

(Cheng et al., 2023). Evidence from industry and cultivation studies shows that wild resources have been heavily depleted by overexploitation, long-term harvesting pressure, and the long growth cycle required to form harvestable rhizomes (Su et al., 2018). This contradiction is likely to intensify under environmental change, because habitat suitability for *P. sibiricum* is projected to decline in the future and shift geographically, adding further pressure to conservation and germplasm utilization (Zhang et al., 2023). Although cultivated *Polygonatum sibiricum* is now an important source for market supply and can provide more stable production, persistent problems remain, including germplasm confusion, unstable quality, low cultivation technology, and insufficient supply of high-quality seedlings (Pan et al., 2022). Seedling production is a central bottleneck because large-scale cultivation depends on reliable nursery systems, yet seed propagation is constrained by deep morphophysiological dormancy, slow germination, and delayed seedling establishment (Liao et al., 2021). Even under production conditions, harvestable rhizomes generally require 3–4 years through rhizome propagation and 5–6 years from seed propagation, which limits rapid expansion and raises the importance of efficient vegetative propagation and early seedling management.

At the same time, the transition from wild collection to cultivation has created higher requirements for seedling standardization and quality consistency. Comparative metabolomic studies indicate that cultivated and wild-grown *P. sibiricum* share many important phytochemicals, but they can also differ in specific compounds and abundance profiles, which means that propagation materials and cultivation practices can directly affect product quality (Pan et al., 2022). Encouragingly, artificially cultivated rhizomes with multiple buds show phytochemical profiles broadly comparable to wild types and contain several therapeutically relevant compounds, supporting the feasibility of cultivation-based substitution if propagation systems are well designed (Cheng et al., 2023). Research on rhizosphere adaptation further suggests that yield and quality are strongly influenced by site conditions such as soil pH and associated beneficial or pathogenic microorganisms, highlighting that high-quality seedling production must be integrated with suitable ecological and agronomic management (Shi et al., 2024). Studies on distribution, phenotype, and common-garden performance likewise show marked variation among *Polygonatum* materials in yield, quality traits, and environmental adaptation, reinforcing the need for standardized propagation pathways, germplasm selection, and nursery evaluation indicators before field expansion (Liao et al., 2023). Therefore, establishing a technical system for rhizome propagation is not only a matter of multiplying planting material, but also a prerequisite for preserving elite germplasm, stabilizing medicinal quality, and supporting scalable industrial production.

This study will explore the construction pathway of a technical system for rhizome propagation and high-quality seedling production of *Polygonatum sibiricum*, with a focus on key issues such as selection of propagation materials, improvement of propagation efficiency, control of seedling uniformity, and subsequent cultivation adaptability. This system is expected to provide technical support for the rapid multiplication of elite germplasm, reduce dependence on wild resources, and promote the large-scale production of standardized seedlings. Meanwhile, this study is of great significance for improving the consistency of raw medicinal materials of *Polygonatum sibiricum*, ensuring the stable supply of medicinal-and-edible homologous products, and promoting industrial modernization. From a broader perspective, the construction of this technical system will help achieve the coordinated integration of germplasm conservation, standardized production, and efficient resource utilization, thereby providing a theoretical and practical basis for the sustainable and high-quality development of the *Polygonatum sibiricum* industry.

2 Biological Basis of Rhizome Propagation

2.1 Structural characteristics

The underground organ of *P. sibiricum* is a perennial rhizome that extends by producing one new segment each year, forming a distinct “annual rhizome” pattern that provides the structural basis for clonal propagation. Within *P. sibiricum*, annual rhizomes show at least two recognizable morphological types, including a thick-ended “Jitou-type” and an atypical type without obvious thickening, indicating that rhizome architecture is variable even within the species (Hu et al., 2022). Artificially cultivated materials with multiple rhizome buds have also been