

Ecology, Biogeography, and Conservation Status of the Rare Medicinal Fungus *Ganoderma resinaceum* in Uzbekistan

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Abstract *Ganoderma resinaceum* Boud., a rare medicinal polypore fungus, exhibits a narrow distribution in Uzbekistan, primarily confined to the Majrumsoy region of the Nurota range. This study integrates field surveys, morphological and molecular analyses, and literature review to assess its biology, ecological role, and population status. The species develops on living, weakened, or dead woody substrates, especially riparian *Salix* L. trees, producing white-rot via ligninolytic enzymes. Fruiting body formation is highly dependent on moisture availability, indicating vulnerability to drought and climate change. Biogeographically, *G. resinaceum* is a Palearctic species adapted to temperate and Mediterranean climate zones, with its occurrence influenced by host availability and environmental conditions. Its facultative pathogenicity and association with stressed or senescent trees suggest a role as a bioindicator of ecological imbalance. Conservation measures, including habitat protection, prevention of illegal logging, and regular monitoring, are essential to safeguard local populations and maintain the functional stability of Nurota range ecosystems. This study provides critical insights into the ecological, biogeographical, and conservation aspects of a rare medicinal fungus, supporting informed management in semi-arid forest landscapes.

Keywords Rare medicinal fungi, Forest ecology, Biogeography, Palearctic, Conservation, Riparian ecosystems, White-rot fungus, Climate sensitivity

1. Introduction

Ganoderma resinaceum Boud. belongs to the Basidiomycota division, class Agaricomycetes, order Polyporales, family Polyporaceae, and genus *Ganoderma*. In forest ecosystems, it grows as a saprotroph or facultative pathogen, decomposing dead or weakened woody tissues.

Species of the genus *Ganoderma* are cosmopolitan basidiomycetes distinguished from other polypores by basidiospores with a characteristic double-walled structure. The genus *Ganoderma* was established by Karsten in 1881, with *G. lucidum* (Curtis) P. Karst. designated as the type species [1].

Ganoderma species are widely distributed worldwide, with fruiting bodies typically growing on living, but more commonly on dead, woody substrates. They can function as facultative parasites on living trees or as saprotrophs on

decaying wood. *Ganoderma* species produce two types of fruiting bodies: glossy, varnished structures with a bright yellowish-reddish surface, or smooth, dull, non-lustrous bodies. These fungi are generally not considered edible, as their fruiting bodies are tough, bitter in taste, and lack palatable texture. The double-walled basidiospores with an internal columnar structure represent a key diagnostic feature of the genus. *Ganoderma* species are of considerable economic importance due to their pharmacological properties [2].

Ganoderma has traditionally been used as a medicinal mushroom, particularly in China, Japan, and Korea, for millennia to promote longevity and enhance overall health. It has been employed as a functional food to prevent and manage a wide range of immunological disorders. Research has confirmed the bioactivity of polysaccharides, proteins, and triterpenoids produced by *Ganoderma*, highlighting its biotechnological potential. In China, *Ganoderma* is known as “Linchzhi” or “Rui-zhi,” in Japan as “Reishi,” and in Korea as “Youngzhi.” Linchzhi has been used as a medicinal agent in traditional Chinese medicine for thousands of years and is regarded as a symbol of happiness, longevity, and protection. It is documented in the pharmacopoeia Shen

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Nong Ben Cao Jing from the Han dynasty and is widely represented in ancient art and literature [3,2,4,1].

The main objective of this study was to analyze the biology, biogeography, and ecological characteristics of the locally occurring medicinal and rare fungus *Ganoderma resinaceum*, as well as to assess the current status of its populations.

2. Materials and Methods

Study object and sample collection

This study investigated the biological characteristics, biogeographical distribution, and ecological status of *G. resinaceum* using an integrated research approach. The methodology combined field surveys, laboratory analyses, and a comparative review of relevant scientific literature.

Field investigations were conducted in natural and cultivated forest ecosystems across Uzbekistan. Living, weakened, and dead woody tree trunks were examined for the presence of basidiocarps. For each recorded specimen, data on geographic location, substrate type, host tree condition, and environmental growth conditions were documented.

Morphological and molecular identification

Morphological analyses were performed under laboratory conditions. Macromorphological characteristics of the fruiting bodies, including shape, size, color, surface texture, thickness, and hymenophore features, were examined. Micromorphological observations were carried out using light microscopy to determine basidiospore shape, size, and wall structure. These characteristics were evaluated as key diagnostic features of the genus *Ganoderma*.

Molecular identification was conducted to confirm species identity. Genomic DNA was extracted from five-day-old pure culture mycelium following a standard extraction protocol. The internal transcribed spacer (ITS) region of ribosomal DNA was amplified by polymerase chain reaction (PCR) using universal primers. The amplified products were purified and sequenced. The resulting sequences were compared with reference data available in the NCBI GenBank database using the BLAST algorithm.

Biogeographical Analysis

For the biogeographical assessment, field data were compared with published sources. Additionally, relevant literature was reviewed to summarize information on the biology, ecological features, and medicinal importance of the genus *Ganoderma*. Based on the collected data, the current status of local *G. resinaceum* populations was evaluated and general conclusions regarding its distribution and conservation were formulated.

3. Results and Discussion

G. resinaceum is characterized by annual, stipitate basidiomata with a distinctly varnished, glossy, reddish-brown pileus

surface. The basidiocarps are relatively thick, measuring 8.0–22.0 × 6.0–10.5 × 2.0–3.0 cm. The pileus margin is slightly incurved (concave), and the surface is smooth to slightly wrinkled. The margin is rounded, light greyish-yellow (ochre-buff), and approximately 1.0–1.5 cm wide. The stipe is short, laterally attached, reddish-brown in color, and measures 5–6 × 2–3 cm. The hymenial surface varies from cream to brown and contains circular to irregular pores, with a density of 2–6 pores per mm and pore diameters ranging from 97 to 306 μm. Basidiospores are yellowish-brown to fuscous, broadly ellipsoid to ovoid, semirugose, and possess a thick wall. Spore dimensions range from 9–13 × 5–8 μm (Figure 1).

The extracted genomic DNA was of sufficient quality for PCR amplification. Successful amplification of the ITS rDNA region and subsequent sequencing confirmed the suitability of the applied molecular protocol for *Ganoderma* samples. Sequence comparison analysis demonstrated 91% similarity with reference *Ganoderma* sequences available in public databases, supporting the taxonomic placement of the studied isolates within the genus.

The functional role of *G. resinaceum* within forest ecosystems was evaluated based on available scientific literature. This species is primarily saprotrophic or occasionally a facultative pathogen, developing on both living and dead woody substrates and causing white rot [5].



Figure 1. Morphological and microscopic characteristics of *Ganoderma resinaceum*: a – young basidiocarp at the initial developmental stage, b – pileus surface showing a laccate, reddish-brown crust, c – Lateral view of a mature basidiocarp attached to the host tree, d–e – Dried basidiocarps (herbarium specimens), f – hymenial surface, g – ellipsoid, double-walled basidiospores observed under light microscopy.

This process is mediated by ligninolytic enzymes produced by *Ganoderma* species – laccase, lignin peroxidase, and manganese peroxidase – which degrade lignin and cellulose, thereby reducing the mechanical strength of the wood and making it susceptible to biological decomposition [2,6].

The ecological role of *G. resinaceum* in forest biocenoses is significant, contributing to nutrient cycling and enhancing soil fertility [7,8]. At the same time, the species exhibits facultative pathogenic behavior, capable of damaging living tissues in weakened or compromised trees and thereby negatively affecting tree phytosanitary condition [6,9].

Due to its association with weakened or senescent trees, *G. resinaceum* is also considered a potential bioindicator of ecosystem stress and anthropogenic pressure. The abundance of wood-decaying fungi and the dynamics of fruiting body formation are often linked to drought, pollution, and habitat degradation, allowing their use as indicators of ecological imbalance in both natural and urban forests [10,11].

Although *G. resinaceum* is widespread in many regions, its distribution varies depending on climate and host tree species. In Europe, it has been recorded on a variety of trees, with a particularly high prevalence on species of *Quercus* L. [8]. This highlights the ecological adaptability of the genus *Ganoderma*, while indicating that its growth and distribution are influenced by environmental conditions and host availability.

In Uzbekistan, the distribution of *G. resinaceum* is relatively restricted. To date, mycological studies have recorded this species only in the Nurota mountain range. Extensive mycological surveys in other regions of the country, including the Western Tianshan, Northern Turkestan, Zarafshan, Bobotag, and Kuhitang ranges, have not detected its presence. Assessment of local populations indicates that in Uzbekistan, *G. resinaceum* occurs in a very narrow area, limited to the Majrumsoy region of the Nurota range. Currently, six populations have been identified in this area. They primarily develop on the trunks of riparian willow (*Salix* L.) trees or on fallen woody debris. This distribution pattern highlights the species' strong dependence on moisture and its close association with riverine and stream ecosystems. In years of low precipitation, fruiting body production declines sharply, indicating high sensitivity to climatic factors, particularly moisture availability. Consequently, intensified drought conditions and ongoing climate change may negatively affect both the size and stability of local populations.

These observations suggest that *G. resinaceum* is a rare and locally distributed species within the mycobiota of Uzbekistan, likely possessing narrow ecological requirements. Its occurrence in only a few areas is probably linked to specific ecological conditions, including particular climate regimes, host tree species, and microhabitat characteristics. Therefore, to conserve these rare medicinal populations, regular monitoring, habitat protection and restoration, and scientifically informed conservation measures are essential.

Climate is a key factor determining the distribution of *G. resinaceum*. The species occurs predominantly in warm

temperate and subtropical zones, where seasonal moisture facilitates its growth and sporulation. Its presence in semi-arid regions, provided that suitable woody substrates are available, indicates an ability to tolerate moderate drought conditions [12–15].

From a biogeographical perspective, *G. resinaceum* belongs to a group of lignicolous species adapted to temperate climates. Their distribution patterns are closely linked to the historical development of broadleaf forest ecosystems in the Palearctic region [16,17]. *Ganoderma* species are widely distributed in temperate and tropical biomes, with their occurrence primarily determined by climatic conditions, the availability of suitable host trees, and the continuity of woody substrates [18,15].

Phylogenetic studies based on ribosomal DNA sequences indicate that *Ganoderma resinaceum* likely belongs to an evolutionary lineage associated with the Palearctic region [19,15]. Its diversification is closely linked to the evolutionary history of temperate broadleaf forests, particularly ecosystems dominated by genera such as *Quercus*, *Fagus*, and *Populus*. It is hypothesized that *G. resinaceum* developed in warm-temperate regions with sufficient moisture and the presence of suitable woody substrates. Climatic fluctuations during the Late Tertiary and Quaternary periods may have played a key role in shaping its present distribution, with forest fragmentation and reconnection promoting both population isolation and dispersal. *G. resinaceum* is primarily a Palearctic species. Its core distribution encompasses Southern and Central Europe, where it is relatively widespread, especially in lowland and submontane areas [12,13]. Its occurrence declines toward Northern Europe, reflecting climatic constraints such as lower temperatures and shorter growing seasons. In Western Asia, including the Caucasus, Turkey, Iran, and the Caspian region, *G. resinaceum* has been recorded under warm-temperate to semi-arid conditions, demonstrating some tolerance to seasonal drought. In general, *G. resinaceum* and related wood-decaying fungi are primarily distributed in temperate and Mediterranean climate zones, characterized by high summer temperatures and relatively low precipitation. This distribution pattern suggests adaptation to seasonal moisture limitations [14,20,21]. In particular, Mediterranean fungal communities are shaped by summer drought and autumn–winter precipitation regimes, indicating that wood-decaying basidiomycetes experience significant hydric stress [22]. Thus, warm and seasonally dry environments provide suitable ecological niches for the development and fruiting of white-rot fungi such as *G. resinaceum*. Outside its main range, *G. resinaceum* has been sporadically recorded in East Asia, including the Chinese and Korean peninsulas [15]. In these regions, its occurrence is often associated with managed landscapes, such as urban parks, botanical gardens, and roadside afforestation areas. In boreal and arid desert regions, the scarcity or absence of suitable host trees limits the natural distribution of the species [14,1]. Such peripheral records may also result from under-sampling, historical misidentifications, or recent anthropogenic introductions. Similar processes have been

observed in other *Ganoderma* species, whose ranges have expanded through the transport of infected seedlings and wood products [20].

Overall, studying the ecology and biogeography of *G. resinaceum* is critical for understanding global fungal distribution patterns, phylogeographic differentiation within the *Ganoderma* lineage, and the functional stability of temperate forest ecosystems under contemporary climate change [17,15].

4. Conclusions

The results of the present study indicate that *G. resinaceum* has a narrow distribution in Uzbekistan and represents a rare, medicinal, and ecologically sensitive species. Current data show that it occurs primarily in the Nurota Mountains, associated with riparian *Salix* trees. Fruiting body formation is strongly dependent on moisture availability, with markedly reduced production during dry years. This highlights the species' high sensitivity to hydric conditions and suggests that its population stability may be threatened under ongoing climate change. From an ecological perspective, *G. resinaceum* plays a crucial role as a white-rot lignicolous fungus, contributing to nutrient cycling in forest ecosystems. By decomposing lignin and other complex polymers, it facilitates the biological degradation of wood and enhances soil fertility. At the same time, its facultative pathogenicity on weakened trees underscores its phytosanitary significance. Its association mainly with stressed or senescent trees also allows it to serve as a potential bioindicator of anthropogenic pressure and ecological imbalance within forest ecosystems. Biogeographically, *G. resinaceum* is a Palearctic species characteristic of temperate and Mediterranean climate zones, with its distribution determined by climatic conditions, the presence of host trees, and the continuity of woody substrates. In Uzbekistan, its restricted distribution reflects its specific ecological requirements. Accordingly, the conservation of local *G. resinaceum* populations requires protection of riparian willow stands, prevention of illegal logging, and regular monitoring under the context of climate change.

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