

can be developed for food, health-care, and nutraceutical uses, suggesting that the industrial chain of *D. officinale* is still widening.

The rising medicinal, nutritional, and commercial demand for *D. officinale* has sharply increased pressure on germplasm resources and seedling supply. Because wild populations were overexploited, the species has been listed as a secondary endangered plant in China, and rational protection together with artificial propagation has become a central issue in its utilization. Although artificial cultivation technology has made progress, current cultivation resources are still mixed, product quality is uneven, and the evaluation system remains imperfect, all of which constrain standardized industrial development. Conventional propagation routes are not sufficient to meet large-scale market demand because they depend on limited source materials and generally cannot provide rapid, uniform, and continuous production of elite seedlings (Xu et al., 2022). This limitation is reflected indirectly by later rapid-propagation studies, which were specifically designed to solve restricted explant availability, low propagation efficiency, and the need for large-batch production. Orchid micropropagation research more broadly identifies low shoot multiplication, clonal instability, poor rooting frequency, and high production cost as major obstacles in medicinal orchid propagation, indicating that propagation efficiency and seedling quality are persistent technical barriers rather than trivial operational details. For *D. officinale* specifically, the transition from in vitro culture to greenhouse or field conditions is another key bottleneck, because tissue-cultured seedlings often show low survival and weak growth after transplanting. This means that even when aseptic seedlings can be produced in vitro, industrial propagation still fails if rooting, hardening-off, substrate selection, microbial symbiosis, and transplant management are not optimized into an integrated technical chain (Wang, 2021; Li et al., 2024).

For that reason, recent studies on *D. officinale* tissue culture have shifted from simple seedling induction toward the construction of complete rapid-propagation systems covering explant disinfection, adventitious bud or protocorm induction, proliferation, differentiation, strong-seedling culture, rooting, hardening, and substrate transplanting. Several reports show that appropriate combinations of basal medium, plant growth regulators, activated carbon, and organic additives such as banana juice, potato extract, or coconut juice can markedly improve shoot multiplication, rooting, and seedling vigor. Likewise, transplant survival is highly sensitive to the hardening process and to the choice of substrate (Li et al., 2023). Reported survival outcomes vary by protocol, from 80% in peat-pine bark-macadam mixtures, to 88% in fine wood substrate, to 95% after sphagnum hardening-off and 97% after matrix transplantation, while some planting methods under optimized cultivation management report survival above 98%. Other work suggests that biological assistance can further improve acclimatization, since *Mycena dendrobii* enhanced seedling survival and growth by promoting stress tolerance and new root formation (Wei et al., 2024). Meanwhile, highly efficient protocorm-like body systems have reported 99% induction, a differentiation coefficient of 50 seedlings per 0.1 g protocorm-like bodies, 100% rooting, and transplant survival above 95%, highlighting the feasibility of industrialized seedling production once the full pathway is optimized.

This study will explore the technical pathways for tissue-culture rapid propagation and improvement of transplant survival rate in *Dendrobium officinale*, and systematically sort out the key links affecting propagation efficiency and post-bottle establishment, including explant selection, medium screening, hormone regulation, rooting enhancement, hardening-off, substrate configuration, and transplant management. The significance of this study lies not only in increasing the multiplication coefficient and shortening the seedling production cycle, but also in stabilizing seedling quality, improving the survival rate of tissue-cultured plantlets, and providing a technical foundation for standardized and large-scale cultivation. From a broader perspective, efficient rapid propagation technology can reduce dependence on wild resources, support the conservation and sustainable utilization of this endangered medicinal orchid, and better meet the growing demand from the pharmaceutical, functional food, and health-product industries. Since pharmacological development, product diversification, and quality control all depend on a stable and sufficient supply of raw materials, establishing reliable rapid-propagation technology and