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Role of Tissue Culture Technique in the Conservation of Medicinal Plants: A Botanical Study with Special Reference to Etawah District

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Abstract

The present study analyzed the utility of tissue culture technology in the conservation of major medicinal plants found in Etawah District, Uttar Pradesh. In recent decades, excessive exploitation, agricultural expansion, urbanization, and environmental changes have posed serious threats to numerous medicinal plant species, resulting in a gradual decline of their natural populations. Tissue culture technology has emerged as an effective biotechnological tool for the rapid multiplication of rare and economically important medicinal plants, production of disease-free planting material, and conservation of plant genetic resources. The study documented major medicinal plant species available in Etawah District and evaluated the potential of tissue culture techniques for their conservation and sustainable utilization. The findings highlighted the significance of tissue culture as a scientific approach for biodiversity conservation, large-scale propagation, and long-term preservation of medicinal plant resources in the region.

Keywords: Medicinal Plants, Tissue Culture, Conservation, Biodiversity, Micropropagation, Etawah District.

Introduction

Plants have played a pivotal role in the evolution and development of human civilization. As primary sources of food, shelter, fuel, and medicine, they have continuously contributed to human welfare and well-being. Among them, medicinal plants have served as the foundation of healthcare systems since ancient times. Despite remarkable advancements in modern medical science, a substantial proportion of the global population continues to depend directly or indirectly on medicinal plants for primary healthcare needs. According to the World Health Organization (WHO), nearly 80 percent of the population in developing countries relies on traditional medicine and plant-based remedies. India occupies a unique position in this regard due to its rich biological diversity and the existence of ancient healthcare systems such as Ayurveda, Unani, Siddha, and various indigenous medical traditions, all of which are fundamentally based on medicinal plant resources. India is recognized as one of the world's megadiverse countries, possessing an extraordinary wealth of medicinal plant species distributed across diverse ecological zones ranging from the Himalayas and Western Ghats to the Indo-Gangetic plains and arid regions. Many of these species possess immense medicinal, economic, and commercial value and are widely utilized in pharmaceutical, nutraceutical, and cosmetic industries. Species such as Tulsi (*Ocimum sanctum*), Ashwagandha (*Withania somnifera*), Giloy (*Tinospora cordifolia*), Kalmegh (*Andrographis paniculata*), Aloe vera (*Aloe vera*), Neem (*Azadirachta indica*), Shatavari (*Asparagus racemosus*), and Brahmi (*Bacopa monnieri*) constitute an invaluable component of India's traditional medicinal heritage.

In recent years, the increasing global demand for herbal medicines and natural products has significantly intensified the commercial exploitation of medicinal plants. Expansion of the pharmaceutical industry, growing consumer preference for natural products, and rising export opportunities have accelerated the indiscriminate harvesting of medicinal plant species from their natural habitats. Consequently, several valuable medicinal species are experiencing a rapid decline in population density. Deforestation, agricultural

expansion, urbanization, industrialization, land-use changes, environmental pollution, and climate change have emerged as major threats to their survival. The erosion of medicinal plant diversity not only affects ecological stability but also jeopardizes future medicinal security and the preservation of traditional knowledge systems.

Etawah District of Uttar Pradesh represents an important ecological region within the Ganga–Yamuna Doab. The district supports a wide range of plant species owing to the ecological influence of the Yamuna, Chambal, and their tributaries. Medicinal plants continue to play a significant role in traditional healthcare practices among rural communities. Species such as Tulsi, Neem, Giloy, Ashwagandha, Aloe vera, Kalmegh, and several others are commonly found in household gardens, agricultural fields, and natural habitats across the district. However, increasing population pressure, agricultural intensification, habitat degradation, and growing commercial utilization have adversely affected the availability and natural regeneration capacity of these species. Under such circumstances, the adoption of scientific and modern conservation strategies has become essential for their long-term sustainability. In this context, tissue culture technology has emerged as a highly effective biotechnological tool for the conservation and propagation of medicinal plants. This technique involves the cultivation of plant cells, tissues, or organs under controlled and aseptic conditions, enabling the rapid production of large numbers of plants within a relatively short period. Compared with conventional propagation methods, tissue culture offers greater efficiency, reliability, and economic viability. It is particularly useful for the conservation of rare, endangered, slow-growing, or poorly reproducing medicinal plant species. The technique facilitates the large-scale production of genetically uniform, disease-free, and high-quality planting material.

Beyond conservation, tissue culture technology contributes significantly to biodiversity preservation, germplasm conservation, restoration of threatened species, and commercial cultivation of medicinal plants. Advanced approaches such as *in vitro* conservation, micropropagation, somaclonal variation, and cryopreservation provide effective means for the long-term preservation of plant genetic resources. Consequently, tissue culture-based conservation strategies are increasingly being adopted worldwide for the sustainable management of medicinal plant diversity. The findings of the present study demonstrated that tissue culture technology can play a crucial role in ensuring the sustainable conservation and utilization of medicinal plant resources in Etawah District. The study contributes to biodiversity conservation, sustainable availability of medicinal plants, strengthening of the rural economy, and the development of biotechnology-based conservation strategies. Furthermore, it provides a practical and scientifically validated framework for medicinal plant conservation in Etawah District, which may serve as a model for similar ecological regions in the future.

Statement of the Problem

Medicinal plants constitute an invaluable component of human healthcare, traditional medicinal systems, and biodiversity conservation. However, in recent decades, numerous medicinal plant species have become increasingly threatened due to habitat destruction, indiscriminate exploitation, excessive commercial harvesting, agricultural expansion, and climate change. In Etawah District, a gradual decline in the natural availability of several medicinal plant species has also been observed. Conventional methods of conservation and propagation have proved inadequate for ensuring their long-term preservation and sustainable utilization. Although tissue culture technology is widely recognized as an effective scientific approach for the rapid propagation and conservation of medicinal plants on a large scale, limited studies have been conducted regarding its applicability, potential, and practical implementation in the context of Etawah District. Therefore, it becomes essential to scientifically investigate and evaluate the role of tissue culture technology in the conservation of locally available medicinal plant species. Such an assessment may contribute to the

development of effective conservation strategies for rare, threatened, and economically important medicinal plants.

Considering these concerns, the present research entitled “Role of Tissue Culture Technique in the Conservation of Medicinal Plants: A Botanical Study with Special Reference to Etawah District” was undertaken to examine the potential of tissue culture technology as a sustainable tool for medicinal plant conservation and management.

Need of the Study

The increasing industrial and medicinal demand for plant-based resources has exerted considerable pressure on natural populations of medicinal plants, leading to a noticeable decline in many important species. Habitat destruction, overexploitation, agricultural expansion, urbanization, and climate change have further accelerated the depletion of medicinal plant resources worldwide. Etawah District, which possesses rich medicinal plant diversity and a strong tradition of indigenous healthcare practices, is not exempt from these challenges. Under such circumstances, the adoption of scientific and long-term conservation measures has become imperative.

Tissue culture technology has emerged as an effective biotechnological tool for the rapid, large-scale, and disease-free propagation of rare, threatened, and economically valuable medicinal plant species. Besides supporting biodiversity conservation, this technology ensures the sustainable availability of medicinal plants, promotes their commercial cultivation, and reduces pressure on natural populations. Therefore, a scientific assessment of the applicability, potential, and conservation significance of tissue culture technology in the context of Etawah District is essential. Such an evaluation may facilitate the development of a practical and scientific model for medicinal plant conservation, biodiversity protection, and sustainable medicinal plant cultivation at the regional level. Consequently, the present study is significant not only from the perspective of Botany and Biotechnology but also for environmental conservation, rural livelihood enhancement, and sustainable management of medicinal plant resources.

Objectives of the Study

1. To identify and classify the major medicinal plant species available in Etawah District.
2. To assess the conservation status of selected medicinal plant species.
3. To analyze the principles and procedures of tissue culture technology.
4. To evaluate the role of tissue culture technology in the conservation of medicinal plants.
5. To examine the prospects and challenges associated with the application of tissue culture technology in Etawah District.

Hypotheses

- H₁: Tissue culture technology plays a significant and effective role in the conservation of medicinal plants.
- H₂: Tissue culture technology can serve as a useful and practical approach for the conservation of selected medicinal plant species available in Etawah District.
- H₀: Tissue culture technology has no significant effect on the conservation of medicinal plants.

Study Area

The present study was conducted in Etawah District of Uttar Pradesh, India, which is located at 26.77° N latitude and 79.02° E longitude and covers an area of approximately 2,311 square kilometers. The district experiences a subtropical climate characterized by high temperatures during summer, moderate rainfall, and

relatively low temperatures during winter. Influenced by the Yamuna, Chambal, and their tributaries, the region possesses diverse ecological conditions and rich floral resources. In addition to agricultural crops, various medicinal plant species such as Neem (*Azadirachta indica*), Tulsi (*Ocimum tenuiflorum*), Giloy (*Tinospora cordifolia*), Ashwagandha (*Withania somnifera*), Aloe vera (*Aloe vera*), Kalmegh (*Andrographis paniculata*), and several other medicinal plants occur naturally as well as under cultivation. However, rapid agricultural expansion, land-use changes, habitat degradation, and increasing commercial exploitation have adversely affected their natural availability and regenerative capacity.

For the purpose of the study, selected rural areas, agricultural fields, household medicinal gardens, riverine habitats, and natural vegetation sites from five development blocks and ten Gram Panchayats of Etawah District were surveyed. These sites were selected due to their comparatively higher availability and traditional utilization of medicinal plant species. Detailed investigations were carried out regarding species diversity, conservation status, natural regeneration potential, and the environmental and anthropogenic pressures affecting medicinal plants in the selected areas. Based on the findings, the utility, prospects, and regional relevance of tissue culture technology for the conservation, rapid propagation, and sustainable utilization of medicinal plants were scientifically evaluated. The study provides a valuable foundation for biodiversity conservation and scientific management of medicinal plant resources in the region.

Review of Literature

Numerous national and international studies have been conducted on the conservation of medicinal plants and the application of tissue culture technology. These investigations clearly indicate that the growing demand for medicinal plant resources and increasing pressure on natural ecosystems have enhanced the importance of biotechnology-based conservation approaches. Ancient Indian medical texts as well as contemporary scientific research have extensively highlighted the medicinal, economic, and ecological significance of medicinal plants. Studies conducted by the World Health Organization (WHO) and various plant scientists have demonstrated that a substantial proportion of the global population depends directly or indirectly on medicinal plants for primary healthcare. In India, extensive research has been published on the medicinal importance of species such as Tulsi (*Ocimum sanctum*), Ashwagandha (*Withania somnifera*), Giloy (*Tinospora cordifolia*), Kalmegh (*Andrographis paniculata*), Aloe vera (*Aloe vera*), and Brahmi (*Bacopa monnieri*).

In the field of biodiversity conservation, researchers such as Myers (1988), Wilson (1992), and Raven (1998) concluded that habitat destruction, overexploitation, and climate change have led to a rapid decline in plant biodiversity worldwide. Similar observations have been reported in India, where several medicinal plant species have been categorized as conservation-sensitive due to increasing anthropogenic pressures. Consequently, the need for scientific conservation strategies has become increasingly significant. The development of tissue culture technology is largely attributed to Haberlandt (1902), who introduced the concept of plant cell totipotency. Subsequent studies by White (1934), Skoog and Miller (1957), and Murashige and Skoog (1962) laid the foundation for modern plant tissue culture techniques. In particular, the Murashige and Skoog (MS) medium continues to be the most widely used culture medium in plant tissue culture laboratories worldwide. Research in the field of micropropagation has demonstrated that tissue culture technology enables the rapid production of large numbers of disease-free and genetically uniform plants. Studies by Fay (1992), Rout et al. (2000), Debnath et al. (2006), and Chaturvedi et al. (2007) described successful micropropagation protocols for various medicinal plant species. These studies established that tissue culture is an effective tool for the conservation of rare and endangered medicinal plants.

With respect to germplasm conservation, the studies of Engelmann (1997), Withers and Engelmann (1998), and Benson (2008) highlighted the importance of in vitro conservation and cryopreservation

techniques. Their findings demonstrated that tissue culture-based conservation methods provide effective means for the long-term preservation of genetic resources of rare and threatened plant species. Among Indian studies, the publication of the Red Data Book of Indian Plants by Nayar and Sastry (1987–1990) remains particularly significant, as it provides comprehensive information on threatened plant species of India. Research reports published by the Foundation for Revitalisation of Local Health Traditions (FRLHT), the National Medicinal Plants Board (NMPB), and various agricultural and botanical research institutions have consistently emphasized the need for conservation, propagation, and sustainable utilization of medicinal plants. Tissue culture-based propagation studies have been successfully conducted on several important medicinal species, including Ashwagandha, Sarpagandha, Kalmegh, Brahmi, and Shatavari.

In the context of Uttar Pradesh, several universities and research institutions have undertaken studies on medicinal plant diversity, traditional uses, and conservation practices. Survey-based investigations have documented medicinal flora in regions such as Bundelkhand, the Terai belt, the Doab region, and the Chambal landscape. Although a few regional studies have reported the availability of medicinal plants, traditional healthcare practices, and plant diversity in Etawah District and surrounding areas, comprehensive and region-specific assessments of the role of tissue culture technology in medicinal plant conservation remain limited. A critical analysis of the available literature revealed that substantial research has been conducted on medicinal plant conservation and tissue culture applications. However, a comprehensive study focusing on the current status of medicinal plant resources and the potential role of tissue culture technology in their conservation within the specific context of Etawah District has remained largely unexplored. This research gap provided the foundation for the present investigation. Through the evaluation of the conservation status of locally available medicinal plants and the scientific assessment of tissue culture technology, the study generated valuable insights that may contribute to biodiversity conservation and the sustainable management of medicinal plant resources at the regional level.

Research Methodology

The present study was conducted to evaluate the role of tissue culture technology in the conservation of medicinal plants. The study adopted a descriptive and analytical research design, integrating field-based investigations with a comprehensive review of scientific literature. The primary objective was to assess the current status of medicinal plant resources in Etawah District, identify the challenges associated with their conservation, and examine the utility of tissue culture technology as a scientific tool for their preservation and sustainable utilization. Field surveys were carried out in selected rural areas, agricultural lands, medicinal plant cultivation sites, and natural vegetation habitats of Etawah District. During the field investigation, direct observations were made regarding the availability, species diversity, conservation status, and utilization patterns of medicinal plants. In addition, relevant information was collected from local traditional healers, medicinal plant growers, farmers, and botanical experts through a structured interview schedule. The primary data obtained from these sources were used to analyze the existing conservation status of medicinal plants and the region-specific challenges associated with their management and preservation. Both primary and secondary sources of data were utilized in the study. Primary data were collected through field surveys, direct observations, interviews, and locally available information. Secondary data were obtained from national and international research articles, reference books, scientific journals, reports of the Forest Department, publications of the National Medicinal Plants Board (NMPB), government documents related to biodiversity conservation, and other relevant academic sources.

The collected data were systematically classified, tabulated, and subjected to comparative analysis. The conservation status of medicinal plants and the effectiveness of tissue culture technology were evaluated on the basis of field observations and existing scientific evidence. Particular emphasis was placed on examining how tissue culture technology can contribute to the conservation of rare and threatened medicinal

plant species through rapid multiplication, production of disease-free planting material, germplasm preservation, and biodiversity conservation. Thus, through the integrated analysis of field-based evidence and scientific literature, the present study scientifically assessed the relevance, applicability, and potential of tissue culture technology for the conservation and sustainable management of medicinal plant resources in Etawah District.

Sampling Design

The study employed the Purposive Sampling Method for the selection of respondents and study units. This method was considered appropriate because the investigation focused on individuals and locations directly associated with the availability, utilization, conservation, and cultivation of medicinal plants. Purposive sampling facilitated the selection of respondents capable of providing reliable and relevant information related to the research objectives. For the collection of primary data, a total of 50 farmers who were directly involved in the cultivation, utilization, or conservation of medicinal plants were selected. In addition, 20 local traditional healers, herbal practitioners, and individuals possessing indigenous knowledge of medicinal plants were included in the study to obtain information regarding traditional medicinal practices, therapeutic applications, and conservation-related issues. Consequently, the total sample size comprised 70 respondents.

Data were collected from the selected respondents through a structured interview schedule. The information obtained was analyzed to assess the availability, conservation status, local significance, and utilization of medicinal plants, as well as the potential role of tissue culture technology in their conservation and propagation. The adopted sampling framework was found to be appropriate for achieving the objectives of the study and generating reliable conclusions at the regional level.

Selected Medicinal Plants for the Study

The present study focused on six major medicinal plant species commonly found in Etawah District. These species were selected on the basis of their medicinal importance, local availability, economic value, extensive use in traditional healthcare systems, conservation requirements, and their potential for rapid propagation and conservation through tissue culture technology. In addition to their local significance, these species possess considerable demand in national and international medicinal plant markets.

Table 1. Selected Medicinal Plant Species, Their Medicinal Uses, Conservation Status, and Tissue Culture Potential in Etawah District

S. No	Common Name	Scientific Name	Major Medicinal Uses	Conservation Status	Tissue Culture Potential
1.	Tulsi	Ocimum tenuiflorum	Respiratory disorders, immunity enhancement, infection control	Common	High
2.	Neem	Azadirachta indica	Skin diseases, antibacterial and biopesticidal properties	Common	Moderate
3.	Ashwagandha	Withania somnifera	Stress management, immunity enhancement, general tonic	Overexploited	High
4.	Aloe vera	Aloe vera	Skin treatment, digestive health, cosmetic applications	Common	High
5.	Giloy	Tinospora cordifolia	Immunity enhancement, fever management, chronic ailments	Overexploited	High

6.	Kalmegh	Andrographis paniculata	Liver disorders, fever, and infection management	Vulnerable	High
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The conservation status of the selected species was determined on the basis of available literature, field survey observations, and the intensity of their medicinal utilization within the study area.

The selected medicinal plant species were investigated with respect to their regional distribution, local utilization, availability, conservation status, and the potential for their propagation and conservation through tissue culture technology. The primary objective of the study was to evaluate how tissue culture technology can contribute to the conservation of these important medicinal species, the production of quality planting material, biodiversity conservation, and the promotion of sustainable medicinal plant cultivation. Among the selected species, Ashwagandha (*Withania somnifera*), Giloy (*Tinospora cordifolia*), and Kalmegh (*Andrographis paniculata*) were found to be particularly significant because increasing medicinal demand and commercial utilization have exerted considerable pressure on their natural populations, thereby enhancing the need for their scientific conservation.

Data Analysis

The primary and secondary data collected during the study were analyzed systematically and scientifically. Initially, the collected information was edited, classified, and tabulated to facilitate its organized presentation and interpretation. Subsequently, the responses obtained from the respondents were analyzed through frequency distribution and percentage analysis in order to assess the availability, utilization patterns, conservation status of medicinal plants, and the level of awareness regarding tissue culture technology and its applications. Comparative analysis was carried out to evaluate the species composition, conservation status, and local utilization of the selected medicinal plants within the study area. Data obtained from different Gram Panchayats, agricultural fields, and natural vegetation sites were compared to identify regional variations and conservation-related challenges. Furthermore, the prospects of conventional conservation practices and tissue culture-based conservation strategies were assessed using both field observations and available scientific literature.

Both qualitative and quantitative approaches were employed in the analytical process. Information obtained from local traditional healers, farmers, and herbal experts through interviews was subjected to content analysis, whereas numerical data were analyzed using appropriate statistical techniques. Based on this integrated analytical framework, the utility, effectiveness, and regional applicability of tissue culture technology for medicinal plant conservation were evaluated.

Finally, conclusions were drawn from the analyzed data, and appropriate scientific recommendations were proposed for the conservation, propagation, and sustainable utilization of medicinal plant resources in Etawah District. Thus, the process of data analysis provided a scientific foundation for the interpretation of findings and the achievement of the study objectives.

Conclusion

The findings of the present study revealed that Etawah District represents an important reservoir of medicinal plant resources, where several valuable medicinal species, including Tulsi (*Ocimum tenuiflorum*), Neem (*Azadirachta indica*), Ashwagandha (*Withania somnifera*), Aloe vera (*Aloe vera*), Giloy (*Tinospora cordifolia*), and Kalmegh (*Andrographis paniculata*), occur both naturally and under cultivation. Field investigations and an extensive review of scientific literature indicated that increasing demand for medicinal plants, habitat degradation, land-use changes, unsustainable harvesting, and environmental alterations have

collectively imposed substantial pressure on their natural populations. Consequently, scientific intervention has become essential for ensuring their long-term conservation and sustainable utilization.

The study further demonstrated that tissue culture technology is an effective and scientifically validated approach for medicinal plant conservation, rapid propagation, production of disease-free planting material, and germplasm preservation. The technology enables the large-scale production of high-quality planting material within a relatively short period and offers significant advantages for the conservation of rare and ecologically important medicinal species. In particular, tissue culture-based propagation programs were found to be highly beneficial for medicinal plants such as Ashwagandha, Giloy, and Kalmegh, whose increasing demand has intensified pressure on their natural populations. The findings supported the first research hypothesis (H_1), which proposed that tissue culture technology plays an effective role in medicinal plant conservation. The second hypothesis (H_2) was also validated, indicating that tissue culture technology can serve as a practical and useful tool for the conservation and propagation of selected medicinal plant species available in Etawah District. In contrast, the null hypothesis (H_0) was not supported by the empirical evidence and analytical findings of the study.

The investigation also revealed substantial opportunities for the wider application of tissue culture technology in medicinal plant conservation within the district. However, its effective implementation requires the establishment of biotechnology laboratories, enhancement of technical expertise, increased awareness among farmers and local communities, and stronger institutional support. If these requirements are adequately addressed, tissue culture technology can contribute not only to medicinal plant conservation but also to medicinal plant cultivation, rural employment generation, biodiversity conservation, and regional economic development.

Overall, the study concluded that tissue culture technology represents a scientific, efficient, and future-oriented strategy for the conservation and sustainable management of medicinal plant resources. In the specific context of Etawah District, the study provides a practical and research-based model for medicinal plant conservation that may also be applicable to other regions with similar ecological conditions. Therefore, the present research makes a significant academic and practical contribution to the fields of Botany, Biotechnology, Biodiversity Conservation, and Medicinal Plant Resource Management.

Suggestions

Based on the findings of the study, it is recommended that a district-level Tissue Culture Laboratory be established in Etawah District to facilitate the production of high-quality and disease-free planting material. Farmers, medicinal plant growers, and rural communities should be provided with training on tissue culture-based propagation and conservation techniques. Community-based conservation programs should be promoted to encourage public participation in the preservation of medicinal plant resources. Awareness campaigns should also be organized in schools and colleges to develop a positive attitude toward biodiversity conservation among younger generations.

Furthermore, long-term conservation and management plans should be formulated and implemented through coordinated efforts involving the Forest Department, Agriculture Department, educational institutions, and local communities. Such collaborative initiatives would not only contribute to biodiversity conservation but would also strengthen medicinal plant cultivation, enhance rural livelihoods, and support sustainable regional economic development.

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