understory vegetation, generating an ecological filtering effect (Lu et al., 2021; Liu et al., 2022). Thus, canopy closure not only determines the light environment but also indirectly influences water balance and neighborhood competition intensity, thereby jointly affecting establishment survival. Nevertheless, quantitative studies examining the gradient response of *T. hemsleyanum* establishment survival to canopy closure and delineating an optimal closure range remain limited.

In addition to light conditions, nursery mode constitutes a key technical factor influencing establishment success. Global-scale restoration studies have shown that seedling size and root development quality significantly affect post-transplant survival (Andivia et al., 2021). Larger seedlings or those with well-developed root systems typically exhibit enhanced water uptake capacity and carbon reserves, thereby improving tolerance to drought or low-light stress (Wu et al., 2024). Container cultivation can improve substrate structure and rhizosphere aeration, contributing to root integrity and facilitating recovery after transplanting, whereas direct field cuttings are more susceptible to soil compaction and pathogen pressure. The degree of matching between seedling quality and stand conditions is therefore critical for successful establishment. However, in the cultivation practice of *T. hemsleyanum*, the combined regulatory effects of nursery mode and canopy closure have not yet been systematically compared or ecologically interpreted.

The present study focuses on the establishment survival rate of *T. hemsleyanum*, systematically comparing responses under different nursery modes and canopy closure conditions. By analyzing their regulatory effects and delineating the optimal canopy closure range, this study aims to provide a scientific basis for large-scale understory cultivation of *T. hemsleyanum* and offer reference insights for ecological suitability studies of other understory medicinal plants.

2 Materials and Methods

2.1 Study area

The experimental site was located in the Lühetang forest region of Shouchang Forest Farm, Zhejiang Province, China. The area is characterized by a subtropical humid monsoon climate, with a mean annual temperature of 16 °C~18 °C and abundant annual precipitation. The terrain consists primarily of low mountains and hills, with elevations ranging from 200 to 400 m above sea level. The soil type is red soil with slightly acidic properties and a soil depth generally exceeding 30 cm. The dominant forest types include *Cunninghamia lanceolata* plantations, *Phyllostachys edulis* (Moso bamboo) forests, natural broadleaf forests, and *Metasequoia glyptostroboides* stands, providing suitable ecological conditions for understory cultivation experiments.

2.2 Cutting propagation experiment design

2.2.1 Nursery mode settings

Cutting propagation experiments were conducted in spring 2021. Cuttings were collected from healthy 1-3-year-old mother plants. Each cutting contained 2-3 nodes, with a length of 10-15 cm and at least two retained leaves.

Three nursery modes were established:

(1) Mode I: Container cultivation in a greenhouse using a self-formulated substrate composed of peat (20%), organic fertilizer (20%), rice husk powder (10%), yellow subsoil (48%), and calcium–magnesium phosphate fertilizer (2%). Container size was 6.5 cm × 6.5 cm.

(2) Mode II: Non-woven fabric container cultivation. The substrate consisted of peat (40%), rice husk powder (10%), organic fertilizer (10%), vermiculite (10%), and perlite (25%). Container size was 5 cm × 8 cm.

(3) Mode III: Direct cutting insertion in prepared field beds in the forest, with trenches 30 cm wide and 30 cm deep.

Each nursery mode included 50 randomly assigned cuttings per replicate, with three replicates per treatment, totaling 450 cuttings.