

However, the same high medicinal and commercial value that has promoted the use of *Paris* spp. has also accelerated the depletion of wild resources. Before the 2000s, *Paris* species were not cultivated in plantations, and the pharmaceutical industry relied primarily on Rhizoma Paridis collected from wild populations; with annual raw-material consumption estimated at about 3 000 000 kg, overharvesting has caused dramatic declines in natural populations. Multiple studies identify overexploitation, illegal collection, habitat degradation, habitat fragmentation, logging, farming, trampling, and weak management as key drivers of decline, and several reviews now describe *P. polyphylla* as vulnerable, endangered, or rare and threatened in different regional and conservation contexts (Thapa et al., 2022; Thakur et al., 2023). Field evidence from the Indian Himalayan Region recorded very low population densities of only 0.42~1.48 individuals/m² and emphasized that unsustainable extraction, poor natural regeneration, and rhizome-focused harvesting place wild populations at risk of local extinction. Similar patterns are reported from Nepal, where accelerating demand has promoted unsustainable legal and illegal harvest, premature collection, and habitat degradation, while trade pressure continues across broad distribution areas (Kunwar et al., 2020). Recent cultivation-oriented work further underscores the severity of the supply crisis, noting that approximately 80% of wild resources are exploited annually and that, in Yunnan alone, demand exceeds 1 000 tons while annual wild production is less than 100 tons (Zhang et al., 2025). Because *Paris* species also grow slowly, regenerate inefficiently, and often depend on harvested rhizomes for both medicinal use and vegetative persistence, wild-resource decline has become a coupled ecological and industrial problem (Wang et al., 2021).

Under these conditions, artificial germplasm restoration has become essential for both conservation and sustainable utilization of *Paris* spp. Conventional propagation remains constrained by slow seed germination, secondary dormancy, long juvenile growth, low multiplication rates, and disease or rot associated with rhizome cutting, while interspecific hybridization can also compromise the uniformity of medicinal raw materials and complicate seed-based breeding. These constraints explain why traditional breeding and propagation have not kept pace with rising herbal-drug demand and why researchers increasingly emphasize ex situ conservation, clonal multiplication, and tissue-culture-based restoration pathways (Thapa et al., 2022). Encouragingly, several studies have demonstrated feasible artificial propagation routes. Direct somatic embryogenesis has achieved successful regeneration with high germination and ploidy stability in regenerated plants. In vitro propagation using optimized plant growth regulators has produced strong shoot induction and 94.4% greenhouse establishment (Puwein and Thomas, 2022). GA₃ treatment can rapidly break dormancy and induce polyapical shoots at 100%, offering a more efficient rhizome propagation strategy. Somatic embryogenesis-based clonal propagation can also generate homogeneous elite materials, support cryopreservation-compatible conservation, and shorten plantlet production by 12~15 months while maintaining favorable biomass and saponin traits (Wang et al., 2023). In parallel, emerging work on seed dormancy regulation indicates that improving reproductive efficiency remains a central scientific challenge for large-scale restoration.

Accordingly, research on the decline of wild *Paris* resources and the pathways for artificial germplasm restoration has both theoretical and practical significance. At the scientific level, the taxonomic complexity of the genus, disputed species boundaries based on morphology, and demand for robust phylogenetic markers indicate that conservation must be linked with accurate germplasm identification and genetic-resource management. At the applied level, restoration research should clarify patterns of wild-resource depletion, identify the biological bottlenecks limiting natural and artificial regeneration, screen elite germplasm with stable medicinal quality, and integrate in situ protection, ex situ conservation, standardized cultivation, and traceable supply systems. It should also connect germplasm restoration with quality formation, since saponin accumulation varies with developmental stage and growth duration, making the relationship between propagation strategy, growth years, and medicinal quality especially important for sustainable production. More broadly, effective restoration can reduce harvesting pressure on wild populations, preserve genetic diversity, stabilize raw-material supply, support rural cultivation economies, and improve the long-term sustainability of biodiversity use under intensifying market demand. For these reasons, analyzing wild resource decline and constructing practical artificial germplasm restoration pathways for *Paris* spp. is a necessary foundation for reconciling medicinal use, industrial development, and species conservation.