other bio-based materials (Hu et al., 2023). Agronomic studies further show that product development can connect directly with cultivation innovation: *P. cyrtonema* can achieve yields of 7.5 t/ha under suitable conditions in Zhejiang, and P. odoratum tender shoots harvested at S2-S3 have edible value while S3-stage management can also improve subterranean yield and quality (Liao et al., 2023; Zheng et al., 2025). Understory and agroforestry systems also expand the industrial pathway by improving soil quality, supporting tuber yield, and increasing forest-land output benefits, making them compatible with large-scale medicinal-and-edible product supply (Xu et al., 2023).

2.3 Major constraints in the development of the *Polygonatum* medicinal and edible industry

The major constraints in the development of the *Polygonatum* medicinal-and-edible industry begin with resource pressure and biological inconsistency. Rising utilization and market demand have made dependence on wild resources increasingly unsustainable, and wild resource depletion has already become a stated challenge for sustainable utilization. At the same time, substantial variation exists among species, provenances, and growing environments in yield and medicinal composition, including significant differences in polysaccharides, saponins, flavonoids, and total phenolics (Liao et al., 2023; Cheng et al., 2026). This heterogeneity creates practical problems for standardization and breeding, especially because current cultivation still suffers from germplasm confusion, lack of elite varieties, indiscriminate cross-regional introduction of seedlings, and insufficient utilization of authentic medicinal sources. Research reviews also note that comparative understanding of the chemical differences among key medicinal species remains incomplete, which weakens standardization of medicinal-food uses across *Polygonatum* resources (Zhao et al., 2018; Yang et al., 2025).

A second set of constraints lies in the industrialization system itself, especially in understory cultivation and downstream market conversion. Field investigations across several provinces show that understory medicinal herb cultivation still faces an underdeveloped service system, insufficient regulatory capacity, low market alignment, immature technical systems, and weak research support. Specific production bottlenecks include high input with low output, mismatch between forest canopy density and plant light requirements, and unclear policy boundaries between ecological protection and commercial utilization, all of which raise trial-and-error costs in technology adoption (Guo et al., 2026). Although studies show that interplanting mode, tree species choice, and microbial regulation can improve soil quality, metabolite profiles, and medicinal value, these findings also imply that successful development depends on precise ecological matching rather than simple area expansion (Xu et al., 2023; Wang et al., 2023). More broadly, current reviews agree that food-sector applications remain underdeveloped relative to medicinal research, underlying mechanisms are still insufficiently clarified, and stronger technical standards, quality certification, and market-oriented product systems are still needed for large-scale, high-quality development (Li et al., 2024; Shu et al., 2026).

3 Understory Cultivation Models and Ecological Adaptability of *Polygonatum*

3.1 Biological characteristics of *Polygonatum* and its suitability for understory cultivation

Polygonatum is biologically well suited to understory cultivation because several species are perennial, rhizomatous herbs that naturally occur in shaded forest habitats and function as characteristic understory plants. *P. cyrtonema* is explicitly described as thriving in shaded understory habitats at 500~2 100 m and has been identified as a key understory economic crop in southern China (Figure 1) (Cheng et al., 2026). More broadly, understory cultivation systems are designed around the symbiosis between forest stands and medicinal plants and make use of forest land, light, and heat resources, which fits *Polygonatum*'s ecological niche.

Species-level evidence also supports strong adaptability within the genus. *P. kingianum* var. *grandifolium* can grow normally both under forest canopy and in the open field, while showing rapid emergence, repeated sprouting, evergreen adult plants, and rhizome biomass more than one time higher than that of *P. cyrtonema*, indicating unusual plasticity and production potential for forest-based cultivation. Transplantation experiments likewise found that this taxon was more adaptive than *P. kingianum* or *P. sibiricum* because it achieved the highest