ENTOMOGENOUS CORDYCEPS AND RELATED GENERA FROM MEXICO WITH DISCUSSIONS ON THEIR HOSTS AND NEW RECORDS

by

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Abstract

Fifteen species of Cordyceps (Ascomycotina, Hypocreales, Clavicipitaceae) and related genera and their anamorphs parasitic on insects have been recorded from Mexico, of which Cordyceps dipterigena (from the State of Veracruz in a subtropical humid forest on flies of the genus Eucalliphora) and C. pruinosa (from Quintana Roo in a tropical rain forest on an unknown host) are first reported for the country. Cordyceps miltaris presents the broadest distribution in the country. The confusion between C. gracilis and C. entomorrhiza is discussed. Cordyceps melolonthae var. rickii only previously known from Chiapas, is now reported from two new localities in Chiapas, and from the States of Oaxaca and Veracruz on larvae of Strategus aloeus (both Coleoptera, Melolonthidae, subfam. Dynastinae, tribus Oryctini).

Key words: Cordyceps dipterigena, C. pruinosa, C. melolonthae var. rickii
Introduction

The first reports of fungi parasitic on insects in Mexico are from the XIX century (Urbina, 1881, and Sánchez, 1886). They described an "animal-planta" (animal-plant) as something rare in nature. Urbina's paper (1881) was a comment in a note from Milne-Edwards about *Sphaeria (Torrubia) sobolifera* (a synonym of *Cordyceps sobolifera*, see Table 1) growing on larvae of *Cicada* (Homoptera). Sánchez (1886) discussed about the "tlalomites", an indian name for insect larvae eaten by the Aztecs parasited by fungi. The fungus reported by Sánchez (1886) was identified by Pérez-Silva (1979) as *Isaria cosmopsaltria*. However, since both fungi illustrated by Sánchez (1886) and Pérez-Silva (1979) are infecting a scarab adult (Coleoptera), and not a tlamolite, then it seems that *I. cosmopsaltria* is an independent fungus of tlamolite larvae. Petch (1933-1934) commented in the discussion of *Cordyceps sobolifera* that the numerous specimens of *Isaria sinclairii* (the anamorph of *Cordyceps sobolifera*) from Mexico at the British Museum are known locally as "chicharra" or "animal-planta". Obviously, there is a mistake in the information, since "chicharra" is the common name of the cicadas. Probably these Mexican specimens were sent to England by Urbina according to his report (Urbina, 1881). Modern reports on *Cordyceps* from Mexico and related genera and its anamorphs are those of Pérez-Silva (1977, 1978, 1979), Blackwell and Gilbertson (1981, 1984), Ulloa and Benavides (1991), Rodríguez et al. (1993) and Rubio-Bustos et al. (1999). In this paper a bibliography and herbarium revision of the Mexican species of the group is presented. *Cordyceps melolonthae var. rickii* is first recorded from Oaxaca and Veracruz, and from two new localities in Chiapas, and two species of *Cordyceps* are reported as new from Mexico.

Materials and methods

The specimens studied were observed by light microscopy with the fungi mounted in KOH 5% and in Congo Red. The majority of the herbarium material is in XAL as dried specimens, but two specimens are in alcohol in the Entomological Collection of the Institute of Ecology (IE) at Xalapa, Veracruz.

The known entomogenous *Cordyceps* and related genera including their anamorph stages from Mexico

According to revisions of ascomycetes from Mexico (Chacón and Guzmán, 1983, García-Romero et al., 1970, Medel et al., 1999), and the reports of Blackwell & Gilbertson (1981, 1984), Díaz-Barriga et al. (1988), Duges (1924), Guzmán (1977), Mains (1951, 1955, 1958, 1959), Pérez-Silva (1977, 1978, 1979), Rodríguez et al. (1993), Rubio-Bustos et al. (1999) and Ulloa and Benavides (1991), there are fifteen species of *Cordyceps* and related genera and its anamorph stages in Mexico. These latter belong to the genera *Aschersonia, Cordycepioideus, Hirsutella, Hymenostilbe, Isaria, Paecilomyces* and *Paraisaria* (Table 1). The oldest references are those of Urbina (1881), Sánchez (1886) and Petch (1933-1934) as previously discussed.

Of the known entomogenous *Cordyceps* species, *C. militaris*, distinguished by its cylindric and orange-red stromata with a finely roughened surface at the apex, as was observed in several specimens at XAL and IBUG (Fig. 11), has the broadest distribution through ten states of the country (Chiapas, Hidalgo, Jalisco, Michoacán, Morelos, Nuevo León, Oaxaca, Sinaloa, State of Mexico and Veracruz) (see Table 1). However, *C. sobolifera*, only known from Coahuila, Guanajuato and Jalisco, is the species most
Introduction

ic on insects in Mexico are from the XIX century. They described an "animal-planta" (animal-plant) as an insect parasitized by fungi. The first one was identified by Pérez-Silva (1979) as Isaria sinclairii (a synonym of Cordyceps sobolifera, see next page) discussed about the larvae eaten by the Aztecs parasited by fungi. The larvae was identified by Pérez-Silva (1979) as Isaria sinclairii illustrated by Sánchez (1886) and Pérez-Silva (Homoptera). Sánchez (1886) discussed about the larvae eaten by the Aztecs parasited by fungi. The larvae was identified by Pérez-Silva (1979) as Isaria sinclairii illustrated by Sánchez (1886) and Pérez-Silva (Homoptera), and not a tlalomite, then it seems that Isaria sinclairii (Fig. 12), with which it has been confused previously in the Aztec period. This is a mistake in the information, as of the cicadas. Probably these Mexican specimens belong to his report (Urbina, 1881). Modern reports on genera and its anamorphs are those of Pérez-Silva (1981, 1984), Ulloa and Benavides (1991), and others (1999). In this paper a bibliography and a species of the group is presented. Cordyceps melolonthae var. rickii and Cordyceps dipterigena. 1-5: C. melolonthae var. rickii, 1: Perithecia, 2: Asci, 3: Secundar ascospores, 4: Caps of the asci, 5: An asci without ascospores. 6-7: C. dipterigena, 6: Caps of the asci, 7: Secundar ascospores (1-5: Wolf2559-I; 5: Robles; 6-7: Ramírez-Guilén 15). Scale bar: 1= 160 μm; 2-7 = 6 μm.


Materials and methods

erved by light microscopy with the fungi mounted in the herbarium material is in XAL as dried n alcohol in the Entomological Collection of the "Cordyceps" species, C. militaris, distinguished by its finely roughened surface at the apex, as was L and MUG (Fig. 11), has the broadest distribution in the world. The distribution of C. militaris is most widespread in Mexico and Veracruz (see Table 1). However, C. militaris, Guanajuato and Jalisco, is the species most
by Petch (1933-1934), Mains (1951) and Brady (1984). *Cordyceps gracilis* according to Mains (1951, 1958), Eckblad (1967), Smith & Smith (1973), Dennis (1978), Brady (1984), Allard (1998) and Zang & Kinjo (1998), has globose red, orange or ochraceous heads, with numerous dark perithecial ostioles on the surface. The perithecia are completely embedded, and the stipe is yellow or yellowish, in contrast to *C. entomorrhiza* which has globose light vinaceous drab, violaceous gray or brown grayish heads, with a verrucose surface due to the projecting perithecia; the stipe being pallid brownish above to deep brown below. *Cordyceps gracilis* is most common on larvae of Lepidoptera and probably restricted to this order, while *C. entomorrhiza* is probably specific to beetle larvae.

Revising the collections of "*C. entomorrhiza*" at XAL, including those reported by Chacón and Guzmán (1983, 1995), Chacón et al. (1995) and Rubio-Bustos et al. (1999), all of them from Veracruz agree well with the concept of *C. gracilis* as discussed above. The material of *C. entomorrhiza* reported by Pérez-Silva (1978) and illustrated (Fig. 2, page 20) clearly belongs to *C. entomorrhiza*, but she described dark red heads and a brownish stipe for the stromata, which is more typical of *C. gracilis*. Rubio-Bustos et al. (1999) considered *C. entomorrhiza* to have brownish-orange or reddish heads, and a brownish stipe. They based their descriptions on the collections at XAL. *Cordyceps gracilis* reported by Rubio-Bustos et al. (1999) from Jalisco was based on the specimens: Álvarez 45, Brown 182, Gutiérrez-Torres 14, Guzmán-Dávalos 4857 and Vázquez 127, which were studied in present work; these agree well with the species concept. It is concluded that *C. entomorrhiza* has been confused with *C. gracilis* in Mexico but that *C. gracilis* is a common entomogenous fungus on Lepidoptera, known from Veracruz and Jalisco. It is recorded here from three new localities in Veracruz, based on the XAL specimens: 1) Xico Municipio, Cofre de Perote Region, Los Gallos, Bandala 661; 2) Banderilla Municipio, Cerro La Martinica, Guzmán 12458; and 3) Xalapa Municipio, Rio Coapexpan, Bandala 1357. The anamorph of *C. gracilis* according to Brady (1984) is *Paraisaria dubia* (Table 1). It is interesting to observe that of the known localities of *C. gracilis* in Veracruz, the Botanical Garden at XAL presents the highest number of specimens. Chacón and Guzmán (1995) reported 57 collections between 1987 and 1990. Of the 10 species of fungi studied by Chacón and Guzmán (1995) in the Botanical Garden, "*Cordyceps entomorrhiza*" was the most common (57 collections again 31-49 the others). From 1991 to the present, however, only a few records of *C. gracilis* have been found, in spite of the frequent mycological explorations in this locality. Allard (1998) found in France a new record of *C. gracilis* after 30 years of the last in the same place.

There is another species of *Cordyceps* recorded in the Botanical Garden at Xalapa, this is *C. dipterigena* (Table 1), a new record for Mexico. This fungus is parasitic on flies probably of the genus *Eucalliphora* (Diptera, Calliphoridae), which are parasites of larvae of Lepidoptera. The stromata are cinnamon orange or cinnamon brown, with the heads around 1-2.5 mm wide, hemisphaerical or subgloboid. The asci are delicate, hyaline, more than 320 μm long, by 6-10 μm wide, with prominent hyaline caps, 5-7 x 6-6.5 μm. The ascospores are filiform, multi septate, breaking up into cylindrical or fusiform-elliptical fragments, hyaline, 6-8 x 1-1.5 μm (Figs. 6-7 & 14-16). Conidial stage not observed. Mains (1958) and Brady (1979) reported *C. dipterigena* from Eastern U.S.A., Costa Rica, Panama, British Guiana, Brazil, Puerto Rico, Trinidad, Sri Lanka, Indonesia, New Guinea, Japan and Ghana. The anamorph of *C. dipterigena* according to Brady (1979) is *Hymenostilbe dipterigena* (Table 1).
Another new record of a Cordyceps from Mexico, is *C. pruinosa* (Table 1), collected in Quintana Roo and deposited in XAL Herbarium (identified by Evans in 1999). The species was previously only known from Asia (Sri Lanka and Japan) and Africa (Congo, today known as Ruanda) (Moureau, 1961) (Table 1). The host of the Mexican specimen is unknown. This species has reddish and roughened stromata (Fig. 13).

**New records of Cordyceps melolonthae var. rickii in Chiapas, Oaxaca and Veracruz**

**Figs. 1-5 & 8, 10**

*Cordyceps melolonthae var. rickii* was thus far known in Mexico only from two collections at Tuxtla Gutiérrez, Chiapas (Pérez-Silva, 1977) (at MEXU and at P). They were found on unidentified Coleoptera larvae (Melolonthidae). We are reporting here four new localities from Chiapas, Oaxaca and Veracruz. The specimens studied agree well with Pérez-Silva (1977) and Mains (1958). The latter reported the fungus from Nicaragua, Brazil, Guyana and probably from Ecuador. The *var. melolonthae* occurs only in the U.S.A on Phyllophaga larvae (Mains, 1958). Evans et al. (1999) discussed the fungi parasitic on *Cochliotus melolonthoides* (Gerst.) a Scarabaeidae from Tanzania, misidentified in Sri Lanka as *Cordyceps melolonthae*. They identified the fungus as *Cordyceps barnesii* Thw. These authors following Mains (1958), concluded that *C. melolonthae* is confined to America, of which *var. melolonthae* occurs only on *Phyllophaga* spp. in the U.S.A. and the *var. rickii* on lamellicorn beetles in tropical North and South America. Mains (1957) first considered *C. rickii* as an independent species, and separated it from *C. melolonthae* by the perithecial layer, which completely covers the upper portion of the stroma in the former, in contrast with the latter, where the perithecial layer develops as irregular patches. Evans et al. (1999) illustrated *C. melolonthae* var. *rickii* on a melolonthid larva buried in forest soil in Amazonian Ecuador, that agrees well with the specimens studied here. Lloyd (1920) described *C. rickii* Lloyd from Brazil, based on a collection by Rick, "growing from the head of some larva", with subcylindric or globose stromata, about 20 mm long, yellow, but with the added observation that they were probably orange when fresh. According to Evans et al. (1999), one of the differences between *C. barnesii* and *C. melolonthae* var. *rickii* is the color of the stroma, drab orange to ginger-brown in the former and conspicuous sulphur-yellow to yellow-brown in the latter. In addition, the part-spores are larger in *C. barnesii*, 9.4 x 2 mm, and only 4.8 x 1.5 mm in *C. melolonthae* (Evans et al., 1999). Mains (1958) described the 1-celled fragment spores, 4-8 x 1-1.5 mm and the stromata 30-130 x 5-15 mm.

In the dried material, the stromata are 20-58 x 2-5 mm, subcylindric, sulphur-yellow to yellowish-brownish, perithecia brown reddish and stipe pale yellowish, 1-1.5 mm wide, occurring solitary or more commonly gregarious. Perithecium 350-450 x 120-200 μm, yellowish, embedded except for the apices, ovoid with acute apex. Ascii 200-220 x 5-5.5 μm, cylindric, with globose caps, 5-6 μm diam. Ascospores filiform, multisepitate, breaking into secondary spores, 1-celled fragments, 4.5-10.5 x 1-1.5 μm, pale olivaceous and thin walled. The microscopic features were observed in the specimens from Oaxaca. The specimen from Veracruz is immature, without ascii, and the specimen from Chiapas is conserved in alcohol and has empty ascii.
Habitat. The material from Chiapas and Oaxaca is on larvae of *Enema endymion* Chevrolat (Coleoptera, Melolonthidae, subfam. Dynastinae, tribus Oryctini). That from Oaxaca was buried c. 5 cm in the soil, in a subtropical humid forest (mesophytic forest), with *Calophyllum*, *Tepipira*, *Laplacea*, *Terminalia*, *Mosquitoxylum*, *Vochysia*, *Enteroxylon*, *Quercus*, *Podocarpus* and scattered *Pinus chiapensis* (Mart.) Andersen. The material from Veracruz was found on larvae of *Strategus aloeus* (L.), also belonging to the tribe Oryctini, in a disturbed tropical evergreen forest and in a subdeciduous tropical forest. The specimens from Chiapas were found in a coffee plantation where the host *Enema endymion* is a scarab root pest, 32-36 mm long, common in tropical regions of Mexico through Brazil and Bolivia. In Mexico it is known from the States of Campeche, Chiapas, Hidalgo, Oaxaca (Chiltepec, Ixtepec, Santo Domingo, Tuxtepec and Valle Nacional), Puebla, Quintana Roo, Tabasco, Tamaulipas and Veracruz (Morón et al. 1997). In Ocozocuautla (Chiapas), one of the authors (MAM) has once observed thousands of flying adults around the light source. The larvae of this beetle may also occur in high densities and large groups of thousand of individuals have been reported as displacing themselves in one direction over the forest floor in Campeche (Mexico) and Guatemala. This insect feeds exclusively on decomposing plant litter. *Strategus aloeus* has also a broad distribution from Mexico to the Amazonian region. Near Villa Las Rosas, Chiapas, a large population of these larvae was observed in seasonally flooded soil. Nine specimens of *Cordyceps melolonthae* var. *rickii* were collected there.

Material studied. Mexico, State of Chiapas, Tenejapa, Patekton splot, alt. 1600 m, Nov. 1999, Robles (in alcohol in the Entomological Collection at the IE). Villa Las Rosas, alt. 1240 m, Oct. 23, 1999, Alcazar (in alcohol in the Entomological Collections at IE and ECOSUR at San Cristóbal de las Casas). State of Oaxaca, W of Sierra Madre del Sur, E of Tehuantepec Isthmus, 31 km NE of Lázaro Cárdenas and Esculapio, road to Santa María Chimalapa (no San Miguel Chimalapa), ca. 9 km from the town, West of Cerro Azul, 16° 51' 45" N, 94° 43' 40" W, alt. 400 m, October 27, 1998, Wolf 2559-1, 2559-2, 2559-3, 2559-4, 2559-5, 2559-6, 2559-7, 2559-8, 2559-9, 2559-10, 2559-11, 2559-12, 2559-13, 2559-14, 2559-15 (all in XAL, except 2559-8, 9 & 13 that are also in the ECOSUR Herbarium, and 2559-2 and 2559-7 that are also in K and NY, respectively). Veracruz, Municipio Catemaco, Ejido López Mateos, alt. 150 m, June 28, 1987, Chacón 4001 (XAL).

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Table 1. Species of entomogenous *Cordyceps* and related genera including their anamorph stages reported from Mexico and new records in XAL Herbarium

<table>
<thead>
<tr>
<th>Species</th>
<th>Distribution</th>
</tr>
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<tbody>
<tr>
<td><em>Cordyceps dipterigena</em> Berk. &amp; Broome <strong>anamorph:</strong> <em>Hymenostilbe dipterigena</em> Petch</td>
<td><strong>First record for Mexico:</strong> Veracruz, Botanical Garden of the Instituto de Ecología at Xalapa, a mesophitic forest, Jan. 23, 1997, <em>Ramírez-Guillén 15</em>; Jan. 17, 2000, <em>Jarvio 456</em> (both in XAL) (Figs. 6-7 &amp; 14-16).</td>
</tr>
<tr>
<td><em>C. gracilis</em> Durieu &amp; Mont. = <em>C. entomorrhiza</em> sensu Chacón &amp; Guzmán (1983, 1995), Chacón et al. (1995) and Rubio-Bustos et al. (1999) <strong>anamorph:</strong> <em>Paraisaria dubia</em> (Delacr.) Samson &amp; B.L. Brady (= <em>Isaria dubia</em> Delacr.)</td>
<td>Jalisco (Medel et al., 1999; Rodríguez et al., 1993; Rubio-Bustos et al., 1999); Veracruz (Chacón &amp; Guzmán, 1983, 1995; Chacón et al., 1995; Rubio-Bustos et al., 2000) (Fig. 12).</td>
</tr>
<tr>
<td><em>C. melolonthae var. rickii</em> (Lloyd) Mains</td>
<td>Chiapas and Jalisco (Chacón &amp; Guzmán, 1983; Pérez-Silva, 1977; Rubio-Bustos et al., 1999); Oaxaca and Veracruz (new records); without locality (Herrera &amp; Ulloa, 1998) (Figs. 1-5 &amp; 8-10).</td>
</tr>
<tr>
<td><em>C. militaris</em> (Fr.) Link</td>
<td>Chiapas, Jalisco, Nuevo León (in XAL), Hidalgo, Michoacán, Morelos, Oaxaca, Sinaloa, State of Mexico and Veracruz (Chacón &amp; Guzmán, 1984; Díaz-Barriga et al., 1988; Fruts &amp; Guzmán, 1983; Pérez-Silva, 1977; Rubio-Bustos et al., 1999; Welden &amp; Guzmán, 1978); without locality (Guzmán, 1977; Herrera &amp; Ulloa, 1998) (Fig. 11).</td>
</tr>
<tr>
<td><em>C. polyarthra</em> Möller</td>
<td>Jalisco (Rubio-Bustos et al., 1999)</td>
</tr>
</tbody>
</table>
eps and related genera including their anamorph and new records in XAL Herbarium

Distribution

Veracruz (Mains, 1959).


First record for Mexico: Veracruz, Botanical Garden of the Instituto de Ecología at Xalapa, a mesophitic forest, Jan. 23, 1997, Ramírez-Guillén 15; Jan. 17, 2000, Jarvio 456 (both in XAL) (Figs. 6-7 & 14-16).

Veracruz (Pérez-Silva, 1978).

Jalisco (Medel et al., 1999; Rodríguez et al., 1993; Rubio-Bustos et al., 1999); Veracruz (Chacón & Guzmán, 1983, 1995; Chacón et al., 1995; Rubio-Bustos et al., 2000) (Fig. 12).

Chiapas and Jalisco (Chacón & Guzmán, 1983; Pérez-Silva, 1977; Rubio-Bustos et al., 1999); Oaxaca and Veracruz (new records); without locality (Herrera & Ulloa, 1998) (Figs. 1-5 & 8-10).

Chiapas, Jalisco, Nuevo León (in XAL), Hidalgo, Michoacán, Morelos, Oaxaca, Sinaloa, State of Mexico and Veracruz (Chacón & Guzmán, 1984; Díaz-Barriga et al., 1988; Frutis & Guzmán, 1983; Pérez-Silva, 1977; Rubio-Bustos et al., 1999; Welden & Guzmán, 1978); without locality (Guzmán, 1977; Herrera & Ulloa, 1998) (Fig. 11).

Jalisco (Rubio-Bustos et al., 1999)

Literature


