

modern *Dendrobium* industry, while new varieties, technical procedures, and standardized cultivation systems have gradually improved industrial capacity (Cheng et al., 2026). Since the beginning of the new century, artificial cultivation of *D. officinale* has made major progress, and greenhouse cultivation, semi-wild cultivation, bionic-facility cultivation, original ecological cultivation, pot cultivation, and epiphytic cultivation have all been developed in response to different production goals (Tan et al., 2023). However, as industrial expansion has shifted supply from wild collection to artificial production, ensuring that cultivated material retains desirable medicinal quality has become a central scientific and practical issue (Yuan et al., 2020; Yang et al., 2023; Yang et al., 2026).

Against this background, wild-simulated and facility cultivation have emerged as two representative development paths for *D. officinale*. Facility cultivation emphasizes controllable environmental conditions, efficient seedling establishment, and relatively high yield, making it an important mode for stable large-scale production. By contrast, wild-simulated cultivation seeks to reconstruct natural or near-natural habitat conditions, so that the ecological environment, plant morphology, and quality traits are closer to those of wild materials. Existing studies indicate that cultivation mode substantially affects the accumulation of active ingredients and the overall metabolite profile. Environmental variables such as temperature, humidity, sunshine duration, pH, and soil nutrients are key drivers of medicinal quality, while light, water, and nutrient supply also influence growth and secondary metabolite accumulation (Yuan et al., 2020; Zhang et al., 2024). Comparative studies further show that wild or wild-simulated materials often contain higher levels of some major active constituents than greenhouse-grown materials, although the pattern is not uniform across all compounds or cultivation settings: one *D. officinale* study found wild plants had the highest polysaccharide content, whereas another found stone epiphytic and greenhouse cultivation exceeded live-tree epiphytic cultivation in polysaccharides, while stone epiphytic plants showed the richest differential metabolite accumulation and strongest antioxidant activity (Yang et al., 2023). Greenhouse cultivation also reshapes environmental drivers and biological interactions, including shifts in high-quality production zones and differences in root fungal endophyte communities that correlate with polysaccharide accumulation. In addition, evidence from related *Dendrobium* species suggests that wild-simulated cultivation can provide better quality and economic returns, and may also offer lower carbon emissions and global warming potential than facility cultivation (Yi et al., 2021).

This study investigates the differences between wild-simulated and facility cultivation modes of *Dendrobium officinale* and their effects on plant growth, quality formation, and industrial development. By systematically comparing the two cultivation modes in terms of growth environment, morphological characteristics, yield formation, active compound accumulation, and quality evaluation, this study aims to clarify the impacts of different cultivation strategies on the medicinal value and industrial attributes of *D. officinale*. Available evidence indicates that with efficient utilization. Furthermore, this study will contribute to the transition of *D. officinale* production from a yield-oriented approach toward quality improvement, ecological coordination, and sustainable development, thereby providing theoretical support for the modernization of the *D. officinale* industry and the high-value utilization of medicinal plant resources.

2 Biological Characteristics and Cultivation Basis of *Dendrobium officinale*

2.1 Growth characteristics and ecological adaptability

Dendrobium officinale is a perennial epiphytic orchid with slow growth and high environmental sensitivity, which helps explain both its rarity in nature and the need for protected or semi-natural cultivation (Ding et al., 2018; Jia et al., 2022; Hou et al., 2025). Wild populations are limited not only by overexploitation but also by biological constraints, including low seed-setting rates, lack of seed endosperm, and dependence on symbiosis with endophytic fungi for natural germination (Liu et al., 2025b; Luo et al., 2024). As an epiphyte, *D. officinale* is adapted to growing on trees, rocks, or other well-aerated supports rather than in compact agricultural soils, and this ecological background remains the biological basis for current stone- and tree-attached production systems (Tan et al., 2023). Current industrial cultivation therefore relies heavily on tissue culture propagation and artificial seedling production to compensate for its low natural reproductive efficiency and endangered status.