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Commercial applications of plant tissue culture in medicinal plant production.

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Introduction

Medicinal plants have long been the cornerstone of traditional and modern healthcare systems. From Ayurvedic remedies to pharmaceutical drugs, these plants offer a rich source of bioactive compounds used to treat a wide range of ailments. However, the growing demand for medicinal plants, coupled with challenges like overharvesting, habitat loss, and inconsistent quality, has prompted the need for sustainable and scalable production methods. One such solution is plant tissue culture, a biotechnological technique that enables the rapid, controlled, and disease-free propagation of medicinal plants. Today, tissue culture is not just a research tool it's a commercial asset driving innovation in the herbal and pharmaceutical industries [1, 2].

Plant tissue culture involves the in vitro cultivation of plant cells, tissues, or organs under sterile conditions on a nutrient medium. This technique exploits the totipotency of plant cells their ability to regenerate into a whole plant. By manipulating growth regulators and environmental conditions, tissue culture allows for the mass production of genetically uniform and high-quality plant material [3,4].

Micropropagation is widely used to produce large numbers of medicinal plants with consistent quality. Examples include Used for stress relief and immune support; micropropagation ensures uniform alkaloid content. Cultivated for its skin-healing properties; tissue culture enables disease-free plantlets. Known for cognitive benefits; propagated in vitro to maintain high bacoside levels. Commercial nurseries use micropropagation to supply pharmaceutical companies, herbal product manufacturers, and cosmetic brands with reliable plant material [5, 6].

Callus culture involves growing undifferentiated plant cells on solid media, while cell suspension cultures use liquid media to grow cells in bulk. These cultures are ideal for producing secondary metabolites the bioactive compounds responsible for medicinal effects. Produces paclitaxel, a potent anticancer drug; cell cultures offer an alternative to harvesting bark [7, 8].

Bioreactors are often used to scale up production, making tissue culture a viable commercial method for metabolite extraction. Hairy root cultures are induced by infecting plant tissues with *Agrobacterium rhizogenes*, which integrates root-inducing genes into the plant genome. These roots grow rapidly and produce high levels of secondary metabolites. One of the biggest challenges in medicinal plant production is variability in phytochemical content. Tissue culture ensures genetic uniformity and controlled growth conditions, leading to consistent quality [9, 10].

Conclusion

Plant tissue culture has evolved from a laboratory technique to a commercial powerhouse in medicinal plant production. By enabling rapid propagation, consistent quality, and sustainable metabolite extraction, it addresses key challenges in the herbal and pharmaceutical industries. As demand for natural remedies and plant-based drugs continues to rise, tissue culture will play a central role in shaping the future of medicine and biodiversity conservation.

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