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A Survey of the Geographic Distribution of *Ophiocordyceps sinensis*[§]

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***Ophiocordyceps sinensis* is one of the best known fungi in Traditional Chinese Medicine. Many efforts have been devoted to locating the production areas of this species resulting in various reports; however, its geographic distribution remains incompletely understood. Distribution of *O. sinensis* at the county level is clarified in this work based on both a literature search and fieldwork. More than 3600 publications related to *O. sinensis* were investigated, including scientific papers, books, and online information. Herbarium specimens of *O. sinensis* and field collections made by this research group during the years 2000-2010 were examined to verify the distribution sites. A total of 203 localities for *O. sinensis* have been found, of which 106 are considered as confirmed distribution sites, 65 as possible distribution sites, 29 as excluded distribution sites and three as suspicious distribution sites. The results show that *O. sinensis* is confined to the Tibetan Plateau and its surrounding regions, including Tibet, Gansu, Qinghai, Sichuan, and Yunnan provinces in China and in certain areas of the southern flank of the Himalayas, in the countries of Bhutan, India and Nepal, with 3,000 m as the lowest altitude for the distribution. The fungus is distributed from the southernmost site in Yulong Naxi Autonomous County in northwestern Yunnan Province to the northernmost site in the Qilian Mountains in Qilian County, Qinghai Province, and from the east edge of the Tibetan Plateau in Wudu County, Gansu Province to the westernmost site in Uttarakhand, India. The clarification of the geographic distribution of *O. sinensis* will lay the foundation for conservation and sustainable use of the species.**

***Keywords*:** distribution, *Ophiocordyceps sinensis*, Tibetan Plateau

Ophiocordyceps sinensis (Berk.) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora [≡ *Cordyceps sinensis* (Berk.) Sacc.] has long been recorded as one of the most valued Traditional Chinese Medicines in a number of ancient codices (Wang, 1694; Wu, 1757; Zhao, 1765). Recent studies have also demonstrated that the fungus can be used to treat a wide range of conditions (Wang, 1995; Zhu *et al*., 1998a, 1998b; Holliday and Cleaver, 2008). It has been officially classified as a drug in the Chinese Pharmacopoeia since 1964 (Committee of Pharmacopoeia, Chinese Ministry of Health, 1964, 2005). The price of natural products of *O. sinensis* has increased sharply in recent years and is now sold at the price of gold or higher. However, the natural resource of this fungus is limited due to its strict host-specificity on moth insects, confined geographical distribution, and over exploitation by humans in recent decades. It has, therefore, been listed as an endangered species under the second class of state protection since 1999 (State Forestry Administration and Ministry of Agriculture, 1999).

O. sinensis parasitizes underground dwelling larvae of moths (Lepidoptera), especially species of *Thitarodes*. The body of the insect host is used by the fungus as substrate to form the mycelium, which is, finally converted into a sclerotium, leaving the exoskeleton intact. When the stroma of the fungus grows from the sclerotium and emerges above the ground, it is collected with the sclerotium as a whole for medicinal use. The larvae of the host insect live underground for their entire larval stage of three to four years or longer, feeding on roots and caudexes of alpine plants. If infected by the fungus, they usually die in the winter. The fungal stroma comes out in the spring or summer of the following year (Yao, 2004). Hyphae of *O. sinensis* can grow at about 2°C with the optimum temperature of 15-18°C, but the hyphal growth is restrained when the temperature reaches 25°C, and stopped below 0°C (Liu *et al*., 1989; Dong and Yao, 2010).

There is a great volume of accounts on *O. sinensis* in the literature (primarily in Chinese), whilst there are not many reports based on fieldwork in the production areas to determine the distribution range of the species. Shen *et al*. (1980) reported the distribution of *O. sinensis* in Yushu Tibetan Autonomous Prefecture, Qinghai Province, China, at an altitude from 4,200-5,000 m on both sides of the watershed. Based on two field trips to Kangding County, Sichuan Province, Xiao *et al*. (1983) reported that *O. sinensis* was distributed from 3,000 m up to the snow line. The vertical distribution of the species was then reported in Sichuan Province from 3,700-4,700 m in Garzê Tibetan Autonomous Prefecture (Yin *et al*., 1990), variable in different locations with the low

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range of 3,450 m in Kangding County and of 4,200 m in Sêrxü County (Li and Cao, 1990), and growing well above 4,500 m and up to about 5,000 m in Baiyü County (Li and Cao, 1990). After investigating the natural distribution and ecological environment of *O. sinensis* in the seven prefectures of Ngari, Qamdo, Lhasa, Nyingch, Nagqu, Xigazê, and Shannan in Tibet, Jiang (1989) reported that the species was distributed in all the prefectures from the altitude of 3,000 to 4,700 m. The distribution range of the fungus was shown as almost the same as the distribution of host insects in Nagqu Prefecture, Tibet, where the host insects were distributed from 4,100-5,000 m altitude, but sparsely between 4,100-4,400 m and above 4,900 m (Chen *et al*., 1999). The vertical distribution of *O. sinensis* along the altitude was also reported to be accordant with that of its host insect in Baima Mountain, Yunnan, from 3,850-5,000 m (Shen *et al*., 1988). According to Yang *et al*. (1993), *O. sinensis* was distributed only in the northwest of Yunnan with an altitude above 4,000 m, but not in the center and northeast of the province even if at the same altitude. Balfour-Browne (1955) described some Himalayan fungi, including *O. sinensis* from the southeast of Tibet, Bhutan and Nepal from 4,200-4,650 m altitude. Kobayasi (1980) reported that the species was collected on the south side of the Himalayas in Bhutan, India and Nepal, with altitudes recorded as 3,500 m in the Annapurna Snow Mountain of Nepal and 4,000 m in Kharka, India. Recently, *O. sinensis* was reported from India on high hills along the border lines with Nepal and China at an altitude ranging from 3,300-4,600 m (Negi *et al*., 2009).

The record of exceptional low altitude for the species was made as 2,900 m by Liu *et al*. (1986), and even as low as 2,260 m and 2,700 m mentioned by Cheng *et al*. (2007) and Liang *et al*. (2008), whilst the majority of the reports were from above 3,000 m. In a recent review, an altitude of 2,600 m for *O. sinensis* was also added by Yang *et al*. (2010).

Several attempts have been made to summarize the distribution of *O. sinensis*. Zang (1979) gave the first general distribution of the species in China as latitudinally from Central Yunnan Plateau to the Qilian Mountains in Qinghai Province and transmeridionally from Mount Daloushan in Guizhou Province to the wide areas of the Himalayas. Recently, coordinates of longitude and latitude for distribution of *O. sinensis* was reported by Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences (2008), indicating Cangshan Mountain (Dali, Yunnan, 25°45′N, 99°34′E) as the southernmost and Qilian Mountains (South of Hexi Corridor in Gansu, 38°49′N, 102°90′E) as the northernmost boundaries. The provincial distribution of the species in China was summarized and illustrated by Pegler *et al*. (1994) as Gansu, Qinghai, Sichuan, Yunnan and Tibet. Winkler (2008) also illustrated the distribution range of *O. sinensis*, including the eastern part in the north, down to the south-eastern part and the south edge of the Tibetan Plateau, with a line to separate the distribution and non-distribution areas starting roughly from the east of Xining City in Qinghai, passing through the west of Nagqu Town and down to Gyangzê or Kangmar county in Tibet, and then around the Himalayas westwards and ended in Uttarakhand in India. In Qinghai Province, an investigation was carried out by the General Investigation Office of Qinghai for Chinese Traditional Medicine Resource in 1990 (Ye *et al*., 1995), with a report of distribution sites and estimation of yield of *O. sinensis* in 29 counties of eight prefectures. In Yushu and Guoluo prefectures of Qinghai Province, the distribution and yield of *O. sinensis* have been well investigated. All the 47 villages and towns of Yushu Prefecture, except eight, were reported to harvest the fungus by Lei (1995) and the amount of harvest in 33 villages was also reported recently by Tseiga *et al*. (2005). A report on five of the six counties in Guoluo Prefecture, except Madoi County, was made by Zhang (2003) with estimations of annual yield. The distribution of *O. sinensis* in Gansu Province was first reported from Wudu and Wenxian counties (Liu *et al*., 1986), and then followed by Luqu and Maqu counties (Dong and Luo, 1996; Fang and Zhang, 2005). For Sichuan Province, Yin *et al*. (1990) reported the distribution in almost every county of Garzê Tibetan Autonomous Prefecture. In addition to the distribution of *O. sinensis* in the seven prefectures of Tibet Autonomous Region reported by Jiang (1989), its distribution at the county level were given by Jin (2003) including 43 counties in eastern and central Tibet. For the distribution of *O. sinensis* in Yunnan Province, Dêqên, Zhongdian (= Xamgyi′nyilha) and Lijiang counties were mentioned by Xu (1991), whereas most counties in northwestern Yunnan were reported by Yang (1997a and 1997b). In addition, the distribution of *O. sinensis* has been spread widely online since the year 2000. Most of the materials online are short articles with a list of localities, often at county level or above, without any analysis (e.g. Jin, 2003). These lists have then been copied and displayed on various websites (e.g. Anon, 2009a, 2009b; and so on) and also reproduced in scientific publications (e.g. Hu *et al*., 2005; Yang *et al*., 2010). The distribution and the impact of *O. sinensis* on local economies in the Himalayan countries, Bhutan, Nepal and India, have also drawn much attention in recent years (Cannon *et al.*, 2009; Kumar *et al.*, 2010; Pant, 2010).

Since the latter part of 1970s, much intensive research work on *O. sinensis* has been carried out, but the distribution of the species was not fully established. The reports or the analyses of the distribution were either on a local scale, up to the provincial level, or in a general statement without specified location. Furthermore, places far from the Tibetan Plateau were also regarded as distribution areas of *O. sinensis*, e.g. Guangdong, Guangxi, Guizhou, Hainan, Hubei, Jilin, Shaanxi, Shanxi, Taiwan, Xinjiang, Zhejiang in China (Guo and Liu, 1958; Liu, 1984; Zhao and Mao, n.d.; Wang, 1995; Zhi, 1998; McKenna *et al*., 2002; Zhuang, 2005) and also Australia, Canada, Finland, Ghana, Italy, Kenya, Japan, Mexico, New Zealand, Norway, Russia, Sweden, The Netherlands, The United States and Tanzania (Wang, 1995; McKenna *et al*., 2002; Dahal, 2004), although they are very doubtful. To clarify this situation, a survey through extensive fieldwork and thorough literature searches was undertaken. The literature was analyzed with the field records made by this group over the past 11 years and specimens preserved in HMAS (Mycological Herbarium, Institute of Microbiology, Chinese Academy of Sciences) and HKAS (Herbarium of Cryptograms, Kunming Institute of Botany, Chinese Academy of Sciences). The results are presented in this paper.

Materials and Methods

This survey covers the reports on *O. sinensis* and also the five species described from the Tibetan Plateau during 1989-1998, including *O. gansuensis* (K.Y. Zhang, C.J. Wang & M.S. Yan) G.H. Sung, J.M. Sung, Hywel-Jones & Spatafora (≡ *Cordyceps gansuensis* K.Y. Zhang *et al.*), *O. crassispora* (M. Zang, D.R. Yang & C.D. Li) G.H. Sung *et al.* (≡ *Cordyceps crassispora* M. Zang *et al.*), *O. multiaxialis* (M. Zang & Kinjo) G.H. Sung *et al.* (≡ *Cordyceps multiaxialis* M. Zang & Kinjo), *O. nepalensis* (M. Zang & Kinjo) G.H. Sung *et al.* (≡ *Cordyceps nepalensis* M. Zang & Kinjo) and *O. kangdingensis* (M. Zang & Kinjo) G.H. Sung *et al.* (≡ *Cordyceps kangdingensis* M. Zang & Kinjo). Among these names, the former four have been proved to be synonyms of *O. sinensis* by several independent investigations using ITS sequence analyses (Kang *et al*., 2000; Liu *et al*., 2001; Kinjo and Zang, 2001); however, the relationship between *O. kangdingensis* and *O. sinensis* still requires clarification (Jiang and Yao, 2004). It is likely that *O. kangdingensis* will be proved to be another synonym of *O. sinensis*, because the former was described from an area within the distribution range of the latter, as seen in the cases of the other synonymous names.

More than 3,600 publications (over 3,100 in Chinese and over 500 in English) related to *O. sinensis* were investigated, including scientific papers, books and online information. The literature search was conducted to find all the available information on the distribution of *O. sinensis*, including the material on the Internet. However, only the earliest and the most representative reports were listed in the Supplementary data Table 1. Field expeditions to Gansu, Qinghai, Sichuan, Yunnan Provinces and Tibet Autonomous Region were carried out by this research group during the years 2000-2010 and the locality, altitude, latitude, and longitude were noted as completely as possible. The fungal collections made during the fieldwork and specimens of *O. sinensis* preserved in HMAS and HKAS, including those under synonyms as listed above, were examined and used to determine the distribution sites of this species. All the related specimens were examined morphologically for identification and some were subjected to molecular analyses.

For the general pattern of distribution of *O. sinensis*, the location sites were based on the county level within Tibet, Gansu, Qinghai, Sichuan and Yunnan, except for Ngari Prefecture in Tibet and Kunming Municipality in Yunnan because there is no further information on distribution in counties available. Locations reported outside of the Tibetan Plateau in China were indicated by the province concerned and those outside of China by the country. The name and the boundary of some counties in China have been changed in recent years, causing some confusion in the analysis. To update the geographic information, the new edition of regionalism for administration promulgated on the website of Ministry of Civil Affairs of the People's Republic of China (2010) is adopted in this survey. English translations for all the localities within China were obtained from the Atlas of China (Di, 2008).

The reported localities for *O. sinensis* were divided into four categories: confirmed distribution site (C), possible distribution site (P), suspicious distribution site (S) and excluded site (E). Confirmed distribution sites were backed by supporting materials in four ways: 1) specimens collected in the fieldwork conducted by this group; 2) specimens preserved in HMAS, HKAS or other herbaria (excluding misidentifications); 3) specimens studied in published research articles and cited with clear information related to the determination and the location of the fungus; 4) ITS sequences from GenBank (http://www.ncbi.nlm.nih.gov/genbank/index.html) which provide clear locality information with correct identification confirmed by the ITS sequence data generated by this research group. Reported localities on the Tibetan Plateau with an altitude above 3,000 m (some of these localities were surrounded by confirmed production sites), were classified as possible distribution sites if no supporting material was found. Localities on the edge of the whole production region with limited acreage higher than 3,000 m, but without supporting evidence of fungal specimen, were considered as suspicious distribution sites. Localities with an altitude lower than 3,000 m and/or far away from the Tibetan Plateau were excluded.

Results

In the fieldwork carried out by this research group since the year 2000, 441 collections were made on the Tibetan Plateau. Among the collections, some 240 were recorded with clear altitude information. The vertical distribution of *O. sinensis* varied in different areas. The lowest altitude recorded was 3,087 m with supporting collections (CS 465, CS 466) made in Xiaojin County, Sichuan Province. It is conceivable that 3,000 m is in general the reliable lowest altitude for the distribution of *O. sinensis*. The highest altitude was recorded as 5,048 m with supporting specimen (CS 187) collected in Nagqu County, Tibet.

Some 53 herbarium specimens under *Cordycpes sinensis* and its synonyms mentioned above, preserved in HMAS (33 specimens) and HKAS (20 specimens), were examined. Among the specimens, six were found to be misidentified (two in HMAS and four in HKAS) including two sites which have never been reported in the literature for the distribution of *O. sinensis*, i.e. Jiangxi Province (HKAS 18226 and 18227) and Daguan County in Yunnan Province (HKAS 13178). Forty seven specimens with correct identification were used in the analysis of distribution sites of the species.

A total of 203 localities (county or above) for the distribution of *O. sinensis* (marked in Figs. 1A, B) were gathered during this survey, including 106 confirmed distribution sites, 65 possible distribution sites, three suspicious distribution sites and 29 excluded sites, which are listed in Supplementary data Table 1 with references, specimen support and notes on distribution. Among the 106 confirmed distribution sites, 88 were supported by voucher collections in addition to other evidence, three by sequence data in GenBank and publications, and 15 by research articles with credible supporting materials. For the 88 sites supported by voucher collections, 80 sites were recorded in 441 field collections made by this group and 20 sites in 47 specimens preserved in both HMAS and HKAS. There are 12 sites supported by both the field collections and the herbarium specimens. A total of 12 sites in Tibet (Chengguan District, and Damxung, Markam, Zogang, Cona, Lhozhag, Qusum, Dinggyê, Gamba, Lhazê, Nyalam, and Sa′gya counties) are first reported here based on the fieldwork carried out by this group (Supplementary data Table 1). *O. sinensis* is confined to the Tibetan Plateau and its surrounding regions, including Tibet, Gansu, Qinghai, Sichuan, and Yunnan provinces in China and in certain areas of the southern flank of the Himalayas, in the countries of Bhutan, India and Nepal. In this survey, it was found that the fungus was distributed from alpine region of northwestern Yunnan, with

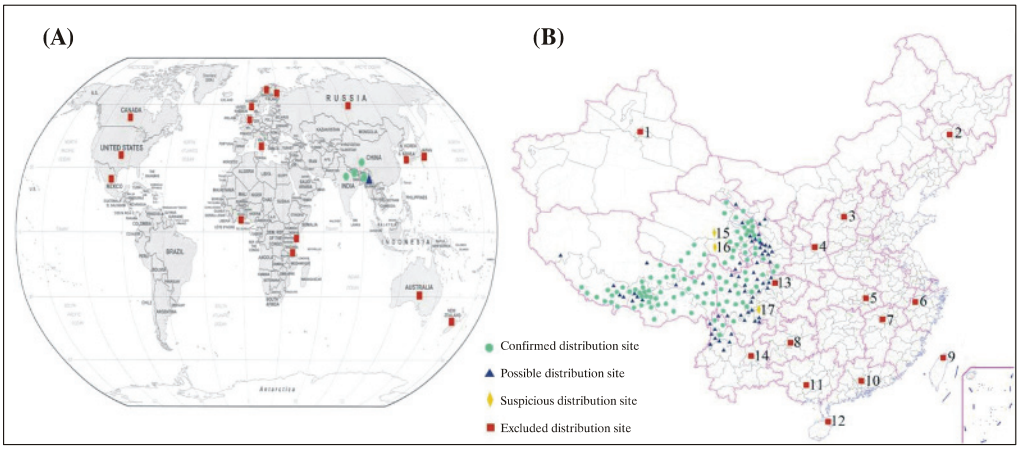

Fig. 1. Geographic distribution of *O. sinensis*. (A) World distribution. (B) Distribution in China. Numbers 1-12 indicate excluded distribution sites at the provincial level of Xinjiang, Jilin, Shanxi, Shaanxi, Hubei, Zhejiang, Jiangxi, Guizhou, Taiwan, Guangdong, Guangxi and Hainan respectively. Numbers 13-14 indicate excluded distribution sites at the city level of Jiangyou City and Kunming Municipality. Numbers 15-17 indicate suspicious distribution sites of Dulan and Madoi counties in Qinghai Province and Mount Emei in Sichuan Province.

Yulong Naxi Autonomous County as the southernmost boundary (27°04′14″, 110°11′43″E, confirmed by field collections CS 17-CS 24 by this research group), to the Qilian Mountains, with Qilian County in Qinghai as the northernmost locality (38°17′46.92″N, 99°17′26.22″E, confirmed by collection CS 262); and from the east edge of the Tibetan Plateau, with Wudu County in Gansu as the easternmost boundary (33°23′N, 104°55′E, supported by HMAS 163296, 163298-163301, and 163303; longitude and latitude cited here were generated by Google Earth Version 5.2.1.1329 beta (http://earth.google.com) using the county locality records of the specimens), to District Pithoragarh of Uttarakhand, India as the westernmost locality (29°34′N, 80°13′E, see Singh and Bhatt, 2010; longitude and latitude coordinates from Google Earth).

Discussion

In this work, all the reported distribution areas of *O. sinensis* were investigated through the literature search in combination with examination of herbarium specimens and field collections gathered in expeditions to the Tibetan Plateau. This is a full-scale survey covering all the production regions of the fungus, and the location sites were reviewed at the county level within the five production provinces in China, including Gansu, Qinghai, Sichuan, Tibet, and Yunnan. The distribution of *O. sinensis* is clarified here as confined to the Tibetan Plateau and its surrounding regions at an altitude above 3,000 m. The reports of the fungus from other regions were either based on misidentification of the specimen concerned or lacked the support of any fungal collection.

It is evident that the upper altitude limit of the species distribution may reach the snowline, whilst the low altitude limit is variable, usually higher in the south and lower in the north. The lowest altitude for the distribution of *O. sinensis*, 3,000 m, was determined based on both the previous reports and the collections made by this research group from the entire production regions of this fungus for 11 years. To verify the altitude record of 2,900 m for the species distribution by Liu *et al*. (1986), an expedition to Gansu was conducted by this group in 2006. Attempts were made to visit collecting sites with the kind help of the senior author of that report, Mr. Liu, but none of the sites were below the altitude of 3,000 m. Furthermore, another research group of Gansu Provincial Grassland Supervision Station (Zhao *et al*., 2010) reported recently the vertical distribution of the fungus in the province as 3,000-4,250 m. For the extreme low altitude records of 2,260 m and 2,700 m, the information on localities of the specimens cited by Cheng *et al*. (2007) and Liang *et al*. (2008), both from a research group of Tongji University, was checked against geographic information (Google Earth Version 5.2.1.1329 beta, http://earth.google.com) based on the provided latitude and longitude for accuracy. The Tongji University group investigated the phylogenetic relationship of host insects of *O. sinensis* using Cytb gene sequences (Cheng *et al*., 2007), and the genetic diversity and structure of the fungus using ISSR technique (Liang *et al*., 2008). The identical materials were used in the two articles as shown by the information of collecting sites and altitudes (Cheng *et al*., 2007; Liang *et al*., 2008) but some of the corresponding longitudes and latitudes for each specimen were inconsistent. For the material collected in Qilian County, Qinghai Province, marked as at the altitude of 2,700 m with the longitude and latitude (38°02′N, 100°22′E) given in Cheng *et al*. (2007) pointed to a site above 3,400 m altitude in Google Earth. When using the longitude and latitude information for the same locality provided by Liang *et al*. (2008, 38°01′N, 100°13′E), the altitude of the site was above 4,000 m. In fact, some 25 specimens of *O. sinensis* were collected in the same county, Qilian, in 2008 by this group, with the lowest altitude for the distribution recorded as 3,221 m. For the material from Huangzhong County, also in Qinghai Province, cited by Cheng *et al*. (2007) and Liang *et al*. (2008) as at an altitude of 2,260 m, the longitude and latitude (36°49′N, 101°57′E) in Cheng *et al*. (2007) pointed outside the boundary of the county, whilst the longi-

tude and latitude (36°29′N, 101°34′E) for the same collection in Liang *et al*. (2008) did fall into the county but at a downtown area with an altitude of 2,700 m. According to our expedition to the county, *O. sinensis* does not occur at the downtown site. In a recent attempt to review the distribution pattern and responses to environmental changes of *O. sinensis*, Yang *et al*. (2010) mentioned that the fungus was found at an elevation of 2,600 m in Gulang, Minle and Tianzhu counties of Gansu Province, located at the north-eastern edge of the Tibetan Plateau, but no supporting evidence was provided. There are areas above altitude of 3,000 m in those three counties and the fungus was collected in Minle County over 3,700 m altitude by this group in 2008 (CS 254-CS 261). The distribution of *O. sinensis* in Minle County is therefore confirmed, while Gulang and Tianzhu counties are considered as possible distribution sites because there is no supporting material available. The record of *O. sinensis* at the altitude of 2,600 m in those three counties is in need of validation by field collections of the species.

The fieldwork carried out on the Tibetan Plateau by this group not only validated many locations of *O. sinensis* reported previously, but also extended them to 12 previously un-reported counties (Supplementary data Table 1). In addition, of the confirmed 106 distribution sites, nearly three quarters (80 counties) were supported by the field collections gathered by this group. Of the 88 distribution sites supported by specimens, almost 90% were verified by our field collections. The specimens collected by this group over the past decade thus serve as important supporting materials to verify the actual distribution of the fungus.

The excluded distribution sites of *O. sinensis* include 11 provinces within China (Guangdong, Guangxi, Guizhou, Hainan, Hubei, Jilin, Shaanxi, Shanxi, Taiwan, Xinjiang, and Zhejiang) and 16 foreign countries (Australia, Canada, Finland, Ghana, Korea, Italy, Japan, Kenya, Mexico, New Zealand, Norway, Russia, Sweden, Tanzania, The Netherlands, and The United States) which are far from the Tibetan Plateau (Figs. 1A, B). Among the provinces in China reported for distribution of the species, citations of specimen support were found for Hubei (HMAS 45960 and 46069) and Xinjiang (HKAS 7724). Examination of these specimens revealed erroneous identification, which in some cases can be found directly from the relevant report, e.g. the fungus illustrated in Zhao and Mao (n.d.) from Xinjiang is apparently not *O. sinensis*. The distribution of *O. sinensis* in Guizhou Province was mentioned in a number of reports (e.g. Zang, 1979; McKenna *et al*., 2002; Holliday and Cleaver, 2004), but both the specimen citation and the detailed locality are lacking. In fact, the highest altitude in Guizhou Province is 2,900.6 m at Mount Jiucaiping, which is apparently not suitable for the growth of *O. sinensis*. Furthermore, Guizhou Province was not included in the distribution areas of the species in a recent volume of 'Flora Fungorum Sinicorum: *Cordyceps*' by Liang (2007), a group of mycologists working on *Cordyceps s. l.* in that province. There are two excluded sites in the five production provinces in China, including two cities: Jiangyou City in Sichuan and Kunming City in Yunnan. The former was excluded because the highest altitude of the city is 2,356 m. The distribution of the species in the latter was based on a specimen (HMAS 01131, Ying and Zang, 1994) purchased from the market, not directly collected from the locality, and therefore the site is excluded for the time being until further evidence is available.

The three suspicious distribution sites of *O. sinensis* are Mount Emei in Sichuan, Dulan and Madoi counties in Qinghai (Fig. 1B). The species on Mount Emei was reported twice with field collections at an altitude above 3,000 m (Chen *et al*., 1973; Zhang, 1987), but the specimens are no longer available for study. It was later considered that Mount Emei might be a distribution site for *O. sinensis* once, but the species is not there now owing to climate changes (Li *et al*., 1991). As Mount Emei is located on the very edge of the Tibetan Plateau with a very limited area higher than 3,000 m, it might be that the habitat for *O. sinensis* has been lost. However, it appears more probable that the collection records from Mount Emei were another species, *O. emeiensis* (A.Y. Liu & Z.Q. Liang) G.H. Sung *et al*. (≡ *Cordyceps emeiensis* A.Y. Liu & Z.Q. Liang), which also parasitizes larvae of *Thitarodes* but has smaller ascospores than that of *O. sinensis*. The type specimen of that species was collected at 3,040 m in Mount Emei in August 1991 (Liu *et al*., 1997). Dulan County lies on the Plateau edge to the eastern side of the Qaidam Basin. It was reported to have the species in Xiangride Town of the county with a total estimated annual yield of 77 kg (Ye *et al*., 1995), but an expedition to the site by this group in June 2008 revealed no evidence for the presence of the species. It is unclear how the previous report on *O. sinensis* was made because the local government officers denied any suggestion of the species occurring in the county during our visit in that year. Madoi County was listed recently by Yang *et al*. (2010) as one of the distribution sites of *O. sinensis*, but it has always been considered as the only county in Guoluo Prefecture without any record of the species (e.g. Diao, 1996; Zhang, 2003). During our fieldwork in the prefecture, carried out in the years of 2005, 2008 and 2010, *O. sinensis* was never found in Madoi County and local government officers kept rejecting the occurrence of the fungus in the county. Although at a high attitude, the county is regarded as not suitable for the growth of the fungus owing to the dry climate and soil conditions.

Most of the possible distribution sites for *O. sinensis* determined here are likely to have a true distribution because they are on the Plateau and adjacent to a confirmed site. However, although these sites may have been reported more than once, even including an estimate of yield, they are not supported by sufficient evidence, e.g. field collection record and/or specimen. For this reason, a broader distribution range (especially for the southernmost boundary) provided by Yang *et al*. (2010) cannot be confirmed until identifiable collections become available.

False distribution sites of *O. sinensis*, which are caused not only by species misidentification but most often by the lack of supporting specimens collected directly from the field, have been found in both Chinese (e.g. Wang, 1995) and English (McKenna *et al*., 2002) publications. It is often the case that an unreliable report was cited by subsequent authors without any checking.

It is worth notice that the 203 localities on the Tibetan Plateau and surrounding regions investigated in the present study have probably not covered the entire distribution area for *O. sinensis*. Many more counties on the Plateau, where

the species may be well established, have not been included in Table S1 because, like the 12 counties first reported for the distribution of *O. sinensis* in this survey, they had not been reported before. On the other hand, among the 106 confirmed distribution counties, there are 88 supported by specimens, and for the possible distribution sites, many only require confirmation through field collections. It is important to clarify the distribution of *O. sinensis* for conservation and for sustainable use of this fungal resource. More fieldwork on the Tibetan Plateau is highly desirable.

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