3 Analysis of the Understory Habitat Adaptability of *Tetrastigma hemsleyanum*

3.1 Adaptability of *Tetrastigma hemsleyanum* to low-light understory environments

Tetrastigma hemsleyanum is naturally distributed mostly in mountain forest margins, valley shrublands, and shaded, humid understory environments, showing strong adaptability to low-light conditions. Compared with open areas exposed to strong light, understory environments can effectively reduce direct solar radiation and create light conditions dominated by diffuse and filtered light, which is highly consistent with the ecological characteristics of *T. hemsleyanum*, namely its preference for shade and moisture and sensitivity to strong sunlight. Light-gradient experiments showed that under full light and 30%, 50%, 70%, and 90% shading treatments, the contents of chlorophyll a, chlorophyll b, total chlorophyll, and carotenoids in *T. hemsleyanum* increased with increasing shading intensity. Most photosynthetic parameters, including net photosynthetic rate, stomatal conductance, transpiration rate, apparent quantum efficiency, and maximum net photosynthetic rate, reached their highest values under approximately 70% shading and then decreased under stronger shading conditions (Xu et al., 2018). This indicates that moderate shading helps *T. hemsleyanum* maintain relatively high photosynthetic activity, whereas excessive light or excessive shading is unfavorable for plant growth.

A low-light understory environment does not mean that less light is always better. Although *T. hemsleyanum* has a certain degree of shade tolerance, its stem and leaf growth, photosynthesis, and tuberous root enlargement still require an appropriate amount of light energy. Earlier studies using 10%, 15%, and 30% of full sunlight showed that under moderate low-light conditions, namely 15% of full sunlight, *T. hemsleyanum* had higher photosynthetic capacity and yield, further indicating that it is adapted to diffuse and moderately weak light under forest canopies rather than full light or extremely dark environments. If stand canopy closure is too high and understory light transmittance is insufficient, plants are prone to vine overgrowth, thin leaves, and elongated internodes, leading to reduced accumulation of photosynthetic products and ultimately affecting underground tuberous root formation. Therefore, understory cultivation of *T. hemsleyanum* should emphasize “moderate shading” rather than “complete shading”. Stable and sufficient diffuse light should be provided by regulating canopy density, pruning branches and leaves, and arranging planting spacing properly.

From the perspective of ecological adaptation, low-light understory environments can provide *T. hemsleyanum* with light conditions close to its natural habitat, helping reduce environmental stress in artificial cultivation. Especially during periods of high temperature and strong light in summer, canopy shading can reduce leaf water loss and the risk of photoinhibition, thereby improving plant survival and growth continuity. Further studies have shown that *T. hemsleyanum* also has strong plasticity in response to changes in light quality. Continuous low-intensity blue light supplementation can significantly increase tuberous root yield, flavonoid content, and antioxidant activity, and enhance photosynthetic efficiency after light saturation, indicating that *T. hemsleyanum* can efficiently utilize limited light by optimizing photochemical processes and antioxidant systems (Zhao et al., 2024). In greenhouse photovoltaic systems, exogenous nitric oxide and phytohormones such as salicylic acid and jasmonic acid can restore photosynthetic parameters, reduce reactive oxygen species accumulation, and enhance plant adaptability to low-light and heterogeneous light environments (Figure 1) (Xie et al., 2022). Therefore, the rational use and regulation of understory light environments constitute an important basis for constructing ecological cultivation models for *T. hemsleyanum* and are also key to coordinating medicinal material yield and quality improvement.

3.2 Adaptability of *Tetrastigma hemsleyanum* to understory soil and moisture conditions

T. hemsleyanum has certain requirements for soil conditions and is suitable for growth in deep, loose, humus-rich, and well-drained soils. Understory soils usually have relatively high organic matter content due to long-term litter return, and their relatively favorable aggregate structure can provide a suitable rhizosphere environment for root extension and tuberous root enlargement. Understory environments are also characterized by strong soil structural heterogeneity, variable moisture conditions, and distinctive microbial communities, all of which jointly affect root development, nutrient absorption, and medicinal component accumulation in *T. hemsleyanum*. Studies have shown that intercropping *T. hemsleyanum* under moso bamboo forests and applying biochar-based organic fertilizer can