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ACKNOWLEDGEMENT. We thank the Director, DRDO-BU Centre for Life Sciences, Coimbatore for permission to use their XRD and SEM facilities.

Received 13 March 2014; revised accepted 25 June 2014

Yar tsa Gunbu [*Ophiocordyceps sinensis* (Berk.) G.H. Sung *et al.*]: the issue of its sustainability

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Any resource of immense value and key relevance to rural livelihood as the main cash source, invariably runs the risk of being overexploited, more so when it remains a common property resource. The current harvest pressure on caterpillar fungus, Yar tsa Gunbu (*Ophiocordyceps sinensis* (Berk.) G.H. Sung *et al.*) serves, as a prime example. The ever-increasing demand for the commodity in the international markets and concomitantly its ever-increasing price, hovering at present at US$ 20,000 per kg, have resulted in not just its rampant exploitation, but also in the degradation of the very habitat, thus endangering its future. The present study conducted across nine broad landscapes in 110 villages and 2511 harvesters within Pithoragarh district, Central Himalaya, highlights the socio-economic changes brought forth by the harvesting of the 'green gold' and discusses the prospects of future availability of the species. The study also provides suggestions for evolving sound mechanisms to lessen the pressure on the species.

Keywords: *Cordyceps sinensis*, economy, harvest pressure, sustainability, traditional belief system.

THE Latin etymology of *Cordyceps sinensis* (Berk.) G.H. Sung *et al.* (= *Cordyceps sinensis* (Berk.) Sacc.), Ophiocordycipitaceae (Ascomycetes) is as follows: *cord* – 'club', *ceps* – 'head' and *sinensis* – 'Chinese'. The mushroom is also called the 'caterpillar fungus', and, more frequently Yar tsa Gunbu, which translates as 'winter worm, summer grass', or locally in Kumaun and Garhwal Himalaya as 'keera ghaas', referring to the larva (syn. keera) and the emergent fruiting body that appears as sprouting grass (syn. ghaas). *Cordyceps* is a genus of mostly entomophagous flask fungi (Pyrenomycetes, Ascomycotina) belonging to the family Ophiocordycipitaceae. The British mycologist Berkeley[1] first described it in 1843 as *Sphaeria sinensis* Berk. Later in 1878, Saccardo[2] renamed it as *Cordyceps sinensis*. Based on molecular phylogenetic study, Sung *et al.*[3] separated the mega genus *Cordyceps* into four genera, viz. *Cordyceps* (40 spp.), *Ophiocordyceps* (146 spp.), *Metacordyceps* (6 spp.) and *Elaphocordyceps* (21 spp.), while the remaining 175 spp. were left in the *Cordyceps* group. As a result, *C. sinensis* was transferred to *Ophiocordyceps*, and hence renamed *Ophiocordyceps sinensis*. However, for convenience of the readers, the most commonly used taxa – *Cordyceps* is used in this communication.

C. sinensis parasitizes various grass root-boring *Thitarodes* (previously *Hepialus*) caterpillars, which hatch as 'ghost moths' when not preempted by *Cordyceps*. The genus *Thitarodes* comprises around 51 species, out of which about 40 species have been identified as being the host of *C. sinensis*[4]. Uninfected larvae typically hibernate deeper in the soil than infected ones; apparently the fungus is able to force the infected host to locate itself nearer the soil surface in a position more favourable to its fruiting. The hyphae of the mycelium develop inside the body of the insect, first feeding on less vital parts before taking over the complete organism. Eventually the insect is completely mummified and emptied of nutrients, and all that remains is the exoskeleton filled and coated with *Cordyceps mycelium*. In spring, the mushroom (the fruiting body or stroma) develops out of the head of the exoskeleton just above the eyes. The slender, brown, club-shaped fruiting body then emerges from the ground,

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reaching a total length of 8–15 cm (Figure 1). It is typically nearly twice as long as its caterpillar host, but in rare cases can be up to four times as long.

According to Kendrick[5], *Cordyceps* fungi have developed a special adaptation to improve their chances of reproductive success. Since reproduction is dependent on a specific host, each spore fragments into 100 or more part-spores so that each fungal fructification produces 32 million propagules, thus increasing the odds of landing on a larva. The propagules usually attach themselves to the larva of the insect, but they can attach themselves to mature moths as well. Apparently, the larva is forced by the fungus to move into its final position before being immobilized, since the fungus needs proximity to the surface to grow its fruiting body (stroma) above ground. Uninfected larvae do not hibernate close to the surface. However, this is of no help, if the fungus is removed before 'spores' are released. This is the case with Yar tsa Gunbu gathered early in the season.

It takes several weeks for the spores to mature. As the insect is the sole source of food for the fungus, the size of its stroma is dependent on the size of the host caterpillar[6]. The fruiting season starts as early as mid-May on the eastern slopes of the Kumaun Himalaya, and consequently the harvesting season lasts locally about six weeks. However, the fruiting is delayed with increasing altitude; thus the fungus can be collected for nearly two months at different altitudes in some areas. By mid-June to mid-July the collection season is over, but mature fruit bodies of low quality are reported to persist into August. *C. sinensis* occurs at altitudes 3200–4800 m amsl, but only where average annual precipitation is at least 350 mm and usually more than 400 mm. In the arid regions of the Himalaya, where annual precipitation is below 300 mm, *C. sinensis* is apparently absent. Invariably, fluctuations in *Cordyceps* populations are related to weather conditions[7–9].

It is probably on account of the above-mentioned fact of differential rainfall that the species has not yet been reported from the adjoining state of Himachal Pradesh.

Figure 1. Slender, brownish-pink stroma (fruiting body) emerging out amongst the foliage is often difficult to locate.

Within Kumaun Himalaya, a number of sites are known to harbour the species; however, the most heavily exploited sites are the following: Chiplakot at the confluence of Darma and Choudas valleys, Sumdum, Philam, Bon, Baling, Dugtu and Daantu in Darma Valley, and Ralam Dhura, Panchachuli base, Nagnidhura and Namik in Dharchula-Munsiari region of Pithoragarh district, and area surrounding the Pindari catchment in the adjoining district of Bageshwar[10–12].

Cordyceps contains a broad range of compounds which are considered nutritional[13,14]. It contains all of the essential amino acids, vitamins E and K, and the water-soluble vitamins B_1, B_2 and B_{12}. In addition, it contains many sugars, including mono-, di- and oligosaccharides, and many complex polysaccharides, proteins, sterols, nucleosides, and trace elements. The most commonly cited pharmacological activities of the fungus (Table 1) could be ascribed to two basic classes of bioactive compounds – (i) polysaccharides account for the anti-inflammatory, antioxidant, anti-tumour, antimetastatic, immunomodulatory, hypoglycaemic, steroidogenic and hypolipidemic effects, and (ii) cordycepin contributes to the anti-tumour, insecticidal and anti-bacterial activity.

During the last two decades, there has been ever-increasing demand for the commodity in the international markets and consequently ever-increasing price, hovering around astoundingly at US$ 20,000 per kg (1 US$ = Rs 60) at present. This has resulted in not just its rampant exploitation, but has also brought about degradation of the prime habitat sites, thereby endangering the very viability of the species for future. The present study attempts to bring forth (i) a comparative statement of the role of Yar tsa Gunbu in bringing about socio-economic changes in the lifestyle of the inhabitants, and (ii) arrive at the issue of its sustainability under current anthropogenic pressure.

The study was conducted in the Pithoragarh district, Kumaun Himalaya. The study sites are located between 3200 and 4000 m amsl and lie between 80°15′–81°5′E long. and 29°5′–30°32′N lat. About 110 villages spread across nine broad landscapes, 902 families, and a total of 2511 informants were covered during the survey, which lasted 2 years (2012–2014). The information was elicited through an open-ended questionnaire, which delved into the following: (i) collections and income earned over the last five-year period; (ii) degradation of the habitat and thus the declined yield of the commodity (if any); (iii) dilution of the traditional conservation practices and of the taboo systems; (iv) comparative study of the income earned out of the sale of the produce (Yar tsa Gunbu) versus the traditional means of livelihood – (a) agro-diversity produce, (b) medicinal and aromatic plants (MAPs) exploited from the wild and (c) livestock population and the products derived from it.

Anyone familiar with fungi is aware of the enormous fluctuations in yearly production of fruiting bodies,

Table 1. Major pharmacological functions of *Cordyceps sinensis*

Broad category	Reported function
Antioxidant	Antioxidant and anti-lipid peroxidation activity; also suppresses LDL oxidation[4,15].
Hepatic function	Stimulation of energy metabolism; activation of Kupffer cell function: water-soluble fraction; reduction of post-hepatitis cirrhosis[16]; CordyMax Cs-4 raises ATP in the liver of mice[17–19].
Renal function	Reduction of aminoglycoside-induced nephrotoxicity; reduction of haematuria and proteinuria in experimental IgA nephropathy (IgAN): low MW sterols (CS-H1-A)[16]; improves kidney function and reduces damage caused by nephrotoxic chemicals. Possible modulation of T cell-mediated immune function[20]. D-mannitol or cordycepic acid has diuretic, antitussive and anti-free radical activities[21].
Endocrine and steroid system	Stimulation of corticosterone production by cultured rat adrenal cells: water-soluble fraction[16]; increases 17-ketosteroid and 17-hydroxycorticosteroid, increases weight of sexual organs, plasma cortisol and testosterone in rats[22–24].
Cardiovascular function	Inhibition of platelet aggregation (adenosine and other related nucleosides); reduction of aconitine, $BaCl_2$ and ouabain-induced arrhythmia (low MW metabolites)[16]. Reduced mean arterial pressure, possibly by stimulating release of nitric oxide and endothelium-derived hyperpolarizing factor[25,26].
Anticancer activities	Inhibits tumour growth; antimetastasis of liver Lewis lung carcinoma and B16 melanoma cells in mice. Inhibits cultured human glomerular mesangial cell induced by LDL[24,27–29]. Antitumour function via immunopotentiation and cytokine production (polysaccharides)[16].
Immunomodulation	Immunopotentiation (polysaccharides); immunosuppressant (cyclosporine-like metabolites and others)[16]. Cordycepin is effective against antibiotic-resistant bacteria[7,23,25,30,31].
Hypoglycaemic activity	Polysaccharides lower serum and plasma glucose in STZ-induced[16] and epinephrine-induced hyperglyacemic mice[32,33].
Erythropoiesis and hemopoiesis	Active ingredient unknown[16].
Hepatitis B	May adjust protein metabolism and correct inversion of albumin and globulin[29].
Improved physical performance and quality of life	May increase energy by improving utilization of oxygen. Cordycepic acid relaxes bronchia and strengthens adrenal glands[7,19,34].
Anti-ageing agent	Jinshuibao capsules treat and relieve symptoms of senile deficiency syndrome by inhibiting the formation of monoamine oxidase[34,35].

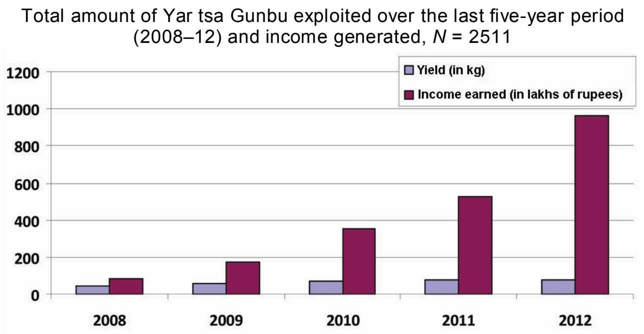

Figure 2. The yield of Yar tsa Gunbu has remained more or less static over the last three years, but the cost per kilogram has multiplied six fold in a mere five-year period.

generally perceived as the result of fluctuations in weather conditions. Additionally, incongruities in data collected at the household level can appear, when collectors do not want to disclose how much they are actually collecting, more so, when the product is valuable; also ambiguity remains as to its legality of exploitation. The results of the survey show that while the yield of Yar tsa Gunbu collectively over the broader landscape has remained more or less steady over the last 5 years, the price of the commodity has increased manifold (Figure 2). In fact, the highest price offered during the penultimate year becomes the base price for the next year. In other words, the price per kg of US$ 20,000 in 2012 became the base price for 2013.

Figure 3 brings out explicitly the decline in yield of Yar tsa Gunbu in three of the landscapes – Johaar, Darma and Gori Paar. The reason for this being that these three landscapes are representative of habitat sites which have been extensively explored for the presence of Yar tsa Gunbu. In the beginning, discovery of new sites only led to increase in the harvest. However, with no new sites left to be explored, concomitant to increased anthropogenic pressure, the yield eventually declined. The declining yields exhibited by these three valleys indicate that the future viability of the produce is intimately bound with the harvest pressure and the resultant denudation of the vegetation cover of the habitat sites.

When the price of the commodity hovers above US$ 20,000/kg locally, it would seem that the harvesters are making a fortune. However, the truth remains that the yield per family averages between 150 and 300 specimens only. Considering the fact that around 3600–4200 Yar tsa Gunbu pieces make up a kilogram, a family usually ends up earning between Rs 1 and 3 lakhs per annum. Considering the fact that the traditional means of sustenance agriculture, livestock and collection of medicinal herbs, is barely substantial, Yar tsa Gunbu has just about enabled these poor people to pursue their small dreams.

Yet another fortunate outcome of the Yar tsa Gunbu phenomenon is that the Bhotiya tribesmen, who had long lost touch with their villages, principally their summer homes, are now returning back. In fact, claimants are

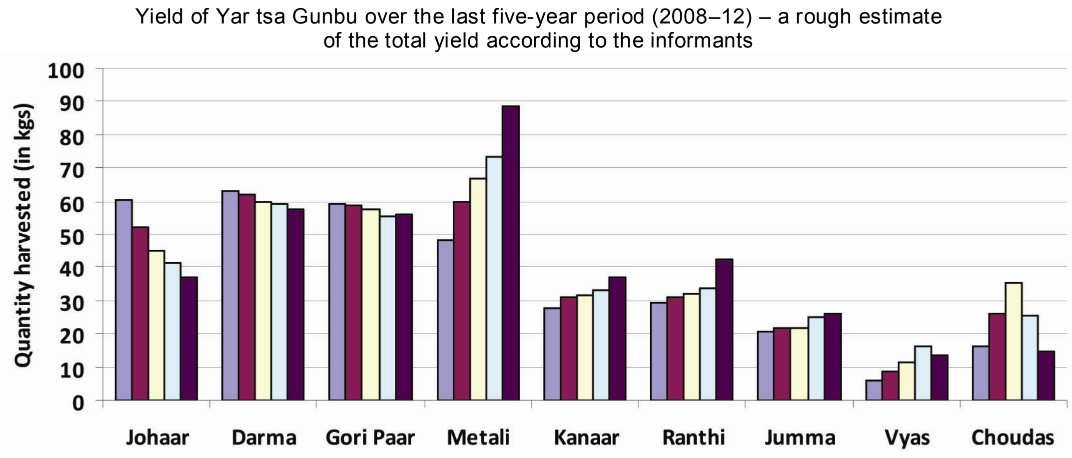

Figure 3. Johaar, Darma and Gori Paar represent landscapes where the Yar tsa Gunbu exploitation started nearly two decades ago. With no additional habitats left, the yield has shown a decreasing trend over the last five years.

Figure 4. The price of the commodity is based on the following – ratio of the size of the stroma and size of the larva (lesser the ratio, better the price offered); bright yellow colour of the larva, and firmness of the larva. Invariably, 70–80% of the harvested lot consists of immature individuals.

busy tracing their roots to a village with Van Panchayat harbouring Yar tsa Gunbu. Thus longer duration of stay in summer homes may in turn encourage the villagers to cultivate crop species like 'Nappal' (durum wheat), the erstwhile main crop of commerce traded with Tibet. In essence, policy makers or enforcement agencies prohibiting the exploitation of Yar tsa Gunbu, need to consider the above facts, and not prevent the locals from harvesting Yar tsa Gunbu; importantly, they must be made aware of the declining yields of the produce, and how best they can stop the trend.

Cordyceps is traded in several categories; the main criteria defining the quality of the produce, in order of preference are the following: lower water content (completely dried samples are preferred than the fresh ones), the state of processing (cleaned rather than uncleaned), and size. Freshly harvested caterpillar encased in black topsoil layer is usually cleaned with a toothbrush and then dried under shade. The degree of dryness of Yar tsa Gunbu is an important factor that controls weight – a price determining factor. Dealers assess the moisture content by the flexibility of the fungus; the less pliable the fungus, the dryer it is. Prices clearly fluctuate through the year, especially depending on the annual harvest.

Another important quality besides larval size is the ratio of the size of the stroma versus the size of the insect larva. Highest value is for the Yar tsa Gunbu whose stroma is a bit shorter than the larva or at least not much longer, since in general this ratio indicates the timing of harvesting (Figure 4). The healing power of Yar tsa Gunbu is in fact believed to be concentrated in the caterpillar filled with *Cordyceps* mycelium. Firmness of the larva is thus important in pricing. The harvesters are thus forced to collect caterpillar fungus early in the season. In fact, 70–80% of the harvested lot consists of immature specimens. The exorbitant price hike only makes the practice more detrimental. Educating the harvesters about the precise life cycle and the importance of the availability of mature specimens for completion of the infective cycle would go a long way in sustaining the future availability of Yar tsa Gunbu.

Until a few years ago, women were not allowed to enter the alpine meadows (considered sacred), which obviously restricted the number of harvesters. However, with increase in the price of the commodity, now women are actually encouraged to go for collection.

Harvesting of medicinal and aromatic plants (MAPs) such as kutki (*Picrorhiza kurrooa*), salampanja (*Dactylorhiza hatagirea*), jatamasi (*Nardostachys jatamansi*) and ginjari (*Chaerophyllum villosum*) would only begin towards the later half of September, post the flowering and shedding of seeds. However, presently exploitation of these species is carried out along with Yar tsa Gunbu.

The future prospects of the produce hinge upon the following facts and how we address them.

(i) Lesser the availability of Yar tsa Gunbu bearing the conspicuous mature sporocarp, lesser would be the

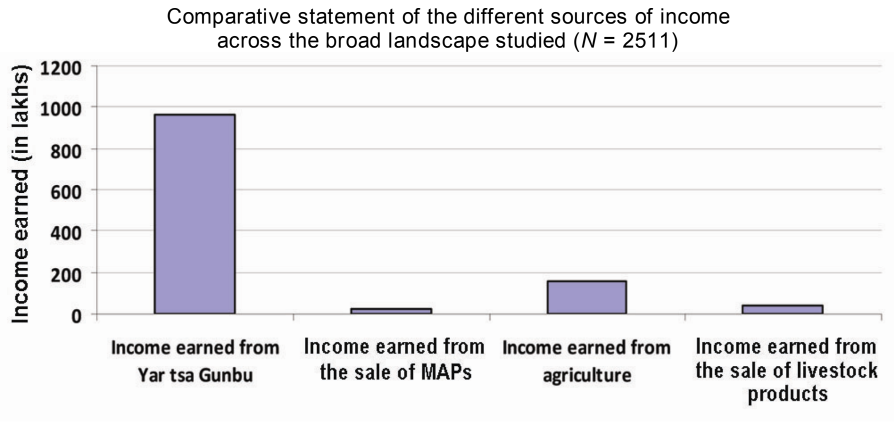

Figure 5. Income earned from the sale of Yar tsa Gunbu far exceeds that earned collectively from traditional crops, livestock or livestock products and sale of medicinal and aromatic plants. This is a cause of concern for long-term sustenance.

chances that reproductive spores would find the likely host insect – the obligate out-crosser (*Thitarode* larva), to complete its life cycle.

(ii) Factors that impede the population size of *Thitarodes* would invariably result in the dwindling size of Yar tsa Gunbu.

(iii) Even though the distribution of *C. sinensis* in the landscape is confined between 3200 and 4800 m elevation – a relatively wide niche, the topography within the zone shows extreme variability in terms of the micro-habitats, which eventually narrows down the area of the niche. Lately, the lower reaches of these habitats have shown signs of degradation (with no yield whatsoever according to the informants), primarily on account of the space being occupied by the harvesters during the harvesting season. Again, the yield of Yar tsa Gunbu is inversely related with the gradient of slope, i.e. greater availability is reported at 15° slope, and it progressively declines with greater inclination of the slope; the erection of tents in the least inclined sites, has a negative impact on the yield of Yar tsa Gunbu.

(iv) Habitat destruction by the ever-increasing harvesters is a major cause of concern. This becomes obvious by the simple fact that now the harvesters themselves have to procure the fuel wood from relatively greater distance downhill, a good distance of 200–300 m. The problem gets accentuated when the local harvesters are outnumbered by the contract labourers from outside. Five years ago, the present authors had successfully implemented an effective mechanism to restrict outsiders – those not belonging to the said Van Panchayat (forest council) by issuing passes only to the local inhabitants of the village. These passes are even distributed to the infirm and the elderly, who then auction the same to outsiders at a price more than US$ 1000 per pass. Yet another latest feature of exploitation (and disliked by the common villagers) is the hiring of labourers on contract basis by the local rich villagers, who make provision for their lodging in the alpine meadows, in return for 50% of their harvested lot.

(v) However, the major determining factor that invariably relates to the future availability of caterpillar fungus is the ever-increasing demand in the international markets. Greater the demand and higher the price of the commodity being traded, greater would be the intensity to harvest the fungus and longer the duration of stay in the habitat sites. In fact, during the last five years, the price of the commodity has multiplied sixfold, from around US$ 3333 per kg in 2008 to US$ 20,000 per kg in 2012. The unbelievable increase in the sale price has only accentuated the pressure on Yar tsa Gunbu. While production has remained more or less constant over the last few years (2010–12), the income earned has more than doubled (Figure 2). In fact, the income generated by Yar tsa Gunbu in a short period of one and half months in a year far exceeds the traditional sources of income combined (Figure 5).

Given the ever-increasing demand in the international markets and the price of the commodity, it would be safe to presume that Yar tsa Gunbu faces a bleak future not because of harvesting, but more on account of the degradation of the very habitat and denuding vegetation cover, upon which its host thrives. Obviously, efforts of the policy makers and enforcement agencies, both at the state and village-level institutions, have failed to stop this trend. There is an urgent need to educate the villagers on the following: (i) sustainable harvesting methods; (ii) the need to restrict the number of harvesters, say, restricting the number of members per household; (iii) shortening the length of their stay in the alpine meadows. Local collectors can be the best stewards of their resources, if they are well informed and understand what is at stake. Under such circumstances they could accept certain regulations – crucially stopping of the collection, once sporulation begins late in the season – as part of sustainable resource management; (iv) ensuring that degradation of the habitats, primarily on account of procuring fuel wood, and thus species, does not take place; (v) an effective mechanism be evolved at the village level to ascertain the quantity of the harvested lot vis-à-vis the extent and duration of the harvesting, and finally (vi) a transparent mechanism for the marketing or trade of the produce. However, one of the first forward steps would be establishing Biodiversity Management Committees at Van Panchayat level, with which management concerns could be shared for implementation.

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ACKNOWLEDGEMENTS. We thank the Ministry of Environment and Forests, New Delhi for financial support and the anonymous reviewer for useful suggestions. The present study would not have been possible without the help of the villagers – the ultimate custodians of biodiversity.

Received 11 April 2014; revised accepted 4 July 2014