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Recent Advances in Tissue Culture to Boost Bioactive Compound Production in Therapeutic Herbs

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Abstract

Plant tissue culture is a crucial technology that facilitates the growth, preservation, and improvement of therapeutic plants. In order to create genetically homogeneous plants, this approach entails cultivating plant cells, tissues, or organs in a regulated setting that is free of pollutants. Since its invention more than a century ago, tissue culture has undergone substantial development, leading to discoveries like totipotency and improvements in nutrient-rich medium. The method makes it easier for plants to multiply quickly, preserve genetic variety, and produce bioactive substances that are necessary for use in medicine. Furthermore, tissue culture is essential for genetic improvement since it makes it possible to select and develop desired features in medicinal plants. Despite its benefits, problems like contamination and the early setup expenses demand strict attention to sterile procedures and appropriate laboratory norms. In general, tissue culture is a key component of the sustainable use and preservation of medicinal plants, providing opportunities for international research and business applications.

Keywords: Tissue Culture, Medicinal Plants, Bioactive Compounds, In vitro Propagation, Phytochemicals, Secondary Metabolites.

1. INTRODUCTION

To preserve, multiply, and improve the therapeutic qualities of medicinal plants, tissue culture research focuses on growing plant cells, tissues, or organs under carefully monitored lab settings. The generation of bioactive chemicals necessary for pharmaceutical applications can be facilitated by this technology, which also enables the fast reproduction of plants with consistent genetic features. Researchers use tissue culture to make sure that medicinal plant resources are used sustainably, optimize plant regeneration, and increase the production of secondary metabolites.

1.1. Plant Tissue culture

Plant tissue culture is the process of growing a full plant in vitro—that is, in glass vessels—from an explant, which can be any cell tissue, organ, or plant component used to start an in vitro culture (shoot tip, leaf, petiole, etc.). The plants that are produced are clones of the chosen genotype. Tissue culture, also known as micropropagation, is mostly utilized for plant multiplication in the commercial sector.

Aseptic settings, which are sterile and devoid of germs, involve maintaining tissue culture in a particular culture medium that supplies nutrients for plant development and often contains one or more plant growth regulators. The environment is also managed to ensure constant temperature, humidity, and length of light. The right ratio of organic and inorganic nutrients in the culture medium has a major role in determining the culture's success. Three fundamental ingredients make up the culture medium used to cultivate plant cells in vitro. i) Vital components provided as an intricate blend of salts. ii) An organic supplement that contains amino acids and vitamins. Usually, a fixed carbon source is sucrose.

Tissue culture techniques are employed in the production of disease-free plants, genetic engineering, agricultural improvement, high yield crop production, large-scale plant multiplication of target species, and fundamental research.

1.2. Basics of Plant Tissue Culture

- In 1902, the German scientist Haberlandt identified and cultivated completely differentiated plant cells from several plants. Plant cell and tissue culture started with this as the initial stage. Additional advancements were made by the Cell Doctrine, which acknowledged the possibility of totipotency in a cell.

- In 1959, Braun successfully recreated the first plant from a fully grown plant cell. In 1960, G.M. Morel discovered a way to multiply the orchid Cymbidium by a million times, which set the groundwork for commercial plant tissue culture. Plant tissue culture then "took off" at the commercial level with the creation of a dependable artificial medium by Murashige & Skoog in 1962.
- After it was discovered that haploid plants could be produced in vitro by culturing, P. Maheshwari of Delhi University began the study on tissue culture in India.
- Plant tissue culture in India has advanced significantly thanks to the efforts of Sipra Guha and Shri S.C. Maheshwari.
- As the man who initially conceptualized the idea of cultivating plant cells in vitro, G. Haberlandt is rightfully called the "father" of tissue culture.

1.3. Bioactive compounds and their role

The growth, development, and metabolic processes of tissue culture are significantly impacted by bioactive substances. They contain auxins and cytokinins, which are essential for tissue propagation because they promote root development and cell division, respectively. Antioxidants ensure the survival of tissues during culture by shielding them from oxidative damage. Furthermore, certain substances have the ability to increase the synthesis of secondary metabolites, which are useful in agriculture and medicine. These functions demonstrate how important it is to maximize tissue culture methods for effective plant regeneration and the synthesis of secondary metabolites.

2. PRINCIPLES OF TISSUE CULTURE

The primary goal of plant tissue culture is to increase the number of plants that have the same genetic makeup as their parent plant. To do this, a "explant," or tiny portion of a plant that has been dissected, is grown into a full plant using tissue culture. This method works well because nearly all plant cells are totipotent, or able to develop into whole plants, meaning that each cell has the genetic material and cellular components needed to create the entire organism.

1) **Cell plasticity:**Plants are sessile and have a longer life span, thus they have adapted better to withstand harsh climatic and biotic circumstances. Plant development and growth are bolstered by this action. A significant amount of plasticity is typically exhibited by plant cells and tissues when they are cultivated in vitro, allowing one kind of organ or tissue to develop from another. It is possible to subsequently rejuvenate the entire plant in this manner.
2) **Totipotency:**Plant tissue culture success is based on totipotency. Every cell has the capacity to regenerate into a whole plant, according to the totipotency idea. All of an organism's traits can be expressed by any somatic cell since it shares the same genetic makeup (DNA sequence) as a zygote. With the right nutrients and plant hormones, single cells, plant cells without cell walls (called protoplasts), fragments of leaves, stems, or roots, or even whole plants, may frequently be grown from seed in culture conditions. Plant Tissue Culture is also known as Plant Cell, Tissue, and Organ Culture since it is practically impossible to handle a single cell. Instead, a tissue or an organ from the plant is typically employed to start the tissue culture activity.

The culture is given the best environment possible for development and multiplication under the regulated circumstances. These prerequisites include the right amount of nutrients, the right pH balance, the right temperature, and the right gaseous and liquid environments.

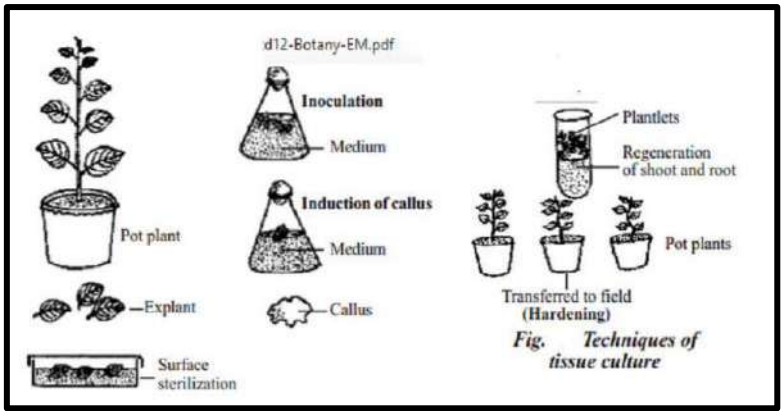

Figure 2: Plant tissue culture

3. Types of Tissue Culture Techniques

The field of tissue culture includes a number of methods that are necessary for investigating and working with cells, tissues, and organs under carefully monitored lab settings. Among these methods are:

- **Cell Culture:** involves cultivating separate, tissue-isolated cells in a medium rich in nutrients. The study of cellular activity, biochemical processes, and the production of monoclonal antibodies and vaccinations are all made possible by cell culture.
- **Organ Culture:** preserves the physiological structure and function of whole organs or tissues by cultivating them in vitro. This method is essential for researching drug testing, organ development, and disorders unique to certain organs.
- **Embryo Culture:** focuses on the development of embryos outside of an organism's body in a synthetic environment. It is essential for genetic engineering, embryology, and endangered species conservation studies.

3.1. Importance of Tissue Culture in Plant Propagation and Conservation:

Tissue culture provided several benefits that transformed plant propagation and conservation:

- **Mass Propagation**: allows plants to grow quickly from tiny bits of tissue or cell, getting beyond the restrictions of seeds. This technique guarantees the propagation of uncommon species and elite genotypes that are challenging to propagate using traditional techniques.
- **Germplasm Conservation**: helps precious genetic material or endangered plant species be preserved in a controlled setting. Plant cells, tissues, or organs can be preserved under ideal circumstances for later use through tissue culture, preserving their genetic integrity.
- **Genetic Improvement:** offers a framework for selecting and manipulating genes to produce desired features. Methods such as somatic embryogenesis and micropropagation enable the development of disease-free plants, increased yield, and stress tolerance.
- **Research and Development:** Supports molecular biology, biochemistry, and plant physiology research. Tissue culture makes it possible to investigate how plants react to hormones, environmental stimuli, and infections, which advances crop development and environmentally friendly farming methods.

4. ROLE OF TISSUE CULTURE IN MEDICINAL PLANTS

Tissue culture offers major benefits over conventional propagation methods and is essential for the propagation, conservation, and improvement of medicinal plants. Tissue culture methods, such micropropagation, allow for the fast, sterile multiplication of plants with desired medical qualities from small quantities of plant tissue, guaranteeing genetic integrity and homogeneity. In addition to quickening the process of reproduction, this technique makes it easier to preserve uncommon and endangered species. Additionally, tissue culture makes it possible to produce secondary metabolites in regulated settings, such as bioactive substances with potential therapeutic applications. This capacity is especially important for preventing

over-harvesting of natural habitats, which in turn helps to maintain a sustainable supply of medicinal plant materials. Furthermore, tissue culture makes it possible to genetically modify medicinal plants using methods like somaclonal variation and genetic transformation, strengthening their therapeutic qualities and disease-resistant nature. Overall, tissue culture is a key component of the sustainable use, improvement, and conservation of medicinal plants. It provides opportunities for both research and business use in the global herbal and pharmaceutical sectors.

4.1. Advantages of Tissue Culture

The tissue culture method has a number of benefits.

1. The newly planted plantlets can be grown quickly.
2. A minimal quantity of starting plant tissue is needed.
3. It's more likely that the newly planted plants and plantlets won't have any infections or illnesses.
4. You may carry out the process all year round and it is not reliant on the seasons.
5. The method only requires a comparatively tiny amount of room (ten times the plants in one-tenth of the area).
6. Tissue culture, on a bigger scale, contributes to the variety and introduction of new subspecies to the consumer market.
7. Tissue culture yields greater results than standard soil culture for those wishing to grow difficult plants, such as certain orchid varieties.

4.2. Disadvantages of Plant Tissue Culture

Although tissue culture has many advantages, there are certain restrictions.

1. The construction of the facility and the cost of outfitting the lab with all the tools and chemicals might be higher when tissue culture is used.
2. Because of their growing habitat, there's a potential that the propagated plants won't be as resistant to illnesses when they're cultivated outside.
3. It is crucial to screen the material before it is cultured, as failing to do so might result in the infection of the newly planted plants.
4. Although there is a good chance of success if the right steps are taken, tissue culture success is not certain. It can be difficult to establish a single functional protocol on your own, which is why precise procedures are required to grow plants in tissue culture settings.
5. In a tissue culture setup, contamination is the main problem. Viral, fungal, and bacterial infections are all possible in plants. For this reason, when practicing tissue culture in your lab, all necessary precautions should be performed and a PPE kit should be utilized.
6. To begin working in the field, one must possess extensive knowledge and competence in tissue culture, since it is an advanced method.

5. CONCLUSION

Plant tissue culture is a revolutionary method that provides unmatched benefits for the multiplication, preservation, and improvement of medicinal plants. Tissue culture ensures genetic purity and uniformity by facilitating the fast replication of plants with desired features through methods like somatic embryogenesis and micropropagation. This technique not only solves the problems associated with conventional propagation, but it also makes a major contribution to the sustainable use of plant resources, especially those that have therapeutic qualities. Tissue culture also makes it easier to produce the bioactive substances needed by the herbal and pharmaceutical sectors, guaranteeing a steady supply chain that is not affected by seasonal fluctuations. Tissue culture continues to be essential for research, development, and commercial applications despite its complexity and early setup costs, suggesting more advancements in plant biotechnology and sustainable agriculture.

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