Diversity of Cordyceps Fungi in Nepal

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Abstract
Fungi are a part of the biodiversity that play a significant role in daily livelihood of the local communities. Yarsagumba (Ophiocordyceps sinensis) is one of the highly valued medicinal fungi that grow in the Tibetan Plateau of China and alpine grasslands of Nepal, Bhutan and India. Genus Cordyceps was recently revised and divided into four genera: Cordyceps, Elaphocordyceps, Metacordyceps and Ophiocordyceps, based on molecular phylogeny and morphology. The recent revision has consequently changed the scientific name of Yarsa gumba from Cordyceps sinensis (Berk.) Sacc. to Ophiocordyceps sinensis (Berk.) Sung et al. In Nepal, scientific study of Cordyceps species started about 60 years ago. During last 30 years, different Cordyceps species have been reported from Nepal. In this paper, Cordyceps species reported from Nepal have been discussed along with their synonyms, morphological characters, hosts and distributions in the global context.

Key words: Cordyceps, Elaphocordyceps, Metacordyceps, Ophiocordyceps, Yarsagumba

Introduction
1) Metacordyceps liangshanensis (Zang et al.) Sung et al., Stud. Mycol. 57:35, 2007. (Fig. 1)

Morphological characters: Stromata solitary or branched, light to dark brown, arising from the thorax of the host, 55–75 × 1.5–2.5 mm; head slightly wider than the stipe; perithecia semi-immersed, ellipsoid, ovoid or oval.

Host: Lepidopteran larvae, vertically buried in the soil.


2) Cordyceps coccinea Penz. and Sacc., Malpighia 11:524, 1897. (Fig. 2)

Morphological characters: Stromata gregarious, filiform, dark red, 4–35 × 0.3–0.5 mm; head wider than stipe, lanceolate, fusiform, cylindrical or clavate in shape, granular on the surface due to prominent perithecial ostiole; perithecia immersed to superficial, compact, ovoid or conic.

Hosts: Coleopterous grubs, lepidopterous larvae and chrysalides pupae. The chitinous covering of the host is somewhat black. The host is subterraneous.

Distribution: Indonesia (Penzig & Saccardo 1897), Sri Lanka (Petch 1924), Japan (Kobayasi 1941), Congo (Moureau 1949) and Nepal (Tanda & Nagase 1994). Morphologically, this species is very similar to C. pruinosa (Teng 1936).

3) C. ishikariensis Kobayasi and Shimizu, Color Icon. Veg. Wasps Pl. Worms Pp. 176, 1994. (Fig. 3)

Morphological characters: Stromata gregarious, brown-yellow, arising from the thorax of the host, 45–65 × 1.5–2 mm; head continuous with the stipe and slightly broader than it; perithecia semi-immersed, ovoid to broadly ovoid.

Host: Cicada nymphs, vertically buried in soil.

Distribution: Japan (Shimizu 1994) and Nepal (Shrestha & Sung 2005). This species was described only in Japanese and has not yet been accompanied by Latin description. Hence, Latin description is necessary to validate its taxonomic status.

4) C. militaris (L.: Fr.) Link, Hand. Gew. 3:347, 1833. (Fig. 4)

Morphological characters: Stromata solitary or gregarious, yellow to orange, 20–110 × 1–6 mm; head continuous with the stipe, but wider than it, cylindrical or slightly spherical; perithecia immersed to semi-immersed, ovoid or flask-shaped.

Hosts: Lepidopteran, coleopteran, hymenoptera and dipteran larvae and pupae, horizontally buried in soil.

Distribution: Worldwide distribution. It was described from Kathmandu Valley of Nepal by Shrestha & Sung (2005). It is the type species of genus Cordyceps (Kobayasi 1941, Sung et al. 2007). This species has been successfully grown in artificial media.

5) C. martialis Speg., Bol. Acad. Nac. Ci. Córdoba 11:535, 1889. (Fig. 5)

Morphological characters: Stromata solitary or gregarious, sometimes branched, brownish orange, 35–65 × 1–3 mm; head broader than the stipe, rough and dotted due to the ostioles of the perithecia; perithecia obliquely immersed, ovoid or flask-shaped with long neck.

Host: Coleopteran grubs, horizontally buried in soil.

Distribution: Brazil (Spegazzini 1889), Trinidad (Petch 1933), China (Teng 1934), North America (Mains 1958), Russia (Koval 1974), Japan (Kobayasi & Shimizu 1982), Korea (Sung 1996) and Nepal (Shrestha & Sung 2005).
6) *C. pruinosa* Petch, *Trans.* *Brit.* *Mycol.* *Soc.* 10:38, 1924. (Fig. 6)

**Morphological characters:** Stromata gregarious, bright red, 15–40 × 0.5–1.5 mm; head continuous with the stipe but broader than it, rough due to ostioles of perithecia; perithecia superficial

**Host:** Lepidopteran pupae, buried in soil.

**Distribution:** Sri Lanka (Petch 1924), China (Teng 1936), Japan (Kobayasi 1941), Congo (Moureau 1961), Russia (Koval 1974), Korea (Sung 1996), Mexico (Guzman *et al.* 2001) and Nepal (Shrestha & Sung 2005, Adhikari 2008). This species is very similar to *C. coccinea* (Teng 1936). It is locally known as Aalu Chhyau in Nepal.


7) *Opiliocordyceps formicarum* (Kobayasi) Sung *et al.*, *Stud.* *Mycol.* 57:43, 2007. (Fig. 7)


**Morphological characters:** Stromata solitary, filiform arising from abdomen and thorax of the host, 30–90 × 0.2–0.3 mm; head distinct, ovate or fusiform, 1.4–2.1 × 0.8–1.4 mm; perithecia obliquely immersed.

**Host:** Hymenopteran adults (ants), covered by decaying leaves or attached to them.

**Distribution:** Japan (Kobayasi 1939), Nepal (Tanda & Nagase 1994), Korea (Sung 1996) and China (Li *et al.* 2002).

8) *O. gracilis* (Grev.) Sung *et al.*, *Stud.* *Mycol.* 57:43, 2007. (Fig. 8)


≡ *C. gracilis* (Grev.) Durieu and Mont., *Fl. Algérie* *Crypt.* 1:449, 1846.

**Morphological characters:** Stromata solitary, occasionally two, stout, creamy white, smooth, arising from thorax, 30–60 × 1–3 mm; head distinct, ovoid to subglobose, pinkish or brown-colored, punctate with ostioles of perithecia, 3–6 × 3–4 mm; perithecia completely immersed.

**Host:** Lepidopteran larvae, horizontally or vertically buried in soil.

**Distribution:** United Kingdom (Greville 1824), Algeria (Durieu 1846), France (Montagne 1856), North America (Ellis & Everhart 1892), Brazil (Müller 1901), Australia (Lloyd 1915), China (Teng 1934), Czech (Fassatióvá 1954), Korea (Sung 1996), Nepal (Shrestha & Sung 2005) and Slovakia (Kautman & Kautmanová 2009).


**Morphological characters:** Stromata solitary, simple, clavate, purplish brown to dark violet, arising from the thorax of the host, 62–75 × 2–4 mm; head abruptly enlarged from stipe with a sterile tip, rough or punctate with ostioles of perithecia; perithecia globoid or ovoid, almost immersed.

**Host:** larvae of *Thitarodes* spp., vertically buried in soil.
Distribution: China (Zang & Kinjo 1998) and Nepal (Adhikari 2008). These species resemble to *O. sinensis*, but differ in micromorphological characters (Zang & Kinjo 1998).


Morphological characters: Stromata clavate, in cluster from two to four, purplish brown to dark brown, arising from thorax of host, 4–52 × 1.5–3 mm; head abruptly enlarged from the stipe with a sterile tip, long cylindrical, slender, punctate with ostioles of perithecia; perithecia globoid, slightly projecting.

Host: larvae of *Thitarodes* spp., vertically buried in soil.

Distribution: China (Zang & Kinjo 1998) and Nepal (Adhikari 2008). It has some resemblance with *O. kangdingensis* in color and host, but differ from the latter in micromorphological characters (Zang & Kinjo 1998).

11) *O. nepalensis* (M. Zang and Kinjo) Sung et al., Stud. Mycol. 57:45, 2007. (Fig. 9)

Morphological characters: Stromata solitary, simple, clavate with a sterile tip, purplish brown to dark brown, arising from the thorax of the host, 41–45 × 2–5 mm; head gradually enlarged from stipe, almost smooth; perithecia globose or ovoid, immersed.

Host: larvae of *Heplius nebulosus*, vertically buried in soil.

Distribution: Endemic to Nepal (Zang & Kinjo 1998, Adhikari 2008). It resembles with *O. sinensis* in color and is often misidentified, but differs from the latter in micromorphological characters (Zang & Kinjo 1998).

12) *O. nutans* (Pat.) Sung et al., Stud. Mycol. 57:45, 2007. (Fig. 10)

Morphological characters: Stromata solitary to few, filiform, erect or somewhat curved, pallid, mainly arising from the thorax region of the host, black except orange yellow or reddish head, glabrous, 50–100 × 0.8–1.5 mm; head distinct, pod-like structure, fusiform or clavate, punctate with ostioles of perithecia; perithecia obliquely immersed with a long neck.

Host: Adults of hemipteran bugs, covered by decaying leaves and sometimes piercing through them.

Distribution: Japan (Patouillard 1887), New Guinea (Sydow 1922), China (Teng 1934), Congo (Moureau 1949), Korea (Lim & Kim 1973), Russia (Kovol 1974) and Nepal (Otani 1982, Shrestha 1985, Tanda & Nagase 1994, Shrestha & Sung 2005).

13) *O. sinensis* (Berk.) Sung et al., 57:46, 2007. (Fig. 11)
≡ *Sphaeria sinensis* Berk., J. Bot. (Hooker) 2:207, 1843.
≡ *C. sinensis* (Berk.) Sacc., Michelia 1:320, 1878.

Morphological characters: Stromata solitary, rarely branched, dark brown to black, arising from the pro-thorax of the host, 40–100 × 2–5 mm; head continuous with the stipe with acuminate sterile tip, broader than stipe, punctate to rough due to ostioles of perithecia; perithecia semi-immersed.


Distribution: Endemic to Tibetan Plateau and alpine grasslands of China, Nepal, Bhutan and India ranging from 3000 to 5000 m above sea level. Its historical records, geographical distributions, morphological variations and taxonomic complexities especially in light of discovery of similar species such as *O. crassispora*, *O. gansuënsis*, *O. kangdingensis*, *O. multiaxialis* and *O. nepalensis* have been recently reviewed (Shrestha et al. 2010). Many recent authors have opined that they are not distinct species; rather they are conspecific with *O. sinensis* and can be treated as its subspecies or forms or clades (Shrestha et al. 2010).

14) *O. sphecocephala* (Klotzsch ex Berk.) Sung et al. 57:47, 2007. (Fig. 12)
Sphaeria sphecocephala Klotzsch ex Berk., J. Bot. (Hooker) 2:206, 1843.


Morphological characters: Stromata solitary or rarely two, filiform, arising from thorax to abdomen region of the host, erect or curved, pale-yellow to brownish-yellow, glabrous, 14~70 × 0.5~1 mm; head distinct, abruptly enlarged from stipe, cylindric or fusiform or spherical; perithecium obliquely immersed with long neck.

Host: Adult wasps, covered by decaying leaves and sometimes attached to them.

Distribution: Cuba (Torrubia 1754), West Indies (Edwards 1764), Jamaica (Berkeley 1843), St. Vincents (Berkeley 1843), Guadeloupe (Tulasne & Tulasne 1865), Argentina (Spegazzini 1881), Japan (Miyoshi 1888), Indonesia (Penzig & Saccardo 1897), Brazil (Mêller 1901), North America (Seaver 1910), Guyana (Petch 1934), China (Teng 1934), Britain (Petch 1938), Czech (Šmarda 1941), Congo (Moureau 1949), India (Sen 1949), Korea (Lim & Kim 1973), Russia (Koval 1974), Nepal (Tanda & Nagase 1994, Shrestha & Sung 2005) and Slovakia (Kautman & Kautmanová 2009).

O. tricentri (Yasuda) Sung et al., 57:47, 2007. (Fig. 13)


Morphological characters: Stromata solitary, yellow, filiform, erect or curved, glabrous, arising from thorax region of the host, 35~50 × 0.25~0.3 mm; head distinct, cylindric, fusiform or spherical; perithecium obliquely immersed.

Host: Adults of Aphrophora spp., covered by decaying leaves and sometimes attached to them, very easy to loose the host during collection due to its tiny size.

Distribution: Japan (Lloyd 1916), China (Teng 1934), Korea (Lim & Kim 1973) and Nepal (Shrestha & Sung 2005). It resembles pretty well with O. sphecocephala except the host.

Besides Cordyceps species, many other entomopathogenic fungi such as Beauveria spp., Hirutella spp. and Isaria (Paecilomyces) spp. such as I. cicadae and I. japonica have been recorded in Nepal (Kobayasi 1965, Otani 1982, Mizuno 1999, Tanda & Nagase 1994, Shrestha & Sung 2005, Shrestha 2010a). The results described above show the richness of valuable entomopathogenic fungi in Nepal, mainly due to its diverse unique eco-geographical regions.

To date, 15 Cordyceps spp., recently classified as Cordyceps (5 spp.), Metacordyceps (1 sp.) and Ophiocordyceps (9 spp.), have been reported from Nepal. However, further collections are required to explore the hidden diversity of Cordyceps species. Nature conservation is of utmost importance to preserve Cordyceps species that depend upon living insects to complete their life cycle. Green Energy Mission/Nepal (GEM/Nepal), a non-profit research and development-oriented non-governmental organization, has been involved in scientific studies and public awareness of Cordyceps fungi and their medicinal values in Nepal.

Acknowledgements

The author wishes to express deep gratitude to Green Energy Mission/Nepal (GEM/Nepal), Kathmandu, Nepal for facilitating him during the research period and manuscript preparation.
References


