It should be noted that the canopy closure gradient in this study was relatively limited and did not constitute a fully factorial design. Accordingly, inferences regarding potential interactions between nursery mode and canopy closure should be made with caution. Future studies should refine canopy closure gradients under controlled forest-type conditions and incorporate high-resolution monitoring of microclimate and soil moisture to further disentangle the relative contributions of light, water availability, and competition. Long-term follow-up experiments are also necessary to verify whether the identified optimal establishment range can be consistently translated into subsequent growth performance and population structural advantages, thereby enhancing both theoretical interpretation and practical management guidance.

5 Conclusion

This study systematically analyzed differences in establishment survival of *Tetrastigma hemsleyanum* under different nursery modes and canopy closure conditions. The results demonstrated that nursery mode significantly affected establishment survival. Container-based substrate cultivation resulted in higher survival rates, indicating that initial seedling quality and root system development are fundamental factors determining establishment stability. Optimization of nursery practices enhances seedling adaptability to understory environments.

Canopy closure exhibited a significant gradient effect on establishment survival, with survival rates displaying a unimodal response pattern along the closure gradient. Based on statistical testing and response curve analysis, the optimal canopy closure range for *T. hemsleyanum* establishment was determined to be 0.6–0.7. Within this range, understory light and microclimatic conditions were relatively balanced, and establishment survival remained comparatively stable.

Overall, establishment success of *T. hemsleyanum* is jointly regulated by seedling quality and stand structure. Developing establishment strategies that align nursery practices with appropriate canopy closure conditions represents an effective technical pathway for improving the stability of large-scale understory cultivation. By delineating the optimal canopy closure range from an ecological regulation perspective, this study provides quantitative support for understory cultivation management of *T. hemsleyanum*.

Author Contributions

Li Jianhui and Xu Yonghong designed and conducted the experiments. Li Jianhui, Zhang Yehua, and Xu Yonghong performed the data analysis and drafted the initial manuscript. Fang Yumin and Fan Jianzhong contributed to the experimental design and analysis of the experimental results. Xu Yonghong conceived and led the project and supervised the experimental design, data analysis, manuscript writing, and revision. All authors have read and approved the final version of the manuscript.

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