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Exploring Progress and Hurdles in Plant Tissue Culture: A Comprehensive Review

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ABSTRACT

Plant tissue culture has revolutionized agriculture, horticulture, and plant science research by offering a platform for mass propagation, germplasm conservation, and genetic transformation of plants. This review comprehensively explores the progress made in plant tissue culture techniques, highlighting their applications and advancements. Additionally, it examines the hurdles and challenges that impede the widespread adoption and optimization of tissue culture methods. Through a detailed analysis of current research and technological developments, this review aims to provide insights into the future directions and potential solutions for overcoming barriers in plant tissue culture. Plant tissue culture stands as a pivotal technique in modern agriculture and plant biotechnology, offering avenues for rapid propagation, genetic manipulation, and conservation of plant species. This review delves into the dynamic landscape of tissue culture methodologies, emphasizing their pivotal role in enhancing crop productivity and preserving genetic diversity. By scrutinizing both progress and obstacles, this exploration seeks to illuminate pathways for further innovation and refinement in plant tissue culture practices.

Keywords: *plant tissue culture, plants, agriculture, horticulture, macro propagation*

Introduction

Plant tissue culture, a technique pioneered by Haberlandt in the late 19th century, involves the aseptic culture of plant cells, tissues, or organs under controlled conditions in a nutrient medium supplemented with growth regulators. Since its inception, tissue culture has become an indispensable tool in plant science, facilitating the propagation of elite plant varieties, conservation of endangered species, and genetic transformation for trait improvement. Plant tissue culture, a pioneering technique introduced by Haberlandt in the late 19th century, marks a significant milestone in plant science, agriculture, and biotechnology. It involves the aseptic culture of plant cells, tissues, or organs in a controlled environment with a nutrient-rich medium supplemented with growth regulators [1-2]. The inception of tissue culture revolutionized traditional methods of plant propagation, providing a novel approach for mass multiplication, germplasm conservation, and genetic transformation of plants.

The versatility of plant tissue culture has enabled researchers and practitioners to explore a wide array of applications across various disciplines.

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Micro-propagation, one of the most prominent applications of tissue culture, facilitates the rapid multiplication of plants from a small piece of tissue, offering an efficient means of propagating elite plant varieties and producing disease-free planting material [3-4]. This technique has significantly contributed to the commercial success of numerous crops and ornamental plants, underscoring its economic and agricultural importance. Beyond propagation, plant tissue culture plays a crucial role in the conservation of plant genetic resources. *In vitro*, gene banks and cryopreservation methods have been developed to safeguard endangered plant species and preserve genetic diversity. Cryopreservation, in particular, offers a long-term storage solution for maintaining the viability of plant germplasm, especially for species with recalcitrant seeds or those that are vegetatively propagated. Moreover, plant tissue culture serves as a powerful tool for genetic transformation, allowing the introduction of novel traits into plants through the integration of foreign DNA. This capability has facilitated the development of genetically modified (GM) crops with enhanced resistance to pests and diseases, improved tolerance to abiotic stresses, and enhanced nutritional profiles [5-6]. The ability to engineer plants for specific traits holds tremendous promise for addressing global challenges such as food security, climate change, and sustainable agriculture.

Despite its myriad advantages, plant tissue culture is not without its challenges and limitations. The genotype-dependent response of plants to tissue culture protocols poses a significant obstacle, requiring the optimization of culture conditions for each target species and genotype. Contamination by microbial pathogens remains a persistent concern, necessitating stringent aseptic techniques and quality control measures throughout the culture process. Furthermore, the high cost associated with establishing and maintaining tissue culture facilities presents a barrier to accessibility, particularly for small-scale growers and research institutions with limited financial resources [7-9].

The procurement of sterile equipment, growth media, and growth regulators adds to the operational expenses, making tissue culture less feasible for many stakeholders.

In light of these challenges, there is a pressing need for continued research and innovation to advance plant tissue culture techniques and address existing limitations. Collaborative efforts between academia, industry, and government agencies are essential to foster knowledge exchange, technology transfer, and capacity building in the field of plant tissue culture. In this comprehensive review, we aim to explore the progress and advancements in plant tissue culture while examining the hurdles and challenges that hinder its widespread adoption and optimization [10-12]. By critically evaluating current research findings and technological developments, we seek to identify potential solutions and future directions for overcoming barriers in plant tissue culture, thereby unlocking its full potential for agricultural sustainability and biodiversity conservation.

Progress in Plant Tissue Culture

Over the years, significant progress has been made in various aspects of plant tissue culture. One of the key advancements is the development of efficient protocols for micro-propagation, allowing the rapid multiplication of plants from a small piece of tissue. Micro-propagation has revolutionized the production of disease-free and genetically uniform plantlets, contributing to the commercial success of numerous crops and ornamental plants. Furthermore, tissue culture techniques have facilitated the conservation of plant genetic resources through the establishment of in vitro gene banks and cryopreservation methods. Cryopreservation, in particular, offers a long-term storage solution for maintaining the genetic diversity of plant species, especially those with recalcitrant seeds or vegetatively propagated crops. In addition to propagation and conservation, plant tissue culture has enabled the genetic transformation of plants for the introduction of desirable traits such as insect resistance, herbicide tolerance, and enhanced nutritional content [13-14]. The development of efficient transformation protocols and the advent of molecular tools have facilitated the generation of transgenic plants with improved agronomic traits, paving the way for sustainable agriculture and food security.

Hurdles in Plant Tissue Culture

Despite its numerous advantages, plant tissue culture still faces several challenges that limit its widespread application and optimization. One of the primary hurdles is the genotype-dependent response of plants to tissue culture protocols, wherein the regeneration potential varies among different plant species and genotypes. This variability often necessitates the optimization of culture conditions and growth regulators for each target species, thereby increasing the time and resources required for protocol development. Contamination remains another significant issue in plant tissue culture, with fungal, bacterial, and viral contaminants posing a threat to culture purity and success. Maintaining strict aseptic conditions throughout the culture process is essential to prevent contamination, but it requires specialized infrastructure and meticulous attention to detail. Furthermore, the high cost associated with establishing and maintaining tissue culture facilities poses a barrier, particularly for researchers and institutions with limited financial resources. The procurement of sterile equipment, growth media, and growth regulators adds to the operational expenses, making tissue culture less accessible to small-scale growers and breeders [15].

Future Directions and Solutions

Addressing the challenges in plant tissue culture requires interdisciplinary efforts encompassing biotechnology, genetics, microbiology, and engineering. Continued research into understanding the molecular and physiological basis of plant responses to tissue culture conditions will enable the development of genotype-independent protocols and improve the efficiency of regeneration systems. Moreover, advancements in automation and bioreactor technology hold promise for reducing labor costs and enhancing the scalability of tissue culture production. Automated systems for culture initiation, subculture, and rooting can streamline the process while minimizing the risk of contamination and human error.

Collaborative initiatives between research institutions, government agencies, and industry stakeholders are essential for promoting knowledge exchange, capacity building, and technology transfer in plant tissue culture. By fostering collaboration and sharing resources, stakeholders can collectively address the challenges and leverage the potential of tissue culture for sustainable agriculture and biodiversity conservation. Plant tissue culture has emerged as a powerful tool for plant propagation, conservation, and genetic improvement, offering unprecedented opportunities for crop improvement and biodiversity conservation. Despite its significant contributions, tissue culture still faces challenges related to genotype-dependent responses, contamination, and high operational costs. Addressing these challenges requires concerted efforts from the scientific community, policymakers, and industry stakeholders to develop innovative solutions and promote the wider adoption of tissue culture technologies. Through collaborative research and strategic investments, plant tissue culture can continue to drive innovation and resilience in agriculture, paving the way for a sustainable future [16-18].

Conclusion

In conclusion, plant tissue culture stands as a cornerstone of modern agriculture and biotechnology, offering unparalleled opportunities for plant propagation, genetic manipulation, and conservation. Throughout this review, we have explored the remarkable progress and advancements achieved in tissue culture techniques, ranging from micropropagation to genetic transformation, and their profound implications for agriculture, horticulture, and biodiversity conservation. Despite the remarkable achievements, plant tissue culture encounters several challenges that warrant attention and concerted efforts from the scientific community, policymakers, and industry stakeholders. The genotype-dependent response of plants, contamination risks, and high operational costs remain formidable barriers that impede the widespread adoption and optimization of tissue culture methods. Addressing these challenges requires interdisciplinary collaborations, innovative approaches, and strategic investments in research and infrastructure, there are promising avenues for advancing plant tissue culture technologies and overcoming existing limitations. Continued research into the molecular and physiological mechanisms underlying plant responses to tissue culture conditions will enhance our understanding and enable the development of genotype-independent protocols. Moreover, advancements in automation, bioreactor technology, and quality control measures hold the potential to streamline processes, reduce costs, and enhance scalability in tissue culture production.

Furthermore, fostering collaboration and knowledge exchange

among researchers, policymakers, and industry stakeholders is crucial for promoting the adoption of tissue culture techniques and facilitating technology transfer to end-users. By leveraging collective expertise and resources, we can address the challenges and harness the full potential of plant tissue culture for sustainable agriculture, food security, and biodiversity conservation. In conclusion, while there are hurdles to overcome, the promise and potential of plant tissue culture as a transformative tool in agriculture and biotechnology are undeniable. Through concerted efforts and innovation, we can pave the way for a future where tissue culture contributes significantly to global food production, environmental sustainability, and the preservation of plant genetic diversity.

References

1. Thomas, P., Duolikun, T., Rumjit, N. P., Moosavi, S., Lai, C. W., Johan, M. R. B., & Fen, L. B. (2020). Comprehensive review on nanocellulose: Recent developments, challenges and future prospects. *Journal of the mechanical behavior of biomedical materials*, *110*, 103884.

2. Smoliga, J. M., Baur, J. A., & Hausenblas, H. A. (2011). Resveratrol and health–a comprehensive review of human clinical trials. *Molecular nutrition & food research*, *55*(8), 1129-1141.

3. Palanisamy, G., Jung, H. Y., Sadhasivam, T., Kurkuri, M. D., Kim, S. C., & Roh, S. H. (2019). A comprehensive review on microbial fuel cell technologies: Processes, utilization, and advanced developments in electrodes and membranes. *Journal of cleaner production*, *221*, 598-621.

4. Wang, H., & Ren, Z. J. (2013). A comprehensive review of microbial electrochemical systems as a platform technology. *Biotechnology advances*, *31*(8), 1796-1807.

5. Sezer, N., & Koç, M. (2021). A comprehensive review on the state-of-the-art of piezoelectric energy harvesting. *Nano energy*, *80*, 105567.

6. Kyriakidis, N. C., López-Cortés, A., González, E. V., Grimaldos, A. B., & Prado, E. O. (2021). SARS-CoV-2 vaccines strategies: a comprehensive review of phase 3 candidates. *npj Vaccines*, *6*(1), 28.

7. Wahab, S., Annadurai, S., Abullais, S. S., Das, G., Ahmad, W., Ahmad, M. F. & Amir, M. (2021). Glycyrrhiza glabra (Licorice): A comprehensive review on its phytochemistry, biological activities, clinical evidence and toxicology. *Plants*, *10*(12), 2751.

8. Asokan, S. M., Mariappan, R., Muthusamy, S., & Velmurugan, B. K. (2018). Pharmacological benefits of neferine-A comprehensive review. *Life sciences*, *199*, 60-70.

9. Atabani, A. E., Silitonga, A. S., Badruddin, I. A., Mahlia, T. M. I., Masjuki, H., & Mekhilef, S. (2012). A comprehensive review on biodiesel as an alternative energy resource and its characteristics. *Renewable and sustainable energy reviews*, *16*(4), 2070-2093.

10. Jan, H., Gul, R., Andleeb, A., Ullah, S., Shah, M., Khanum, M., & Abbasi, B. H. (2021). A detailed review on biosynthesis of platinum nanoparticles (PtNPs), their potential antimicrobial and biomedical applications. *Journal of Saudi Chemical Society*, *25*(8), 101297.

11. Sahu, P. K., Sao, R., Mondal, S., Vishwakarma, G., Gupta, S. K., Kumar, V & Das, B. K. (2020). Next generation sequencing based forward genetic approaches for identification and mapping of causal mutations in crop plants: A comprehensive review. *Plants*, *9*(10), 1355.

12. Dhyani, V., & Bhaskar, T. (2018). A comprehensive review on the pyrolysis of lignocellulosic biomass. *Renewable energy*, *129*, 695-716.

13. Ghaffour, N., Bundschuh, J., Mahmoudi, H., & Goosen, M. F. (2015). Renewable energy-driven desalination technologies: A comprehensive review on challenges and potential applications of integrated systems. *Desalination*, *356*, 94-114.

14. George, E. F., Hall, M. A., & De Klerk, G. J. (Eds.). (2007). *Plant propagation by tissue culture: volume 1. the background* (Vol. 1). Springer Science & Business Media.

15. Igwegbe, C. A., Oba, S. N., Aniagor, C. O., Adeniyi, A. G., & Ighalo, J. O. (2021). Adsorption of ciprofloxacin from water: a comprehensive review. *Journal of Industrial and Engineering Chemistry*, *93*, 57-77.

16. Sanjay, M. R., Siengchin, S., Parameswaranpillai, J., Jawaid, M., Pruncu, C. I., & Khan, A. (2019). A comprehensive review of techniques for natural fibers as reinforcement in composites: Preparation, processing and characterization. *Carbohydrate polymers*, *207*, 108-121.

17. Rani, L., Thapa, K., Kanojia, N., Sharma, N., Singh, S., Grewal, A. S. & Kaushal, J. (2021). An extensive review on the consequences of chemical pesticides on human health and environment. *Journal of cleaner production*, *283*, 124657.

18. Mardani, A., Zavadskas, E. K., Streimikiene, D., Jusoh, A., & Khoshnoudi, M. (2017). A comprehensive review of data envelopment analysis (DEA) approach in energy efficiency. *Renewable and Sustainable Energy Reviews*, *70*, 1298-1322.