

quality. For *T. hemsleyanum*, when cultivated under different colored films at 70% total light transmittance, blue film (BF) was most favorable for promoting growth and yield formation, whereas red film (RF) was most effective in increasing PAL activity and flavonoid content (Bai et al., 2021). These results suggest that, on the basis of relatively stable 65%~70% shading, blue-enriched light spectra may be used during the vegetative expansion stage, while red-enriched spectra or films may be applied during the later medicinal quality formation stage to achieve stage-specific coordination between growth promotion and quality enhancement.

7.3 Optimization of cultivation models and quality evaluation systems

In addition to adjusting shading nets and spectral composition, optimizing cultivation models is also important for stabilizing the yield and quality of *T. hemsleyanum*. Comparative studies of different planting bases and cultivation modes have shown that greenhouse cultivation produces the thickest stems, longest leaves, and greatest aboveground and underground biomass, and that the total flavonoid content in tuberous roots under greenhouse cultivation is higher than that under understory cultivation. Under greenhouse conditions, the stereoscopic cultivation mode further increases the contents of indicator compounds, including polydatin, resveratrol glycoside, resveratrol, and kaempferol, compared with creeping cultivation (Hu et al., 2023). These findings suggest that “greenhouse + stereoscopic structure + optimized shading” may be a comprehensive cultivation model with strong potential for industrial production of *T. hemsleyanum*.

To support the above cultivation models, a systematic quality evaluation system and light regulation decision-making tools are also needed. A review on *T. hemsleyanum* pointed out that a scientific, universal, and measurable quality control system is still lacking, and called for the establishment of quality markers related to antitumor and anti-inflammatory activities (Hu et al., 2021). In other medicinal plants, comprehensive evaluation methods such as entropy-weighted TOPSIS have been used to screen combinations of red-blue light ratios, field water-holding capacity, and shading treatments, and to identify optimal cultivation conditions by comprehensively scoring growth, photosynthesis, and saponin content. Similar multi-index evaluation models can also be applied to *T. hemsleyanum*, using biomass and key components, such as flavonoids, resveratrol-like compounds, and polysaccharides, as core indicators. Combined with controlled shading regimes, such models can help establish standardized cultivation protocols, guide the construction of regional planting models, and support traceable quality evaluation from field production to market circulation.

8 Conclusion and Prospects

Existing studies clearly indicate that the light environment is a core ecological factor determining the growth performance and medicinal quality of *Tetrastigma hemsleyanum*. As an understory vine adapted to shaded environments, *T. hemsleyanum* exhibits systematic changes in photosynthetic pigments, gas exchange, and light-response parameters along shading gradients; unsuitable conditions such as strong light, high temperature, and low humidity can reduce photosynthetic activity and slow plant growth. Light quality is equally important. Under different colored film treatments, blue film can promote vegetative growth and yield formation, whereas red film enhances PAL activity and flavonoid accumulation, directly indicating that spectral composition is closely associated with biomass formation and active component accumulation. At the cultivation system level, compared with understory cultivation, greenhouse cultivation with a stereoscopic structure can significantly increase aboveground and underground biomass and improve total flavonoid content in tuberous roots, further confirming that integrated light environment regulation is a key approach for simultaneously improving yield and medicinal quality.

Multiple experiments have shown that moderate shading is the most effective strategy for coordinating vegetative growth, photosynthetic performance, and active component accumulation in *T. hemsleyanum* and similar shade-tolerant medicinal plants. In *T. hemsleyanum*, photosynthetic pigments and most photosynthetic indicators increase with enhanced shading and reach maximum values under approximately 70% shading during both rapid and slow growth stages; thereafter, excessive shading reduces photosynthetic capacity. Therefore, 70% shading has been considered suitable for different growth stages. Similarly, 67% shading results in the highest leaf area and net photosynthetic rate, whereas light stronger than that under 50% shading inhibits photosynthesis, and