Review on "Advancements in *In Vitro* Plant Propagation"

Md. Iftekhar Chowdhury*

Department of Agricultural Science, Jahangirnagar University, Dhaka, Bangladesh

Corresponding Author*

Md. Iftekhar Chowdhury
Department of Agricultural Science,
Jahangirnagar University,
Dhaka,
Bangladesh
E-mail: iftekharustc290@gmail.com

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Abstract

In vitro plant propagation, commonly referred to as tissue culture or micro propagation, has completely changed the area of plant research by making it possible to produce numerous uniform and disease-free plantlets. The objective of this review is to present a thorough overview of recent developments in *in vitro* plant propagation methods, including somatic embryogenesis, organogenesis, shoot proliferation, and genetic transformation. It examines the uses, difficulties, and potential of *in vitro* plant propagation while underlining the importance of this technique for the commercial production, preservation, and genetic advancement of plants.

Keywords: Plant propagation • Micro propagation • *In vitro* • Somatic embryogenesis

Introduction

In vitro plant propagation techniques have been extensively utilized for the rapid production of high-quality plants, overcoming limitations associated with traditional propagation methods [1]. The ability to generate a large number of uniform and disease-free plantlets has immense applications in various sectors, including agriculture, horticulture, and forestry. The concept of *in vitro* plant propagation was first introduced by Gautheret in the 1950's, who successfully regenerated tobacco plants from isolated cells. Since then, significant advancements have been made in understanding the underlying physiological and molecular processes involved in plant tissue culture. These developments have paved the way for the establishment of efficient and reproducible protocols for mass plant propagation.

This review aims to provide a comprehensive overview of the recent advancements in *in vitro* plant propagation techniques. It will discuss the basic principles of tissue culture, including explant selection, sterilization, media formulation, and plant growth regulators. Additionally, it will delve into the advancements in somatic embryogenesis, organogenesis, shoot proliferation, and genetic transformation techniques. The review will explore the diverse applications of *in vitro* plant propagation, highlight the challenges associated with this technology, and provide insights into future prospects and emerging trends in the field.

Literature Review

The selection of appropriate explants is crucial for the success of *in vitro* plant propagation. Various plant parts, such as leaves, stems, roots, and embryos, can serve as explants, depending on the desired outcome. Factors such as age, health, and physiological status of the donor plant play a significant role in explant selection. The establishment of aseptic conditions is essential to prevent contamination during *in vitro* culture. Explants are subjected to surface sterilization using disinfectants such as sodium hypochlorite or ethanol. Proper sterilization protocols ensure the elimination of microbial contaminants while preserving the viability of the explants [2].

Plant growth regulators, including auxins, cytokinins, and gibberellins, are essential for regulating various stages of *in vitro* plant propagation. These hormones influence callus induction, shoot regeneration, and rooting processes. The composition of the culture media, including nutrient components, vitamins, and carbohydrates, also significantly impacts the success of tissue culture. Callus induction is a critical step in *in vitro* plant propagation, where de-differentiated cells undergo unorganized growth and form a mass of cells. Subsequent shoot regeneration from callus involves the manipulation of growth regulators and culture conditions to induce organogenesis or somatic embryogenesis. Rooting of regenerated shoots is essential for the successful establishment of *in vitro*-derived plantlets in soil. The addition of auxins, such as Indole-3-Butyric Acid (IBA) or Indole-3-Acetic Acid (IAA), to the culture medium promotes root formation. Acclimatization of plantlets to *ex vitro* conditions is a critical step before transferring them to the field or greenhouse.

Discussion

Advances in *in vitro* plant propagation techniques

Somatic embryogenesis: Somatic embryogenesis is a powerful technique that involves the induction of embryogenic cells from explants, leading to the development of somatic embryos. It offers significant advantages in terms of mass production, genetic stability, and conservation of plant genetic resources [3].

Organogenesis: Organogenesis refers to the regeneration of shoot and root organs from explants or callus tissues. The manipulation of plant growth regulators and culture conditions can induce the formation of shoots or roots, enabling the production of multiple plantlets from a single explant.

Shoot proliferation: Shoot proliferation techniques involve the rapid multiplication of shoots using axillary buds or meristematic tissues. These methods allow for the production of a large numberof uniform plantlets within a short period, facilitating commercial propagation and germplasm conservation.

Genetic transformation: Genetic transformation techniques enable the introduction of desired genes into plant cells, leading to the development of transgenic plants. This approach has revolutionized crop improvement by conferring traits such as resistance to pests and diseases, tolerance to abiotic stresses, and enhanced nutritional value.

Applications of *in vitro* plant propagation: Commercial production of ornamental and horticultural crops: *In vitro* plant propagation has been widely employed for the mass production of ornamental plants, such as roses, orchids, and carnations. The production of disease-free and uniform plantlets ensures high-quality ornamental crops for the market.

Clonal propagation of elite plant varieties: *In vitro* propagation allows for the clonal multiplication of elite plant varieties with desirable traits, including improved yield, disease resistance, and high-quality produce. This approach ensures the rapid dissemination of superior genotypes, preserving their genetic integrity.

Conservation and preservation of endangered and rare species: *In vitro* plant propagation techniques have been instrumental in the conservation and preservation of endangered and rare plant species. By establishing *in vitro* cultures from limited plant material, these species can be safeguarded from extinction and later reintroduced into their natural habitats.

Secondary metabolite production: Plant cell cultures derived from *in vitro* propagation have been extensively utilized for the production of secondary metabolites with pharmaceutical and industrial applications. These metabolites, including alkaloids, flavonoids, and terpenoids, possess therapeutic properties and have immense commercial value.

Disease eradication and pathogen-free plant production: *In vitro* plant propagation provides a means to produce disease-free plantlets by eliminating pathogens through meristem culture and *in vitro* treatments. This approach is crucial for the establishment of pathogen-free planting material and the management of viral, bacterial, and fungal diseases.

Challenges and limitations

Contamination issues and culture losses: Maintaining aseptic conditions during *in vitro* culture is essential to prevent contamination by bacteria, fungi, and other microorganisms [4]. Contamination can result in the loss of cultures and compromise the success of *in vitro* propagation.

Genetic instability and somaclonal variation: Genetic instability and somaclonal variation are common challenges in *in vitro* plant propagation. Genetic changes can occur due to the influence of culture conditions, such as prolonged subculture, high hormone concentrations, or tissue culture-induced stress.

High costs and scalability concerns: The initial establishment and maintenance of *in vitro* propagation facilities can be costly, requiring specialized equipment, culture media, and skilled personnel. Scaling up the production process to meet commercial demands can also be challenging.

Ethical and regulatory considerations: The use of genetic transformation techniques in *in vitro* plant propagation raises ethical and regulatory concerns regarding the release of Genetically Modified Organisms (GMOs) into the environment. Adhering to biosafety guidelines and regulatory frameworks is crucial to ensure the responsible use of genetically modified plants.

Future perspectives and emerging trends

Bioreactors and automation in *in vitro* propagation: The integration of bioreactor systems and automation technologies holds great potential for improving the efficiency and scalability of *in vitro* plant propagation. Bioreactors offer precise control over culture conditions and nutrient supply, while automation reduces labor-intensive tasks [5].

Integration of genomics and omics approaches: Advancements in genomics, transcriptomics, proteomics, and metabolomics have the potential to enhance our understanding of the molecular mechanisms underlying *in vitro* plant propagation. Integrating omics approaches can facilitate the identification of key genes and pathways involved in tissue culture responses.

Cryopreservation and long-term conservation strategies: Cryopreservation techniques, such as vitrification and encapsulation-dehydration, allow for long-term storage of plant germplasm in liquid nitrogen. Developing efficient cryopreservation protocols for diverse plant species is crucial for the conservation of genetic resources.

Advances in synthetic biology and genome editing: Emerging technologies, such as synthetic biology and genome editing (e.g. CRISPR/Cas9), hold great promise for enhancing *in vitro* plant propagation. These tools enable precise modification of plant genomes and the creation of novel traits, further expanding the scope of plant biotechnology.

Conclusion

In vitro plant propagation techniques have revolutionized plant science, providing unprecedented opportunities for mass production, conservation, and genetic improvement of plants. This review has highlighted the recent advancements in tissue culture methods, including somatic embryogenesis, organogenesis, shoot proliferation, and genetic transformation. The diverse applications of *in vitro* plant propagation in commercial production, conservation, and secondary metabolite production have been discussed. Despite challenges related to contamination, genetic stability, costs, and ethical considerations, the future of *in vitro* plant propagation looks promising with the integration of bioreactors, omics approaches, cryopreservation, and synthetic biology. Continued research and innovation in this field will contribute to sustainable agriculture, conservation of biodiversity, and advancements in plant biotechnology.

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