDA/ARS Systematic Entomology Laboratory, Beltsville, MD for identification. Collection size ranged from 33 to 119 FAW larvae. 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 parasitic nematodes has been previously reported (Molina-Ochoa et al. 2003a).

Collection dates, geographic location, altitude, crop, sample size and total parasitism of FAW larvae in six Mexican states are presented in the Table 1. A Garmin GPS III Plusˇ was used for obtaining the coordinates and altitude data.

Results and Discussion

Out of 5591 FAW larvae collected, 772 produced parasitoids, for a parasitism rate of 13.8%. These parasitoids represented 13 genera from three families of Hymenoptera: six Braconidae, four Ichneumonidae, and three Eulophidae. Nine of the 64 collections produced no parasitoids, six of 12 collections from whorl-stage corn in Michoacán, two of 13 in Jalisco, and only one of 11 in Colima. The highest rates of parasitism in each state were found in C4 (33.3%) in Colima, J12 (21.1%)in Jalisco, M12 (14.4%) in Michoacán, N9 (18.9%) in Nayarit, S5 (27.4%) in Sinaloa, and V4 (11.5%) in Veracruz (Table 1). The most diverse collections of parasitoids were found in the locations C5, J12, and N9 with 5, 4, and 4 species, respectively, (Tables 2 and 3). The collection from S5 produced the highest rate of parasitism for a single species with 22.1%; the braconid *Meteorus laphygmae* Viereck was the most common parasitoid collected from Sudangrass. Other parasitoids in that collection were the eulophid *Euplectrus plathypenae* Howard (2 individuals), and the ichneumonid *Ophion flavidus* Brulle (1 individual). The braconid *C. insularis* occurred in 29 of the 64 collections from the six states, and it was the most widely distributed parasitoid. Another important braconid was *M. laphygmae*, occurring in 21 of the 64 collections. The ichneumonid parasitoids, *O. flavidus*, and *Pristomerus spinator* F., occurred in 18, and 17 of the 64 collections, respectively. *E. plathypenae* was the most important and widely distributed eulophid, occurring in 16 of the 64 collections (Tables 2 and 3).

Chelonus insularis was the most widely distributed parasitoid of FAW larvae in this survey, occurring in all the six Mexican States, and it was the braconid species with the second highest parasitism rate per location with 16.7%. Thus, *C. in-*

TABLE 1. GEOGRAPHIC LOCATION, DATE, ALTITUDE, CROP (*), SAMPLE SIZE (*N*), AND TOTAL PERCENT *SPODOPTERA FRUGIPERDA* LARVAE PARASITIZED IN SIX MEXICAN STATES (**) DURING 2000.

Code	Date	Location	Coordinates	Alt (m)	*	N	Percentage parasitized
C1	08/04	El poblado, Coquimatlán	19°3.698'N 103°47.722'W	422	C	90	17.8
C2	08/04	Pueblo Juárez, Coquimatlán	19°10.752'N 103°54.634'W	279	C	90	4.4
C3	08/04	Amachico, Coquimatlán	19°10.667'N 103°56.351'W	328	C	90	12.2
C4	08/06	Los mezcales, Comala	19°20.811'N 103°47.176'W	608	C	90	33.3
C5	08/06	El remate, Comala	19°24.825'N 103°47.639'W	817	C	90	13.3
C6	08/06	Carrizalillo, Quesería	19°25.389'N 103°41.000'W	1550	C	90	1.1
C7	08/06	Quesería	19°23.362'N 103°34.882'W	1304	c	90	10.0
C8	08/06	Villa de Alvarez	19°17.201'N 103°47.030'W	515	c	90	4.4
C9	08/06	Juluapan, Villa de Alvarez	19°18.890'N 103°49.611'W	539	c	90	4.4
C10	08/07	Tepames, Colima	19°08.231'N 103°37.996'W	519	c	90	0.0
C11	08/07	Estapilla, Colima	18°59.549'N 103°31.140'W	304	c	90	21.1
J1	08/08	Ciudad Guzmán	19°40.011'N 103°28.830'W	1557	c	90	0.0
J2	08/15	Los pinitos, Tonila	19°25.343'N 103°32.447'W	1326	c	90	2.2
J3	08/15	Pialla, Tuxpan	19°27.293'N 103°28.514'W	1079	c	90	0.0
J4	08/15	Atenquique, Tuxpan	19°31.778'N 103°27.851'W	1338	c	90	1.1
J5	08/17	Canoas, Zapotiltic	19°34.073'N 103°27.324'W	1391	c	90	3.3
J6	08/17	Apastepe	19°38.060'N 103°30.950'W	1709	c	90	1.1
J7	08/17	Teocuitatlán	20°07.035'N 103°32.704'W	1369	c	90	10.0
J8	08/17	Zacoalco de Torres	20°11.988'N 103°33.806'W	1425	c	90	4.4
J9	08/17	Acatlán de Juárez	20°25.362'N 103°33.406'W	1575	c	96	2.1
J10	08/17	Tlajomulco de Zúñiga	20°29.396'N 103°28.298'W	1607	c	92	4.3
J11	08/18	Zapopan	20°43.129'N 103°29.041'W	1670	c	90	4.4
J12	08/18	Magdalena	20°53.008'N 103°55.477'W	1496	c	93	21.5
J13	08/23	Crucero de Magdalena	20°56.300'N 104°02.509'W	1386	c	92	2.2
M1	08/09	Totolán	19°58.890'N 102°40.183'W	1590	c	90	0.0
M2	08/09	Santa Inés Tocumbo	19°44.502'N 102°34.967'W	1630	c	90	1.1
M3	08/09	Peribán	19°33.106'N 102°26.586'W	1475	c	90	1.1
M4	08/10	Cointzio	19°41.609'N 101°16.398'W	1932	c	90	0.0

*Corn (c), gran sorghum (gs), forage sorghum (fs), and Sudan grass (sg).
**Colima (C), Jalisco (J), Michoacan (M) Nayarit (N), Sinaloa (S), and Veracruz (V).

TABLE 1. (CONTINUED) GEOGRAPHIC LOCATION, DATE, ALTITUDE, CROP (*), SAMPLE SIZE (*N*), AND TOTAL PERCENT *SPODOPTERA FRUGIPERDA* LARVAE PARASITIZED IN SIX MEXICAN STATES (**) DURING 2000.

Code	Date	Location	Coordinates	Alt (m)	*	N	Percentage parasitized
M5	08/10	Cerro "La Esperanza"	19°41.223'N 101°18.980'W	1998	c	90	1.1
M6	08/11	Tejabán	19°13.342'N 101°53.714'W	587	c	90	0.0
M7	08/11	Carretera a Nueva Italia	19°03.290'N 102°02.458'W	442	c	90	0.0
M8	08/11	Presa de Zicuirán	18°56.191'N 101°54.650'W	292	c	63	0.0
M9	08/11	El ceñidor, Nueva Italia	18°59.651'N 102°11.577'W	350	c	57	1.8
M10	08/12	La Guadalupe Parácuaro	19°07.472'N 102°12.519'W	540	fs	90	1.1
M11	08/12	Las yeguas Parácuaro	18°57.308'N 102°16.733'W	359	fs	90	1.1
M12	08/12	El cirián, Nueva Italia	18°53.661'N 102°07.483'W	255	c	90	42.2
N1	08/18	Santa María del Oro	21°20.121'N 104°40.174'W	1160	c	90	3.3
N2	08/18	El rincón, Tepic	21°32.472'N 104°56.123'W	849	c	96	10.4
N3	08/18	El pichón, Tepic	21°33.479'N 104°56.937'W	774	c	95	4.2
N4	08/19	Xalisco	21°19.601'N 104°55.060'W	1042	c	107	2.8
N5	08/19	El refilión, Xalisco	21°19.407'N 104°55.323'W	964	c	90	8.9
N6	08/19	Compostela	21°17.858'N 104°54.044'W	920	c	93	1.1
N7	08/19	La presa, Compostela	21°13.714'N 104°52.162'W	928	c	90	1.1
N8	08/20	Las lumbres, Acaponeta	22°20.795'N 105°18.141'W	48	C&gs	60	5.0
N9	08/23	Seboruco	21°20.850'N 104°40.749'W	1134	c	90	18.9
N10	08/23	Ahuacatlán	21°06.331'N 104°27.427'W	1120	c	90	5.6
S1	08/21	Bacurimi, Culiacán	24°51.668'N 107°29.478'W	70	gs	97	4.1
S2	08/21	La campana, Culiacán	24°58.415'N 107°33.517'W	143	gs	100	5.0
S3	08/21	Pericos, Mocorito	25°03.574'N 107°39.547'W	80	gs	95	9.5
S4	08/21	Rancho viejo, Mocorito	25°06.033'N 107°43.165'W	89	gs	98	13.3
S5	08/22	Aguapepito, Mocorito	25°03.861'N 107°39.547'W	68	sg	95	27.4
S6	08/22	Comanito, Mocorito	25°09.006'N 107°39.645'W	91	gs	95	3.2
S7	08/22	La poma, Badiraguato	25°15.749'N 107°40.739'W	157	c	100	13.0
S8	08/22	La majada, Badiraguato	25°14.076'N 107°39.781'W	145	c	92	7.6
V1	09/02	Seis de Enero, Xalapa	19°34.115'N 96°50.207'W	950	c	91	6.6
V2	09/02	Altolucero, Almolonga	19°35.063'N 96°47.384'W	908	c	33	12.1

*Corn (c), gran sorghum (gs), forage sorghum (fs), and Sudan grass (sg).
**Colima (C), Jalisco (J), Michoacan (M) Nayarit (N), Sinaloa (S), and Veracruz (V).

TABLE 1. (CONTINUED) GEOGRAPHIC LOCATION, DATE, ALTITUDE, CROP (*), SAMPLE SIZE (*N*), AND TOTAL PERCENT *SPODOPTERA FRUGIPERDA* LARVAE PARASITIZED IN SIX MEXICAN STATES (**) DURING 2000.

Code	Date	Location	Coordinates	Alt (m)	*	N	Percentage parasitized
V3	09/02	Actopan	19°34.623'N 96°48.589'W	775	c	64	3.1
V4	09/02	Los González, Actopan	19°31.894'N 96°41.294'W	432	c	113	11.5
V5	09/02	Bocana, Actopan	19°24.416'N 96°36.731'W	311	c	119	4.2
V6	09/03	El volador, Coatepec	19°21.594'N 96°51.037'W	709	c	90	3.3
V7	09/03	Palmillas	19°12.293'N 96°46.221'W	702	c	59	6.8
V8	09/03	Tierra Colorada	19°13.255'N 96°21.916'W	46	c	45	4.4
V9	09/04	Cerro gordo	19°25.252'N 96°39.566'W	443	c	45	8.9
V10	09/04	La cumbre	19°23.320'N 96°38.807'W	366	c	66	6.1

*Corn (c), gran sorghum (gs), forage sorghum (fs), and Sudan grass (sg).
**Colima (C), Jalisco (J), Michoacan (M) Nayarit (N), Sinaloa (S), and Veracruz (V).

sularis is one of the most abundant natural enemies of fall armyworm larvae in the Western Coast and Gulf of Mexico. *Chelonus insularis* has been reported as an important parasitoid controlling FAW populations in the US (Lugingill 1928; Vickery 1929). Ashley (1986) and Andrews (1988) listed *C. insularis* occurring in Central America and the US, highlighting its role as parasitoid of FAW in southern Florida where 63% of the FAW larvae were attacked. Recently, Molina-Ochoa et al., (2003b) reported *C. insularis* syn. *C. texanus* as the braconid with the broadest distribution in Latin America, including South America (Uruguay and Venezuela), the Caribbean Basin (Trinidad and Puerto Rico), and the US. In that inventory *Chelonus* sp. is also reported in Brazil, Mexico, and Peru. Lewis and Nordlund (1980) emphasized its role considering it as an excellent candidate for the following augmentative approaches: a) release throughout its overwintering zone; b) early-season colonization, and c) direct therapeutic release on target crops.

In a previous survey, Molina-Ochoa et al. (2001) commented on the importance and need of more study in Mexico on the taxonomy of the genus *Chelonus* (P. M. Marsh, pers. comm.).

Meteorus laphygmae occurred in 21 of the 64 collections. The highest rate of parasitism for a single location was obtained in S5 with 22.1%. This parasitoid occurred in all of the collections from Sinaloa, and the rate of parasitism ranged from 2.1 to 22.1%. *Meteorus laphygmae* was also collected in Colima, Nayarit, Michoacán, Jalisco, and Veracruz occurring in 45.5%, 30%, 25%, 10%, and 8.3% of the collections, respectively. This braconid was reported by Ashley (1986) occurring in the Continental US, exhibiting its greatest impact on FAW collected from grass. Other reports were made by Alvarado-Rodríguez (1987) in Sinaloa, Mexico attacking *Spodoptera exigua* (Hübner) infesting tomatoes with a parasitism rate of 9.0%. A similar rate of parasitism was reported by Molina-Ochoa et al. (2001) in a single collection of FAW larvae made in El Mante, Tamaulipas with 10.3%. Molina-Ochoa et al. (2003b) listed several reports from countries of Central and South America, such as Honduras, Nicaragua, Mexico, Chile, Colombia, and Suriname, where *M. laphygmae* was collected from other crops such as maize, rice, cotton, sorghum, peanuts, and Bermudagrass, and was one of the most prevalent parasitoids in South America.

Low rates of occurrence and parasitization of *Cotesia* sp. probably *marginiventris* (Cresson), *Glyptapanteles* sp. probably *militaris* (Walsh), *Aleiodes* sp., and *Homolobus* sp. probably *mellea* (Cresson) were recorded. They were found in 5, 2, 1, and 1 of the 64 collections, respectively.

Cotesia sp. occurred in Colima, Jalisco, Nayarit with lower parasitization rates than 2.3%. Similar rates were reported by Molina-Ochoa et al. (2001) in a previous survey conducted in four Mexican States. This parasitoid is reported attacking FAW larvae in Argentina, Brazil, Chile, Honduras, Lesser Antilles, Mexico, Nicaragua, Puerto Rico, Suriname (Molina-Ochoa et al. 2003b), but it has been often reported as a parasitoid of FAW in the US (Ashley 1986) with parasitization rates of 6.3% on FAW larvae collected from maize (Riggin et al. 1993) and from less than 1% to 40% collected from maize and Bermudagrass, respectively (Ashley et al. 1983).

TABLE 2. PERCENTAGE OF *SPODOPTERA FRUGIPERDA* LARVAE PARASITIZED BY EACH SPECIES OF BRACONIDAE AT EACH LOCATION.

	Braconidae					
Code*	*Aleoides*	*Chelonus*	*Cotesia*	*Glyptapanteles*	*Homolobus*	*Meteorus*
C1	0.0	3.3	0.0	0.0	0.0	2.2
C2	0.0	0.0	0.0	0.0	0.0	1.1
C3	0.0	7.8	0.0	0.0	0.0	0.0
C4	0.0	16.7	1.1	0.0	0.0	0.0
C5	0.0	1.1	1.1	0.0	0.0	4.4
C6	0.0	0.0	0.0	0.0	0.0	0.0
C7	0.0	1.1	1.1	0.0	0.0	0.0
C8	0.0	2.2	0.0	0.0	0.0	1.1
C9	0.0	1.1	0.0	0.0	0.0	2.2
C10	0.0	0.0	0.0	0.0	0.0	0.0
C11	0.0	14.4	0.0	0.0	0.0	0.0
J1	0.0	0.0	0.0	0.0	0.0	0.0
J2	0.0	0.0	0.0	0.0	0.0	0.0
J3	0.0	0.0	0.0	0.0	0.0	0.0
J4	0.0	0.0	0.0	0.0	0.0	0.0
J5	0.0	0.0	0.0	0.0	0.0	0.0
J6	0.0	1.1	0.0	0.0	0.0	0.0
J7	0.0	3.3	0.0	0.0	0.0	1.1
J8	0.0	4.4	0.0	0.0	0.0	0.0
J9	0.0	0.0	0.0	0.0	0.0	0.0
J10	0.0	3.3	0.0	0.0	0.0	0.0
J11	0.0	1.1	0.0	0.0	0.0	0.0
J12	0.0	15.1	1.1	0.0	0.0	0.0
J13	0.0	1.1	0.0	0.0	0.0	0.0
M1	0.0	0.0	0.0	0.0	0.0	0.0
M2	0.0	0.0	0.0	0.0	0.0	1.1
M3	0.0	0.0	0.0	0.0	1.1	0.0
M4	0.0	0.0	0.0	0.0	0.0	0.0
M5	0.0	0.0	0.0	0.0	0.0	0.0
M6	0.0	0.0	0.0	0.0	0.0	0.0
M7	0.0	0.0	0.0	0.0	0.0	0.0
M8	0.0	0.0	0.0	0.0	0.0	0.0
M9	0.0	0.0	0.0	0.0	0.0	1.8
M10	0.0	1.1	0.0	0.0	0.0	0.0
M11	0.0	0.0	0.0	0.0	0.0	1.1
M12	0.0	14.4	0.0	0.0	0.0	0.0
N1	0.0	0.0	0.0	0.0	0.0	0.0
N2	1.0	1.0	0.0	8.3	0.0	0.0
N3	0.0	1.1	0.0	0.0	0.0	2.1
N4	0.0	0.0	0.0	1.9	0.0	0.9
N5	0.0	1.1	0.0	0.0	0.0	2.2
N6	0.0	0.0	0.0	0.0	0.0	0.0
N7	0.0	0.0	0.0	0.0	0.0	0.0
N8	0.0	5.0	0.0	0.0	0.0	0.0
N9	0.0	5.6	2.2	0.0	0.0	0.0
N10	0.0	2.2	0.0	0.0	0.0	0.0
S1	0.0	0.0	0.0	0.0	0.0	2.1
S2	0.0	1.0	0.0	0.0	0.0	4.0
S3	0.0	0.0	0.0	0.0	0.0	8.4
S4	0.0	1.0	0.0	0.0	0.0	12.2
S5	0.0	0.0	0.0	0.0	0.0	22.1
S6	0.0	0.0	0.0	0.0	0.0	3.2

Aleiodes sp., *Chelonus* sp. Probably *insularis* Cresson, *Cotesia* sp. probably *marginiventris* Cresson, *Glyptapanteles* sp. probably *militaris* Walsh, *Homolobus* sp. probably *mellea* Cresson, *Meteorus* sp. probably *laphygmae* Viereck.

TABLE 2. (CONTINUED) PERCENTAGE OF *SPODOPTERA FRUGIPERDA* LARVAE PARASITIZED BY EACH SPECIES OF BRACONIDAE AT EACH LOCATION.

	Braconidae					
Code*	*Aleoides*	*Chelonus*	*Cotesia*	*Glyptapanteles*	*Homolobus*	*Meteorus*
S7	0.0	2.0	0.0	0.0	0.0	10.0
S8	0.0	0.0	0.0	0.0	0.0	6.5
V1	0.0	3.3	0.0	0.0	0.0	1.1
V2	0.0	0.0	0.0	0.0	0.0	0.0
V3	0.0	0.0	0.0	0.0	0.0	0.0
V4	0.0	0.0	0.0	0.0	0.0	0.0
V5	0.0	0.0	0.0	0.0	0.0	0.0
V6	0.0	1.1	0.0	0.0	0.0	0.0
V7	0.0	0.0	0.0	1.7	0.0	0.0
V8	0.0	0.0	0.0	0.0	0.0	0.0
V9	0.0	0.0	0.0	0.0	0.0	0.0
V10	0.0	0.0	0.0	0.0	0.0	0.0

Aleiodes sp., *Chelonus* sp. Probably *insularis* Cresson, *Cotesia* sp. probably *marginiventris* Cresson, *Glyptapanteles* sp. probably *militaris* Walsh, *Homolobus* sp. probably *mellea* Cresson, *Meteorus* sp. probably *laphygmae* Viereck.

Glyptapanteles sp. was found in Nayarit in two collections, N2 and N4, with parasitization rates of 8.3% and 1.9%, respectively, and in one location in Veracruz (V7) with 1.7% of parasitism rate. Rohlfs & Mack (1985), and Cave (1993) reported the occurrence of this parasitoid attacking FAW larvae in the US and Honduras, collected from sorghum and maize, respectively. Steffey (2001) reported *G. militaris* attacking armyworms and other caterpillars in Illinois. He speculated that this braconid and other natural enemies could suppress armyworm populations and keep them well below economic levels. Recently, Reis et al. (2003) suggested that the parasitoid may be well adapted to the Azorean agricultural systems in Portugal, characterized by prevalence of the grass, *Lolium perenne* L., throughout the year. The armyworm, *Pseudaletia unipuncta* (Haworth) when fed on fresh leaves of *L. perenne* is the most suitable host for the mass rearing of this braconid.

Aleiodes sp. occurred only in one collection in Nayarit (N2), and *Homolobus* sp. was found in Michoacán (M3), and their parasitism was lower than 1.2%. Ruíz-Cancino (1991) reported species of *Rogas* (Syn: *Aleiodes*) occurring in "La Reserva de la Biosfera *El Cielo*" in Tamaulipas, Mexico, and the family Braconidae is the second more abundant with 10% of the individuals, these braconids were attacking insect pest of annual, perennial and ornamental crops. *Aleiodes laphygmae* was reported by Molina-Ochoa et al. (2001) with a low parasitism rate (0.3%) on FAW larvae in Tamaulipas, Mexico. This braconid, *A. laphygmae* was the most abundant parasitoid attacking FAW larvae (12.8% parasitism) in South Georgia (Riggin et al. 1993).

Homolobus sp. probably *mellea* (Cresson), syn: *Zele mellea* (Cresson) was previously found in small numbers attacking FAW larvae in Honduras (Cave 1993), Nicaragua (Huis 1981) and the US (Vickery 1929; Wilson 1933; Riggin et al. 1992), but was not previously reported in Mexico. Parasitism by this species was low (1.1%), but finding it contributes to our knowledge on the occurrence and diversity of beneficial insects affecting FAW populations in Michoacán.

The ichneumonid parasitoids, *O. flavidus, P. spinator,* and *C. flavicincta* were the most frequently reared species in 18, 17, and 14 of the 64 collections, respectively. *Ophion flavidus* was recovered in more locations in Michoacán, and Colima (5 and 4 locations, respectively), but the highest parasitism rate for a single location was obtained in Colima (C7) with 6.7%. Similar results were reported by Molina et al. (2001), and Riggin et al. (1993). Recently, Molina-Ochoa et al., (2003b) listed the occurrence of *O. flavidus* in Argentina, Brazil, Honduras, Mexico, Nicaragua, and the US. Ashley et al. (1983) reported that *Ophion* sp. attacked FAW larvae developing on volunteer corn and Paragrass at Homestead, Florida. Gross & Pair (1991) emphasized that the tachinid *Archytas marmoratus* (Townsend) and *O. flavidus* provide opportunities for advancing biological strategies for managing FAW, with the development of economical methods for mass-propagation.

P. spinator was the second most widely distributed ichneumonid parasitoid. It was recovered in 17 of the 64 collections, 7 in Colima, 2 in Jalisco, 4 in Michoacán, and Nayarit, but this species was not recovered from Sinaloa, and Veracruz. The highest rate of parasitism for a single location was obtained in Michoacán (M12) with 22.2%. *Pristomerus spinator* has been reported in Mexico occurring in Quintana Roo, Tamaulipas (Carrillo 1980), and Michoacán, Colima, and Jalisco (Molina-Ochoa et al.

TABLE 3. PERCENTAGE OF *Spodoptera frugiperda* LARVAE PARASITIZED BY EACH SPECIES OF ICHNEUMONIDAE AND EULOPHIDAE AT EACH LOCATION.

	Ichneumonidae				Eulophidae		
Code*	C.f	E.v	O.f	P.s	*A*.sp	*E*.p	*H*.sp
C1	0.0	0.0	0.0	12.2	0.0	0.0	0.0
C2	0.0	2.2	0.0	1.1	0.0	0.0	0.0
C3	0.0	0.0	0.0	4.4	0.0	0.0	0.0
C4	0.0	1.1	0.0	14.4	0.0	0.0	0.0
C5	0.0	0.0	5.6	1.1	0.0	0.0	0.0
C6	1.1	0.0	0.0	0.0	0.0	0.0	0.0
C7	0.0	0.0	6.7	1.1	0.0	0.0	0.0
C8	0.0	0.0	1.1	0.0	0.0	0.0	0.0
C9	0.0	0.0	1.1	0.0	0.0	0.0	0.0
C10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
C11	0.0	0.0	0.0	6.7	0.0	0.0	0.0
J1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J2	0.0	0.0	0.0	2.2	0.0	0.0	0.0
J3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J4	0.0	0.0	1.1	0.0	0.0	0.0	0.0
J5	0.0	0.0	0.0	3.3	0.0	0.0	0.0
J6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J7	1.1	0.0	4.4	0.0	0.0	0.0	0.0
J8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
J9	2.1	0.0	0.0	0.0	0.0	0.0	0.0
J10	1.1	0.0	0.0	0.0	0.0	0.0	0.0
J11	3.3	0.0	0.0	0.0	0.0	0.0	0.0
J12	3.2	0.0	2.1	0.0	0.0	0.0	0.0
J13	0.0	0.0	0.0	0.0	0.0	1.1	0.0
M1	3.3	0.0	1.1	0.0	0.0	0.0	0.0
M2	2.2	0.0	0.0	3.3	0.0	0.0	0.0
M3	0.0	0.0	3.3	1.1	0.0	0.0	0.0
M4	0.0	0.0	1.1	1.1	0.0	0.0	0.0
M5	1.1	0.0	0.0	0.0	0.0	0.0	0.0
M6	0.0	3.3	0.0	0.0	0.0	0.0	0.0
M7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M8	0.0	0.0	0.0	0.0	0.0	1.6	0.0
M9	0.0	0.0	1.8	0.0	0.0	0.0	0.0
M10	0.0	0.0	1.1	0.0	0.0	1.1	0.0
M11	0.0	2.2	0.0	0.0	0.0	0.0	0.0
M12	0.0	5.6	0.0	22.2	0.0	0.0	0.0
N1	2.2	0.0	0.0	1.1	0.0	0.0	0.0
N2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N3	0.0	1.1	0.0	0.0	0.0	0.0	0.0
N4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N5	1.1	0.0	1.1	3.3	0.0	0.0	0.0
N6	0.0	0.0	1.1	0.0	0.0	0.0	0.0
N7	1.1	0.0	0.0	0.0	0.0	0.0	0.0
N8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
N9	3.3	0.0	0.0	7.8	0.0	0.0	0.0
N10	2.2	0.0	0.0	1.1	0.0	0.0	0.0
S1	0.0	0.0	2.1	0.0	0.0	0.0	0.0
S2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S3	0.0	0.0	1.1	0.0	0.0	0.0	0.0
S4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
S5	0.0	0.0	1.1	0.0	0.0	4.2	0.0
S6	0.0	0.0	0.0	0.0	0.0	0.0	0.0

C.f = *Campoletis flavicincta* Ashmead, E.v = *Eiphosoma vitticolle* Cresson, O.f = *Ophion flavidus* Brulle, P.s = *Pristomerus spinator* Fabricius, *A*.sp. = *Aprostocetus* sp., *E*.p = *Euplectrus plathypenae* Howard, *H*.sp. = *Horismenus* sp.

TABLE 3. (CONTINUED) PERCENTAGE OF *Spodoptera frugiperda* LARVAE PARASITIZED BY EACH SPECIES OF ICHNEUMONIDAE AND EULOPHIDAE AT EACH LOCATION.

	Ichneumonidae				Eulophidae		
Code*	C.f	E.v	O.f	P.s	*A*.sp	*E*.p	*H*.sp
S7	0.0	0.0	0.0	0.0	0.0	1.0	0.0
S8	0.0	0.0	0.0	0.0	0.0	1.1	0.0
V1	0.0	0.0	0.0	0.0	0.0	2.2	0.0
V2	0.0	0.0	0.0	0.0	3.0	6.1	3.0
V3	0.0	0.0	0.0	0.0	0.0	3.1	0.0
V4	0.0	0.0	0.0	0.0	0.0	11.5	0.0
V5	0.0	0.0	0.0	0.0	0.0	4.2	0.0
V6	0.0	0.0	0.0	0.0	0.0	2.2	0.0
V7	0.0	0.0	0.0	0.0	0.0	5.1	0.0
V8	0.0	0.0	0.0	0.0	0.0	4.4	0.0
V9	0.0	0.0	0.0	0.0	0.0	8.9	0.0
V10	0.0	0.0	0.0	0.0	0.0	6.1	0.0

C.f = *Campoletis flavicincta* Ashmead, E.v = *Eiphosoma vitticolle* Cresson, O.f = *Ophion flavidus* Brulle, P.s = *Pristomerus spinator* Fabricius, *A*.sp. = *Aprostocetus* sp., *E*.p = *Euplectrus plathypenae* Howard, *H*.sp. = *Horismenus* sp.

2001). Two collections from Michoacán during 1998 and 2000 exhibited the highest parasitism rates for a single location (El Hueso, and El Cirián, Nueva Italia) with 12.7%, and 22.2%, respectively. The ichneumonid was previously reported from Brazil, Honduras, Mexico, Nicaragua, and the US (Molina-Ochoa et al. 2003b).

Campoletis flavicincta was found in 14 of 64 collections, one in Colima, 5 in Jalisco, 3 in Michoacán, and 5 in Nayarit, but it was not recovered in Sinaloa, and Veracruz. *Campoletis flavicincta* had an overall parasitism range from 0 to 3.3%. The highest parasitism rate for a single location was obtained in N9. In a previous survey conducted by Molina-Ochoa et al. (2001), *C. flavicincta* accounted for 23% of parasitism in El Batillero, Michoacán, a location surrounded by avocado orchards and pine forest near to Apo, Michoacán; however, the FAW larvae from nearby locations in this survey (M1 and M2) showed low parasitism rates (3.3%, and 2.2%, respectively) by this parasitoid. It appears that, *C. flavicincta,* prefers or was associated with locations with high altitude; in this survey, it was found in locations with altitudes with an average of 1417 meters, as well as in locations near forests mainly constituted with pine and oak trees. Molina-Ochoa et al. (2003b) reported *C. flavicincta* occurring in Brazil, Honduras, Mexico, Nicaragua, and the US. This species was also reported attacking beet armyworm larvae fed on cotton in Georgia, USA (Ruberson et al. 1993, 1994).

Eiphosoma vitticole was the ichneumonid with the most limited distribution in this survey, found in 6 of the 64 collections. *E. vitticole* occurred in 2 locations in Colima, 3 locations in Michoacán, and 1 location in Nayarit. The highest rate of parasitism for a single location was recorded in M12 with 5.6%. This species showed low parasitism rates, and it was not found in Jalisco, Sinaloa, and Veracruz. It was collected from locations with an average altitude of 472m, with a range between 255 and 744m. Pair et al. (1986) reported the occurrence of *E. vitticole* in Texas, and Tamaulipas, Mexico. It also has been reported from Bolivia, Brazil, Colombia, Honduras, and Nicaragua (Molina-Ochoa et al. 2003b)

Three species of eulophid parasitoids were found in this survey, *Aprostocetus* sp., *Euplectrus plathypenae* Howard, and *Horismenus* sp. *Euplectrus plathypenae* was the most widely distributed eulophid, occurring in 16 of the 64 collections. It was found in Veracruz in all collections (10), Sinaloa in 3 collections, 2 in Michoacán, and one in Jalisco. Molina-Ochoa et al. (2001) reported a parasitism rate of 8.3% by *E. plathypenae* in a single collection in El Mante, Tamaulipas, similar rates in several locations in Veracruz, and low rate of about 1% in Michoacán. We also did not find levels higher than 1.6% in Michoacán; however, we found a range of parasitism in Sinaloa between 1% and 4.2%. The highest level of parasitism for a single location was obtained in the location V4 with 11.5%. Montoya-Burgos (1980) reported natural parasitism of about 15% by *Euplectrus* sp. against L2 FAW developing on corn in Veracruz. *Euplectrus plathypenae* is an important and well distributed parasitoid in the tropical Americas, and the US (Molina-Ochoa et al. (2003b).

The other eulophids, *Aprostocetus* sp. and *Horismenus* sp., occurred only in the location V2, with a parasitism rate of 3.0% for both species. This is the first report of *Aprostocetus* sp. and *Horismenus* sp. as parasitoids of FAW larvae. *Aprostocetus* sp. has been reported as a hyperparasitoid of *Gelechia senticetella* (Stgr.) (Lepidoptera:

Gelechiidae) fed on *Juniperus excelsa* in Bulgaria (Mirchev et al. 2001). *Aprostocetus* sp. also was reported as an egg parasitoid of mango leafhoppers (Fasih & Srivatava 1990). *Aprostocetus diplosis* Crawford is a parasitoid of *Stenodiplosis sorghicola*, a dipterous pest of sorghum in Brazil (Campos et al. 1998). *Horismenus* sp. has been reported to be a parasitoid of prepupae and pupae of the Citrus leafminer, *Phyllocnistis citrella* (Lepidoptera: Gracillariidae) in Mexico (Perales et al. 1996, Bautista-Martínez et al. 1998). Coffelt & Schultz (1993) mentioned that it is very common to find species of this genus acting as hyperparasitoids.

Our results demonstrate that hymenopteran parasitoids of FAW differentially occurred throughout the six Mexican states surveyed. However, this may have been influenced by the size of the FAW larvae collected. The hymenopteran parasitoids caused significant mortality of FAW larvae in most of the localities of this survey. It is important to highlight the occurrence and role on the FAW larval mortality caused by the braconids, *C. insularis*, and *M. laphygmae,* the ichneumonids, *O. flavidus*, *P. spinator,* and *C. flavicincta*, as well as the eulophid *E. plathypenae*. Our findings agree with Ashley (1986) in that no single parasitoid species exerted significant mortality throughout a major portion of the range of FAW. Another important aspect to note is the need for more taxonomic studies on two genera, *Chelonus* and *Meteorus*, which are important sources of mortality for FAW larvae.

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