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# DIVERSITY AND DISTRIBUTION OF PARASITOIDS OF *ANTHONOMUS EUGENII* (COLEOPTERA: CURCULIONIDAE) FROM MEXICO AND PROSPECTS FOR BIOLOGICAL CONTROL

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ABSTRACT

A survey of parasitoids of the pepper weevil (*Anthonomus eugenii* Cano), one of the most important pests of peppers in North America, was conducted in Mexico as part of a search for biological control agents of this pest. Surveys were conducted in different years on the Pacific and Atlantic Coasts in Mexico. We recovered parasitoid species belonging to 7 genera: *Triaspis eugenii* Wharton & López-Martínez, *Urosigalphus* sp., *Bracon* spp.; *Catolaccus hunteri* Crawford; *Eurytoma* spp.; *Eupelmus* sp.; and *Ceratoneura* sp. The latter species might be a newly recorded genus for this pest. *Catolaccus hunteri*, *T. eugenii*, and *Urosigalphus* sp. represented 96% of all recovered specimens. *Triaspis eugenii* was collected only in Nayarit, and *Urosigalphus* sp. predominated in Oaxaca; both locations are on the Pacific Coast. *Catolaccus hunteri* was present at every sample site. The biology of the braconids *T. eugenii* and *Urosigalphus* sp. would seem to make them best suited for biological control of pepper weevil due to their presumed host specificity and habit of attacking the host egg.

Key Words: *Capsicum* spp. pepper weevil, biological control, native natural enemies

RESUMEN

Como parte de una búsqueda de agentes de control biológico del picudo del chile (*Anthonomus eugenii* Cano), una de las plagas más importantes de este cultivo en Norteamérica, se realizaron colectas de parasitoides de esta plaga en México. Durante varios años se colectó material de las costas del Pacífico y del Atlántico, y se encontraron varias especies pertenecientes a siete géneros: *Triaspis eugenii* Wharton & López-Martínez, *Urosigalphus* sp., *Bracon* spp.; *Catolaccus hunteri* Crawford; *Eurytoma* spp.; *Eupelmus* sp. y *Ceratoneura* sp. De estos géneros sólo el último se reporta por primera vez para esta plaga. *Catolaccus hunteri*, *T. eugenii*, y *Urosigalphus* sp. representaron 96% del material collectado. *Triaspis eugenii* se collectó sólo en Nayarit, y *Urosigalphus* sp. predominó en Oaxaca, ambas localidades en la costa del Pacífico. *C. hunteri* se encontró en cualquier sitio de colecta. Parece ser que la biología de los bráconidos *T. eugenii* y *Urosigalphus* sp. podría ofrecer algunas ventajas para el control biológico del picudo del chile debido a su particular hábito de atacar el huevo del huésped y presumiblemente a su especificidad.

Translation provided by the authors.

The pepper weevil, *Anthonomus eugenii* Cano (Coleoptera: Curculionidae), was originally described from Guanajuato, Central Mexico, in 1894 (Cano & Alcacio 1894) and soon afterward (1904) was reported in the United States (Walker 1905). In both cases, attention was drawn to this insect because of damage observed on cultivated pepper (*Capsicum* spp.). Presently, the importance of this pest on peppers has been reported from some Caribbean islands, Central America, Mexico, the southern United States, and Hawaii (Elmore et al. 1934; Velasco 1969; Burke & Woodruff 1980; Abreu & Cruz 1985; Andrews et al. 1986; Riley & King 1994; Coto 1996; Arcos et al. 1998).

The pepper weevil feeds and develops on several species of Solanaceae; however, it is a pest only on *Capsicum* spp. (Elmore et al. 1934; Wilson 1986; Patrock & Schuster 1992). Adults feed on buds, flowers, fruits, and even young foliage; larvae feed and develop completely inside floral buds and immature fruits. Premature abscission is a consequence of feeding and development inside buds and fruits, resulting in loss of production (Cano & Alcacio 1894; Walker 1905; Pratt 1907;

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Elmore et al. 1934). Because all immature stages are protected within the fruits, insecticides can only target adults, and therefore, may not prevent insect damage. Fruit loss can reach 30 to 90% of the yield if treatment is not implemented (Campbell 1924; Elmore et al. 1934; Goff & Wilson 1937; Velasco 1969; Genung & Ozaki 1972; Riley & Sparks 1995).

A hundred years after the first report in Mexico and introduction into the United States, management practices against this pest are a combination of cultural and chemical control (Walker 1905; Elmore et al. 1934; Riley & King 1994). Biological control has not been considered an option, possibly because natural enemies of pepper weevil are poorly known. In the United States where this pest is not native, only 2 ant species (*Solenopsis geminata* F., *Tetramonium guinense* F.), 3 pteromalids (*Catolaccus hunteri* Crawford, *C. incertus* Ashmead, and *Habrocytus piercei* Crawford), and a braconid (*Bracon mellitor* Say) have thus far been identified (Pratt 1907; Pierce et al. 1912; Cross & Chesnut 1971; Wilson 1986). However, these natural enemies are not specific and are not thought to play an important role in the control of the pepper weevil (Pratt 1907; Elmore et al. 1934; Elmore & Campbell 1954; Genung & Ozaki 1972). A eupelmid (*Eupelmus cushmani* Crawford), a pteromalid (*C. hunteri*), and a braconid (*Triaspis vestiticida* Viereck) were released in the U.S. as part of 2 unsuccessful attempts at classical biological control of pepper weevil before 1950 (Clausen 1978). These 3 parasitoid species had been obtained from biological control programs against the boll weevil (*Anthonomus grandis* Boheman). No additional attempts have been made to introduce natural enemies of this pest in the United States until recently (Toapanta 2001; Rodríguez-Leyva 2006).

Central and southern Mexico have been suggested as a possible center of origin and domestication of *Capsicum annuum* L. (Vavilov 1951; MacNeish 1964; Pickersgill & Heiser 1971; Eshbaugh 1976; Loaiza-Figueroa et al. 1989) and consequently, of the pepper weevil and its parasitoids. However, the only published survey of native parasitoids of the pepper weevil from Mexico was conducted recently in the state of Nayarit on the Mexican Pacific Coast (Mariscal et al. 1998). These authors found 4 species of Braconidae, 2 species of Pteromalidae, and 1each of Eulophidae, Eupelmidae, and Eurytomidae. That report, and a complementary survey of the same area made by Toapanta (2001), indicated that *Triaspis eugenii* Wharton and López-Martínez (Hymenoptera: Braconidae) (Wharton & López-Martínez 2000) was the most abundant parasitoid of pepper weevil in Nayarit. Here we include additional surveys of Nayarit and other locations in Mexico, in addition to some unpublished Mexican references referring to natural enemies of this pest, with the objective of providing a better understanding of diversity and distribution of pepper weevil parasitoids in the region of likely origin of both *C. annuum* and the pepper weevil.

## Materials and Methods

Ten surveys were conducted on pepper production regions in Mexico between 1995 and 2003 (Table 1). Pepper fruits were collected from the Pacific and Gulf Coast of Mexico that exhibited signs of pepper weevil damage including presence of feeding and/or oviposition punctures. Fruits were collected from plants and/or those on the ground, usually in abandoned crops where infestation was high and insecticides no longer used. Different varieties

Table 1. Survey of pepper weevil parasitoids conducted between 1995 and 2003 in Mexico.

| Location | Date | Pepper fruits | Parasitoid specimens | Pepper weevil emerged | Collector |
|---|---|---|---|---|---|
| Tapachula, Chiapas | Dec 24-30, 1995 | 100 | 10 | 20 | Stansly |
| Tabasco | Apr 1, 1996 | 150 | 28 | 521 | Stansly |
| Col. S. Marmol, Col. H. Pino S., and Jalpa de Méndez, Tabasco | May 28-29, 1997 | 1499 | 5 | 575 | Stansly & Schuster |
| Col. H. Pino S., Tabasco | Sep 1997 | 501 | 2 | 108 | Stansly |
| Yecapixtla, Morelos | Mar 1999 | 45 | 1 | 7 | Rodríguez-Leyva |
| Santiago Suchiquiltongo, Oaxaca | Jun 1999 | No data | 360 | Not indicated | Bravo |
| Puente Nacional, Veracruz | Apr 2000 | 180 | 20 | 98 | Rodríguez-Leyva |
| Hato de la Higuera, Veracruz | Nov 2000 | 115 | 5 | 20 | Rodríguez-Leyva |
| Santiago Ixcuintla, Nayarit | Apr 4-6, May 15-18, 2003 | 50 kg | 139 | 4734 | Rodríguez-Leyva |
| Abasolo, Cuilapan de Guerrero, Santiago Suchiquiltongo, San Juan Guelatilla, Oaxaca | Jul 2003 | 16 kg | 48 | 434 | Stansly |
| Total | | | 618 | 6517 | |

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of *Capsicum annuum* L. were collected, especially 'Serrano' but also 'Serranillo', 'Caloro', 'Jalapeño', 'Poblano', 'Chile de agua', 'Solterito' and 'Habanero' (*C. chinense*). Fruits were held in the laboratory in 3.8-L plastic containers provided with holes measuring 3 cm in diameter covered with organdy for ventilation. Some peppers were held at a room temperature of 25°C in the Colegio de Postgraduados, in Mexico, and others were received in the quarantine facilities at the Florida Department of Agriculture and Consumer Services, Division of Plant Industry, in Gainesville, Florida. There, peppers were held in the maximum security room at 25 to 28°C, 50 to 70% R.H. and 12:12 (L:D) photoperiod.

Approximately 90 kg of peppers infested by pepper weevil were sampled from both the Pacific and Atlantic Coasts in Mexico. The pepper fruits were not dissected, so it was not possible to be certain from which host stage the parasitoids emerged. Furthermore, there was always the possibility that parasitoids could emerge from different hosts, even though we included only pepper fruits with signs of pepper weevil damage. Such hosts could include Diptera that can develop in mined rotten fruit, the pepper flower-bud moth, *Symmetrischema capsica* (Bradley & Polovny) (Lepidoptera: Gelechiidae), which is known from Mexico (Bradley & Polovny 1965; Bennett 1995), or other parasitoids and hyperparasitoids. Therefore, the biology and hosts records of all collected parasitoid species were verified in the literature and the references cited in the text.

Percent of parasitism of *A. eugenii* was calculated by dividing the number of parasitoids by the total number of insects emerged (parasitoids plus weevils) and multiplying by 100 (Mariscal et al. 1998; Toapanta 2001).

All emerged parasitoids were preserved in 70% alcohol except for *T. eugenii* and *Urosigalphus* sp., which were used to establish a colony in quarantine in 2003. Preserved specimens were identified with the aid of available literature (Burks 1954; DiGiulio 1997; Gibson 1997; Quicke 1997; Schauff et al. 1997; Sharkey 1997; Wharton & López-Martínez 2000), and sent to specialists for verification. R. Wharton and R. Lomelí (Texas A&M University) verified Braconidae and parasitic Chalcidoidea, respectively, when the material was in the United States, and J. A. Sánchez from the Instituto Politécnico Nacional (IPN-CIDIR-Oaxaca-Mexico) verified braconids in Mexico. Voucher specimens are held at the Division of Plant Industry, Florida State Collection of Arthropods, Florida Department of Agriculture and Consumer Services, Gainesville, Florida; and the Entomology and Acarology Program at the Colegio de Postgraduados, Mexico.

## Results and Discussion

Weevils and parasitoids were present in each region, although abundance and diversity varied among locations and years (Table 1). A total of 618 parasitoids were recovered during our surveys along with an estimated 6,500 pepper weevil adults. Seven parasitoid species, which emerged from weevil-infested fruit, were collected by us and 6 more have been reported in the literature (Table 2). Parasitoids represented 3 genera of Braconidae, and 1 of Pteromalidae, Eulophidae, Eupelmidae, and Eurytomidae. Only *Ceratoneura* sp. (Eulophidae) was a new record for *A. eugenii*, although the host was not verified. Two species of Braconidae, *Triaspis eugenii* Wharton & López-Martínez and *Urosigalphus* sp., and the pteromalid *Catolaccus hunteri* Crawford represented 96% of all recovered parasitoids during our surveys. However, the relative proportion of each species varied among surveys, most notably with the dominance of *T. eugenii* reported from Nayarit (Mariscal et al. 1998; Toapanta 2001), and the large number of *Urosigalphus* sp. that were collected during our surveys in the state of Oaxaca (Table 2).

### Braconidae: Helconinae: Brachistini

*Triaspis eugenii*. This species has only been reported from Nayarit (Fig. 1), where high levels of parasitism (18-40%) were reported (Mariscal et al. 1998; Toapanta 2001). These authors found that *T. eugenii* constituted 29% of 2,475 parasitoids, and 88.4% of 1,210 parasitoids, respectively. Nevertheless, 2 collections of infested fruit made at the same sites in 2003 yielded almost 5,000 pepper weevils, but only 9 *T. eugenii* (Rodríguez-Leyva 2006). A possible explanation for the paucity of *T. eugenii* in 2003 is the destruction of the pepper crops or alternate hosts and nectar sources by hurricane Kenna (October 24, 2002). Furthermore, the delayed season following replanting assured continued use of insecticides during the latter months of that season when collections were made.

*Urosigalphus* sp. According to Bravo (unpublished data) this undescribed species of wasp parasitized almost 30% of the population of the pepper weevil in experimental plots free of insecticides in Santiago Suchiquiltongo, Oaxaca. However, much fewer were collected from there and 3 others in the same region (Table 2, Fig. 1) during 2003, presumably due to the intense use of insecticides directed at the pepper weevil.

This genus also was reported on pepper weevil from Nayarit by Mariscal et al. (1998) and Toapanta (2001), although incidence in Nayarit was very low (5 specimens, Table 2). An *Urosigalphus* species attacking pepper weevil also was observed in Morelos (Table 2). Further taxonomic and ecological research will be required to understand the abundance of this genus in some places in Mexico.

*Aliolus* sp. Specimens were not recovered during our surveys, although Mariscal et al. (1998) collected 3 specimens of this genus which is the only reference relating it to the pepper weevil.

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TABLE 2. PARASITOIDS OF THE PEPPER WEEVIL RECORDED FROM MEXICO.

| Parasitoid species | Location and date | Individuals collected | Reference |
|---|---|---|---|
| Braconidae | | | |
| *Triaspis eugenii* Wharton & López-Martínez | Santiago Ixcuintla, Nayarit, Jan to Apr 1997 | 729 | Mariscal et al. (1998) |
| | Mar 1999 | 241 | Toapanta (2001) |
| | May 1999 | 278 ♀, 188 ♂ | Toapanta (2001) |
| | Mar and Apr 2000 | 198 ♀, 165 ♂ | Toapanta (2001) |
| | Apr and May 2003 | 5 ♀, 4 ♂ | Rodríguez-Leyva (2006) |
| *Urosigalphus* sp. | Santiago Ixcuintla, Nayarit, Jan to Apr 1977 | 4 | Mariscal et al. (1998) |
| | Santiago Suchiquiltongo, Oaxaca, Jun 1999 | 360 | Bravo (unpublished) |
| | Yecapixtla, Morelos, Mar 1999 | 1 ♀ | Rodríguez-Leyva (unpublished) |
| | Santiago Ixcuintla, Nayarit | Not indicated | Toapanta (2001) |
| | Santiago Suchiquiltongo, Oaxaca, Jul 2003 | 14 ♀, 9 ♂ | Stansly (unpublished) |
| | Juan José Ríos, Ahome, Sinaloa | 1 | Cortéz et. al. (2002) |
| *Aliolus* sp. | Santiago Ixcuintla, Nayarit, January to Apr 1977 | 1 ♀, 2 ♂ | Mariscal et al. (1998) |
| *Bracon mellitor* Say | Apodaca, Nuevo León | Not indicated | Barajas (1986) |
| *Bracon* sp. | Santiago Ixcuintla, Nayarit, Jan to Apr 1997 | 11 | Mariscal et al. (1998) |
| | Santiago Ixcuintla, Nayarit | Not indicated | Toapanta (2001) |
| | Santiago Ixcuintla, Nayarit, Apr 2003 | 1 ♀, 1 ♂ | Rodríguez-Leyva (2006) |
| | Cuilapan de Guerrero, Oaxaca, Jul 2003 | 1 ♀ | Stansly (unpublished) |
| | Valle de Culiacán, Sinaloa, 2003 | 2 | Pérez et al. (2003) |
| | Río Bravo, Tamaulipas, 2003 | 2 | Rodríguez del Bosque & Reyes-Rosas (2003) |
| Pteromalidae | | | |
| *Catolaccus hunteri* Crawford | Tapachula, Chiapas, Dec 1995 | 10 | Schuster and Stansly (unpublished) |
| | Jalpa Méndez, Tabasco, Apr 1996 | 28 | |
| | Tabasco, May and Sep 1997 | 5 ♀, 4 ♂ | Idem (unpublished) |
| | Baja California Sur, Mar to Jul 1995 | Not indicated | Aguilar & Servín (2000) |
| | Santiago Ixcuintla, Nayarit, Jan to Apr 1997 | 87 | Mariscal et al. 1998 |
| | Todos Santos, Baja California Sur, Jun 2000 | 5 ♀, 3 ♂ | B. Calderón (unpublished) |
| | Puente Nacional, Veracruz; Apr 2000 | 12 ♀, 6 ♂ | Rodríguez-Leyva (unpublished) Rodríguez-Leyva (2006) |
| | Hato de la Higuera, Veracruz; Nov 2000 | 2 ♀, 3 ♂ | |
| | Santiago Ixcuintla, Nayarit, Apr and May 2003 | 88 ♀, 27 ♂ | |
| | Santiago Ixcuintla, Nayarit, Mar-May 1999-2000 | 102 | Toapanta (2001) |
| | Juan José Ríos, Ahome, Sinaloa | 65 | Cortéz et al. (2002) |
| | Santiago Suchiquiltongo, Oaxaca, Jul 2003 | 10 ♀, 5 ♂ | Stansly (unpublished) |
| | Río Bravo, Tamaulipas, 2003 | 37 | Rodríguez del Bosque & Reyes-Rosas (2003) |
| *Catolaccus* sp. | Apodaca, Nuevo León | Not indicated | Barajas (1986) |
| | Valle de Culiacán, Sinaloa | 52 | Pérez et al. (2003) |
| Eulophidae | | | |
| *Euderus* sp. | Santiago Ixcuintla, Nayarit, Jan to Apr 1997 | 2 | Mariscal et al. (1998) |
| *Sympiesis* sp. | Santiago Ixcuintla, Nayarit, Jan to Apr 1997 | 7 ♀, 1♂ | Mariscal et al. (1998) |
| *Ceratoneura* sp. | Cuilapan de Guerrero, Oaxaca; Jul 2003 | 7 ♀, 1 ♂ | Stansly (unpublished) |
| Eupelmidae | | | |
| *Eupelma* sp. | Apodaca, Nuevo León | Not indicated | Barajas (1986) |
| *Eupelmus* sp. | Santiago Ixcuintla, Nayarit, Jan to Apr 1997 | 12 | Mariscal et al. (1998) |
| | Santiago Ixcuintla, Nayarit | Not indicated | Toapanta (2001) |
| | Valle de Culiacán, Sinaloa | 1 | Pérez et al. (2003) |

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TABLE 2. (CONTINUED) PARASITOIDS OF THE PEPPER WEEVIL RECORDED FROM MEXICO.

| Parasitoid species | Location and date | Individuals collected | Reference |
|---|---|---|---|
| | Santiago Ixcuintla, Nayarit, May 2003 | 6 ♀, 1 ♂ | Rodríguez-Leyva (2006) |
| | Río Bravo, Tamaulipas, 2003 | 4 | Rodríguez del Bosque & Reyes-Rosas (2003) |
| Eurytomidae | | | |
| *Eurytoma* sp. | Apodaca, Nuevo León | Not indicated | Barajas (1986) |
| | Santiago Ixcuintla, Nayarit, Jan to Apr 1997 | 4 ♀, 5 ♂ | Mariscal et al. (1998) |
| | Santiago Ixcuintla, Nayarit, Apr and May 2003 | 5 ♀, 2 ♂ | Rodríguez-Leyva 2006 |
| | Puente Nacional, Veracruz, Apr 2000 | 1 ♀, 1 ♂ | Rodríguez-Leyva (unpub) |
| | Valle de Cualiacán, Sinaloa, Jan to Jun 2003 | 18 | Pérez et al. (2003) |

The genus *Aliolus* has been reported as a primary parasitoid of Cerambycidae, Curculionidae, and Mordellidae (Martin 1956). *Aliolus* is represented in the United States and northern Mexico with possibly more than 30 species, although the most are undescribed (Martin 1956; Sharkey 1997). *Aliolus curculionis* (Fitch) and *A. rufus* (Riley) have been identified as primary parasitoids of the cotton boll weevil in the United States and Mexico and might parasitize other species (Cross & Chesnut 1971). More studies are needed to describe the biology of this genus, although low levels of parasitism indicate only incidental attack of pepper weevil.

Braconidae: Cheloninae

*Chelonus* sp. Although we did not collect specimens of this genus, it was collected by Toapanta (2001) in Nayarit, and by Pérez et al. (2003) in Sinaloa (Fig 1). This genus is included in the subfamily Cheloninae, a group that is characterized as being egg-larval endoparasitoids of Lepidoptera, especially microlepidoptera (Hentz et al. 1997; Shaw 1997). *Chelonus phtorimaeae* Gahan and *Chelonus* sp. have been collected from the pepper flower-bud moth, cited earlier. Consequently, it may have emerged from a host other than the pepper weevil in the previous reports and is not included in Table 2.

Braconidae: Braconinae

*Bracon mellitor* Say was long ago recorded as a parasitoid of the cotton boll weevil and the pepper weevil (Pratt 1907; Pierce et al. 1912). This generalist ectoparasitoid has more than 20 known hosts (Cross & Chesnut 1971). *Bracon mellitor* was the most abundant native parasitoid of the cotton boll weevil in the United States and possibly northern Mexico (Cross & Chesnut 1971), and also reported by Barajas (1986) on pepper weevil from Nuevo León (Fig. 1). Because females search for hosts mainly on cotton plants and not on the ground, where the third instar host is often found in abscised floral buds, it is not considered to have potential in being an effective biological control agent of the boll weevil (Adams et al. 1969; Cate 1985; Cate et al. 1990). It may have the same limitations as a natural enemy of pepper weevil in that infested floral buds and immature fruits often abscise (Cano & Alcacio 1894; Walker 1905; Pratt 1907; Elmore et al. 1934).

*Bracon* sp. This genus was one of the least abundant parasitoids recovered from the pepper weevil, with only 2 specimens from Oaxaca and 1 from Nayarit. A few specimens of this genus were reported by Mariscal et al. (1998) and Toapanta (2001) from Nayarit, Pérez et al. (2003) from Sinaloa, and Rodríguez del Bosque & Reyes-Rosas (2003) from Tamaulipas (Fig. 1). We know that the 3 specimens collected from Oaxaca and Nayarit during 2003 are not *B. mellitor* Say (R. Lomelí 2005, personal communication), but comparisons with the other specimens were not possible.

Pteromalidae

*Catolaccus hunteri* was one of the first parasitoids reported from the pepper weevil (Pratt 1907; Pierce et al. 1912; Wilson 1986; Rodríguez-Leyva et al. 2000). It is a cosmopolitan and generalist ectoparasitoid of at least 17 species of Curculionidae and 2 of Bruchidae (Cross & Chesnut 1971). It also seems to be present throughout Mexico (Fig. 1), and represented 30% of the parasitoids collected.

*Catolaccus hunteri* has been collected from the Peruvian coast parasitizing the Peruvian cotton boll weevil, *Anthonomus vestitus* Boheman (Townsend 1912; Gahan 1951). In Central America it parasitizes the cotton boll weevil and the pepper weevil (Cross & Mitchell 1969; Cross & Chesnut 1971; Schuster & Stansly, unpublished data). In many places in Mexico it has been collected parasitizing

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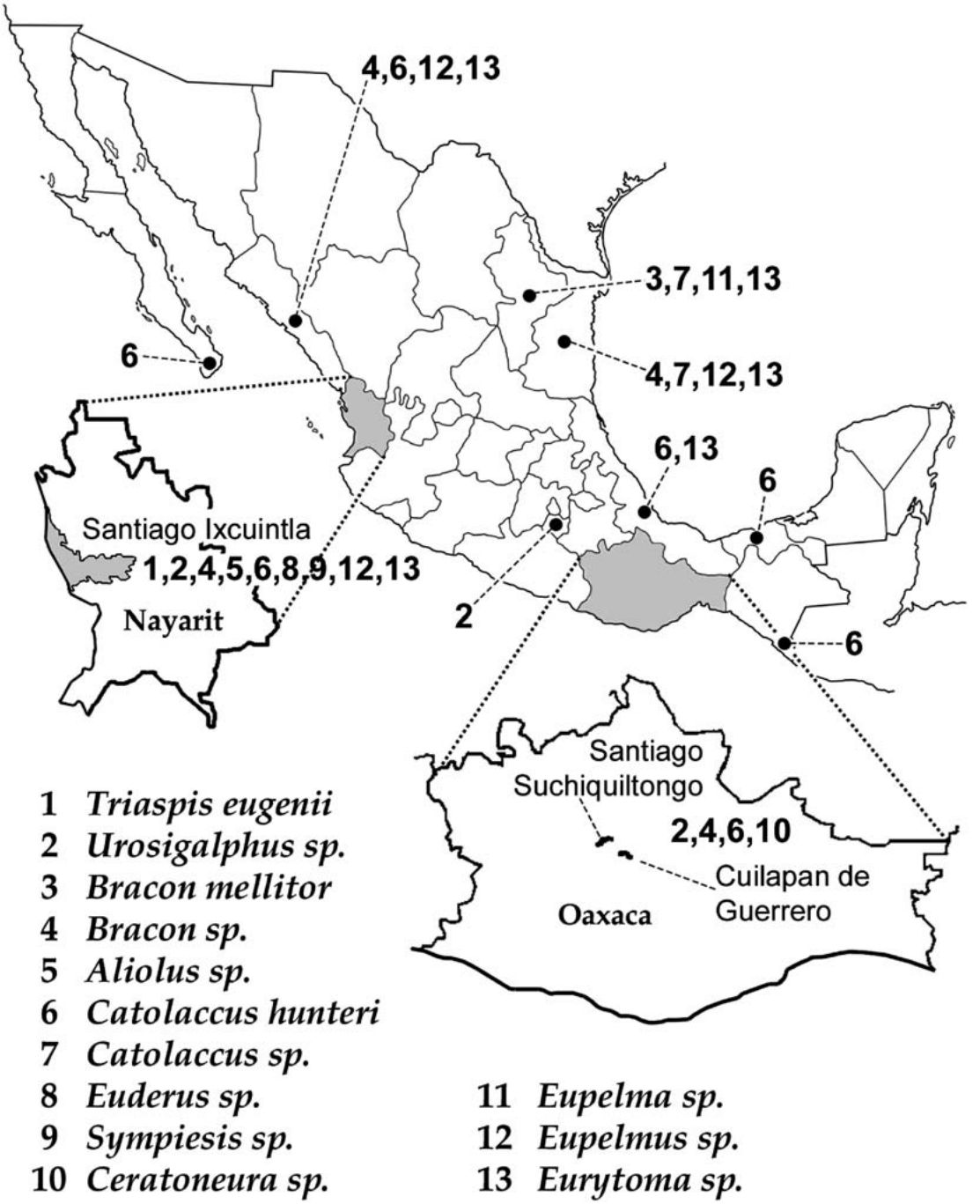



Fig. 1. Distribution of pepper weevil parasitoids reported from Mexico.

cotton boll weevil, pepper weevil, and *A. hunteri* (Cross & Mitchell 1969; Cross & Chesnut 1971; Cate et al. 1990; Bárcenas et al. 1997; Mariscal et al. 1998; Aguilar & Servín 2000; Toapanta 2001), and in the southern and eastern United States it parasitizes cotton boll weevil, pepper weevil (Cross & Mitchell 1969; Wilson 1986; Schuster & Stansly, unpublished data) and *Anthonomus macromalus* Gyllenhal (Hunsberger & Peña 1997).

The wide host range of this species provided an opportunity to mass rear at a moderate scale on the cowpea weevil, *Callosobruchus maculatus* F.

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(Coleoptera: Bruchidae), (Rodríguez-Leyva et al. 2002; Vazquez et al. 2005). Subsequent laboratory studies show that *C. hunteri* has greater fecundity and intrinsic rate of increase than pepper weevil (Rodríguez-Leyva et al. 2000; Seal et al. 2002), which stimulated and supported the plan of evaluating *C. hunteri* as a biological control agent of pepper weevil. However, releases of 1,050 *C. hunteri* per hectare in Sinaloa, Mexico, were not effective in combating pepper weevil on bell pepper (Corrales 2002). Nevertheless, augmentative releases of this parasitoid before crop establishment on the alternative host plant nightshade (equivalent of 7,900 *C. hunteri* / ha/ wk), which has small fruits, followed by releases on adjacent pepper reduced the number of weevil-damaged fruits (Schuster 2007). Releases early in the crop cycle when fruits are small, or in small fruit varieties, might be effective because the host is accessible to *C. hunteri*. Unfortunately, once the fruits increase in size, the ability of the parasitoid to attack pepper weevil is very limited. In fact, Riley and Schuster (1992) indicated that *C. hunteri* was not detected in fallen fruits larger than 2.5 cm in diameter.

Eulophidae

*Euderus* sp. *Sympiesis* sp. and *Ceratoneura* sp. are genera of Eulophidae recorded from pepper fruits infested by the pepper weevil (Table 2). *Euderus* species have been reported as primary parasitoids of Lepidoptera, Coleoptera, and even some Hymenoptera, especially Cynipidae (Schauff et al. 1997). *Sympiesis* species are indicated as parasitoids of leaf-mining Lepidoptera. *Ceratoneura* species are associated with galls, usually of Cecidomiidae (Schauff et al. 1997), or as primary parasitoids of some Curculionidae (Lomelí, personal communication). It is remarkable that no species of the 3 genera have been reported as parasitoids of the cotton boll weevil (*A. grandis*) in spite of decades of search for natural enemies in the United States, Mexico, and Central America (Pierce et al. 1912; Cross & Mitchell 1969; Cross & Chesnut 1971). This is evidence that the relationship between these species and pepper weevil is still unclear.

Eupelmidae

*Eupelmus* sp. Seven specimens were recovered from Nayarit in 2003. This or a similar species was recovered in small numbers by Barajas (1986), Mariscal et al. (1998), and Pérez et al. (2003). *Eupelmus* is a large genus with many species distributed worldwide. They are reported as primary or secondary parasitoids of different holometabolous insects, usually concealed hosts protected by cocoons, galls, or other plant tissue (Gibson 1997). There is no information about its biology on the pepper weevil. *Eupelmus cushmani* Crawford and *E. cyaniceps* Ashmead have been identified as primary parasitoids of cotton boll weevil; the first collected from Sonora in the north of Mexico and Guatemala (Clausen 1978), and the second from Morelos and Guerrero, in the south of Mexico (Cross & Chesnut 1971). It was introduced and released at the same time as *C. hunteri* in Hawaii during 1934-1937 in a classical biological program against pepper weevil. This natural enemy is established in Hawaii (Clausen 1978) but we do not have any information of its importance on the pepper weevil.

Eurytomidae

*Eurytoma* sp. We recovered 9 specimens from this genus, 2 from the Gulf Coast in Veracruz, and 7 from the Pacific Coast in Nayarit (Table 2). At least 3 different species were collected, although their identities remain undetermined (R. Lomelí, personal communication). A few specimens of this genus were collected by Mariscal et al. (1998) in Nayarit, Barajas (1986) in Nuevo León, and Pérez et al. (2003) in Sinaloa (Fig. 1). Species of the genus *Eurytoma* are known to be solitary ectoparasitoids of Coleoptera, Lepidoptera, Diptera, Hymenoptera and Homoptera (DiGiulio 1997). The species *E. gossypii* was identified as a primary parasitoid of the cotton boll weevil (Cross & Chesnut 1971), and an unknown species (*Eurytoma* sp.) was indicated as hyperparasitoid of *Zatropis* sp. in Morelos, Mexico (Pérez 1985). It is possible that the hyperparasitic habit and the low numbers recovered during different surveys make this an unlikely candidate for biological control of the pepper weevil.

*T. eugenii* and *Urosigalphus* sp.
as Biological Control Agents of Pepper Weevil

The genera *Triaspis* Haliday, and *Urosigalphus* Ashmead (Hymenoptera: Braconidae: Heliconinae: Brachistini) (Martin 1956; Sharkey 1997) are distributed worldwide, with nearly 100 known species each in the New World. However, only a few have been described from Mexico and Central America (Sharkey 1997).

The biology and life histories of most species are little known; many are egg-larval parasitoids of weevils, bruchids, and anthribids, with an ectoparasitic phase in the last instar (Clausen 1954; Shaw & Huddleston 1991; Berry 1947; Sharkey 1997). *Triaspis eugenii* from Nayarit, and *Urosigalphus* sp. from Oaxaca (Rodríguez-Leyva, unpublished data), are solitary parasitoids that attack the egg of their pepper weevil host, develop as endoparasitoids in early instars and emerge at the end of the last instar to feed as ectoparasitoids. The host is completely consumed, leaving only the cephalic capsule (Rodríguez-Leyva 2006).

Despite the fact that 11 parasitoid genera have been collected from the pepper weevil (Pratt 1907;

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Pierce et al. 1912; Elmore et al. 1934; Cross & Chesnut 1971; Barajas 1986; Mariscal et al. 1998; Toapanta 2001; Rodríguez-Leyva 2006), only *T. eugenii* from Nayarit and *Urosigalphus* sp. from Oaxaca are known to parasitize the egg of this pest (Rodríguez-Leyva, unpublished data). The egg of the pepper weevil could be considered the stage more ecologically susceptible to be parasitized because it is deposited close to the surface of the pepper fruit, and therefore, is more accessible to parasitism than later stages located within the interior of the fruit. This is evident by the relatively high levels of parasitism of pepper weevil by *T. eugenii* (18-40%, Mariscal et al. 1998; Toapanta 2001) and *Urosigalphus* sp. (30%, E. Bravo, unpublished data) in the field. The potential for augmentative biological control may be much higher, based on laboratory results of 70-90% parasitism (Rodríguez-Leyva, unpublished data). Numerous records and high levels of parasitism suggest that these 2 species require further studies in order to (a) better understand their roles as natural enemies of the pepper weevil in there respective regions of Mexico, (b) further evaluate their potential as biological control agents of this pest, and (c) establish tactics for including them in IPM programs against the pepper weevil.

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