The underground part of *T. hemsleyanum* forms typical tuberous roots, which may be calabash-shaped, spindle-shaped, or ovoid. These tuberous roots usually occur singly or as several bead-like connected segments. The epidermis is mostly yellowish brown and relatively smooth, although wrinkles, lenticel-like protrusions, or depressions with residual roots may also be observed (Guo et al., 2019; Ji et al., 2020). The tuberous root is the main medicinal part of *T. hemsleyanum* and is also an important indicator for evaluating yield, commercial value, and medicinal quality in artificial cultivation. Anatomical studies have shown obvious differences among fibrous roots, bar-shaped roots, and calabash-shaped roots in vascular bundle integrity and intracellular inclusion accumulation, reflecting the gradual transformation of the underground part from a nutrient-absorbing organ into a medicinal storage organ (Xiang et al., 2021).

In terms of growth habits, *T. hemsleyanum* is naturally distributed mostly in shaded and humid environments, such as forest understories on mountain slopes, valley margins, shrublands, and rock crevices. It exhibits ecological characteristics of preferring shade and moisture, tolerating low light, and being sensitive to strong sunlight exposure (Guo et al., 2019). As a climbing plant, *T. hemsleyanum* mainly relies on tendrils opposite the leaves to twine around surrounding vegetation, supports, or rock walls and grow upward. This characteristic determines its spatial ecological niche in warm-temperate evergreen forests and subtropical understory shrublands (Guo et al., 2019). There is a certain coordination between aboveground vine growth and underground tuberous root enlargement: the early stage is dominated by stem and leaf expansion and vegetative growth, while the later stage gradually shifts toward underground tuberous root accumulation. Therefore, in understory ecological cultivation, the perennial habit, vine-like growth, climbing ability, and medicinal use of the tuberous roots of *T. hemsleyanum* should be comprehensively considered, and suitable support structures, moderate light, and a stable rhizosphere environment should be provided.

2.2 Requirements of *Tetrastigma hemsleyanum* for light, temperature, and humidity

T. hemsleyanum shows strong selectivity for ecological environments, especially in terms of light, temperature, and humidity. In its natural distribution, it is commonly found at elevations of approximately 300~1 300 m in humid grassland patches, mountain slopes, valleys, stream banks, and rock crevices with diffuse light, and it is suitable for growth in cool, humid, humus-rich soils (Guo et al., 2019). Its suitable soils are mostly yellow or yellow-brown acidic soils, with a pH of approximately 4.3~7.7. Meanwhile, *T. hemsleyanum* is highly sensitive to strong light and drought; excessive radiation and water deficit may lead to leaf water loss, reduced photosynthetic efficiency, and inhibited plant growth (Ji et al., 2020). Ecological niche modeling further indicates that the potential suitable habitats of *T. hemsleyanum* are constrained by climatic factors such as mean diurnal temperature range and precipitation during the warmest quarter. Under future climate warming scenarios, its highly suitable distribution areas may shrink significantly, suggesting that this species has a relatively narrow climatic niche.

T. hemsleyanum has strong low-light adaptability and is suitable for growth in semi-shaded or diffuse-light environments. Physiological and cultivation studies have shown that approximately 67% shading is more favorable for the growth of *T. hemsleyanum*, whereas excessive light suppresses its physiological activity and plant development (Zhu et al., 2020). Excessive direct sunlight can easily cause leaf scorching, enhanced transpiration, and decreased photosynthetic efficiency, while excessive shading may also lead to vine overgrowth, thin leaves, and insufficient accumulation of photosynthetic products, which is unfavorable for tuberous root enlargement. Therefore, the key to understory ecological cultivation is not simply to increase shading, but to create an understory microclimate with moderate shading, sufficient diffuse light, and good ventilation. Light quality and other environmental factors can also regulate biomass and active compound accumulation in *T. hemsleyanum*. Continuous low-intensity blue light treatment can increase tuberous root yield, photosynthetic efficiency after light saturation, flavonoid content, and antioxidant activity, indicating that moderate light stress may promote both plant growth and medicinal quality formation (Zhao et al., 2024). Therefore, in constructing understory ecological cultivation models, attention should be paid to the influence of canopy-filtered light environments on the quality formation of *T. hemsleyanum*.