

increased the frequency of callus formation from leaf explants. BAP with different concentrations (0.5, 1.0, 2.5, 5.0) in which BAP at 5.0 mg/L yielded the highest shoot regeneration rate is found to be effective for micropropagation of *C. forskohlii* then Distal leaf segments showed superior regeneration compared to proximal and middle segments, likely due to the presence of more meristematic tissues in the proximal area (Krishna et al., 2010).

4.6 Shoot organogenesis

Focuses on the development of callus from *C. forskohlii* leaf segments in a sterile environment under controlled conditions. The results show that cytokinin and auxin plays a crucial role in shoot differentiation. Kinetin, when combined with NAA or IAA, leads to the highest shoot regeneration frequency. The study also found that rooting efficiency is highest in half-strength MS medium without growth regulators. The study confirms that in vitro-produced plants maintain clonal purity and forskolin content, making it viable for commercial propagation (Sairam Reddy et al., 2001).

4.7 Large scale clonal propagation

Large scale clonal propagation leaf lamina is used as an explant and it is achieved in the media containing 2 μ M BA + 0.1 μ M NAA Where a highest number of 35 shoots/explant were produced. Later they transferred to root induction medium comprising of IBA, NAA and IAA (1-5 μ M) in half-strength MS medium to determine the Most suitable shoot length for proper root induction. The rooted plantlets were acclimatized in field conditions after proper hardening (Sahai and Shahzad, 2010).

4.8 Roots cultivated in shake flask

Forskolin production from *C. forskohlii* roots can be achieved through various cultivation methods, including shake flasks and bioreactors. The transformed hairy root cultures, initiated via *Agrobacterium rhizogenes*, can produce forskolin in significant quantities, with optimal conditions yielding up to 14 mg/L after 21 days. Hormone-free media and sucrose additions enhance growth and forskolin production, with specific elicitors like methyl jasmonic acid boosting yields. Cutting roots without negatively impacting growth or productivity is a notable advantage in scaling up production (Krombholz et al., 1992).

4.9 Somatic embryogenesis

In vitro plant regeneration through somatic embryogenesis in *Coleus forskohlii* Briq. has been successfully established using leaf explants (Gopi and Mary, 2014). Research indicates that the combination of plant growth regulators (PGRs) significantly influences the regeneration process (Yasmin et al., 2001).

Specifically, a medium containing 2,4-dichlorophenoxyacetic acid (2,4-D) and 6-benzylaminopurine (BAP) yielded the highest frequency of direct somatic embryogenesis, achieving up to 80% success in embryo maturation and conversion to plantlets. Additionally, alternative methods utilizing direct organogenesis from leaf explants have shown promise, with protocols achieving up to 35 shoots per explant using optimized concentrations of BAP and auxins (Dode et al., 2003).

These findings highlight the potential for both somatic embryogenesis and direct organogenesis as effective strategies for the mass propagation and conservation of this medicinally important species, although the reliance on specific PGR combinations may limit broader applicability.

5 Conclusion

The comprehensive evaluation of propagation strategies for *Coleus forskohlii* (Briq.) underscores its standing as a premier medicinal resource, primarily due to the unique pharmacological profile of forskolin. As the global demand for natural adenylate cyclase activators grows, the limitations of traditional vegetative propagation such as low multiplication indices, high susceptibility to soil-borne pathogens, and seasonal dependency have become significant bottlenecks for the pharmaceutical supply chain.