humid conditions are conducive to flavonoid enrichment (Shi et al., 2022). In addition, metabolomic and origin-tracing studies have identified catechin, darendoside B, resveratrol derivatives, and other compounds as key quality markers. These compounds differ among production areas and may be related to cultivation environments and cultivation history (Hu et al., 2023; Chu et al., 2024). Therefore, in production practice, age-specific management and timely harvesting systems should be established, and harvesting standards suitable for different understory cultivation models should be gradually developed based on production area conditions and quality testing results.

7 Benefit Analysis of Understory Ecological Cultivation of *Tetrastigma hemsleyanum*

7.1 Ecological benefits of understory cultivation of *Tetrastigma hemsleyanum*

Understory ecological cultivation of *Tetrastigma hemsleyanum* can make full use of forestland space and form a compound ecological structure integrating the tree layer, shrub-herb layer, and medicinal plant layer. Compared with monoculture open-field cultivation, understory cultivation is closer to the natural growth environment of *T. hemsleyanum* and can reduce the adverse effects of strong light, high temperature, and drought on plants, allowing *T. hemsleyanum* to grow in a relatively stable understory microclimate. Meanwhile, canopy shading, litter cover, and soil humus accumulation help maintain soil moisture, regulate surface temperature, and enhance the stability of forestland ecosystems. Existing studies have pointed out that understory vegetation plays an important role in forest ecosystem functioning by promoting ecosystem productivity, nutrient cycling, organic matter decomposition, and ecosystem self-renewal (Deng et al., 2023).

During understory cultivation, *T. hemsleyanum* causes relatively little disturbance to the original forestland structure. It does not require large-scale land clearing or intensive tillage, thereby helping reduce soil erosion and surface exposure. Especially in mountainous, hilly, and sloping forest areas, developing understory ecological cultivation of *T. hemsleyanum* can improve land-use efficiency while protecting forest vegetation and avoid ecological damage caused by blind land reclamation. Meta-analyses and review studies have shown that maintaining diverse understory plants helps preserve soil organic carbon, total nitrogen, soil water content, pH, and microbial biomass, whereas removing understory vegetation increases soil temperature and significantly reduces multiple soil properties (Zhang et al., 2022). In oil palm plantations, increasing understory cover, namely avoiding herbicide use, can improve the diversity and abundance of soil macrofauna and enhance litter decomposition rates, without obvious negative effects on soil fertility. This indicates that retaining and utilizing the understory vegetation layer has positive significance for maintaining soil ecological functions.

In addition, understory cultivation of *T. hemsleyanum* contributes to the conservation of medicinal plant resources. In the past, *T. hemsleyanum* resources depended largely on wild harvesting, and overharvesting could easily lead to the decline of wild populations and habitat degradation. Artificial understory ecological cultivation can reduce dependence on wild resources to a certain extent and promote a shift from “wild resource harvesting” to “conservation-oriented artificial cultivation”. Studies on mixed forests and agroforestry systems further show that diversified understory layers can improve ecosystem functions. A global meta-analysis of mixed plantations showed that, compared with monocultures, tree species mixing significantly increased understory plant biomass, cover, and species richness by approximately 30%~55%, while also improving soil nutrients, nutrient availability, microbial biomass, and carbon sequestration capacity (Guo et al., 2025). On the Loess Plateau, higher taxonomic and phylogenetic diversity of understory plants was positively correlated with ecosystem multifunctionality, especially in terms of nitrogen and phosphorus cycling, water conservation, and productivity enhancement (Sha et al., 2024). As a shade-tolerant medicinal vine with relatively deep roots, *T. hemsleyanum* can serve as a structural and functional understory component in bamboo forests, fruit forests, or broad-leaved forests, improving biodiversity and promoting soil processes while reducing herbicide use and the need for intensive surface disturbance.

7.2 Economic benefits of understory cultivation of *Tetrastigma hemsleyanum*

T. hemsleyanum has high medicinal development value and market utilization potential, and its tuberous roots, as the main medicinal part, have considerable economic value. *T. hemsleyanum* is widely regarded as a high-value