

membrane-damage markers, and antioxidant defense indices (Mahmood et al., 2022). A single indicator is not sufficient for this task, because drought and other stress responses are controlled by multiple traits and pathways; comprehensive evaluation using PCA, correlation analysis, grey correlation, drought indices, or entropy-weight methods gives a more objective basis for classification (Baha et al., 2025). Recent grading studies in maize further show that multimodal phenotypic systems can classify seedling quality with high accuracy, and that a reduced set of key indices such as plant height, stem diameter, leaf area, root volume, and shoot and root biomass can support efficient automated grading (Zhang et al., 2024; Yu et al., 2025).

For nursery release of *P. sibiricum*, a three-level standard is practical. First-grade seedlings should have balanced morphology, well-developed fibrous roots, high DQI or comparable composite quality scores, stable chlorophyll fluorescence and SPAD values, and low membrane-damage indicators under routine hardening tests (Lee et al., 2026). Second-grade seedlings may show moderate variation in size or biomass allocation but should still maintain acceptable root morphology, photosynthetic activity, and biochemical stability for field establishment (Baha et al., 2025). Rejected seedlings should include weak, top-heavy, root-deficient, physiologically unstable, or stress-sensitive individuals showing poor root volume, unbalanced shoot-root ratio, depressed fluorescence traits, or excessive MDA accumulation (Shin et al., 2021). In practice, release standards should be validated against local field performance and revised iteratively, because seedling quality indices are species- and site-dependent rather than universally transferable (Robonen et al., 2023).

8 Conclusion

This paper systematically examines the construction of a technical system for rhizome propagation and high-quality seedling production of *Polygonatum sibiricum*, covering the biological basis of rhizome propagation, propagation techniques, rhizome formation and harvest standards, storage and vigor maintenance, standardized seedling production, and seedling quality evaluation. The findings indicate that the rhizome of *P. sibiricum* is not only the main medicinal part but also the core organ for vegetative propagation. Its segmented structure, bud development, nutrient reserves, and environmental responses jointly determine propagation efficiency and seedling quality. Compared with seed propagation, rhizome propagation has the advantages of a shorter production cycle, stable trait inheritance, and suitability for rapid multiplication of elite germplasm, making it an important technical pathway for large-scale cultivation and standardized seedling production of *P. sibiricum*.

In terms of technical system construction, rhizome propagation of *P. sibiricum* should be based on the selection of superior mother plants and the quality control of healthy rhizome sources. Whole-rhizome propagation, division propagation, segment propagation, bud-section propagation, and tissue culture rapid propagation should be integrated to establish a hierarchical propagation model for different production purposes. Meanwhile, rhizome harvesting should comprehensively consider growth duration, seasonal differences, rhizome morphology, and the accumulation of active constituents, so as to establish grading standards based on morphological indicators, agronomic traits, and chemical components. During postharvest storage, cleaning, disinfection, anti-decay treatment, suitable temperature and humidity control, and pathogen management should be adopted to maintain rhizome vigor, reduce decay and nutrient depletion, and provide stable propagation materials for subsequent seedling production.

High-quality seedling production of *P. sibiricum* also depends on a standardized nursery management system, including appropriate site selection, substrate optimization, precise water-fertilizer regulation, shading management, and green pest and disease control. Before nursery release, a comprehensive quality evaluation system should be established based on morphological indicators, root-related indicators, physiological and biochemical traits, and stress resistance assessment, while grading standards should be dynamically revised according to different cultivation regions and production goals. Overall, constructing a technical system for rhizome propagation and high-quality seedling production of *P. sibiricum* can improve seedling uniformity and transplanting survival rate, promote the conservation and rapid multiplication of elite germplasm, reduce dependence on wild resources, and provide technical support for the standardized, large-scale, sustainable, and high-quality development of the *P. sibiricum* industry.