

The first record of the genus *Plega* Navás, 1928 (Neuroptera: Rhachiberothidae: Symphrasinae) as a parasitoid of the sawfly genus *Monoctenus* Dahlbom, 1835 (Hymenoptera: Symphyta: Diprionidae)

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Abstract. The genus *Plega* Navás, 1928, belongs to the subfamily Symphrasinae, a group recently transferred from Mantispidae to Rhachiberothidae. This genus is herein reported as parasitoid of the symphytan family Diprionidae for the first time, becoming the first record of association between this neuropteran subfamily and non-aculeate Hymenoptera. This new association was discovered in “Ixcateopan de Cuauhtémoc”, in the Mexican state of Guerrero, where *Plega spinosa* Ardila *et al.*, 2019 was found associated with immatures of the sawfly *Monoctenus cuauhtemoci* De Lira, 2021, a pest in forests of *Juniperus flaccida* Schlechtendal (white cedar). The neuropteran was found to be the most abundant parasitoid of this symphytan, becoming a potential candidate for biological control of phytophagous sawflies in juniper forests, an economically important plant species for the wood industry in the region. Considering the behavior and morphological aspects of the primary larvae and the behavior of the adults of *Plega*, three possible scenarios in which the primary larvae of *P. spinosa* board the larvae of *Monoctenus* to complete its life cycle are outlined. This finding reinforces the hypothesis of a generalist ectoparasitoid lifeway of the larvae of the genus *Plega* on larvae and pupae of holometabolous insects.

Keywords. Ectoparasitoid; Lacewing; Biological control; Life cycle; Juniper; Mexico.

INTRODUCTION

Sawflies (Hymenoptera: Symphyta: Diprionidae) are recognized as important pests of coniferous forests in Mexico (Haak & Mattson, 1993). Epidemic-level defoliation caused by sawflies has been recorded in the Mexican states of Chihuahua, Durango, Jalisco, Michoacán, Guerrero, Oaxaca, and San Luis Potosí (Cibrián *et al.*, 1995; Quiñonez, 2006; Smith *et al.*, 2010; Ordaz-Silva *et al.*, 2014a; González-Gaona & Sánchez, 2018; Aguirre-Hidalgo *et al.*, 2020). The genera *Zadiprion* Rohwer,

1918, *Neodiprion* Rohwer, 1918, and *Monoctenus* Dahlbom, 1835 have been recognized as the main pests, of which the first two attack *Pinus* spp., whereas the latter affects white cedar, *Juniperus flaccida* Schlechtendal (Smith, 1988; Smith *et al.*, 2016; González-Gaona & Sánchez, 2018).

The genus *Monoctenus*, includes twelve species distributed in Europe, Japan, and North America (Taeger & Blank, 2008; Smith *et al.*, 2010). Four species of this genus are known to occur in the Nearctic region, of which only *M. sadadus* Smith, 1975 has been recorded in Mexico, spe-

cifically in the states of Durango and Veracruz, which indicates this genus may be uncommon (Smith, 1975; Taeger & Blank, 2008). Nevertheless, in 2009 an epidemic outbreak was detected in "Sierra de Álvarez", Armadillo de los Infante, San Luis Potosí, from where *M. sanchezi* Smith, 2010 was discovered and described (Smith et al., 2010). During 2019, this species was also found in Xichú, Guanajuato. Before of its description, an epidemic outbreak of *Monoctenus cuauhtemoci* De Lira, 2021 (De Lira-Ramos et al., 2022) was reported in 2017, when 460 trees of white cedar were harmed in "Ixcateopan de Cuauhtémoc", Guerrero. This epidemic became spread during the following three years, until reaching 4,320 damaged hectares in 2020 (De Lira-Ramos et al., 2019). It is worth mention that white cedar is used in the manufacture of wooden furniture and the impact on this plant is a matter of concern for the inhabitants of Ixcateopan de Cuauhtémoc (Unidad de Microrregiones, 2005).

A parasitoid is defined as an organism that develops on or in another single host organism, from which it extracts nourishment until it is killed as a result of its development (Eggleton & Gaston, 1990). A parasitoid way of life is found in the holometabolous insect orders Diptera, Coleoptera, Hymenoptera, Lepidoptera, and Neuroptera (Eggleton & Belshaw, 1992). Within the latter, the family Mantispidae is widely known for a complex postembryonic development, distinguished by substantial morphological and behavioral changes through the different larval stages (Redborg, 1998). This attribute has led to refer this insect group as hypermetamorphic, as the first larval instar (also known as planidium) is active and campodeiform, while the second and third are scarabaeiform and with limited movement (Redborg, 1998; Snyman et al., 2020). However, most of the species of Mantispidae, whose biology has been documented, belong to the subfamily Mantispininae, the best known among the Mantispoidea (i.e., Berothidae, Rhachiberothidae, and Mantispidae) (Redborg, 1998; Snyman et al., 2020). Mantispininae is widely known as spider-egg predators, attacking a wide number of families of Araneae, and showing different strategies to reach their principal food source (Redborg & MacLeod, 1985). Some species have the capability to feed on spider hemolymph temporarily, until eggs are available, thus behaving as true parasites (Redborg, 1998; Snyman et al., 2020). The phylogenetic relationships of the mantispoid families have been difficult to elucidate, and the familial designation of some of their subfamilies has been controversial (Liu et al., 2015; Winterton et al., 2018; Ardila-Camacho et al., 2021a). Traditionally, the Mantispidae was composed of four subfamilies, namely Symphrasinae, Drepanicinae, Calomantispininae, and Mantispininae (Lambkin, 1986a, b). However, recent morphological and molecular studies have provided support of a non-monophyletic Mantispidae, considering Symphrasinae as a highly derived subfamily of Rhachiberothidae (Winterton et al., 2018; Ardila-Camacho et al., 2021a).

The extant fauna of Symphrasinae is restricted to the New World, and includes three genera, *Anchieta* Navás, 1909, *Plega* Navás, 1928, and *Trichoscelia* Westwood,

1852 (Lambkin, 1986a). This subfamily is distributed from southwestern United States to Argentina, yet the higher species richness is concentrated in northern South America, Central America, and Mexico (Ardila-Camacho et al., 2019). Species of Symphrasinae are ectoparasitoids of larvae and pupae of holometabolous insects, including Coleoptera, Lepidoptera, and primarily aculeate Hymenoptera (Eggleton & Belshaw, 1992; Hook et al., 2010; Ardila-Camacho et al., 2021b). Among the three genera, the biology of *Plega* is better known, and the larvae of this group have been found attacking solitary and social wasps and bees of the families Apidae, Crabronidae, Megachilidae, Vespidae, Colletidae, and Pompilidae (Maia-Silva et al., 2013; Ardila-Camacho et al., 2021b). However, the biological knowledge of the whole subfamily is still incipient, and most of the published records are product of fortuitous rearing (Redborg, 1998; Hook et al., 2010; Maia-Silva et al., 2013). Currently, the genus *Plega* includes 17 species distributed from southwestern United States to Bolivia and Brazil, although the highest diversity is found in Mexico, where 11 species have been reported so far (Ardila-Camacho et al., 2019).

In Mexico, the government institution responsible for the management of epidemic outbreaks of sawflies is "Comisión Nacional Forestal" (CONAFOR). This institution controls the sawfly epidemic in an aerial way, by applying a mixture of generalist entomopathogens (i.e., *Bacillus thuringiensis*, *Beauveria bassiana*, *Metarhizium anisopliae*, and *Paecilomyces lilacinus*) until parasitoids begin to regulate the populations of the sawfly and/or until the outbreak goes into decline. The parasitoids that have been detected affecting sawflies in Mexico, belong to the order Diptera: Tachinidae (*Winthemia* Robineau-Desvoidy, 1830, *Chetogena* Rondani, 1856, *Lespesia* sp., *Vibrissina mexicana* (Aldrich, 1931)), Bombyliidae (*Hemipenthes jaenickeana* (Osten Sacken, 1886)), and Hymenoptera: Ichneumonidae (*Endasys subclavatus* (Say, 1835), *Olesicampe* Forster, 1869, and *Exenterus* Hartig, 1837), of which the most common is *Olesicampe*; also *Perilampus* Latreille, 1809 (Perilampidae), has been also reported as natural enemy of sawflies, although it is a hyperparasitoid (Cisneros, 1970; Arnaud, 1978; Huerta, 2014; Ordaz-Silva et al., 2014b; Ruiz-Cancino & Khalaim, 2015; González-Gaona & Sánchez, 2018).

In the present study, adults of *Plega* were reared from subterranean sawfly pupae of the genus *Monoctenus* collected in the state of Guerrero, observations that were reported in a preliminary way by De Lira-Ramos et al., (2019). So far, members of Symphrasinae have been found solely in association with representatives of aculeate Hymenoptera, and consequently, the parasitoidism association of this group on a different suborder of Hymenoptera constitutes a significant finding to better understand the evolution of Symphrasinae and the whole Mantispoidea. Furthermore, the discovery of this new parasitoid of sawflies offers an alternative of biological control for the management of sawfly pests of these important wood resources. Considering it, the aim of the present work is to present the first record of the association between Symphrasinae and Symphyta, and to

present hypotheses of the interaction between the three involved species, namely *Monoctenus cuauhtemoci* De Lira, 2021, *Plega spinosa* Ardila et al., 2019, and *Juniperus flaccida* Schlechtendal.

MATERIAL AND METHODS

The outbreak of *Monoctenus cuauhtemoci* was discovered at endemic level in 2015 in "Ixcateopan de Cuauhtémoc", Guerrero, Mexico (18°32'05.56"N; 99°47'15.60"W, 1,741 m.a.s.l.) in a white cedar or juniper forest (*Juniperus flaccida*) in "Sierra de Cuauhtémoc", about 40 km from Taxco, Guerrero (Fig. 1). The affected forest has a density of 500 trees of 20 cm in diameter per ha, the climate in the area is semi-warm, subhumid (A) c (w1) with an annual average temperature of 18°C with rainfall from May to November, with 1,250 mm of average annual precipitation. The affectionation is located in the northwest position on hill slopes with slopes of 20 to 40%.

Sawfly larvae were collected on September 8, 2017 from the foliage of white cedar, and cocoons from the ground of affected trees were collected on January 25, 2018 and May 29, 2019. Cocoons were collected from surrounding ground of 10 trees each month from April 27 to September 27, 2018. The larvae and cocoons were put inside plastic containers (4.0 L) and transferred in coolers to the Forest and Agricultural Health Laboratory of "Campo Experimental Pabellón" (CEPAB), Pabellón de Arteaga, Aguascalientes. The larvae were fed with foliage from the natural host. Cocoons obtained from larval rearing or collected from the ground were placed in 250 mL plastic bottles and were placed in a 720 KBW E5.1 Binder constant climate chamber at a temperature of $26 \pm 2^\circ\text{C}$, and a photoperiod of 14:10 light and dark, respectively. The cocoons were sprayed with water twice a week to avoid dehydration. The emergence of adults or parasitoids was monitored three times a week. The neuropter-

an parasitoids were identified at genus level following the key of Reynoso-Velasco & Contreras-Ramos (2008). For the specific determination, keys and descriptions by Ardila-Camacho et al. (2019) were utilized. High resolution images were produced using an AxioCam MRc5 digital camera attached to a Zeiss AxioZoom V16 stereomicroscope. Series of photographs were stacked and processed with software ZENpro201. Distribution map was produced with the software ArcMap (ESRI, Redlands, CA, USA).

RESULTS

The sawfly

Monoctenus cuauhtemoci is a black sawfly with 8.0 mm in length, orange head and anterior part of the thorax, and with black antennae (Figs. 2A-C). The sex of the adults is differentiated based on the antennae, bipectinate in the males and pectinate in the females (Fig. 2C). The difference with other species described for the genus lies in the dark spot beneath the ocellar area, which continues the face and reaches the upper and middle portion of the orbit of the compound eyes (absent in *M. sanchezi*) and is interrupted by an orange area at the level of the antennal sockets (in *M. sadadus* it is continuous) (Fig. 2C) (De Lira-Ramos et al., 2022).

The phenology of this *Monoctenus* species was studied by González-Gaona et al. (2019). Adult emergence occurs during the rainy season, from July 18 to August 24. As in *M. sanchezi*, there is a high dominance of females, and the males are rarely found. The presence of the larvae is observed from July 18 to September 29 with the peak in August. The larvae feed in solitary, contrary to *Zadiprion* spp. and *Neodiprion* spp., which are gregarious (Fig. 3A). The larvae are olive green with a pale brown head with a longitudinal black spot on the coronal suture (Figs. 2D, E). In dorsal view, they present a longitudinal dark stripe on the middle portion, two pale stripes on the sides and a dark subdorsal stripe. The migration of larvae towards the ground to form the cocoons takes place in the cedar trunks since the beginning of September (Fig. 3B). The construction of the cocoons begins after October, and the latter are located superficially in the ground, at five centimeters deep. The larvae (completely green, without stripes inside the cocoons), remain in diapause, being more numerous in November and December. The inactive larvae remain in this condition until April, when the pupae are formed and wait until the rainy season to emerge as adults. Considering the aforementioned data, a single generation per year probably occurs.

Parasitoids

The cocoons on the ground were recognized either as active, due to the presence of green larvae and pupae, or inactive, because: an emergence hole of an adult

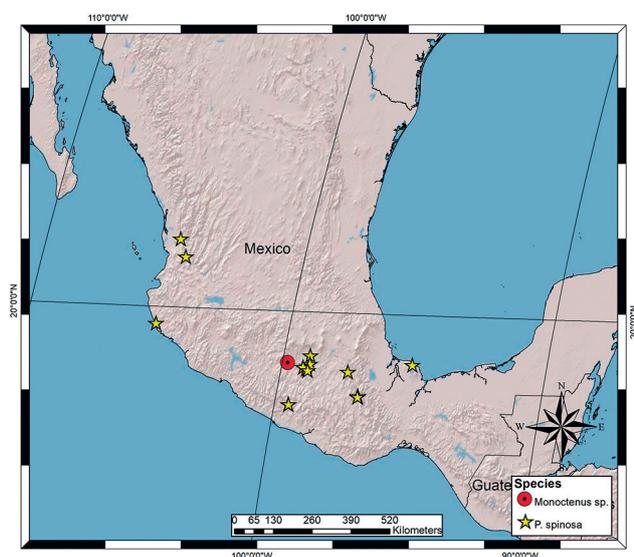


Figure 1. Distribution map of the species studied: *Plega spinosa* = yellow stars (records from Ardila-Camacho et al., (2019)); *Monoctenus cuauhtemoci* = red circle (Ixcateopan de Cuauhtémoc, Guerrero).

is present (one end cut off with linear edges), they are damaged by rodents, attacked by *Beauveria bassiana* (larvae with white mycelium), by *Metarhizium anisopliae* (larvae with green mycelium), parasitized by Tachinidae (presence of pupa inside the cocoon or emergence hole at one end composed of crown-shaped outward projections) or Bombyliidae, parasitoid hole present (at end of cocoon with irregular edge), or hyperparasitoid evidence (presence of holes in the middle of the cocoon) (González-Gaona & Sánchez, 2018).

In total, 8,212 cocoons were collected from the surrounding ground of the affected cedars (Table 1). Of these, 3,639 were active with the presence of larvae in diapause (green larvae) or already transformed into pupae. Of the inactive cocoons (4,573), 1,385 had characteristics of emergence of adult sawflies, 829 showed symptoms of predation by rodents, 308 by entomopathogenic fungi, where *Beauveria bassiana* was the most common. Of the parasitized cocoons, 246 were attacked by Tachinidae, 523 by Bombyliidae, 911 by different parasitoids, and 386

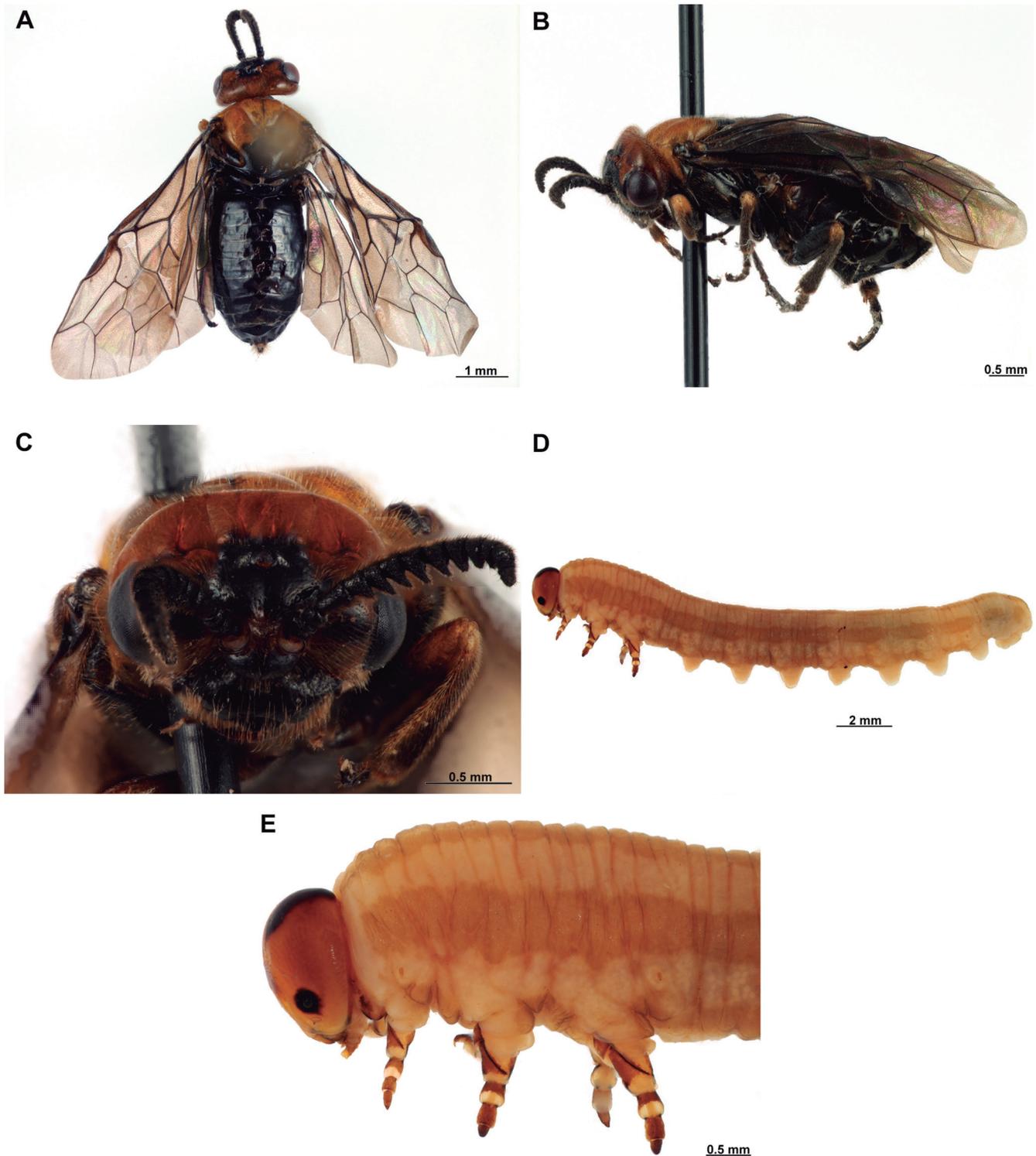


Figure 2. Habitus of adults and larvae of *Monoctenus cuauhtemoci* De Lira reared from pupae collected in Ixcateopan de Cuauhtémoc (Guerrero): (A) habitus of adult female, dorsal. (B) habitus of adult female, lateral. (C) adult female, head frontal. (D) habitus of mature larva, lateral. (E) head and thorax of mature larva, lateral.

by hyperparasitoids (Table 1). Consequently, it is considered that the population of *Monoctenus cuauhtemoci* in the soil was mainly affected by parasitoids and rodents.

Under controlled conditions, the emergence of adults of *Monoctenus cuauhtemoci* was observed from September 30 to October 3 (Table 2), which represents a delay compared to what occurs naturally (July to September). This indicates that the emergence is probably triggered by the rain. Alternatively, this could mean that the diapause does not occur under laboratory conditions. Regarding the sex ratio, in total, 36 females and one male emerged, which is consistent with what occurs in natural conditions (Table 2).

Of the emerged parasitoids, the most frequent was *Plega spinosa* Ardila-Camacho et al., 2019 with 81 adults (Table 2) (Figs. 4A, B). Only an adult of *Plega* per attacked cocoon was observed, indicating that each sawfly larva is apparently attacked by a single *Plega* larva. This species is distinguished from others in the genus because the area around frontal sutures is conspicuously sunk-

en, the suprantennal area is raised and densely covered with thickened, reclined setae, the antennal scape is short, and the male gonocoxites IX lack digitiform processes. This species is probably endemic to Mexico, and is known from the states of Guerrero, Jalisco, Morelos, Nayarit, Oaxaca, Puebla, and Veracruz (Ardila-Camacho et al., 2019) (Fig. 1). It is unknown if the entomopathogenic fungi can affect the development of *Plega* larvae, a matter that could have implications for the use of this neuropteran as a biological control agent. Parker & Stange (1965) mentioned they found an infested cell of *Megachile* (*Austromegachile*) *exaltata* Smith, 1863 with the bee larva and its ectoparasitoid *Plega* larvae killed by a fungus.

Tachinidae were the second most frequent parasitoids, with 28 specimens emerged from the attacked cocoons, while a single adult of Ichneumonidae (*Exenterus* sp.) was obtained (Table 2). In the case of Tachinidae, they disperse micro-eggs in the foliage, which are ingested by the sawfly larvae when consum-



Figure 3. Larvae of *Monoctenus cuauhtemoci* De Lira, 2021 in the field (Ixcateopan de Cuauhtémoc, Guerrero): (A) larva feeding on leaves of *Juniperus flaccida*. (B) migration of the mature sawfly larvae on the trunk of *Juniperus flaccida* to pupate in the surrounding ground.

Table 1. Number and characteristics of the cocoons of *Monoctenus cuauhtemoci* De Lira collected from the surrounding ground of affected white cedar trees.

Condition	Characteristics of the cocoon	Total	Percentage
Active	Green larvae in diapause	3481	42.38%
	Presence of pupa	158	1.92%
Total		3639	44.31%
Inactive	Empty (sawfly adult emergence)	1385	16.86%
	Preyed by rodent mammal	829	10.09%
	Presence of white hyphae	258	3.14%
	Presence of green hyphae	50	0.60%
	Presence of other fungi	183	2.22%
	Parasitized by Tachinidae	246	2.99%
	Parasitized by Bombyliidae	523	6.36%
	Presence of parasitoid emergence hole	911	11.09%
	Presence of hyperparasitism	386	4.70%
Total		4573	55.68%

Table 2. Number of parasitoids and sawfly adults (males and females) emerged from cocoons of *Monoctenus cuauhtemoci* collected in the present study.

Date	<i>Plega spinosa</i>	Tachinidae	<i>Exenterus</i> sp.	Males	Females
29.VIII.2018	0	2	0	0	0
30.VIII.2018	0	1	0	0	0
10.IX.2018	3	0	0	0	0
11.IX.2018	0	3	0	0	0
12.IX.2018	0	3	0	0	0
13.IX.2018	3	1	0	0	0
14.IX.2018	3	7	0	0	0
15.IX.2018	0	1	0	0	0
17.IX.2018	7	4	1	0	0
18.IX.2018	6	0	0	0	0
19.IX.2018	1	0	0	0	0
20.IX.2018	5	0	0	0	0
24.IX.2018	6	0	0	0	0
25.IX.2018	9	0	0	0	0
26.IX.2018	3	0	0	0	0
27.IX.2018	1	1	0	0	0
28.IX.2018	0	2	0	0	0
30.IX.2018	0	0	0	1	3
01.X.2018	1	1	0	0	17
02.X.2018	10	0	0	0	10
03.X.2018	1	0	0	0	5
04.X.2018	13	1	0	0	0
05.X.2018	2	0	0	0	0
08.10.2018	5	0	0	0	0
09.X.2018	1	1	0	0	0
11.X.2018	0	0	0	0	1
15.X.2018	0	0	0	0	0
17.X.2018	1	0	0	0	0
Total	81	28	1	1	36

ing the cedar foliage (González-Gaona & Sánchez, 2018). Regarding *Exenterus* sp. wasps, they parasitize the mature larvae that are going to the ground to construct the cocoon.

DISCUSSION

Species of the subfamily Symphrasinae are considered as ectoparasitoids of larvae and pupae of holome-

tabolous insects (Eggleton & Belshaw, 1992; Ardila-Camacho et al., 2021b). Adults of *Plega* are sometimes collected in large amounts in light traps, which may indicate massive emergence of adults, a fact related with massive infestations like those reported by Parker & Stange (1965) and Maia-Silva et al. (2013). Another relevant characteristic of this genus that have been noticed in previous studies, is that the females apparently have a targeted mechanism to locate food sources for the larvae, as egg chorions have been found in crevices of nests of their hymenopteran hosts (Hook et al., 2010). However, considering all the published records of associations of *Plega* with other insects, which include solitary and eusocial bees and wasps, as well as subterranean pupae of Coleoptera and Lepidoptera (Woglum, 1935; Werner & Butler-Jr., 1965), this genus is likely a generalist and opportunistic predator of vulnerable immature stages of insects with complete metamorphosis. Besides of this, there are manipulative studies in laboratory in which different types of immature insect preys similar to those reported in the literature (e.g., larvae and pupae of Noctuidae, Pyralidae, Crabronidae, and Curculionidae) have been offered to primary larvae of two Nearctic species, with which successfully started their development (MacLeod & Redborg, 1982). Based on these sources of evidence, the hypothesis of an opportunistic, rather than specialized ectoparasitoid lifeway in the genus *Plega* has been supported (Ardila-Camacho et al., 2021b), as firstly suggested by MacLeod & Redborg (1982).

The females of the subfamily Symphrasinae are distinguished by the presence of a long, hose-shaped ovipositor, composed of the gonocoxites IX (Aspöck & Aspöck, 2008); Ardila-Camacho et al., 2021a (Fig. 4B). Such a structure is unique among the mantispoid subfamilies, and is utilized to lay the lacrimiform, sessile eggs inside crevices of tree bark, or muddy nests of hymenopteran hosts (MacLeod & Redborg, 1982; Hook et al., 2010; Ardila-Camacho et al., 2021b). Nonetheless, it has been proposed that this structure is also useful to lay the eggs inside cells of the nests of eusocial Epiponini hosts of the genus *Trichoscelia* (Dejean & Canard, 1990), whose species in general have a shorter ovipositor (Ardila-Camacho, unpublished data). Considering such adaptation of the females of *Plega*, the active and fully ambulatory first instar larvae (Fig. 4C) emerge massively from crevices of tree trunks seeking for suitable hosts, probably guided by chemical cues (Ardila-Camacho et al., 2021b). Due to the behavior and morphological characteristics of the primary larvae of Symphrasinae, three scenarios for the infestation of the sawfly larvae are hypothesized.

The first hypothesis consists of the boarding of the mature sawfly larvae when they are feeding on the leaves of the white cedar. This scenario could be related to a possible targeted mechanism of the females to find hosts for the larvae. According to this, the females would reach the trees affected by the sawfly larvae and would oviposit in the crevices of the bark of the white cedar. From there, the primary larvae of *Plega* start hatching approximately one month after the oviposition in search of potential hosts, in this case, the mature sawfly larvae

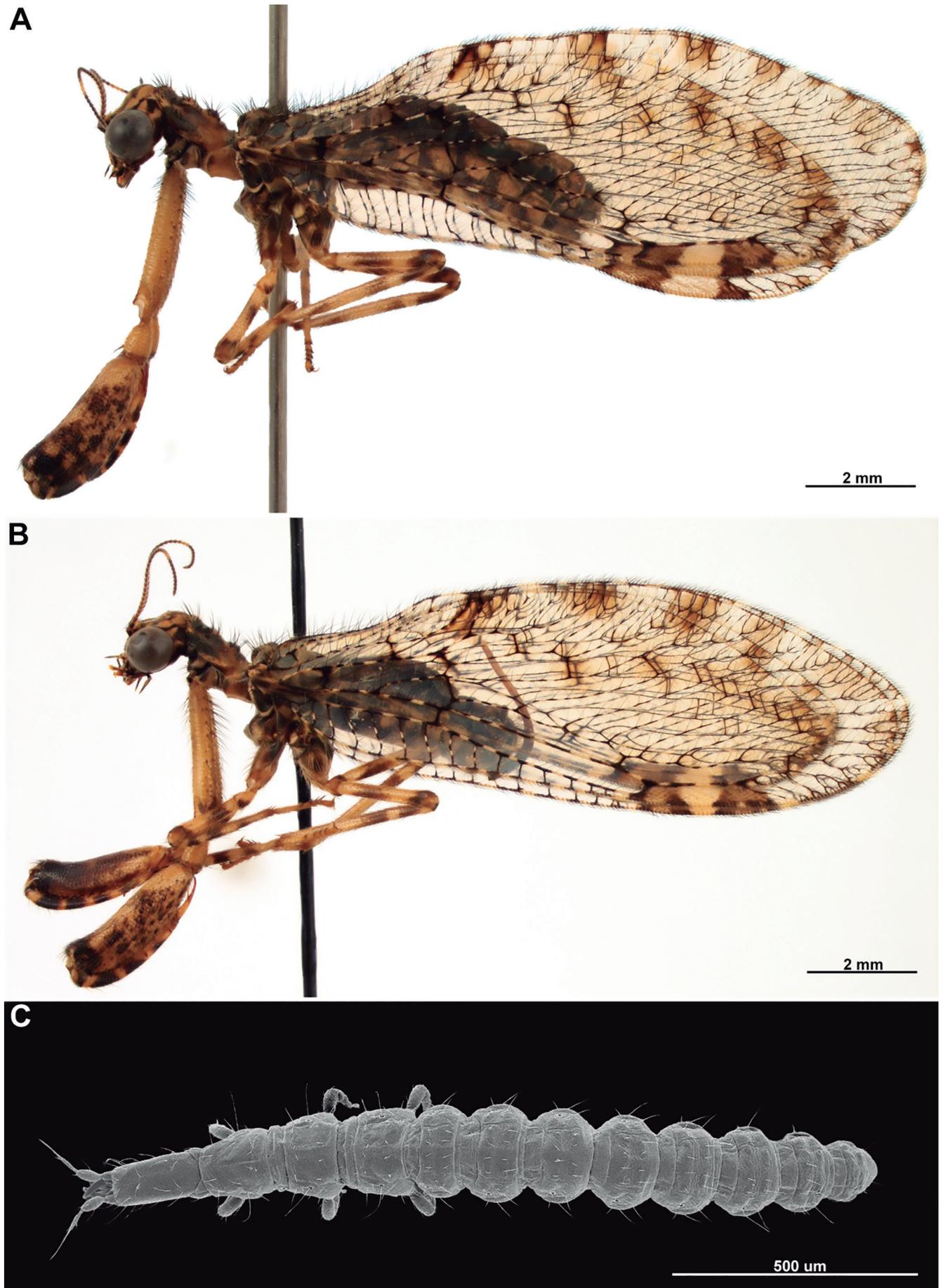


Figure 4. Habitus of adults of *Plega spinosa* Ardila-Camacho *et al.*, 2019 and primary larva of *Plega* sp: (A) habitus of adult male, lateral. (B) habitus of adult female, lateral. (C) habitus of primary larva of *Plega* sp., dorsal.

found on the leaves. Considering all the known biological associations of the genus *Plega* with other insects, this hypothesis is very likely, yet it is uncertain whether the primary larvae of the ectoparasitoid start sucking on the hemolymph of the sawfly larvae while they are on the leaves, or if they remain attached on their host without feeding until they migrate to the soil to start their metamorphosis.

In the second scenario, the planidia do board the sawfly larvae when they are going down the trunk of the white cedar to form the cocoon in the soil. Once the primary larvae of *Plega* have successfully boarded their hosts, they are probably adhered on a weakly sclerotized, vulnerable area of the cuticle of the sawfly larva, in order to pierce and suck hemolymph using their curved, mandibulo-maxillary stylets (Ardila-Camacho et al., 2021b) (Fig. 4C). According to MacLeod & Redborg (1982), the first instar larvae of *Plega* produce a sticky substance that allows them to adhere themselves to the surface of the host. Alternatively, the first instar larvae of *Plega* could start feeding until the sawfly larva have penetrated the soil or constructed the cocoon.

Finally, another possible scenario could involve an infestation directly in the soil. Considering the short interval of time in which the sawfly larvae can reach the soil implicit in the second scenario, the hatching of the primary larvae of *Plega* would need to start exactly at the same time as the migration of the hosts begins. This would imply a high specialization of the neuropteran larvae, a rather unlikely attribute of the genus *Plega*. In this regard, the wandering neuropteran larvae that emerged from the eggs laid in the bark of the white cedar would find the sawfly larvae in the soil either, just in the period before the construction of the cocoons, or during their construction. Nevertheless, if this scenario is true, then the targeted mechanism of the females of *Plega* would be uncertain, so the finding of hosts by the primary larvae could be only a random process, which would match with a generalist lifeway of the larvae of this genus.

As discussed by MacLeod & Redborg (1982), the fact that the adult emergence of *Plega spinosa* occurs from the cocoons of *Monoctenus*, would indicate that a single larva or several (as reported for *Plega yucatanae* by Parker & Stange (1965)), would remain with a single host through the different larval stages, until a cocoon is silken inside the cocoon of the host, as happens in other species attacking aculeate Hymenoptera.

Usage of biocontrol agents constitutes an important strategy to achieve a considerable decrease in pest abundance. This effect increases when multiple control agent species are released thanks to a synergistic effect (Stiling & Cornelissen, 2005) as observed herein with multiple species attacking the sawfly larvae. Considering all the known interactions of the genus *Plega* with other insect species (Ardila-Camacho et al., 2021b), this group is herein hypothesized as an opportunistic and generalist. Despite that there has been a debate regarding the advantages of specialists over generalists in biocontrol efficacy, recent data have favored the generalists (Symondson et al., 2002; Stiling & Cornelissen, 2005). The

effects of generalist control agents tend to be stronger compared to specialists, and the effect of predatory species is stronger compared to parasites as they may subsist on alternative prey when pest density is low (Stiling & Cornelissen, 2005). Generalist species may locally drive pests to extinction without necessarily declining in number and efficacy, and they also have the potential to affect non-targeted organisms (Stiling & Cornelissen, 2005). Considering that many of these attributes are expressed by the genus *Plega*, the larvae of this group could become potential candidates for biological control in *Juniperus* forests, a matter that deserves research.

AUTHORS' CONTRIBUTIONS: **KVDLR, AAC, EGG:** Conceptualization; **KVDLR, EGG:** Data curation, Methodology; **KVDLR, AAC:** Formal Analysis, Writing – original draft; **KVDLR, AAC, EGG, ACR:** Funding acquisition, Visualization, Writing – review & editing; **KVDLR, AAC, EGG, NGG:** Investigation; **KVDLR, EGG, ACR:** Project administration, Resources, Supervision; **AAC:** Software; **AAC, EGG, ACR:** Validation. All authors actively participated in the discussion of the results, they reviewed and approved the final version of the paper.

CONFLICTS OF INTEREST: Authors declare there are no conflicts of interest.

FUNDING INFORMATION: AAC acknowledges Consejo Nacional de Ciencia y Tecnología (CONACyT, Mexico) for the financial support through a doctoral scholarship. We are grateful for the financial support to the CONACyT-CONAFOR Sectorial fund through the CONAFOR 2017 CO2 project no. 291304. General support to this research is acknowledged through project "Biodiversidad de Neuroptera en México: un enfoque taxonómico integrativo" (CONACyT CB2017-2018, A1-S-32693) and "Biodiversidad de grupos selectos de Neuropteroidea de la Península de Baja California" (PAPIIT IN209721).

ACKNOWLEDGMENTS: We are grateful for all the facilities provided by the City Council of Ixcateopan de Cuauhtémoc, Guerrero through the councilors of Ecology Víctor Leyva Guerrero and María Dolores Bustamante Cirilo. AAC acknowledges Posgrado en Ciencias Biológicas, UNAM for general support along his doctoral studies. Thanks are due to Susana Guzman and Berenit Mendoza Garfias from LaNaBio, Instituto de Biología, UNAM for their support with high resolution, optical microscopy, and electron microscopy. AAC and ACR acknowledge Instituto de Biología, UNAM for general support for this research.

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