

standardized seedlings, intensive water-fertilizer regulation, substrate optimization, and real-time environmental monitoring, which makes production more uniform and easier to schedule at large scale (Cheng et al., 2019). The two systems therefore differ not only in openness versus controllability, but also in biological regulation: wild-simulated cultivation uses niche matching and moderate stress to guide plant development, whereas facility cultivation uses technical intervention to reduce environmental variability and stabilize growth (Zhang et al., 2020). In practical terms, wild-simulated cultivation is closer to the ecological habit of an epiphytic orchid, while facility cultivation is closer to a standardized industrial production platform (Tan et al., 2023; Hou et al., 2025).

5.2 Comparative effects on yield, quality, and accumulation of active compounds

Across studies, facility cultivation tends to perform better for yield stability and production efficiency, while wild-simulated cultivation more often favors medicinal quality and the accumulation of diverse active compounds. Reviews of the industry consistently note that semi-wild systems usually have lower yields and higher labor costs, whereas greenhouse systems are used precisely because they can alleviate supply shortages and support stable large-scale output (Cheng et al., 2019). Comparative work in *Dendrobium huoshanense* likewise found that greenhouse cultivation had higher productivity and was more suitable for daily functional-food or health-product use (Hu et al., 2024). Facility systems can also be optimized further through standardized seedling production, strain selection, and controlled additive or nutritional treatments, all of which improve biomass or transplant survival (Liu et al., 2025a). Even so, yield advantage does not consistently translate into superior medicinal quality, because greenhouse conditions often reshape growth patterns and metabolite allocation relative to more natural environments (Yang et al., 2026; Yi et al., 2026).

Across *D. officinale* and related *Dendrobium* species, the available evidence tends to favor, especially when multiple compound classes or functional outcomes are considered. Simulative habitat cultivation produced morphology closer to wild material and higher quality than facility cultivation in *D. huoshanense* (Yi et al., 2021), and wild-simulated material showed higher levels of polysaccharides, flavonoids, alkaloids, amino acids, and other nutritional constituents in several comparative studies. In *D. officinale*, stone-epiphytic material showed 58 up-regulated metabolites relative to tree-epiphytic and greenhouse material, including seven amino-acid derivatives and eighteen flavonoids, and it also showed stronger protective effects in a chronic atrophic gastritis cell model (Hou et al., 2025). Wild-simulated or epiphytic systems also produced higher non-starch polysaccharide ratios and stronger antioxidant activity than facility cultivation in *D. catenatum*. However, this pattern is not absolute: one *D. huoshanense* study found higher total polysaccharide content in greenhouse-grown samples (Hu et al., 2024), and one *D. officinale* comparison reported that greenhouse and lithophytic cultivation both exceeded living-tree epiphytic cultivation in polysaccharide content. The strongest conclusion is therefore that facility cultivation can perform well for selected indicators, especially bulk polysaccharide production, but wild-simulated cultivation more consistently improves composite quality, metabolite richness, and some bioactivity-related outcomes.

5.3 Comparison of economic benefits and industrial applicability

From an economic perspective, the two modes serve different market positions. Facility cultivation is more suitable for scale, standardization, and stable supply, which is why it has become a major foundation of the modern *D. officinale* industry and of the transition from wild collection to commercial cultivation (Cheng et al., 2019). It supports expansion of planting areas, integration with seedling factories and processing chains, and the reliable supply of raw materials for pharmaceuticals, dietary supplements, foods, and related products (Liu et al., 2025a). Facility cultivation also fits precision agriculture and standardized production goals, especially as technical procedures, improved substrates, and environmental regulation systems continue to advance (Yang et al., 2026). For these reasons, facility cultivation has the broader industrial applicability in mass-market contexts, particularly where output consistency, traceability, and scalable processing matter most (Wang et al., 2025).

Wild-simulated cultivation has a different economic logic: it is less advantageous for maximum output, but often more advantageous for premium positioning, ecological value, and high-end medicinal use. One direct comparison in *D. huoshanense* reported that simulated habitat cultivation had high income, the lowest