biomass while improving soil pH, organic carbon, and microbial community structure, supporting bamboo-forest intercropping as a feasible under-forest pathway (Zhang et al., 2020). Simulated-wild cultivation under tree canopies in hilly mountain regions exposes plants to cooler, more heavily shaded, rain-fed conditions than greenhouse systems, and these environmental differences produce detectable physiological and isotopic distinctions between cultivation modes (Wang et al., 2026). At the same time, stand type involves tradeoffs: greenhouse plus stereoscopic planting improved both yield and quality relative to understory planting in one cultivation comparison, so under-forest systems are ecologically suitable but not automatically superior for all production targets (Hu et al., 2023). The under-forest industry basis of *T. hemsleyanum* lies in its moderate-shade preference, moisture dependence, and sensitivity to soil microecology, while the optimal stand should be chosen by balancing ecological suitability, target quality traits, and local management capacity.

4 Under-Forest Cultivation and Production Models of *Tetrastigma hemsleyanum*

4.1 Under-forest wild-simulated cultivation model

The under-forest wild-simulated cultivation model of *Tetrastigma hemsleyanum* is essentially an agroforestry production pathway that places the species under forest canopies or near-natural shaded habitats to reproduce the microenvironment of wild populations, especially moderated light, cooler temperature, higher humidity, and biologically active forest soils (Li et al., 2025). This model has become attractive because simulated-wild and wild-labeled *T. hemsleyanum* products command higher market prices than greenhouse-grown material, and existing evidence indicates that agroforestry-grown products are generally regarded as higher quality than conventionally cultivated counterparts (Wang et al., 2026). Its practical logic also matches the broader medicinal-plant literature, which shows that forest farming is a promising alternative to continued wild harvesting when natural populations are under pressure (Naud et al., 2010; Pang et al., 2024). For *T. hemsleyanum* specifically, the model is ecologically plausible because the species naturally grows under the shade of mountainous cliffs, requires 3-5 years to form tubers in natural environments, and is increasingly dependent on artificial cultivation because of overexploitation and harsh habitat constraints (Shi et al., 2022).

Current evidence supports the quality advantage of this model, but also shows that the advantage is not produced by shade alone. Forest understory cultivation of *T. hemsleyanum* typically produces flavonoid concentrations 30~35% higher than dryland greenhouse systems, and the likely reason is the combined effect of acidic forest soils, higher organic matter, and distinct microbial communities that conventional dryland soils do not provide (Zhang et al., 2026). Stable-isotope work also shows that simulated-wild and greenhouse products can be distinguished scientifically, with greenhouse tissues having more positive δ13C and δ15N values, which supports the idea that cultivation pathway leaves measurable ecological and metabolic signatures (Wang et al., 2026). At the same time, the wild-simulated model is not identical to undisturbed wild growth, because commercial systems often use in situ pots to avoid competition from dominant native species and to facilitate tuber harvest, so the model should be understood as a controlled approximation of wild habitat rather than a perfect replica. In production practice, its success therefore depends on matching the natural habitat as closely as possible while retaining operational control over planting density, harvest, and soil regulation (Wen et al., 2025; Zhang et al., 2025).

4.2 Forest-medicinal plant integrated management model

The forest-medicinal plant integrated management model goes beyond simple under-canopy planting and treats the forest and the medicinal crop as a coupled production system in which canopy structure, soil processes, microbial communities, and economic outputs are managed together (Yu et al., 2023). This model is widely recommended because understory medicinal-plant cultivation can make fuller use of land, light, and heat resources while promoting the protection and sustainable use of forest resources and biodiversity (Li et al., 2025). The agronomic premise is that stand structure and interspecific interactions are manageable variables rather than background conditions: tree species, stand density, canopy openness, crop position, and intercropping combinations all influence understory light, humidity, soil traits, and ultimately yield and active-compound formation (Zubay et al., 2021; Wen et al., 2025). In this sense, the model is especially relevant for *T.*