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

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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: Aleoideae, 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: Aleoideae, 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 fue de 42.2%, representando a tres especies de parasitoides en Michoacán. La especie más ampliamente distribuida fue Chelonus insularis Cresson, presentándose en 45.3% de las localidades inventariadas. Pristomerus spinator (F.), y Meteorus laphygmae (Viereck), mostraron las tasas 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...
giperda

cost and one state in the Gulf of Mexico, during
grass fields from five Mexican states in the Pacific
region (Carrillo 1980; Lezama-Gutiérrez et al. 2001;
have been carried out in different regions of Mex-
ical location, soil, and climatic characteristics, as
well as human factors. Scientific evidence sug-
gests 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 crop-
ning systems have prevented outbreaks in Latin
America (Altieri 1994).

The fall armyworm (FAW), Spodoptera fru-
giperda (J. E. Smith), is a voracious pest inflict-
ing damage to a multiplicity of annual crops in the
Americas, and it is commonly controlled with syn-
thetic 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 primar-
ily on forage grasses and rice (Pashley et al. 1987).
Both FAW strains exhibited differences in resis-
tance to chemical and biological insecticides (Ad-
amczyk 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 alterna-
tive to insecticides for controlling FAW infesta-
tions (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 under-
standing of the natural distribution of the FAW
parasitoid complex and natural enemies, surveys
have been carried out in different regions of Mex-
ico (Carrillo 1980; Lezama-Gutiérrez et al. 2001;
Molina-Ochoa et al. 2001, 2003a).

Here, we report the natural distribution of par-
asitoids 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. fru-
giperda 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, Nayarat, Jalisco, Colima, and
Michoacán, and in the Gulf of Mexico state of Ve-
racruz. 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 (Labo-

**RESULTS AND DISCUSSION**

Out of 5591 FAW larvae collected, 772 pro-
duced 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 Mich-
ocaín, 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 loca-
tions C5, J12, and N9 with 5, 4, and 4 species, re-
spectively, (Tables 2 and 3). The collection from S5
produced the highest rate of parasitism for a sin-
gle species with 22.1%; the braconid Meteorus la-
phygmae Viereck was the most common
parasitoid collected from Sudangrass. Other
parasitoids in that collection were the eulophid Eu-
pectrus plathypenae Howard (2 individuals), and
the ichneumonid Ophion flavidus Brulle (1 indi-
vidual). 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 para-
sitoids, O. flavidus, and Pristomerus spinator F.,
occurred in 18, and 17 of the 64 collections, re-
spectively. E. plathypenae was the most impor-
tant and widely distributed eulophid, occurring in
16 of the 64 collections (Tables 2 and 3).

Chelonus insularis was the most widely dis-
tributed parasitoid of FAW larvae in this survey,
occuring in all the six Mexican States, and it was
the braconid species with the second highest par-
asitism rate per location with 16.7%. Thus, C. in-
TABLE 1. GEOGRAPHIC LOCATION, DATE, ALTITUDE, CROP (*), SAMPLE SIZE (N), AND TOTAL PERCENT *SPODOPTERA FUGIPERDA* 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°18.880'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 | Atenqueique, Tuxpan       | 19°31.778'N 103°27.851'W | 1338    | c  | 90  1.1                |
| J5   | 08/17 | Canoa, 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 | 18°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| Aguanepito, 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).
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 (Luginill 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* (Hubner) 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 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°34.623N 96°48.589W | 775      | c | 64 | 3.1                    |
| V4   | 09/02| Los González, Actopan | 19°31.894N 96°41.294W | 432      | c | 113 | 11.5                  |
| V5   | 09/02| Bocana, Actopan | 19°24.416N 96°36.731W | 311      | c | 119 | 4.2                    |
| V6   | 09/03| El volador, Coatepec | 19°21.594N 96°51.037W | 709      | c | 90  | 3.3                    |
| V7   | 09/03| Palmillas | 19°12.293N 96°46.221W | 702      | c | 59  | 6.8                    |
| V8   | 09/03| Tierra Colorada | 19°13.255N 96°21.916W | 46       | c | 45  | 4.4                    |
| V9   | 09/04| Cerro gordo | 19°25.252N 96°39.566W | 443      | c | 45  | 8.9                    |
| V10  | 09/04| La cumbre | 19°23.320N 96°38.807W | 366      | c | 66  | 6.1                    |

*Corn (c), grain sorghum (gs), forage sorghum (fs), and Sudan grass (sg).

**Colima (C), Jalisco (J), Michoacan (M) Nayarit (N), Sinaloa (S), and Veracruz (V).
Table 2. Percentage of *Spodoptera frugiperda* larvae parasitized by each species of *Braconidae* at each location.

| 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            | 0.0       | 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.
Zele mellea (Riggin et al. 1993). FAW larvae (12.8% parasitism) in South Georgia. This braconid, with a low parasitism rate (0.3%) on FAW larvae in perennial and ornamental crops. Conids were attacking insect pest of annual, abundant with 10% of the individuals, these braconids were the second more abundant ichneumonid parasitoid. It was recovered in 18, 17, and 14 of the 64 collections, respectively. 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 ichneumon 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. (2003b) reported that Ophion sp. attacked FAW larvae developing on volunteer corn and Paragrass at Homestead, Florida. Gross & Pair (1991) emphasized that the tachinid parasitoids, P. spinator and Archytas marginiventris (Townsend) and O. flavidus provide opportunities for advancing biological strategies for managing FAW, with the development of economical methods for mass-propagation.

**TABLE 2. (CONTINUED) PERCENTAGE OF Spodoptera frugiperda Larvae parasitized by each species of Braconidae at each location.**

| Code* | Aleoides | Chelonus | Cotesia | Glyptapanteles | Homolbus | 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      |

Aleoides sp., Chelonus sp. Probably insularis Cresson, Cotesia sp. probably marginiventris Cresson, Glyptapanteles sp. probably mellea Cresson, Homolbus sp. probably laphygmae Vieeck.
TABLE 3. PERCENTAGE OF *Spodoptera frugiperda* LARVAE PARASITIZED BY EACH SPECIES OF ICHNEUMONIDAE AND EULOPHIDAE AT EACH LOCATION.

| Code*   | Ichneumonidae |       |       |       | Eulophidae |       |       |
|---------|---------------|-------|-------|-------|------------|-------|-------|
|         | 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        | 0.0   | 1.1   |
| M1      | 3.3           | 0.0   | 1.1   | 0.0   | 0.0        | 0.0   | 0.0   |
| M2      | 2.2           | 0.0   | 2.1   | 0.0   | 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        | 0.0   | 1.6   |
| 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        | 0.0   | 1.1   |
| 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   | 0.0   | 2.1   | 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   | 0.0   | 0.0   | 0.0        | 0.0   | 1.6   |
| 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.
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).

*Campeotis 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. *Campeotis 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: *Spodoptera frugiperda* Larva 469

| Code* | Ichneumonidae | Eulophidae |
|-------|---------------|------------|
|       | C.f | E.v | O.f | Ps | 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 | 1.0  |

C.f = *Campeotis flavicincta* Ashmead, E.v = *Eiphosoma vitticole* Cresson, O.f = *Ophion flavidus* Brulle, Ps = *Pristomerus spinator* Fabricius, A.sp = *Aprostocetus* sp., E.p = *Euplectrus plathypenae* Howard, H.sp = *Horismenus* sp.
Gelechiidae) fed on Juniperus excelsa in Bulgaria (Mirchev et al. 2001). Aprostocetus sp. also was reported as an egg parasitoid of mango leaffoppers (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, Phylocnistis 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. la phygmae, 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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