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An Overview of Indian Plant Tissue Culture Industry to Meet the Needs of Agriculture and Food Supply: A Review

Amit Kumar Kanu and Vivek Srivastava
Department of Biotechnology, Faculty of Engineering and Technology, Rama University, Kanpur 209217, INDIA
Email Id: *drviveksrivastava.fet@ramauniversity.ac.in*

ABSTRACT:

Over the past century, the area of plant tissue culture has made remarkable advancements by embracing new technologies and ideas. To reduce the dependency on natural resources, scientists have worked on creating plants artificially. In response to the desire for high-yielding and disease-resistant cultivars, large-scale production methods that can create thousands of plants from a single explant have been created. Globalization has driven the commercialization of PTC worldwide, particularly due to the increasing demand from developing countries. Modified micropropagation techniques have been effectively applied in forestry, medicine, and agriculture in India by the PTC industry. In situ conservation, germplasm sharing, pilot trials, and protocol improvement are some strategies that have revolutionized the Indian PTC market, contributing to its significant progress. Ensuring food security is crucial, and although India produces enough cereals, there is a shortage of pulses and oilseeds. To tackle this, promoting crop diversification and improving related sectors are necessary.

KEYWORDS: PTC, micropropagation, commercialization, conservation, germplasm, food security.

INTRODUCTION :

Plants are the primary source of important nutrients for humans as well as animals, including carbs, vitamins, and all the essential nutrients contributing to a balanced diet and overall health. Through the process of photosynthesis, plants release oxygen into the atmosphere, enabling the survival of all living organisms, including humans[5, 6]. They act as carbon sinks, reducing the concentration of atmospheric carbon and helping to regulate global temperatures. Plants form the foundation of terrestrial ecosystems, providing habitats, food, and shelter for a diverse array of organisms. They contribute to biodiversity and ecological stability, maintaining the balance of ecosystems and supporting wildlife. Plant roots bind the soil, preventing erosion and improving soil structure[1, 30, and 31]. They help retain water, enhance soil fertility, and reduce the risks of landslides and desertification[3, 4]. Plants also play a role in phytoremediation, removing pollutants from contaminated soil. Many plants have therapeutic qualities, and both conventional and modern medicine employ them to treat a variety of diseases. They provide a vast array of natural compounds with therapeutic potential, leading to the development of pharmaceutical drugs[8].

Plants enhance the beauty of landscapes, gardens, and parks, contributing to aesthetic value and improving the quality of urban environments[7]. They provide recreational opportunities for activities such as hiking, gardening, and nature appreciation. Plants are a significant source of economic value. They form the basis of various industries, including agriculture, forestry, horticulture, pharmaceuticals, cosmetics, and textiles[22, 23, 24]. Plant-based products and raw materials contribute to economic growth and employment opportunities. Plants play a vital role in purifying the air by filtering pollutants and releasing oxygen[25].

They help reduce air pollution, including harmful gases and particulate matter, improving overall air quality and human health. Plants can reduce stress, improve mood, and enhance cognitive function, contributing to a healthier

and happier lifestyle[27, 28]. This method enables the creation of genotype-specific true-to-type clones[30]. The controlled atmosphere offers the best environment for development and reproduction, including nutrient availability, pH, temperature, and atmospheric composition.

In numerous contexts, including plant propagation and disease eradication, plant tissue culture has become increasingly important, plant growth regulation, and secondary metabolite production. It enables the rapid multiplication of plants from small tissue samples, yielding hundreds or even thousands of plants[17]. If there are variations in the seasons, this process can be done all year. The effective preservation and propagation of threatened or rare plant species is one of the main benefits ofmicropropagation[16].

By multiplying plant material with high multiplication coefficients and low space requirements, valuable genotypes can be conserved and multiplied. Furthermore, tissue culture of plant plays a crucial role by developing somaclonal and gametoclonal variants. High-quality plants with improved resistance to disease and resistance to stress could be produced using this technique[12, 15]. However, it is important to note that somaclonal heterogeneity may occur, resulting in offspring with inherited characteristics different from those of the parent plants, particularly in callus cultures heterogeneity. High-quality plants with improved resistance to disease and resistance to stress could be produced using this technique, this technique, also referred to as the "in vitro" approach, makes use of a variety of methods for the aseptic cultivation of cells, tissues, organs, or whole plants under carefully monitored nutritional supplements and environmental circumstances is primarily focused on producing plant clones[13,14].

In this review paper section, one contains introduction of this review, section two provide history details, section three contains Commercialization of PTC Laboratories in India, section four contains the details of Micropropagation techniques, section five describe the Role of NCSTCP in Plant Tissue Culture Industry, section six contains details of Micropropagation of Widely Consumable Fruit Crop and section seven explain the conclusion of this review paper.

HISTORY:

- German botanist Wilhelm Hofmeister's discovery of cell division and tissue differentiation in the late 19th century is credited with establishing the origins of plant tissue culture. In the early 20th century, American botanist Gottlieb Haberlandt achieved a breakthrough by successfully growing undifferentiated cell masses called callus from plant tissues.

- Researchers like P.C. Maheshwari and F.C. Steward invented organ culture techniques in the middle of the 20th century, making it possible to cultivate and regenerate plant parts like root systems, shoots, and embryos. Auxins and cytokinin in particular, which were discovered as plant hormones in the 1940s, helped enhance methods like roots and organogenesis. During the 1960s and 1970s, scientists like Toshio Murashige and Folke Skoog developed nutrient media formulations that supported the growth and Micropropagation became a well-known use of plant tissue culture in the 1980s [21,22]. Using this method, plants are quickly multiplied by growing small tissue samples, resulting in the creation of several identical plant clones.

Commercialization of PTC Laboratories in India:

The extent of globalization increased consumer demand for both food products and medicines. As a result of increased medication production, the pharmaceutical industry grew, which increased demand for raw materials including chemical compounds and plant extracts. Although PTC is now engaged in micropropagation, this is a totally different process from commercial or large-scale production and can only be done on a lab basis. To produce the plant products needed by the pharmaceutical industry, PTC industries must be built with all necessary infrastructures. The first PTC commercial application was developed in the US in the 1970s with orchid micropropagation. Cardamom plants were cloned, and the clones included superior genotypes of a chosen variety; this was done by the A.V. Thomas Company, Kerala, and was the first commercial tissue culture in India. The plants were improved by being multiplied. To advance the tissue culture industry in the country, the government offers them financial and technological support. Maharashtra and Karnataka states are major producer of plant tissue culture plants. Despite the harsh climate in these areas, plant production facilities are running at full capacity in places like Rajasthan and Darjeeling. These entities have different levels of management and production ability. The lowest output, however, is carried out by Rallis India Ltd. in

Bengaluru, Karnataka, and Cost ford Promoted Unit in Thiruvananthapuram, Kerala, both of which produce 0.1 million plants annually. The majority of the facilities produce 5 to 10 million plants annually. In terms of annual production, Maharashtra is in first place with 25 units producing 31 million plants.

Table 1: Commercial Plant Tissue Culture Industries in India

PTC Industry Name	Place	State
ABT Tissue Culture Lab	Ananthapur	Andhra Pradesh
Micro Laboratories Pvt. Ltd.	Chittor	Andhra Pradesh
Sri Soma Biotech,	Guntur	Andhra Pradesh
Hecure Agro Plants Pvt. Ltd.	Muzaffarpur	Bihar
Aastha Nursery	Chhattisgarh	Chhattisgarh
AKF Plant sciences Pvt Ltd,	Chhattisgarh	Chattisgarh
COE AIB Tissue Culture Lab	Raipur	Chattisgarh
Devleela Biotech's	Raipur	Chattisgarh
Narmada Phosphate Limited	Bilaspur	Chhattisgarh
Yash Biotech	Raipur	Chattisgarh
AKF Plant sciences Pvt Ltd	Chhattisgarh	Chattisgarh
ABC Agrobiotechnology Pvt. Ltd.	Ahmedabad	Gujarat
Greenfield Biotech	Gandhinagar	Gujarat
GNFC Tissue Culture Laboratory	Bharuch	Gujarat
GSFC Aggrotech Ltd.-New Lab	Gujarat	Gujarat

IRM Enterprises Pvt. Ltd.	Ahmedabad	Gujarat
Kutch Crop Services Ltd.	Mundra	Gujarat
Kalptaru Agro Biotech	Nadiad	Gujarat
Maltbio Agri-food Pvt. Ltd., Dist.	Bharuch	Gujarat
MANU'S LABS	Gandhinagar	Gujarat
Metrogen Biotech, Dist.	Gandhinagar	Gujarat
Nation Agri Biotech	Gujarat	Gujarat
Natural Life Sciences, Dist.	Gujarat	Gujarat
NUMICS BIOTECH	Gujarat	Gujarat
PAC Bio Fungbact Pvt. Ltd.	Surat	Gujarat
Palaj Agrotech	Gandhinagar	Gujarat
Sarjan Biotech Pvt. Ltd.	Bhuj-Kutch.	Gujarat
Siddhi Plantek	Dist. Anand	Gujarat
S.G.K.U.S.M. Limited	Bharuch	Gujarat
Sri Ratnam Biotech LLP	Gujarat	Gujarat
Shree Abhimanyu Biotech	Navli	Gujarat
UMA Biotech Industries	Mehsana	Gujarat
Vitrigold Biotech Pvt. Ltd	Hadgud-Vadod	Gujarat
Shree Abhimanyu Biotech	Navli	Gujarat
UMA Biotech Industries	Mehsana	Gujarat
The Energy and Resources Institute	Gurugram	Haryana
Sheel Biotech Ltd.	Gurugram	Haryana
Dessons Tissue Culture Lab	Natwal	Haryana
Nishant Biotech	Bilaspur	Himanchal Pradesh
Technico Agri Sciences Ltd	Solan	Himanchal Pradesh
Sashanka Agro Tech Private Ltd.	Ranchi	Jharkhand
Annapoorna Plant Tech	Udupi	karnataka
Biotechnology Centre, Dept. of Horticulture	Karnataka	Karnataka
FLORANCE FLORA FARM	Bangalore,	Karnataka
Green Leaf Plant Technology	Bangalore	Karnataka
H.U. Gugle Biotech Pvt. Ltd.	Bangalore	Karnataka
Jagadamba Bio Plant	Bangalore	karnataka
K F Biotech Pvt Ltd.	Bangalore	Karnataka
Mysore Organic Farms Pvt. Ltd.	Mysore	Karnataka
Novel Biotech	Bangalore	Karnataka
Shaanthi Agrotech	Bengaluru	Karnataka
SLR Greentech Pvt. Ltd.	Karnataka	Karnataka
Sree Adithya Biotech	Bangalore	Karnataka
Advent Plantech LLP	Nashik	Maharashtra
Ajeet Seeds Ltd.	Aurangabad	Maharashtra
ALMAQ Biotech LLP	Latur	Maharashtra
Callus Biotech Pvt. Ltd.	Kolhapur	Maharashtra
Futura Bioplants Pvt.Ltd.	Dist. Pune	Maharashtra
Jain Irrigation Systems Limited	Jalgaon	Maharashtra
Janani Biotech	Kolhapur	Maharashtra
K.F. Bioplants	Pune	Maharashtra
Kimya Biotech Pvt. Ltd	Sangli	Maharashtra
Kshitij Biotech Corporation	Satara	Maharashtra
Mahabeej Biotechnology Centre	Nagpur	Maharashtra
Namo Bioplants	Nashik	Maharashtra
Ram Biotech	Jalgaon	Maharashtra
Ruddhi Biotech Pvt. Ltd.	Kolhapur	Maharashtra

Seema Biotech	Kolhapur	Maharashtra
Arihanth Biotech	Madhya Pradesh	Madhya Pradesh
Celgen Biotech India	Vidisha	Madhya Pradesh
Reva Flora Culture	Barwani	Madhya Pradesh
Sachdev Nursery	Damoh	Madhya Pradesh
Shri Mukund Biotech, Dist.	Jabalpur	Madhya Pradesh
Tirupati Fresh Agro Crop Science Pvt. Ltd.	Dist. Khargone	Madhya Pradesh
Excel Plant Link Pvt. Ltd.	Dhenkanal	Orissa
Ganapati Biotech	Kalahandi	Orissa
Regional Plant Resource Centre	Bhubaneswar	Orissa
Bhatti Tissue Tech	Jalandhar	Punjab
PepsiCo India Holding Pvt. Ltd.	Hoshiarpur	Punjab
Mahindra Hzpc Pvt. Ltd.	Mohali	Punjab
Tissue Culture Laboratory (CoE Potato)	Punjab	Punjab
Bhatti Tissue Tech.	Jalandhar	Punjab
PepsiCo India Holding Pvt. Ltd.	Hoshiarpur	Punjab
Atul Rajasthan Date Palms Ltd.	Jodhpur	Rajasthan
Annai Meenashi Biotech	Hosur	Tamilnadu
Genewin Biotech	Hosur	Tamilnadu
Growmore Biotech Ltd.	Hosur	Tamilnadu
Hosur Hortitech,	Hosur	Tamilnadu
Sree Bairava Nursery	, Hosur	Tamilnadu
Sree Visal Bioteck	Hosur	Tamilnadu
Thulasi Biotech	Jolarpet	Tamilnadu
ACE Agro Technologies	Secunderabad	Telangana
Agri Vitro Tech Laboratories	Hyderabad,	Telangana
Microsun Bioplants (India) Pvt. Ltd	Secunderabad	Telangana
Rodasy Biotechnologies	Hyderabad	Telangana
Vitroplant	Hyderabad	Telangana
Dr. MC Saxena Group of Colleges	Lucknow	Uttar Pradesh
GRS Bioplants Pvt. Ltd.	Firozabad	Uttar Pradesh
Merino Industries Ltd.	Hapur	Uttar Pradesh
Sagar Agrisciences Pvt. Ltd. (UNIT-II)	Dulhipur	Uttar Pradesh
Elegant Flower Company Pvt. Ltd.	Kolkata	West Bengal
Pallishree Ltd.	Kolkata	West Bengal

MICROPROPAGATION TECHNIQUE:

Stage 0: Making the donor plant ready

To reduce contamination, the donor plant, which is strong and robust, is grown in ideal conditions outside of the in vitro culture[37, 38, 41].

Stage I: The Beginning

From the donor plant, an explant (plant tissue) is removed and sterilised to remove impurities. For surface sterilization, chemical solutions like sodium hypochlorite, calcium hypochlorite, ethanol, or mercuric chloride are frequently used. The sterilised explant is subsequently placed in a growth chamber's nutrition medium.

Stage II: The stage of multiplication

The objective of this stage is to produce additional propagules (plantlets). The explant is routinely subcultured onto brand-new nutritive media in order to increase the number of plantlets until the appropriate quantity is obtained.

Stage III: The Rooted Phase

The same culture media used for multiplication may be used for rooting the plantlets, although occasionally a modification in the media's makeup is necessary. To initiate rooting and encourage strong root growth, nutritional alterations and growth regulator tweaks are applied.

Stage IV: Stage of Acclimatization

The plantlets are increasingly acclimatized and toughened at this stage. The plants are moved to a suitable substrate (such as sand, peat, or compost), and the humidity and light levels are gradually reduced from high to low. The plantlets are further toughened under controlled circumstances in a greenhouse.

ROLE OF NCSTCP IN PLANT TISSUE CULTURE INDUSTRY:

The National Certification System for Tissue Culture Plants (NCS-TCP) is administered by the Department of Biotechnology (DBT), which is part of the Ministry of Science and Technology of the Government of India[39,40]. The NCS-TCP is a key player in the nation's regulation and accreditation of tissue culture facilities. The NCS-TCP was formed with the purpose of ensuring the quality, standardization, and certification of plants grown in tissue culture in India. It intends to give farmers, horticulturists, and other agricultural industry participants disease-free, genetically uniform, and high-quality planting material. The NCS-TCP sets policies, procedures, and benchmarks for the growth of tissue culture plants. Facilities and tissue culture labs that apply for NCS-TCP certification go through a thorough assessment and inspection process. DBT has supported various initiatives, research projects, and capacity building programs related to plant tissue culture in India.DBT is the primary source of funding for R&D projects in India. It aids in the development and enhancement of PTC research at multiple academic institutions, research sites, and institutes. Six national centers for viral detection, diagnosis, quality control, and maintenance have been established, and these facilities supply virus-free plants.

MICROPROPAGATION OF WIDELY CONSUMABLE FRUIT CROP:

a) Banana

The propagation of native banana cultivars through tissue culture is challenging due to the occurrence of growth arrest mediated by apical dominance. However, in vitro regeneration of banana can be achieved through shoot tip culture, which enables direct organogenesis[7]. The use of different types of cytokinin and auxins has been explored for the micropropagation of banana cultivars, with the rate of shoot proliferation significantly influenced by the specific cultivar type and its genomic constitution. Nowadays, the focus of in vitro micropropagation of bananas is primarily on developing disease-free clones. Bananas are considered one of the most affordable fruits available throughout the year. They hold significant economic importance in India and are rich in carbohydrates, proteins, vitamins, and minerals. The global production of bananas totals 97.38 million metric tons and is grown throughout 127 nations over an area of 4.90 million hectares[2]. With a yearly production of 27 million metric tons, India in particular leads the globe in banana production. A highly efficient protocol has been established for the micropropagation of a specific banana cultivar, Poovan, using shoot tip as the starting explant. This finding suggests that TDZ has a greater impact on shoot development in the micropropagation process of Poovan banana cultivar.

b) Mango

The in vitro production of mango plants using techniques for plant tissue culture is referred to as mango tissue culture. It comprises the growth and development of mango plantlets from small plant tissue samples in a controlled laboratory setting, such as shoot tips, nodal segments, or embryonic tissues. The explants are surface sterilized to eliminate any contaminants. This is typically done by treating the explants with disinfectants like sodium hypochlorite or alcohol. On a sterile nutrient media, such as Murashige and Skoog (MS) medium, supplied with the proper plant growth regulators, the sterilized explants are subsequently put. For the start of tissue culture, this medium offers the nutrients and growth factors required. The explants begin to develop numerous shoots or buds in the following stage. The concentration and mix of plant growth regulators, particularly cytokinin like benzylaminopurine (BAP) or kinetin, are adjusted to achieve this. These regulators promote shoot proliferation and multiplication. The actively growing shoots or buds are periodically transferred to fresh nutrient media to ensure their continued growth and multiplication. This process, known as sub culturing, allows for the production of a large number of healthy shoots. When there are enough shoots, they are moved to a rooting media that also contains auxins like indole-3-butyric acid (IBA) or naphthalene acetic acid (NAA). These hormones encourage the growth and production of roots in the shoots.

Table2: Indian states having PTC units' yearly results[25]

State	Annual Production (million)
Maharashtra	31
Karnataka	31
West Bengal	5
Kalimpong (Darjeeling)	1
Andhra Pradesh	10
Delhi	7
Tamil Nadu	27
Kerala	25
Haryana	13
Gujarat	12
Uttar Pradesh	25
Punjab	2
Himachal Pradesh	5
Odisha	1
Rajasthan	1

c) Guava

The guava, also known as the "apple of the tropics," is a highly prized tropical and subtropical fruit that is an essential part of the diet in many countries. It contains a substantial amount of minerals like calcium, phosphorus, iron, and pectin as well as a significant number of high-grade antioxidants like lycopene, carotenoids, and polyphenols. Due to its superior nutritional value and versatility as a fresh or processed fruit, the guava offers many advantages as a crop species. In fruit trees like the guava, which are the subject of extensive global breeding research, genetic engineering, in vitro propagation, and synthetic seed or artificial seed technologies may be advantageous in place of sterile and elite materials.

d) Pomegranate

The pomegranate is one of the first edible fruits that have been cultivated. It is frequently linked to fertility and is mentioned in both the Bible and the Koran. Consuming pomegranate juice and extract has long been associated with a number of health benefits beyond nutrition, mostly as a consequence of multiple preclinical studies. But in 2010, the European Food Safety Authority (EFSA) concluded that it was difficult to demonstrate a causal relationship between the use of goods produced from pomegranates and all of the made-up health benefits. There haven't been any additional EFSA opinions on pomegranate-specific health claims in the last ten years.

CONCLUSION:

The nation's agriculture depends heavily on the Indian plant tissue culture industry to meet its needs. Plant tissue culture has become a potent tool for agricultural development, the preservation of endangered species, and the mass production of disease-free plants as a result of technological and scientific advancements. The review of the Indian plant tissue culture industry has highlighted several key points. Firstly, the industry has witnessed significant growth over the years, with numerous private and public sector companies actively engaged in tissue culture research and

production. This growth has been driven by the increasing demand for high-quality planting material, improved crop varieties, and the need to overcome challenges such as disease outbreaks and limited land resources. In addition, the review highlighted the various ways that plant tissue culture is being used to address issues in agriculture. Higher agricultural yields and better crop quality are the results of the use of tissue culture techniques to make disease-free and genetically homogeneous planting material. Furthermore, tissue culture has been crucial for the preservation of rare and endangered plant species, ensuring their survival and possibly reintroducing them into their native environments. Furthermore, the review emphasized the importance of research and development in driving innovation within the industry. Ongoing research efforts have focused on improving tissue culture protocols, developing new techniques, and exploring the potential of genetic engineering to enhance crop traits. These advancements are crucial for meeting the evolving needs of agriculture, such as climate resilience, increased productivity, and nutritional enhancement. Despite the notable progress, the review also highlighted certain challenges faced by the Indian plant tissue culture industry. Issues such as high production costs, lack of skilled personnel, limited infrastructure, and regulatory constraints pose obstacles to its widespread adoption and commercialization. Addressing these challenges through collaborative efforts between academia, industry, and policymakers will be crucial for the sustainable growth of the industry. The utilization of plant tissue culture has brought about significant benefits to the agriculture and horticulture industries, revolutionizing modern-day food production. The ability to produce plants free of viruses, diseases, and pests has emerged as one of this method's most impressive benefits. Additionally, the evolution of plants with bio fortified traits and a biotic stress resistance has had a significant impact on the direction of agriculture. These advancements have truly transformed the landscape of farming and the production of food. If many obstacles including sophisticated research facilities, financial considerations, and marketing are addressed, the commercial production of plants using plant tissue culture (PTC) industries possesses enormous scope and potential. With its numerous agro climatic zones and inexpensive labour, India has the potential to excel in this industry to new heights. By leveraging support from the government and implementing measures to retain self-sufficiency in agricultural production, India can unlock the full potential of PTC industries and pave the way for a prosperous future.

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