

3.2 Growth performance and quality formation

Under wild-simulated conditions, *D. officinale* generally shows growth patterns closer to wild plants than those observed under greenhouse production (Lan et al., 2022). This mode does not always maximize biomass or total yield, but it better matches the species' ecological habit and often improves structural and sensory characteristics associated with traditional high-quality material (Yi et al., 2021). Growth performance in such systems remains strongly constrained by water availability and climate stress, especially in karst forest environments where drought and high temperature can slow growth and reduce yield. For this reason, strain screening for drought adaptation and physiological resilience has become an important support technology for wild-simulated production (Luo et al., 2024).

The main strength of wild-simulated cultivation lies in quality formation. Studies in *D. officinale* show that wild stone-epiphytic material contains higher polysaccharide, flavonoid, and alkaloid levels than greenhouse material, and stone epiphytic stems can accumulate substantially more up-regulated metabolites, especially flavonoids, than tree-epiphytic or greenhouse stems. In one comparative study, stone-epiphytic stems also showed stronger protective effects in chronic atrophic gastritis cell models, linking metabolite differences to functional differences (Hou et al., 2025). Related evidence across *Dendrobium* species is consistent: wild-simulated cultivation often yields higher levels of polysaccharides, flavonoids, alkaloids, amino acids, or non-starch polysaccharides than greenhouse cultivation, even though some individual studies report higher total polysaccharides in greenhouse-grown samples, showing that quality differences depend on the compound measured and the cultivation context (Hu et al., 2024). Mechanistically, this likely reflects the combined effects of habitat-like stress, niche-specific light and water regimes, and richer microbial interactions, all of which promote secondary metabolite accumulation and alter biosynthetic gene expression (Zhang et al., 2020).

3.3 Advantages, limitations, and application value

Compared with facility cultivation, wild-simulated cultivation offers several clear advantages. It restores the wild habitat more faithfully, produces plant morphology closer to traditional medicinal standards, and often increases the content of major active constituents and overall medicinal quality (Hou et al., 2025). Semi-wild systems are also associated with lower planting density, greater resistance to pests and diseases, reduced chemical residues, and stronger ecological compatibility. At the industry level, this mode fits the transition from purely sheltered mass production toward diversified ecologically friendly cultivation and helps connect commercial production with biodiversity conservation (Cheng et al., 2019; Wang et al., 2021). It is therefore valuable not only for medicinal quality control, but also for sustainable branding of high-end medicinal, edible, and health products derived from *D. officinale* (Liu et al., 2025b; Wang et al., 2025).

Its limitations are equally clear. Wild-simulated cultivation usually has lower yield, slower growth, and higher labor dependence than facility cultivation, and its outcomes are more vulnerable to drought, abnormal temperature, and site heterogeneity (Luo et al., 2024). Quality is often better, but not uniformly so across all indicators; for example, some studies found greenhouse or lithophytic systems superior to tree-epiphytic systems for polysaccharide content, and greenhouse-grown *D. huoshanense* showed higher total polysaccharides than imitation wild plants in one dataset (Hu et al., 2024). These mixed findings indicate that wild-simulated cultivation is not simply a high-quality shortcut, but a mode whose value depends on correct site selection, suitable germplasm, fungal support, and targeted quality indicators (Lan et al., 2022). Overall, wild-simulated cultivation is best understood as a quality-oriented and conservation-compatible production pathway with strong application value for premium *D. officinale*, especially when combined with standardized seedlings, ecological regulation, and modern quality evaluation methods (Yang et al., 2026).

4 Facility Cultivation Mode of *Dendrobium officinale*

4.1 Environmental regulation and standardized production technologies

Facility cultivation of *Dendrobium officinale* is a production mode centered on artificial environmental control, standardized seedling use, and integrated cultivation management to achieve stable and large-scale supply (Cheng et al., 2019). In recent years, greenhouse cultivation has become one of the main artificial cultivation modes