3.3 Cultivation models and technical characteristics of understory *Polygonatum* production

Current understory *Polygonatum* production mainly follows intercropping, orchard underplanting, bamboo agroforestry, and under-forest wild-imitating planting models. In moso bamboo forests, intercropping significantly increased soil quality relative to bamboo monoculture, and the M1 density of 1 750 culms/ha produced the best combination of improved soil fertility and higher *Polygonatum* tuber yield (Xu et al., 2023). Stand density was the main factor controlling tuber yield in that system, exceeding the direct effects of altitude, SOC, and nitrate nitrogen, which means understory production technology must prioritize structural canopy management (Xu et al., 2023). In *Camellia oleifera* forests, intercropping with *P. cyrtonema* increased soil bacterial diversity, improved soil fertility, and enhanced tree-crop productivity, suggesting that *Polygonatum* can serve not only as an understory crop but also as a functional component of broader agroforestry systems (Kong et al., 2025).

Technical evidence also shows that understory models differ by tree species and by management intensity. For *P. sibiricum*, plants grown under oak trees showed better growth, less disease, and higher yield than those under citrus, Platycladus, pine, peach, or osmanthus, likely because deciduous stands formed thicker humus layers and better preserved soil moisture. Microbiome-metabolome work further found that understory interplanting increased rhizosphere bacterial and endosphere fungal diversity relative to field cultivation, and that metabolite changes were driven more strongly by rhizosphere than endosphere microorganisms (Wang et al., 2023). For *P. kingianum*, under-forest wild-imitating planting includes seedling selection, sand-bed pregermination, soil preparation, furrowing, transplanting, fertilization, disease control, and weeding, and it has been reported to shorten growth time, reduce pesticide and fertilizer residues, improve quality, and support both smallholder and corporatized production. In addition, crop regulation techniques such as topping in *P. odoratum* at the S3 stage while retaining 8~11 leaves can improve both edible shoot harvest and subterranean yield and quality, showing that understory production technology should integrate medicinal and edible targets rather than treat them separately (Zheng et al., 2025).

4 Integrated Development Pathways between Medicinal and Edible Utilization and Understory Cultivation of *Polygonatum*

4.1 Establishment of high-quality germplasm resources and standardized understory production systems

The first pathway is to build high-quality germplasm resources as the biological foundation of large-scale understory production. Provenance and common-garden studies show that *Polygonatum* differs significantly among species, provenances, and sites in yield, stem and leaf traits, and medicinal components, with substantial repeatability and clear selective-breeding potential. In *P. cyrtonema*, Songyang and Yunhe provenances achieved the highest comprehensive scores and are recommended as elite breeding materials, while long-term commercial validation is still needed because economic harvest usually occurs after 2~3 years rather than in a single screening season (Cheng et al., 2026). Species selection also matters at the cultivation stage: *P. cyrtonema* can reach 7.5 t/ha in Zhejiang, and stem diameter can be used as a practical harvest indicator in variety screening (Liao et al., 2023).

The second task is to convert germplasm advantages into a standardized understory production system. Current cultivation is constrained by germplasm confusion, lack of elite varieties, indiscriminate cross-regional seedling introduction, and weak use of authentic medicinal sources, all of which impede standardized industrial development (Liao et al., 2023). Molecular identification tools can directly address this bottleneck: an MNP-based fingerprinting system for *P. cyrtonema* distinguished all tested accessions with 99.90% accuracy and was proposed for cultivar authentication, seedling purity testing, germplasm conservation, and new-variety protection (Tang et al., 2026). At the production end, recent policy analysis recommends a variety-suitability framework based on canopy density classification, ecological cultivation protocols, and independent standards for understory medicinal herbs, which fits *Polygonatum*'s natural occurrence in shaded understory habitats and its role as a key forest economic crop (Guo et al., 2026).

4.2 Improvement of processing technologies and diversified product development of *Polygonatum*

The second pathway is to improve processing technologies so that raw *Polygonatum* resources translate into stable medicinal and edible value. Across the genus, polysaccharides are repeatedly identified as key active components,