ISSN: 3049-0677 (Online)

PhytoTalks

December 2025; Volume 2: Issue 4: 610-616
https://doi.org/10.21276/pt.2025.v2.i4.4

Review Article

OPEN ACCESS

Article History
Received: 17.10.2025
Revised: 02.12.2025
Accepted: 15.12.2025
Online
Version: 1

Additional Information
Peer review: The publisher expresses gratitude to the anonymous reviewers and sectional editors for their invaluable contributions during the peer review process.

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https://phytotalks.com/journal/index.php/PT/open_acess_policy

Publisher's note: Regarding jurisdictional claims in published maps and institutional affiliations, PhytoTalks maintains its objectivity.

Cite this article: Tripathi A, Bhandari AK. *Ophiocordyceps sinensis* (Keera Jari/ Himalayan Viagra): Pharmacological properties and their therapeutic potential. *PhytoTalks*. 2025; 2(4): 610-616.

Ophiocordyceps sinensis (Keera Jari/ Himalayan Viagra): Pharmacological properties and their therapeutic potential

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Abstract
Ophiocordyceps sinensis (Keera jari), also known as caterpillar fungus, is a member of the Ophiocordycipitaceae family of fungi that parasitizes ghost moth larvae and produces a fruiting body valued as herbal medicine. Due to its numerous uses in the pharmaceutical and medical fields, *Cordyceps* species are commonly referred to as traditional Chinese medicine (TCM). Keera jari has been acknowledged in Nepal for many years, and in India it is known as 'keera jari' or 'keera ghas.' It is among the most promising therapeutic mushrooms in the world. People all throughout the world use the caterpillar fungus for its tremendous therapeutic properties. It grows between 3500 and 4500 meters above sea level on the upper Himalayan plateau. This review's goal is to gather information on Keera jari (Yarsagumba), including its history, cultivation, taxonomic traits, several medicinal applications, and phytochemical research that has been done thus far.

Keywords: *Ophiocordyceps sinensis,* Keera Jari, Himalayan Viagra, Medicinal applications, Himalayan plateau.

1. Introduction
Ophiocordyceps sinensis (Berk.) G. H. Sung, J. M. Sung, Hywel-Jones & Spatafora [Syn. *Cordyceps sinensis* (Berk.) Sacc.] is also referred to as Yarsagumba (fungus cum larvae) in Nepali[1,2] and caterpillar fungus[3, 4]. This fungus is employed extensively in research and clinical therapies. *Thitarodes armoricanus* (*Hepialus armoricanus*) is a species of ghost moth (family Hepialidae) that acts as the host for *Ophiocordyceps sinensis*.

Lepidopteran larvae are infected by the parasitic fungus *Ophiocordyceps sinensis* (syn. *Cordyceps sinensis*). The diseased larva is prized for its therapeutic qualities and is usually referred to as a fungal caterpillar. Locally referred to as "keera jari" in Uttarakhand, it is typically found in meadows between 3,500 and 5,000 meters above sea level. The fungus infects the larva at the end of autumn and gradually spreads throughout its entire body, killing it[5, 6]. The larva stays buried in the ground throughout the winter. However, the fungus-infected larva sporulates and forms a structure resembling a plant's shoot after the snow begins to melt[7]. *O. sinensis* is quite expensive and has a large market because of its possible medical usefulness. As a result, the natives now have a reliable stream of money from its collection. The Pithoragarh district's Chiplakot, Ultapara, Brahmkot, Najari, and Nangnidhura–Munshyari regions, as well as the Chamoli district's Ghat, Dewal, Niti, and Mana valleys, are the main locations for *O. sinensis* in Uttarakhand.

However, the supply frequently falls short of demand since *Ophiocordyceps* is an uncommon and challenging material to collect. The harvesting season in Central Himalaya lasts from April to May. After gathering it in a camp with friends and family, the local collectors sell it to approved organizations like the Forest Department Corporation.

Local collectors exhibit a more balanced male-to-female ratio, but non-residents—outsiders who travel to the collection areas are predominately male. 'Keera jari' can be collected using a variety of techniques, such as digging a tiny hole or using a knife to delicately remove it from the ground[8]. Prior to or early in the spring, the caterpillar fungus is more useful. The upper portion of the mushroom may split during the last stages of sporulation, and the host larva becomes mushy and unattractive[9]. China has long been familiar with the uncommon and exotic medicinal mushroom *O. sinensis*. One that is said to have several extensive therapeutic benefits.

In the last twenty years or so, most Westerners have become aware of this uncommon herbal remedy. Chinese practitioners have known for generations that it is effective in treating a wide range of medical issues, and contemporary scientific research into its seemingly remarkable spectrum of therapeutic powers has confirmed this. The description and use of this once-rare medicinal gem are summarized in this chapter[7, 10].

1.1 Name and general description

Ophiocordyceps sinensis, an Ascomycetes fungus that is closely related to mushrooms and has a long and distinguished history as a medicinal herb. Despite not being a true mushroom in the taxonomic sense, it has long been considered and referred to as a therapeutic mushroom. The Latin words cord and ceps, which imply "club" and "head," respectively, are the source of the name *Cordyceps*. The club fungus *Ophiocordyceps sinensis,* whose stroma or fruitbody extends from the mummified bodies of insect larvae—typically caterpillar larvae of the Himalayan Bat Moth, *Hepialis armoricanus*—is appropriately described by the Latin conjugation.

Although many other closely similar species fall under the general category of *Cordyceps*, the term "Cordyceps" typically refers primarily to the species *Ophiocordyceps sinensis* in historical and common usage. The most well-known species of *Ophiocordyceps* in the world may be *O. sinensis*, however there are numerous additional species in the genus *Ophiocordyceps* that have been shown to have useful therapeutic qualities by contemporary research. Since many of the several species of *Ophiocordyceps* suit the description and applications disclosed here, we shall generally use the name *Ophiocordyceps* without the species designator in this study. In cases when a particular species identification is significant, the species name will also be provided[11, 12].

For many decades, Traditional Chinese Medicine (TCM) has recognized and utilized *Ophiocordyceps sinensis*. It is hard to locate and harvest because it is only found at high elevations on the Himalayan Plateau. *Cordyceps* has long been one of the costliest medications known due to the challenges associated with harvesting this exotic medicinal. Due of its expensive cost, it was historically out of the reach of the typical Chinese subject and was only available to members of the emperor's court and other Chinese nobles. The extraordinary list of therapeutic applications for *Ophiocordyceps* has made it a highly prized mainstay of Chinese medicine, despite its high price and scarcity.

Only in 1726, when it was presented at a scientific conference in Paris, did Western scientific audiences learn about these amazing phenomena, which had been acknowledged as a natural wonder for more than 2000 years in China and the surrounding Orient. The first specimens were brought back to France by a Jesuit priest who wrote about his encounters with the *Ophiocordyceps* mushroom while he was at the Chinese Emperor's court. Although *Ophiocordyceps* has always been rare in nature, modern technological advancements in cultivation have made the possibility of affordable *Cordyceps* a reality[11].

1. Taxonomy and Description

Kingdom: Fungi; Phylum: Ascomycota; Class: Ascomycetes; Order: Hypocreales; Family: Clavicipataceae; Genus: *Ophiocordyceps*; Species: *Ophiocordyceps sinensis*

Basionym: *Sphaeria sinensis*; Synonym: *Cordyceps sinensis*

Vernacular names: Cordyceps mushroom, caterpillar fungus, totsu kasu, tochukasu (Japanese), hia tsao tong tchong, and dongchongxiacao (Chinese) are examples of colloquial names.

1.2 *Description*

The *Ophiocordyceps sinensis* mushroom's ascocarp, or fruitbody, begins at its base on an insect larval host, most commonly the larva of the Himalayan bat moth, *Hepialis armoricanus*, though other insect hosts are occasionally found. It concludes with the stipe and stroma at the club-like cap. The fruitbody is dark brown to black, and the organism's "root," the larval body that has been infected by the mycelium of the mushroom, is yellowish to brown in color. It has a caterpillar-like shape and color, measuring 5–15 cm in length and 0.14–0.4 cm in thickness. Its stem, which is between two and five centimeters long, is either brown or black. There are two varieties based on color; the white yellow variety is larger and of higher quality. The other kind is smaller, copper-colored, and of lower quality. Under ideal circumstances, the spores are finally released and either fall within a few centimeters of their source or are carried away by wind[13].

1.3 *Habitat*

The fungus *Ophiocordyceps* appears annually. The months of April through June are typically when harvesting occurs. *Ophiocordyceps*, which feeds on the moths' larvae, only grows at elevations higher than 3,800 meters above sea level in the chilly, grassy alpine meadows of the Himalayan Plateau, which includes modern-day India, Tibet, Nepal, and the Chinese provinces of Sichuan, Gansu, Hubei, Zhejiang, Shanxi, Guizhon, Qinghai, and Yunnan. In the spring, the caterpillar exhibits subsurface symptoms of the fungal infection, at which point the mycelium starts to break down the host until fruiting is triggered. This occurs when winter gives way to spring and summer, when the thawing of snow at lower elevations makes it easier for foragers to locate the mushroom, and the food source (the caterpillar) has been exhausted. Although it seems improbable, it is currently unknown if it also bears fruit under the snow during the harsher months[14].

1.4 *Ophiocordyceps*: *Parasite or Symbiont?*

It is important to note that the entomopathogenic aspects of the *Ophiocordyceps* mushroom is debatable, even though the spore may be an "infectious" agent that targets the moth larvae. Many eminent researchers believe that keera jari (*O. sinensis*) truly has a symbiotic relationship with the host, meaning that the interaction is mutually beneficial rather than pathogenic, based on an increasing amount of logical and empirical data. Given the isolated and hostile setting in which the moth/*Ophiocordyceps* partnership takes place, this makes sense. Because parasites typically cause the host's mortality, nature tends to choose against them. As is known when other animals eat *Ophiocordyceps*, a more plausible explanation for the unusual combination of an insect and this fungus would be a mutually beneficial symbiosis, in which the moth might get an energy boost from the *Ophiocordyceps* living in its body[15].

Ophiocordyceps frequently displays a single-celled, yeast-like anamorph development stage when cultivated. Other insects have been shown to have similar yeast-like symbionts of the genus *Cordyceps*, which are most likely beneficial to the host insect[3]. If this is the case with the *Ophiocordyceps* /moth relationship, the stressor that causes the *Cordyceps* to generate its fruitbody could be the insect host's death. The *Ophiocordyceps* would have to enter a "reproduce or die" mode once the host insect perished. The mycelium, as opposed to the more commonly observed fruitbody, is the stable-state life form in most fungi. In the kingdom of fungi, it is most usual for fruitbody production to occur only when a significant stressor forces this defensive reproductive-phase response. In the

natural world, these stressors are typically heat and cold, fire and flood, or the full use of the food supply and the consequent lack of nutrients. It is quite challenging to get *Ophiocordyceps* to produce fruiting body in the lab, but when it does, it usually reacts to one or more of these stresses[15].

1.5 *Edibility*

Because of its small size, scarcity, and harsh texture, it is not typically regarded as an edible fungus. *Ophiocordyceps* has historically been eaten as a medicinal soup with a variety of meats, depending on the intended medical condition[16]. In modern medicine, *Ophiocordyceps* is frequently taken alongside vitamin C, which has been shown to help the body absorb and digest the mushroom's therapeutic ingredients. A parasitic fungus called *O. sinensis* infects lepidopteran larvae. The diseased larva is prized for its therapeutic qualities and is usually referred to as a fungal caterpillar.

Locally referred to as "keera jari" in Uttarakhand, it is typically found in meadows between 3,500 and 5,000 meters above sea level. At the end of autumn, the larva contracts the fungus, which gradually spreads throughout its entire body until it dies[14]. Throughout the winter, the larva remains hidden in the dirt. However, the fungus-infected larva sporulates when the snow starts to thaw, forming a structure that looks like a shoot. Because of its potential medical benefits, O. sinensis has a sizable market and is pricey. The villagers now have a steady source of income from their collection as a result. However, excessive exploitation is problematic[17].

2. Review of Literature

Ophiocordyceps sinensis (syn. *C. sinensis*) is generally found in China from the Central Yunnan Plateau to the Qilian Mountains in Qinghai Province, and from Mount Daloushan in Guizhou Province to the vast regions of the Himalaya. However, this fungus's strong host-specificity on moth insects and restricted geographic distribution seem to limit its environmental association. According to reports, the caterpillar fungus can be found between 2200 and 5000 meters in China, between 4200 and 5200 meters in Bhutan, between 3500 and 5050 meters in Nepal, and between 3200 and 4800 meters in India. The caterpillar fungus was initially discovered in India in the late 1990s[18]. The species has been found in alpine meadows in several protected areas, including Askot Wildlife Sanctuary in Uttarakhand, Dehang-Debang Biosphere Reserve in Arunachal Pradesh, Nanda Devi Biosphere Reserve, and Kanchendzonga Biosphere Reserve in Sikkim. Most of the product for commerce is reported from Uttarakhand along the borders with China and Nepal, despite reports of the species coming from three states in the Indian Himalaya[19]. Caterpillar fungi often inhabit alpine and subalpine meadows and shrublands with an average annual precipitation of at least 350 mm[4]. Although the upper altitude limit may reach the snowline areas above 5000 m asl, it grows best in the altitudinal range of 3000–5000 m asl[12].

2.1 *Ecology*

During the monsoon, or wet season, the fungus grows on the caterpillar. The fungus's spores terminate and develop on a living caterpillar. Eventually, the caterpillar perishes. The fungus needs five to seven years to finish its life cycle and generate the natural product. Keera jari only thrives in extremely particular, difficult-to-replicate environments[19]. Only the Himalayas are home to the species. All year round, the temperature is low there. The amount of oxygen available is limited by the high altitude. Growing *Cordyceps* is ideal in these extreme conditions, which make life challenging even for most fungus. Kutki (*Picrorhiza scrophulariiflora*), Jatamansi (*Nardostachys grandiflora*), Bukiphool (*Anaphalis* sp.), and other high-altitude grasses are linked with this species[20].

2.2 *Medicinal Properties*

For decades, the insect and fungal remains have been manually gathered, dried, and utilized in traditional Chinese medicine to treat weariness, sickness, kidney disease, and low libido. When it came to the use of *O. sinensis* parts, those who lived in the uplands used to just gather the elevated fungal portion. Individuals are wise enough to use *O. sinensis* for a variety of objectives. Practically

speaking, this fungus is used by the majority of highland indigenous people to treat a variety of conditions, including headaches, rheumatism, liver disease, diarrhea, and—most importantly—as an aphrodisiac. Nyamnyi Dorje, a Tibetan physician and lama who lived from 1439 to 1475, provided the first known account of Yarsagumba. Yarsagumba is described as a sexual tonic in his textbook, An Ocean of Aphrodisiacal Qualities. Yarsagumba contains bioactive compounds with immunomodulating, anti-inflammatory, and anticancer activities, according to in vitro research[20]. *Ophiocordyceps* extract-containing products and supplements have rapidly gained popularity because of their many health advantages. The medicinal uses of the fungus by locals and traditional healers, claims that Sikkim's traditional healers have been using the fungus for more than eighteen ailments, with the folk healers recommending its use as an aphrodisiac. The number of stoners for a disease is used to gauge the strength of the allegations. In the launching and Lachen region of Sikkim, this fungus is traditionally utilized by both macho and womanly people to treat sexual dysfunction, improve general health and appetite, and boost life. In order to increase their sexual energy and desire, people of both sexes typically consume one fragment of *O. sinensis* with one cup of milk[21]. As an aphrodisiac, the Bhutia communities mix one piece of *O. sinensis* with one cup of locally produced alcohol (chang), leave it for an hour, and then drink it in the morning and evening. Instead of using alcohol, some people utilize hot water. The original people claim that fungus is more effective than ginseng and that it is also useful to treat tuberculosis, cancer, exhaustion, chronic pain, liver, and other ailments. Though mindfulness has only grown since 1995, the indigenous people of Sikkim have been acknowledging that their ancestors utilized this medication prior to the Chogel period, which occurred between 1200 and 1600 BC. The primary active components of *O. sinensis* are cordycepin and cordycepic acid. This tiny plant is a remarkable hybrid of a mushroom (fungus) and a yellow caterpillar. It has all the essential amino acids, water-soluble vitamins B1, B2, and B12, and vitamins E and K. Numerous sugars, including mono-, di-, and oligosaccharides; proteins; sterols; nucleosides; and macro- and microelements (Fe, Cu, K, Na, Ca, Mg, Mn, Zn, Al, Si, Pi, Se, Ni, Sr, Ti, Ga, Cr, V, and Zr) are also present. Men's testosterone levels are raised by *Ophiocordyceps*. In Oriental society, it has long been used as a tonic supplement for reproductive and sexual dysfunctions. Additionally, it raises energy levels. Men's testosterone levels are raised by *Ophiocordyceps*. In Oriental society, it has long been used as a tonic supplement for reproductive and sexual dysfunctions. Additionally, it boosts both men's and women's energy levels and reproductive capacities. For many decades, Traditional Chinese Medicine (TCM) has valued *C. sinensis* for its potential to promote health and stimulate sexual desire[22].

2.3 *Sustainability Issues*

The availability and abundance of the species in its natural habitat are shown to be unaffected by the current Keera jari collection practices. Once the 'Keera Jari' is selected or harvested, more of them are reportedly discovered growing around the pit of the previous year's harvest the next year[26].

2.4 *Socio-Economic and Policy Issues*

For almost ten years, the government has prohibited the trade and collection of this substance without any scientific justification. Nonetheless, this commodity is still being collected and traded illegally. It is one of the main sources of income for people in the Himalayas[24, 26].

2.5 *Current Policy*

In some countries it is prohibited to gather, use, sell, distribute, transport, or export this commodity. Before being gathered for trade, the harvestable fungus body disperses its spores for renewal (part of the spores meet the larvae). However, illegal collecting is made possible by differences in the prices set by the government and the market. This necessitates legislation to prevent

overexploitation and conservation. It is recommended that the keera jari be collected should be made alternate year. Strict measures should be taken to stop illicit supply and collection [13, 25, 26].

3. Conclusion

The elucidation of *O. sinensis* host insects may provide a fundamental understanding for efficient insect resource management techniques as well as for the preservation and sustainable usage of the fungus. Therefore, as soon as the moth population starts to drop, they should be reintroduced to the ecosystem and spread in any way possible. Construction, farming, livestock grazing, large-scale human migration, and other practices that upset the ecology should be discouraged. Furthermore, more research is obviously needed to develop effective management measures to ensure the long-term survival of this fungus due to growing harvest pressure and the lack of trustworthy basal data. It is necessary to develop alternative revenue streams that are specifically designed to sustain indigenous people who depend on *Ophiocordyceps*. Only when local communities are involved in decision-making and execution do government-issued regulations and directives have a decent chance of succeeding. Due to its limited range, this species is likely to experience genetic erosion (rapid habitat fragmentation leading to decreasing gene pools, with human activities being the main culprit), which requires attention. To guarantee its economic and ecological values, more cooperative research both domestic and international is required. Researchers and medical experts continue to be interested in its possible therapeutic properties, making it a valuable natural resource for holistic medicine. Most of the research has been done by researchers thus far. This may be because *Ophiocordyceps* has only lately made its way into the western world and is not readily accessible there. As a result, it has been shunned by default, which has resulted in a lack of awareness, even though it is frequently utilized at home and by local healers in addition to pharmaceutical uses. Nonetheless, *Ophiocordyceps* is becoming increasingly well-liked globally because of its potent therapeutic properties and its aphrodisiac property, especially among those who favor herbal medicines over chemical or synthetic drugs. The many components of *Ophiocordyceps sinensis* are summed up in this overview. With so many benefits, it is essential that every effort be made to make this myco-medical herb available to the medical community worldwide.

Author contributions

AKB: Conception, study and data collection and manuscript preparation. **AT:** Investigations, Formal analysis, conceptualization, manuscript writing.

Data Availability

All data produced or examined in this study are contained within this published article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgements

The authors gratefully acknowledging Herbal Research and Development Institute, Mandal, Gopeshware, Chamoli (Uttarakhand).

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