

This review identifies a critical shift toward biotechnological interventions as the most viable path forward. The synthesis of current research demonstrates that:

- (1) Micropropagation Efficiency: In vitro protocols, specifically direct organogenesis from leaf lamina and apical meristem culture, offer a robust mechanism for the rapid turnover of disease-free, genetically uniform planting material. The optimization of BAP and NAA concentrations remains the most effective hormone regime for maximizing shoot induction.
- (2) Regenerative Innovation: Somatic embryogenesis has emerged as a high-efficiency alternative, with maturation rates reaching 80%. This method provides a sophisticated platform for germplasm conservation and large-scale clonal propagation that exceeds the capacity of conventional stem cuttings.
- (3) Enhanced Phytochemistry: The integration of brassinosteroids and elicitors (such as methyl jasmonic acid) during the culture process not only facilitates superior rooting but also significantly enhances the biosynthetic pathways of secondary metabolites, leading to higher forskolin concentrations.
- (4) Sustainability and Scaling: Advanced cultivation techniques, including hairy root cultures and shake-flask bioreactors, present a sustainable model for metabolite extraction that bypasses the need for destructive harvesting of wild or field-grown plants.

In conclusion, while field-level optimizations like the "ridge and furrow" method provide incremental gains in yield, the future of *C. forskohlii* lies in the synergy between tissue culture technology and molecular elicitation. Adopting these biotechnological frameworks is essential for ensuring a consistent, high-quality supply of forskolin while simultaneously preserving the genetic diversity and sustainability of this endangered medicinal species. Future research should prioritize the refinement of bioreactor parameters and the exploration of genetic markers to further stabilize forskolin yields in commercial-scale production.

Authors' contributions

Sanjaai Kumar and Santhosh Raj conducted the literature review, collected the data regarding various propagation methods, and drafted the manuscript. Jones Ponuraj conceived of the study, participated in its design and coordination, and helped to draft the manuscript. All authors read and approved the final manuscript.

Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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